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Jets as Diagnostics of the Circumstellar Medium and the Explosion Energetics of Supernovae: The Case of Cassiopeia A, [Schure, K. M.](#); [Vink, J.](#); [García-Segura, G.](#); [Achterberg, A.](#), The Astrophysical Journal, Volume 686, Issue 1, pp. 399-407

We present hydrodynamical models for the Cassiopeia A (Cas A) supernova remnant and its observed jet/counterjet system. We include the evolution of the progenitor's circumstellar medium, which is shaped by a slow red supergiant wind that is followed by a fast Wolf-Rayet (WR) wind. The main parameters of the simulations are the duration of the WR phase and the jet energy. We find that the jet is destroyed if the WR phase is sufficiently long and a massive circumstellar shell has formed. We therefore conclude that the WR phase must have been short (a few thousand years), if present at all. Since the actual jet length of Cas A is not known, we derive a lower limit for the jet energy, which is $\sim 10^{48}$ erg. We discuss the implications for the progenitor of Cas A and the nature of its explosion.

The Search for Muon Neutrinos from Northern Hemisphere Gamma-Ray Bursts with AMANDA, [Achterberg, A.](#); [Ackermann, M.](#); [Adams, J.](#); [Ahrens, J.](#); [Andeen, K.](#); [Auffenberg, J.](#); [Bahcall, J. N.](#); [Bai, X.](#); [Baret, B.](#); [Barwick, S. W.](#); [Bay, R.](#); [Beattie, K.](#); [Becka, T.](#); [Becker, J. K.](#); [Becker, K.-H.](#); [Berghaus, P.](#); [Berley, D.](#); [Bernardini, E.](#); [Bertrand, D.](#); [Besson, D. Z.](#); [Blaufuss, E.](#); [Boersma, D. J.](#); [Bohm, C.](#); [Bolmont, J.](#); [Böser, S.](#); [Botner, O.](#); [Bouchta, A.](#); [Braun, J.](#); [Burgess, C.](#); [Burgess, T.](#); [Castermans, T.](#); [Chirkin, D.](#); [Christy, B.](#); [Clem, J.](#); [Cowen, D. F.](#); [D'Agostino, M. V.](#); [Davour, A.](#); [Day, C. T.](#); [De Clercq, C.](#); [Demirörs, L.](#); [Descamps, F.](#); [Desiati, P.](#); [DeYoung, T.](#); [Diaz-Velez, J. C.](#); [Dreyer, J.](#); [Dumm, J. P.](#); [Duvoort, M. R.](#); [Edwards, W. R.](#); [Ehrlich, R.](#); [Eisch, J.](#); [Ellsworth, R. W.](#); [Evenson, P. A.](#); [Fadiran, O.](#); [Fazely, A. R.](#); [Filimonov, K.](#); [Foerster, M. M.](#); [Fox, B. D.](#); [Franckowiak, A.](#); [Gaisser, T. K.](#); [Gallagher, J.](#); [Ganugapati, R.](#); [Geenen, H.](#); [Gerhardt, L.](#); [Goldschmidt, A.](#); [Goodman, J. A.](#); [Gozzini, R.](#); [Griesel, T.](#); [Gross, A.](#); [Grullon, S.](#); [Gunasingha, R. M.](#); [Gurtner, M.](#); [Hallgren, A.](#); [Halzen, F.](#); [Han, K.](#); [Hanson, K.](#); [Hardtke, D.](#); [Hardtke, R.](#); [Hart, J. E.](#); [Hasegawa, Y.](#); [Hauschildt, T.](#); [Hays, D.](#); [Heise, J.](#); [Helbing, K.](#); [Hellwig, M.](#); [Herquet, P.](#); [Hill, G. C.](#); [Hodges, J.](#) et al; The Astrophysical Journal, Volume 674, Issue 1, pp. 357-370

We present the results of the analysis of neutrino observations by the Antarctic Muon and Neutrino Detector Array (AMANDA) correlated with photon observations of more than 400 gamma-ray bursts (GRBs) in the northern hemisphere from 1997 to 2003. During this time period, AMANDA's effective collection area for muon neutrinos was larger than that of any other existing detector. After the application of various selection criteria to our data, we expect ~ 1 neutrino event and < 2 background events. Based on our observations of zero events during and immediately prior to the GRBs in the data set, we set the most stringent upper limit on muon neutrino emission correlated with GRBs. Assuming a Waxman-Bahcall spectrum and incorporating all systematic uncertainties, our flux upper limit has a normalization at 1 PeV of $E^2\Phi_{\nu} < 6.3 \times 10^{-9} \text{ GeV cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1}$, with 90% of the events expected within the energy range of ~ 10 TeV to ~ 3 PeV. The impact of this limit on several theoretical models of GRBs is discussed, as well as the future potential for detection of GRBs by next-generation neutrino telescopes. Finally, we briefly describe several modifications to this analysis in order to apply it to other types of transient point sources.

Search for Ultra-High-Energy Neutrinos with AMANDA-II, [Ackermann, M.](#); [Adams, J.](#); [Ahrens, J.](#); [Andeen, K.](#); [Auffenberg, J.](#); [Bai, X.](#); [Baret, B.](#); [Barwick, S. W.](#); [Bay, R.](#); [Beattie, K.](#); [Becka, T.](#); [Becker, J. K.](#); [Becker, K.-H.](#); [Beimforde, M.](#); [Berghaus, P.](#); [Berley, D.](#); [Bernardini, E.](#); [Bertrand, D.](#); [Besson, D. Z.](#); [Blaufuss, E.](#); [Boersma, D. J.](#); [Bohm, C.](#); [Bolmont, J.](#); [Böser, S.](#); [Botner, O.](#); [Bouchta, A.](#); [Braun, J.](#); [Burgess, T.](#); [Castermans, T.](#); [Chirkin, D.](#); [Christy, B.](#); [Clem, J.](#); [Cowen, D. F.](#); [D'Agostino, M. V.](#); [Davour, A.](#); [Day, C. T.](#); [De Clercq, C.](#); [Demirörs, L.](#); [Descamps, F.](#); [Desiati, P.](#); [de Vries-Uiterweerd, G.](#); [DeYoung, T.](#); [Diaz-Velez, J. C.](#); [Dreyer, J.](#); [Dumm, J. P.](#); [Duvoort, M. R.](#); [Edwards, W. R.](#); [Ehrlich, R.](#); [Eisch, J.](#); [Ellsworth, R. W.](#); [Evenson, P. A.](#); [Fadiran, O.](#); [Fazely, A. R.](#); [Filimonov, K.](#); [Finley, C.](#); [Foerster, M. M.](#); [Fox, B. D.](#); [Franckowiak, A.](#); [Franke, R.](#); [Gaisser, T. K.](#); [Gallagher, J.](#); [Ganugapati, R.](#); [Geenen, H.](#); [Gerhardt, L.](#); [Goldschmidt, A.](#); [Goodman, J. A.](#); [Gozzini, R.](#); [Griesel, T.](#); [Groß, A.](#); [Grullon, S.](#); [Gunasingha, R. M.](#); [Gurtner, M.](#); [Ha, C.](#); [Hallgren, A.](#); [Halzen, F.](#); [Han, K.](#); [Hanson, K.](#); [Hardtke, D.](#); [Hardtke, R.](#); [Hasegawa, Y.](#); [Hauschildt, T.](#); [Heise, J.](#) et al; *The Astrophysical Journal*, Volume 675, Issue 2, pp. 1014-1024

A search for diffuse neutrinos with energies in excess of 10^5 GeV is conducted with AMANDA-II data recorded between 2000 and 2002. Above 10^7 GeV, the Earth is essentially opaque to neutrinos. This fact, combined with the limited overburden of the AMANDA-II detector (roughly 1.5 km), concentrates these ultra-high-energy neutrinos at the horizon. The primary background for this analysis is bundles of downgoing, high-energy muons from the interaction of cosmic rays in the atmosphere. No statistically significant excess above the expected background is seen in the data, and an upper limit is set on the diffuse all-flavor neutrino flux of $E^2\Phi_{90\%CL} < 2.7 \times 10^{-7} \text{ GeV cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1}$ valid over the energy range of 2×10^5 to 10^9 GeV. A number of models that predict neutrino fluxes from active galactic nuclei are excluded at the 90% confidence level.

Faranoff-Riley type I jet deceleration at density discontinuities. Relativistic hydrodynamics with a realistic equation of state, [Meliani, Z.](#); [Keppens, R.](#); [Giacomazzo, B.](#), *Astronomy and Astrophysics*, Volume 491, Issue 2, 2008, pp.321-337

Aims. We propose a model that could explain the sudden jet deceleration in active galactic nuclei, thereby invoking density discontinuities. Motivated particularly by recent indications from HYbrid MORphology Radio Sources (HYMORS) that Fanaroff-Riley classification is induced in some cases by variations in the density of the external medium. We explore how one-sided jet deceleration and a transition to FR I type can occur in HYMORS, which start as FR II (and remain so on the other side).

Methods: We implemented the Sygne-type equation of state introduced in the general polytropic case by Meliani et al. (2004, *A&A*, 425, 773) into the relativistic hydrodynamic grid-adaptive AMRVAC code. To demonstrate its accuracy, we set up various test problems in an appendix, which we compare to exact solutions that we calculate as well. We use the code to analyse the deceleration of jets in FR II/FR I radio galaxies, following them at high resolution across several hundred jet beam radii. **Results:** We present results for 10 model computations that vary the inlet Lorentz factor from 10 to 20, include uniform or decreasing density profiles, and allow for cylindrical versus conical jet models. As long as the jet propagates through uniform media, we find that the density contrast sets most of the propagation characteristics, fully consistent with previous modelling efforts. When the jet runs into a denser medium, we find a clear distinction in the deceleration of high-energy jets depending on the encountered density jump. For fairly high-density contrast, the jet becomes destabilised and compressed, decelerates strongly (up to subrelativistic speeds), and can form knots. If the density contrast is too weak, the high-energy jets continue with FR II characteristics. The trend is similar for the low-energy jet models, which start as underdense jets from the outset, and decelerate by entrainment into the lower region as well. We point out differences that are found between cylindrical and conical jet models, together with dynamical details like the Richtmyer-Meshkov instabilities developing at the original contact interface.

Linear wave propagation in relativistic magnetohydrodynamics, [Keppens, R.](#); [Meliani, Z.](#), *Physics of Plasmas*, Volume 15, Issue 10, pp. 102103-102103-11 (2008).

The properties of linear Alfvén, slow, and fast magnetoacoustic waves for uniform plasmas in relativistic magnetohydrodynamics (MHD) are discussed, augmenting the well-known expressions for their phase speeds with knowledge on the group speed. A 3+1 formalism is purposely adopted to make direct comparison with the Newtonian MHD limits easier and to stress the graphical representation of their anisotropic linear wave properties using the phase and group speed diagrams. By drawing these for both the fluid rest frame and for a laboratory Lorentzian frame which sees the plasma move with a three-velocity having an arbitrary orientation with respect to the magnetic field, a graphical view of the relativistic aberration effects is obtained for all three MHD wave families. Moreover, it is confirmed that the classical Huygens construction relates the phase and group speed diagram in the usual way, even for the lab frame viewpoint. Since the group speed diagrams correspond to exact solutions for initial conditions corresponding to a localized point perturbation, their formulae and geometrical

construction can serve to benchmark current high-resolution algorithms for numerical relativistic MHD.

Extragalactic jets with helical magnetic fields: relativistic MHD simulations, [Keppens, R.](#); [Meliani, Z.](#); [van der Holst, B.](#); [Casse, F.](#), *Astronomy and Astrophysics*, Volume 486, Issue 3, 2008, pp.663-678

Context: Extragalactic jets are judged to harbor dynamically important, organized magnetic fields that presumably aid in the collimation of the relativistic jet flows. Aims: We here explore the morphology of AGN jets pervaded by helical field and flow topologies by means of grid-adaptive, high-resolution numerical simulations. We concentrate on morphological features of the bow shock and the jet beam behind the Mach disk, for various jet Lorentz factors and magnetic field helicities. We investigate the influence of helical magnetic fields on jet beam propagation in an overdense external medium. We adopt a special relativistic magnetohydrodynamic (MHD) viewpoint on the shock-dominated AGN jet evolution. Due to the adaptive mesh refinement (AMR), we can concentrate on the long-term evolution of kinetic energy-dominated jets, with beam-averaged Lorentz factor $\Gamma \simeq 7$, as they penetrate denser clouds. These jets have near-equipartition magnetic fields (with the thermal energy) and radially varying $\Gamma(R)$ profiles within the jet radius $R < R_j$ maximally reaching $\Gamma \sim 22$. Methods: We used the AMRVAC code, with a novel hybrid block-based AMR strategy, to compute ideal plasma dynamics in special relativity. We combined this with a robust second-order shock-capturing scheme and a diffusive approach to controlling magnetic monopole errors. Results: We find that the propagation speed of the bow shock systematically exceeds the value expected from estimates using beam-average parameters, in accordance with the centrally-peaked $\Gamma(R)$ variation. The helicity of the beam magnetic field is effectively transported down the beam, with compression zones between the diagonal internal cross-shocks showing stronger toroidal field regions. In comparison with equivalent low-relativistic jets ($\Gamma \simeq 1.15$), which get surrounded by cocoons with vortical backflows filled by mainly toroidal field, the high speed jets only demonstrate localized, strong toroidal field zones within the backflow vortical structures. These structures are ring-like due to our axisymmetry assumption and may further cascade to a smaller scale in 3D. We find evidence of a more poloidal, straight field layer, compressed between jet beam and backflows. This layer decreases the destabilizing influence of the backflow on the jet beam. In all cases, the jet beam contains rich cross-shock patterns, across which part of the kinetic energy gets transferred. For the high-speed reference jet considered here, significant jet deceleration only occurs beyond distances exceeding $O(100 R_j)$, as the axial flow can reaccelerate downstream to the internal cross shocks. This reacceleration is magnetically aided by field compression across the internal shocks that pinch the flow.

Relativistic hydrodynamic simulation of jet deceleration in GRB, [Meliani, Z.](#); [Keppens, R.](#); [Casse, F.](#), *GAMMA-RAY BURSTS 2007: Proceedings of the Santa Fe Conference*. AIP Conference Proceedings, Volume 1000, pp. 452-45

Using the novel adaptive mesh refinement code, AMRVAC, we investigate the interaction between collimated ejecta (jetlike fireball models with various opening angle)

with its surrounding cold Interstellar Medium (ISM). This is relevant for Gamma Ray Bursts, and we demonstrate that, thanks to the AMR strategy, we resolve the internal structure of the shocked shell-ISM matter. We determine the deceleration from an initial Lorentz factor $\gamma = 100$ up to the almost Newtonian $\gamma \sim O(3)$ phase of the flow. We discuss the effect of varying the opening angle on the deceleration, and pay attention to differences with their 1D isotropic GRB equivalents. These are due to thermally induced sideways expansions of both shocked shell and shocked ISM regions. The propagating 2D ultrarelativistic shell does not accrete all the surrounding medium located within its initial opening angle. The difference with isotropic GRB models is quite pronounced for shells with small opening angle. In the most collimated ejecta (open angle of 1°), the deceleration phase (once the reverse shock has traversed the shell structure) shows distinct modulation, attributed to repeated rarefactions traversing the shell. These may have a clear impact on the emitted afterglow radiation.

Accretion funnels onto weakly magnetized young stars, [Bessolaz, N.](#); [Zanni, C.](#); [Ferreira, J.](#); [Keppens, R.](#); [Bouvier, J.](#), Astronomy and Astrophysics, Volume 478, Issue 1, January IV 2008, pp.155-162

Aims. We re-examine the conditions required to steadily deviate an accretion flow from a circumstellar disc into a magnetospheric funnel flow onto a slow rotating young forming star. **Methods:** New analytical constraints on the formation of accretion funnel flows due to the presence of a dipolar stellar magnetic field disrupting the disc are derived. The Versatile Advection Code is used to confirm these constraints numerically. Axisymmetric MHD simulations are performed, where a stellar dipole field enters the resistive accretion disc, whose structure is self-consistently computed. **Results:** The analytical criterion derived allows to predict a priori the position of the truncation radius from a non-perturbative accretion disc model. Accretion funnels are found to be robust features which occur below the co-rotation radius, where the stellar poloidal magnetic pressure becomes both at equipartition with the disc thermal pressure and is comparable to the disc poloidal ram pressure. We confirm the results of Romanova et al. (2002, ApJ, 578, 420) and find accretion funnels for stellar dipole fields as low as 140 G in the low accretion rate limit of $10^{-9} M_\odot \text{ yr}^{-1}$. With our present numerical setup with no disc magnetic field, we found no evidence of winds, neither disc driven nor X-winds, and the star is only spun up by its interaction with the disc. **Conclusions:** Weak dipole fields, similar in magnitude to those observed, lead to the development of accretion funnel flows in weakly accreting T Tauri stars. However, the higher accretion observed for most T Tauri stars ($\dot{M} 10^{-8} M_\odot \text{ yr}^{-1}$) requires either larger stellar field strength and/or different magnetic topologies to allow for magnetospheric accretion.

Magnetohydrostatic Solar Prominences in Near-Potential Coronal Magnetic Fields, [Petrie, G. J. D.](#); [Blokland, J. W. S.](#); [Keppens, R.](#), Subsurface and Atmospheric Influences on Solar Activity ASP Conference Series, Vol. 383, proceedings of the conference held 16-20 April 2007 at the National Solar Observatory, Sacramento Peak, Sunspot, New Mexico, USA. Edited by R. Howe, R. W. Komm, K. S. Balasubramaniam and G. J. D. Petrie. San Francisco: Astronomical Society of the Pacific, 2008, p.413

We present numerical magnetohydrostatic (MHS) solutions describing the gravitationally stratified, bulk equilibrium of cool, dense prominence plasma embedded in a near-potential coronal field. These solutions are calculated using the FINESSE magnetohydrodynamics equilibrium solver and describe magnetic fields in and around prominences and the cool prominence plasma that these fields support. The many examples computed here with temperature and entropy prescribed as a free functions of the magnetic flux function include one which reproduces precisely the three-part structure often encountered in observations: a cool dense prominence surrounded by a cavity, within a flux rope embedded in a hot corona.

Evolution of magnetic fields in supernova remnants, [Schure, Klara](#); [Vink, Jacco](#); [Achterberg, Bram](#); [Keppens, Rony](#), 37th COSPAR Scientific Assembly. Held 13-20 July 2008, in Montréal, Canada., p.2791

Supernova remnants (SNR) are now widely believed to be a source of cosmic rays (CRs) up to an energy of 10¹⁵ eV. Electrons (and possibly protons) are accelerated at the forward shock through diffusive shock acceleration. The magnetic fields required to accelerate CRs to sufficiently high energies need to be much higher than can result from compression of the circumstellar medium (CSM) by a factor 4, as is the case in strong shocks. Non-thermal synchrotron maps of these regions indicate that indeed the magnetic field is much stronger. How these magnetic fields get enhanced is not yet fully understood. We use an adaptive mesh refinement MHD code, AMRVAC, to simulate the evolution of supernova remnants and their magnetic fields. For now, we evaluate the ideal MHD equations to follow the evolution of the SNR with different configurations of the initial magnetic field and CSM. We have also started to incorporate test particles in order to track cosmic ray acceleration in the remnant.

Supernova remnants with magnetars: Clues to magnetar formation, [Vink, Jacco](#), Advances in Space Research, Volume 41, Issue 3, p. 503-511

In this paper I discuss the lack of observational evidence that magnetars are formed as rapidly rotating neutron stars. Supernova remnants containing magnetars do not show the excess of kinetic energy expected for such a formation scenario, nor is there any evidence for a relic pulsar wind nebula. However, it could be that magnetars are formed with somewhat slower rotation periods, or that not all excess rotational energy was used to boost the explosion energy, for example as a result of gravitational radiation. Another observational tests for the rapid initial period hypothesis is to look for statistical evidence that about 1% of the observed supernovae have an additional 10^{40} 10^{44} erg/s excess energy during the first year, caused by the spin down luminosity of a magnetar. An alternative scenario for the high magnetic fields of magnetars is the fossil field hypothesis, in which the magnetic field is inherited from the progenitor star. Direct observational tests for this hypothesis are harder to formulate, unless the neutron star formed in the SN1987A explosion emerges as a slowly rotating magnetar. Finally, I point out the possible connection between the jets in Cas A and its X-ray point source: the jets in Cas A may indicate that the explosion was accompanied by an X-ray flash, probably powered by a rapidly rotating compact object. However, the point source in Cas A does

not seem to be a rapidly rotating neutron star. This suggests that Cas A contains a neutron star that has slowed down considerably in 330 yr, requiring a dipole magnetic field of $B > 5 \times 10^{13}$ G. The present day lack of evidence for a relic radio pulsar wind nebula may be used to infer an even higher magnetic field of 10^{15} G.

Cosmic ray acceleration in the supernova remnant RCW 86, [Helder, Eveline;](#) [Bassa, Cees;](#) [Ghavamian, Parviz;](#) [Vink, Jacco](#), 37th COSPAR Scientific Assembly. Held 13-20 July 2008, in Montréal, Canada., p.1216

We present preliminary results of our research on the shock acceleration of the X-ray synchrotron and gamma-ray source RCW 86; a shell-type supernova remnant. Shell-type supernova remnants are the main candidates for accelerating cosmic rays, at least up to the knee in the cosmic ray spectrum at 1015 eV. In order to emit X-ray synchrotron at a shock, the shock needs to have a high velocity and a turbulent magnetic field. Earlier research on the shock velocity in the West of the remnant show a rather modest value of 600 km/s. In the less bright East side of the remnant is X-ray synchrotron radiation detected, which already points towards shock acceleration. We took VLT spectra of the Balmer dominated shock in the East side, in order to determine the shock velocity. This turns out to be around 1000 km/s, which is less than earlier estimates, based on the shock velocity needed to get X-ray synchrotron emission, but higher than the shock velocities found in other parts of the remnant. The X-ray synchrotron emission can therefore be explained by assuming a cosmic ray dominated shock, in which the proton temperature does not follow the standard Hugoniot relation, or the X-ray synchrotron emission is caused by electrons accelerated in the past. Magnetic field estimates suggest a synchrotron loss time of 500 yr.

The Kinematics of Kepler's Supernova Remnant as Revealed by Chandra, [Vink, Jacco](#), The Astrophysical Journal, Volume 689, Issue 1, pp. 231-241

I have determined the expansion of the supernova remnant of SN 1604 (Kepler's supernova) based on archival Chandra ACIS-S observations made in 2000 and 2006. The measurements were done in several distinct energy bands, and were made for the remnant as a whole, and for six individual sectors. The average expansion parameter indicates that the remnant expands on average as $r \sim t^{0.5}$, but there are significant differences in different parts of the remnant: the bright northwestern part expands as $r \sim t^{0.35}$, whereas the rest of the remnant's expansion shows an expansion $r \sim t^{0.6}$. The latter is consistent with an explosion in which the outer part of the ejecta has a negative power law slope for density ($\rho \sim v^{-n}$) of $n=7$, or with an exponential density profile [$\rho \sim \exp(-v/v_e)$]. The expansion parameter in the southern region, in conjunction with the shock radius, indicates a rather low value ($< 5 \times 10^{50}$ erg) for the explosion energy of SN 1604 for a distance of 4 kpc. A higher explosion energy is consistent with the results if the distance is larger. The filament in the eastern part of the remnant, which is dominated by X-ray synchrotron radiation, seems to mark a region with a fast shock speed $r \sim t^{0.7}$, corresponding to a shock velocity of $v=4200$ km s^{-1} , for a distance to SN 1604 of 4 kpc. This is consistent with the idea that X-ray synchrotron emission requires shock velocities in excess of ~ 2000 km s^{-1} .

The X-ray-based expansion measurements reported are consistent with results based on optical and radio measurements but disagree with previous X-ray measurements based on ROSAT and Einstein observations.

Discovery of gamma-ray emission from the shell-type supernova remnant RCW 86 with H.E.S.S., [Hoppe, S.](#); [Lemoine-Goumard, M.](#); [Vink, J.](#), HIGH ENERGY GAMMA-RAY ASTRONOMY: Proceedings of the 4th International Meeting on High Energy Gamma-Ray Astronomy. AIP Conference Proceedings, Volume 1085, pp. 332-335 (2008)

The shell-type supernova remnant (SNR) RCW 86, possibly associated with the historical supernova SN 185, with its relatively large size (about 40' in diameter) and the presence of non-thermal X-rays is a promising target for γ -ray observations. The high sensitivity, good angular resolution of a few arc minutes and the large field-of-view of the High Energy Stereoscopic System (H.E.S.S.) make it ideally suited for the study of the γ -ray morphology of such extended objects. H.E.S.S. observations have indeed led to the discovery of the SNR RCW 86 in very high energy (VHE $E > 100$ GeV) γ -rays. Within 31 hours of observation time, the source is detected with a statistical significance of 8.5 standard deviations and is found significantly more extended than the H.E.S.S. point spread function. Morphological studies have been performed and show that the γ -ray flux does not correlate perfectly with the X-ray emission. The flux from the remnant is $\sim 10\%$ of the flux from the Crab nebula, with a similar photon index of about 2.5. Possible origins of the VHE γ -ray emission, either via Inverse Compton scattering by electrons or the decay of neutral pions produced by proton interactions, are discussed on the basis of spectral features obtained both in the X-ray and VHE γ -ray regimes.

Multiwavelength Signatures of Cosmic Ray Acceleration by Young Supernova Remnants, [Vink, Jacco](#), HIGH ENERGY GAMMA-RAY ASTRONOMY: Proceedings of the 4th International Meeting on High Energy Gamma-Ray Astronomy. AIP Conference Proceedings, Volume 1085, pp. 169-180 (2008).

An overview is given of multiwavelength observations of young supernova remnants, with a focus on the observational signatures of efficient cosmic ray acceleration. Some of the effects that may be attributed to efficient cosmic ray acceleration are the radial magnetic fields in young supernova remnants, magnetic field amplification as determined with X-ray imaging spectroscopy, evidence for large post-shock compression factors, and low plasma temperatures, as measured with high resolution optical/UV/X-ray spectroscopy. Special emphasis is given to spectroscopy of post-shock plasma's, which offers an opportunity to directly measure the post-shock temperature. In the presence of efficient cosmic ray acceleration the post-shock temperatures are expected to be lower than according to standard equations for a strong shock. For a number of supernova remnants this seems indeed to be the case.

Linking ^{44}Ti explosive nucleosynthesis to the dynamics of core-collapse supernovae, [Martin, Pierrick](#); [Vink, Jacco](#), *New Astronomy Reviews*, Volume 52, Issue 7-10, p. 401-404.

We have searched for the three decay lines of the ^{44}Ti in Cassiopeia A with the spectrometer SPI on-board INTEGRAL. The lines at 78.4 and 1157.0 keV have been detected with a flux of $(2.1 \pm 0.7) \times 10^{-5}$ ph cm $^{-2}$ s $^{-1}$, consistent with all previous measurements combined. The spectral capabilities of SPI indicate that the ^{44}Ti ejecta expands at about 430 km s $^{-1}$ and moves away from the observer at about 500 km s $^{-1}$. Such a small expansion velocity together with the ^{44}Ti yield of the event are consistent with a spherical explosion but an asymmetric explosion due for instance to prolate neutrino emission could not be definitely excluded.

Spectral and temporal variations of the isolated neutron star RX J0720.4-3125: new XMM-Newton observations, [Hohle, M. M.](#); [Haberl, F.](#); [Vink, J.](#); [Hambaryan, V.](#); [Turolla, R.](#); [Zane, S.](#); [de Vries, C. P.](#); [Mendez, M.](#), eight pages, submitted to A&A in August 15th, 2008 eleven pages, revised version submitted to A&A in December 15th, accepted by A&A February 14th

In the past, the isolated, radio-quiet neutron star RX J0720.4-3125 showed variations in the spectral parameters (apparent radius, temperature of the emitting area and equivalent width of the absorption feature) seen in the X-ray spectra, not only during the spin period of 8.39s, but also over time scales of years. New X-ray observations of RX J0720.4-3125 with XMM Newton extend the coverage to about 7.5 years with the latest pointing performed in November 2007. Out of a total of fourteen available EPIC-pn datasets, eleven have been obtained with an identical instrumental setup (full frame read-out mode with thin filter), and are best suited for a comparative investigations of the spectral and timing properties of this enigmatic X-ray pulsar. We analysed the new XMM Newton observations together with archival data in order to follow the spectral and temporal evolution of RX J0720.4-3125 All XMM-Newton data were reduced with the standard XMM-SAS software package. A systematic and consistent data reduction of all these observations was emphasised in order to reduce systematic errors as far as possible. We investigate the phase residuals derived from data from different energy bands using different timing solutions for the spin period evolution and confirm the phase lag between hard and soft photons. The phase shift in the X-ray pulses between hard and soft photons varies with time and changes sign around MJD=52800 days, regardless of the chosen timing solution.

On the origin of microturbulence in hot stars, [Cantiello, M.](#); [Langer, N.](#); [Brott, I.](#); [de Koter, A.](#); [Shore, S. N.](#); [Vink, J.](#); [Voegler, A.](#); [Yoon, S. -C.](#), to appear in *Comm. in Astroseismology - Proceedings of the 38th LIAC/HELAS-ESTA/BAG*, 2008

We present results from the first extensive study of convection zones in the envelopes of hot massive stars, which are caused by opacity peaks associated with iron and helium ionization. These convective regions can be located very close to the stellar surface.

Recent observations of microturbulence in massive stars from the VLT-Flames survey are in good agreement with our predictions concerning the occurrence and the strength of sub-surface convection in hot stars. We argue further that convection close to the surface may trigger clumping at the base of the stellar wind of massive stars.

Characterizing the Nonthermal Emission of Cassiopeia A, [Helder, E. A.](#); [Vink, J.](#), The Astrophysical Journal, Volume 686, Issue 2, pp. 1094-1102.

We report on our analysis of the 1 Ms Chandra observation of the supernova remnant Cas A in order to localize, characterize, and quantify the nonthermal X-ray emission. More specifically, we investigated whether the X-ray synchrotron emission from the inside of the remnant is from the outward shock, but projected toward the inner ring, or from the inner shell. We tackled this problem by employing a Lucy-Richardson deconvolution technique and measuring spectral indices in the 4.2-6 keV band. We show that most of the continuum emission is coming from an inner ring that coincides with the previously reported location of the reverse shock. This inner ring also includes filaments whose X-ray emission has been found to be dominated by X-ray synchrotron emission. The X-ray emission from these filaments, both at the forward shock and from the inner ring, have relatively hard spectra with spectral index > -3.1 . The regions emitting hard X-ray continuum contribute about 54% of the total X-ray emission in the 4.2-6 keV. This is lower than that suggested by extrapolating the hard X-ray spectrum as measured by BeppoSAX PDS and INTEGRAL. This can be reconciled by assuming a gradual steepening of the spectrum toward higher energies. We argue that the X-ray synchrotron emission is mainly coming from the western part of the reverse shock. The reverse shock in the west is almost at rest in our observation frame, corresponding to a relatively high reverse shock velocity of $\sim 6000 \text{ km s}^{-1}$ in the frame of the freely expanding ejecta.

XMM-Newton X-ray spectra of the SNR 0509-67.5: data and models, [Kosenko, D.](#); [Vink, J.](#); [Blinnikov, S.](#); [Rasmussen, A.](#), Astronomy and Astrophysics, Volume 490, Issue 1, 2008, pp.223-230

Aims. We report on X-ray observations of the supernova remnant 0509-67.5 in the Large Magellanic Cloud acquired by the XMM-Newton X-ray observatory. We use the imaging spectroscopy (EPIC) and Reflective Grating Spectrometer (RGS) data to investigate properties of the remnant and its environment. **Methods:** The X-ray spectra were analyzed with SPEX software package. In addition, we performed a numerical hydrodynamic simulation of the remnant. **Results:** The EPIC data show prominent Fe K line emission, but the deduced overall amount of iron in the shocked ejecta is low. The data also show that the remnant has an asymmetric ejecta structure: the bright southwest region of the remnant shows an overabundance of metals. The analysis of the RGS spectrum shows that the remnant has a high line velocity broadening of 5000 km s^{-1} . We developed a hydrodynamical model for the remnant with basic hydrodynamical and spectral parameters that are similar to those observed. **Conclusions:** The data analysis indicates that the reverse shock just recently reached iron layers of the ejecta. The

brightness enhancement in the southwest region could be a sign of an asymmetric explosion or it could be the result of a density enhancement in the interstellar medium. We constructed numerical models that are in good agreement with the observations, with circumstellar density of $3 \times 10^{-25} \text{ g/cm}^3$, age of ~ 400 years, velocities of $\sim 5000 \text{ km s}^{-1}$, and an electron-to-ion temperature ratio of 10^{-2} .

The Spektr-RG x-ray calorimeter, [den Herder, J. W.](#); [Kelley, R.](#); [McCammon, D.](#); [Mitsuda, K.](#); [Aarts, H.](#); [van Baren, C.](#); [Buntov, M.](#); [Churazov, E.](#); [Costantini, E.](#); [Cottam, J.](#); [Dubbeldam, L., IV](#); [Ezoe, Y.](#); [Friedrichs, P.](#); [Fujimoto, R.](#); [Gilvanov, M.](#); [Ishisaki, Y.](#); [Kaastra, J.](#); [Kilbourne, C.](#); [Kuntz, K.](#); [Mushotzky, R.](#); [Murakami, M.](#); [Nakagawa, T.](#); [Ohashi, T.](#); [Pavlinisky, M.](#); [Petre, R.](#); [Porter, F. Scott](#); [Predehl, P.](#); [Sato, Y.](#); [Semena, N.](#); [Shinozaki, K.](#); [Smith, R. K.](#); [Snowden, S.](#); [Sunyaev, R.](#); [Sugita, H.](#); [Takei, Y.](#); [Tkachenko, A.](#); [Vink, J.](#); [de Vries, C. P.](#); [White, N.](#); [Yamasaki, N.](#); [Zwart, F.](#), Space Telescopes and Instrumentation 2008: Ultraviolet to Gamma Ray. Edited by Turner, Martin J. L.; Flanagan, Kathryn A. Proceedings of the SPIE, Volume 7011, pp. 70110K-70110K-11 (2008).

Spatially resolved X-ray spectroscopy with high spectral resolution allows the study of astrophysical processes in extended sources with unprecedented sensitivity. This includes the measurement of abundances, temperatures, densities, ionisation stages as well as turbulence and velocity structures in these sources. An X-ray calorimeter is planned for the Russian mission Spektr Röntgen-Gamma (SRG), to be launched in 2011. During the first half year (pointed phase) it will study the dynamics and composition of the hot gas in massive clusters of galaxies and in supernova remnants (SNR). During the survey phase it will produce the first all sky maps of line-rich spectra of the interstellar medium (ISM). Spectral analysis will be feasible for typically every $5^\circ \times 5^\circ$ region on the sky. Considering the very short time-scale for the development of this instrument it consists of a combination of well developed systems. For the optics an extra eROSITA mirror, also part of the Spektr-RG payload, will be used. The detector will be based on spare parts of the detector flown on Suzaku combined with a rebuild of the electronics and the cooler will be based on the design for the Japanese mission NeXT. In this paper we will present the science and give an overview of the instrument.

Non-thermal bremsstrahlung from supernova remnants and the effect of Coulomb losses, [Vink, Jacco](#), Astronomy and Astrophysics, Volume 486, Issue 3, 2008, pp.837-841

Aims. We investigate the shape of the electron cosmic ray spectrum in the range up to $\sim 1000 \text{ keV}$, assuming that the acceleration process at the shock results in a power law in momentum, and that downstream of the shock the spectrum is affected by Coulomb interactions with background electrons only. **Methods:** In the non-relativistic regime one can analytically determine the energy of an electron starting with a certain energy, and use this result to produce an electron cosmic ray spectrum, modified by Coulomb losses. **Results:** An analytic expression for the electron spectrum is obtained that depends on the parameter n_{et} , which can be estimated from a similar parameter used to characterize the

line spectra of supernova remnants. Conclusions: For the brightest supernova remnants $n_{\text{et}} > 10^{11} \text{ cm}^{-3} \text{ s}$, and most of the electrons accelerated to $<100 \text{ keV}$ have lost their energy. Because of its high radio flux, Cas A is the most likely candidate for non-thermal bremsstrahlung. Although it has $n_{\text{et}} \sim 2 \times 10^{11} \text{ cm}^{-3} \text{ s}$, one may expect to pick up non-thermal bremsstrahlung above 100 keV with current hard X-ray detectors.

Detection of hot gas in the filament connecting the clusters of galaxies Abell 222 and Abell 223, [Werner, N.](#); [Finoguenov, A.](#); [Kaastra, J. S.](#); [Simionescu, A.](#); [Dietrich, J. P.](#); [Vink, J.](#); [Böhringer, H.](#), *Astronomy and Astrophysics*, Volume 482, Issue 3, 2008, pp.L29-L33

Context: About half of the baryons in the local Universe are invisible and - according to simulations - their dominant fraction resides in filaments connecting clusters of galaxies in the form of low density gas with temperatures in the range of $10^5 < T < 10^7 \text{ K}$. This warm-hot intergalactic medium has never been detected indisputably using X-ray observations. Aims: We aim to probe the low gas densities expected in the large-scale structure filaments by observing a filament connecting the massive clusters of galaxies A 222 and A 223 ($z = 0.21$), which has a favorable orientation approximately along our line-of-sight. This filament has been previously detected using weak lensing data and as an over-density of colour-selected galaxies. Methods: We analyse X-ray images and spectra obtained from a deep observation (144 ks) of A 222/223 with XMM-Newton. Results: We present observational evidence of X-ray emission from the filament connecting the two clusters. We detect the filament in the wavelet-decomposed soft-band (0.5-2.0 keV) X-ray image with a 5σ significance. Following the emission down to the 3σ significance level, the observed filament is $\approx 1.2 \text{ Mpc}$ wide. The temperature of the gas associated with the filament, determined from the spectra, is $kT = 0.91 \pm 0.25 \text{ keV}$, and its emission measure corresponds to a baryon density of $(3.4 \pm 1.3) \times 10^{-5} (l/15 \text{ Mpc})^{-1/2} \text{ cm}^{-3}$, where l is the length of the filament along the line-of-sight. This density corresponds to a baryon over-density of $\rho / \langle \rho_c \rangle \approx 150$. The properties of the gas in the filament are consistent with results of simulations of the densest and hottest parts of the warm-hot intergalactic medium.

Stellar Evolution, Stellar Structure

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Dynamical mass of a star cluster in M 83: a test of fibre-fed multi-object spectroscopy, [Moll, S. L.](#); [de Grijs, R.](#); [Anders, P.](#); [Crowther, P. A.](#); [Larsen, S. S.](#); [Smith, L. J.](#); [Portegies Zwart, S. F.](#), *Astronomy and Astrophysics*, Volume 490, Issue 1, 2008, pp.125-133

Aims. We obtained VLT/FLAMES+UVES high-resolution, fibre-fed spectroscopy of five young massive clusters (YMCs) in M 83 (NGC 5236). This forms the basis of a pilot study testing the feasibility of using fibre-fed spectroscopy to measure the velocity dispersions of several clusters simultaneously, in order to determine their dynamical masses. In principle, this reduces the telescope time required to obtain a statistically significant sample of dynamical cluster masses. These can be used to assess the long-term survivability of YMCs by comparing their dynamical and photometric masses, which are necessary to ascertain the potential evolution of YMCs into second-generation globular clusters. **Methods:** We adopted two methods for determining the velocity dispersion of the star clusters: cross-correlating the cluster spectrum with the template spectra and minimising a χ^2 value between the cluster spectrum and the broadened template spectra. We also considered both red giant and red supergiant template stars. Cluster 805 in M 83 (following the notation of Larsen) was chosen as a control to test the reliability of the results obtained by this observational method, through a comparison with the results obtained from a standard echelle VLT/UVES spectrum obtained by Larsen & Richtler. **Results:** We find no dependence of the velocity dispersions measured for a cluster on the choice of red giant versus red supergiant templates, nor on the method adopted. However, we do find that the standard deviation of the results obtained with only one method may underestimate the true uncertainty. We measure a velocity dispersion of $\sigma_{\text{los}} = 10.2 \pm 1.1 \text{ km s}^{-1}$ for cluster 805 from our fibre-fed spectroscopy. This is in excellent agreement with the velocity dispersion of $\sigma_{\text{los}} = 10.6 \pm 1.4 \text{ km s}^{-1}$ determined from the standard echelle UVES spectrum of cluster 805. Our FLAMES+UVES velocity dispersion measurement gives $M_{\text{vir}} = (6.6 \pm 1.7) \times 10^5 M_{\odot}$, consistent with previous results. This value of the virial mass is a factor of ~ 3 greater than the cluster's photometric mass, indicating a lack of virial equilibrium. However, based on its effective star formation efficiency, the cluster is likely to virialise, and may survive for a Hubble time, in the absence of external disruptive forces. Unfortunately, our observations of the other M 83 star clusters have insufficient signal-to-noise ratios to determine robust cluster velocity dispersions. **Conclusions:** We find that reliable velocity dispersions can be determined from high-resolution, fibre-fed spectroscopy. The advantages of observing several clusters simultaneously outweighs the difficulty of accurate galaxy background subtraction, providing that the targets are chosen to provide sufficient signal-to-noise ratios, and are much brighter than the galaxy background.

Spectroscopy of globular clusters in the low-luminosity spiral galaxy NGC 45, [Mora, M. D.](#); [Larsen, S. S.](#); [Kissler-Patig, M.](#), *Astronomy and Astrophysics*, Volume 489, Issue 3, 2008, pp.1065-1071

Context: Extragalactic globular clusters have been studied in elliptical galaxies and in a few luminous spiral galaxies, but little is known about globular clusters in low-luminosity spirals. **Aims:** Past observations with the ACS have shown that NGC 45 hosts a large

population of globular clusters (19), as well as several young star clusters. In this work we aim to confirm the bona fide globular cluster status for 8 of 19 globular cluster candidates and to derive metallicities, ages, and velocities. Methods: VLT/FORS2 multislit spectroscopy in combination with the Lick/IDS system was used to derive velocities and to constrain metallicities and $[\alpha/\text{Fe}]$ element ratio of the globular clusters. Results: We confirm the 8 globular clusters as bona fide globular clusters. Their velocities indicate halo or bulge-like kinematics, with little or no overall rotation. From absorption indices such as $\text{H}\beta$, $\text{H}\gamma$, and $\text{H}\delta$ and the combined $[\text{MgFe}]'$ index, we found that the globular clusters are metal-poor $[\text{Z}/\text{H}] \leq -0.33$ dex and $[\alpha/\text{Fe}] \leq 0.0$ element ratio. These results argue in favor of a population of globular clusters formed during the assembling of the galaxy.

Based on data collected at the Cerro Paranal, Chile run by the European Southern Observatory (ESO) under programme ID 077.D-0403(A) and 077.D-0403(B).

ACS imaging of star clusters in M 51. II. The luminosity function and mass function across the disk, [Haas, M. R.](#); [Gieles, M.](#); [Scheepmaker, R. A.](#); [Larsen, S. S.](#); [Lamers, H. J. G. L. M.](#), Astronomy and Astrophysics, Volume 487, Issue 3, 2008, pp.937-949

Context: Whether or not there exists a physical upper mass limit for star clusters is as yet unclear. For small cluster samples the mass function may not be sampled all the way to the truncation, if there is one. Data for the rich cluster population in the interacting galaxy M 51 enables us to investigate this in more detail. Aims: Using HST/ACS data, we investigate whether the cluster luminosity function (LF) in M 51 shows evidence for an upper limit to the mass function. The variations of the cluster luminosity function parameters with position on the disk are addressed. Methods: We determine the cluster LF for all clusters in M 51 falling within our selection criteria, as well as for several subsets of the sample. In that way we can determine the properties of the cluster population as a function of galactocentric distance and background intensity. By comparing observed and simulated LFs we can constrain the underlying cluster initial mass function and/or cluster disruption parameters. A physical upper mass limit for star clusters will appear as a bend dividing two power law parts in the LF, if the cluster sample is large enough to sample the full range of cluster masses. The location of the bend in the LF is indicative of the value of the upper mass limit. The slopes of the power laws are an interplay between upper mass limits, disruption times and evolutionary fading. Results: The LF of the cluster population of M 51 is better described by a double power law than by a single power law. We show that the cluster initial mass function is likely to be truncated at the high mass end. We conclude from the variation of the LF parameters with galactocentric distance that both the upper mass limit and the cluster disruption parameters are likely to be a function of position in the galactic disk. At higher galactocentric distances the maximum mass is lower, cluster disruption slower, or both.

Based on observations made with the NASA/ESA Hubble Space Telescope, obtained from the data archive at the Space Telescope Science Institute. STScI is operated by the

association of Universities for Research in Astronomy, Inc., under the NASA contract NAS 5-26555.

SixPak: a wide-field IFU for the William Herschel Telescope, [Venema, Lars B.](#); [Schoenmaker, Ton](#); [Verheijen, Marc](#); [Trager, Scott](#); [Rutten, René](#); [Bershady, Matthew](#); [Larsen, Søren](#); [Peletier, Reynier](#); [Spaans, Marco](#), Ground-based and Airborne Instrumentation for Astronomy II. Edited by McLean, Ian S.; Casali, Mark M. Proceedings of the SPIE, Volume 7014, pp. 70140L-70140L-9 (2008)

We intend to construct SixPak, a wide-field fibre-based IFU for the 4.2-meter William Herschel Telescope on La Palma. The fibre bundle will consist of 238 fibres, each 3.0 arcsec in diameter, piping light from the Nasmyth focal plane of the WHT to the existing WYFFOS bench spectrograph. A total of 217 fibres will be densely packed to span a hexagonal field of view of 64×55 arcsec. The remaining 21 fibres will collect light from the sky background. SixPak is optimized for 2-dimensional spectroscopy at intermediate resolutions of extended objects of low surface brightness. At Nasmyth focus, a focal reducer matches the f-ratio of the telescope (f/11) to the "optimal" f-ratio of the fibres (f/3) to reduce the losses due to focal ratio degradation in the fibres. Microlenses convert the output f-ratio of the fibres to the f-ratio of the WYFFOS collimator (f/8.2). By means of an exchangeable slit at the pupils of the microlenses, a spectral resolution of $R = 10,000$ can be achieved. The intention is that SixPak will be open for general use in order to allow easy access to the broadest possible astronomical community.

Hawk-I - First Results from Science Verification, [Kissler-Patig, Markus](#); [Fontana, Andrea](#); [Venemans, Bram](#); [Kneib, Jean-Paul](#); [Doherty, Michelle](#); [Lidman, Christopher](#); [Kuntschner, Harald](#); [Norris, Mark](#); [Larsen, Soeren](#); [Gieles, Mark](#); [Mora Fernandes, Alcione](#); [McCaughrean, Mark](#); [Preibisch, Thomas](#); [Seifahrt, Andreas](#); [Willis, Jon](#); [Wehner, Elizabeth](#), The Messenger, vol. 132, p. 7

The VLT wide-field near-infrared imager HAWK-I was commissioned in 2007 and Science Verification (SV) programmes were conducted in August 2007. A selection of results from among the twelve Science Verification proposals are summarised.

Variation of the Cluster Luminosity Function Across the Disk of M51, [Haas, M. R.](#); [Gieles, M.](#); [Scheepmaker, R. A.](#); [Larsen, S. S.](#); [Lamers, H. J. G. L. M.](#); [Bastian, N.](#), Mass Loss from Stars and the Evolution of Stellar Clusters ASP Conference Series, Vol. 388, proceedings of the conference held 29 May - 1 June 2006, in Lunteren, The Netherlands. Edited by Alex de Koter, Linda J. Smith, and Laurens B. F. M. Waters. San Francisco: Astronomical Society of the Pacific, 2008., p.405

We study the luminosity function (LF) of the star clusters in M51. Comparing the observed LF with the LF resulting from artificial cluster populations suggests that there

exists an upper mass limit for clusters and that this limit and/or the cluster disruption varies with galactocentric distance.

Observational Constraints on Cluster Evolution, [Larsen, S. S.](#), Mass Loss from Stars and the Evolution of Stellar Clusters ASP Conference Series, Vol. 388, proceedings of the conference held 29 May - 1 June 2006, in Lunteren, The Netherlands. Edited by Alex de Koter, Linda J. Smith, and Laurens B. F. M. Waters. San Francisco: Astronomical Society of the Pacific, 2008., p.279

Current observational constraints on the dynamical evolution of star clusters are reviewed. Theory and observations now agree nicely on the mass dependency and time scales for disruption of young star clusters in galactic disks, but many problems still await resolution. The origin of the mass function of old globular clusters, and its (near) invariance with respect to host galaxy properties and location within the host galaxy remain prominent puzzles. Most current models fail to reproduce the globular cluster mass function as a result of dynamical evolution from an initial power-law, except under very specific conditions which are not generally consistent with observations. How well do we actually know the proper initial conditions? The cluster initial mass function (CIMF) seems to be consistent with a power-law with exponent $\alpha \approx -2$ in most present-day star forming galaxies, but the limits of the mass range over which this approximation is valid remain poorly constrained both observationally and theoretically. Furthermore, there are hints that some dwarf galaxies may have CIMFs which deviate from a power-law.

Anatomy of a young massive star cluster: NGC 1569-B, [Larsen, S. S.](#); [Origlia, L.](#); [Brodie, J.](#); [Gallagher, J. S.](#), Monthly Notices of the Royal Astronomical Society, Volume 383, Issue 1, pp. 263-276

We present new H-band echelle spectra, obtained with the NIRSPEC spectrograph at Keck II, for the massive star cluster 'B' in the nearby dwarf irregular galaxy NGC 1569. From spectral synthesis and equivalent width measurements, we obtain abundances and abundance patterns. We derive an Fe abundance of $[\text{Fe}/\text{H}] = -0.63 \pm 0.08$, a supersolar $[\alpha/\text{Fe}]$ abundance ratio of $+0.31 \pm 0.09$, and an O abundance of $[\text{O}/\text{H}] = -0.29 \pm 0.07$. We also measure a low $^{12}\text{C}/^{13}\text{C} \sim 5 \pm 1$ isotopic ratio. Using archival imaging from the Advanced Camera for Surveys onboard the Hubble Space Telescope (HST), we construct a colour-magnitude diagram (CMD) for the cluster in which we identify about 60 red supergiant (RSG) stars, consistent with the strong RSG features seen in the H-band spectrum. The mean effective temperature of these RSGs, derived from their observed colours and weighted by their estimated H-band luminosities, is 3790 K, in excellent agreement with our spectroscopic estimate of $T_{\text{eff}} = 3800 \pm 200$ K. From the CMD, we derive an age of 15-25 Myr, slightly older than previous estimates based on integrated broad-band colours. We derive a radial velocity of $\langle v_r \rangle = -78 \pm 3$ km s⁻¹ and a velocity dispersion of 9.6 ± 0.3 km s⁻¹. In combination with an estimate of the half-light radius of 0.20 ± 0.05 arcsec from the HST data, this leads to a dynamical mass of (4.4 ± 1.1)

$\times 10^5 M_{\text{solar}}$. The dynamical mass agrees very well with the mass predicted by simple stellar population models for a cluster of this age and luminosity, assuming a normal stellar initial mass function. The cluster core radius appears smaller at longer wavelengths, as has previously been found in other extragalactic young star clusters.

Based in part on data obtained at the W. M. Keck Observatory, which is operated as a scientific partnership among the California Institute of Technology, the University of California, and the National Aeronautics and Space Administration (NASA). The Observatory was made possible by the generous financial support of the W. M. Keck Foundation. Also based on observations with the NASA/ESA Hubble Space Telescope, obtained from the data archive at the Space Telescope Science Institute (STScI). STScI is operated by the association of Universities for Research in Astronomy, Incorporated, under the NASA contract NAS 5-26555.

A peculiar planetary nebula candidate in a globular cluster in the Fornax dwarf spheroidal galaxy, [Larsen, S. S.](#), Astronomy and Astrophysics, Volume 477, Issue 2, January II 2008, pp.L17-L20

Context: Until now, only one planetary nebula (PN) has been known in the Fornax dwarf spheroidal galaxy. Aims: The discovery of a second PN candidate, associated with one of the 5 globular clusters in the Fornax dwarf, is reported. Methods: Spectra of the globular cluster H5, obtained with the UVES echelle spectrograph on the ESO Very Large Telescope, show [O III] line emission at a radial velocity consistent with membership of the Fornax dwarf. A possible counterpart of the [O III] emission is identified in archival images from the Wide Field Planetary Camera 2 on board the Hubble Space Telescope. The source of the emission is located about 1.5 arcsec (less than one core radius) southwest of the centre of the cluster. Results: The emission line source is identified as a likely PN, albeit with several peculiar properties. No H β , He I, or He II line emission is detected and the [O III]/H β ratio is >25 (2σ). The expansion velocity inferred from the [O III] 5007 Å line is $V_e \approx 55 \text{ km s}^{-1}$, which is large for a PN. The diameter measured on the HST images is about 0.23 arcsec or 0.15 pc at the distance of the Fornax dSph. Conclusions: This object doubles the number of known PNe in Fornax, and is only the 5th PN associated with an old GC for which direct imaging is available. It may be a member of the rare class of extremely H-deficient PNe, the second such case found in a GC.

Based on observations collected at the European Southern Observatory, Chile under programme 078.B-0631(A), and with the NASA/ESA Hubble Space Telescope.

A peculiar object in M 51: fuzzy star cluster or a background galaxy?, [Scheepmaker, R. A.](#); [Lamers, H. J. G. L. M.](#); [Larsen, S. S.](#); [Anders, P.](#), Astronomy and Astrophysics, Volume 477, Issue 1, January I 2008, pp.117-123

Aims. We study a peculiar object with a projected position close to the nucleus of M 51. It is unusually large for a star cluster in M 51 and we therefore investigate the three most likely options to explain this object: (a) a background galaxy, (b) a cluster in the disk of M 51 and (c) a cluster in M 51, but in front of the disk. Methods: We use broad-band images of the Advanced Camera for Surveys and the Near Infrared Camera and Multi-Object Spectrometer, both on board the Hubble Space Telescope, to study the properties of this object. Assuming the object is a star cluster, we fit the metallicity, age, mass and extinction using simple stellar population models. Assuming the object is a background galaxy, we estimate the extinction from the colour of the background around the object. We study the structural parameters of the object by fitting the spatial profile with analytical models. Results: We find de-reddened colours of the object which are bluer than expected for a typical elliptical galaxy, and the central surface brightness is brighter than the typical surface brightness of a disc galaxy. It is therefore not likely that the object is a background galaxy. Assuming the object is a star cluster in the disc of M 51, we estimate an age and mass of $0.7^{+0.1}_{-0.1}$ Gyr and $2.2^{+0.3}_{-0.3} \times 10^5 \sim M_{\odot}$, respectively (with the extinction fixed to $E(B-V)=0.2$). Considering the large size of the object, we argue that in this scenario we observe the cluster just prior to final dissolution. If we fit for the extinction as a free parameter, a younger age is allowed and the object is not close to final dissolution. Alternatively, the object could be a star cluster in M 51, but in front of the disc, with an age of $1.4^{+0.5}_{-0.2}$ Gyr, mass $M = 1.7^{+0.8}_{-0.3} \times 10^5 \sim M_{\odot}$. Its effective radius is between ~ 12 -25 pc. This makes the object a “fuzzy star cluster”, raising the issue of how an object of this age would end up outside the disc.

Based on observations made with the NASA/ESA Hubble Space Telescope, obtained from the data archive at the Space Telescope Institute. STScI is operated by the association of Universities for Research in Astronomy, Inc., under the NASA contract NAS 5-26555.

Photometric evolution of star clusters models, [Kruijssen, J. M. D.](#);
[Lamers, H. J. G. L. M.](#), VizieR On-line Data Catalog: J/A+A/490/151. Originally published in: 2008A&A...490..151K

The SPACE star cluster models contain evolution data for clusters with five different metallicities, two stellar initial mass functions, with/without stellar remnants, with/without the preferential loss of low-mass stars, and three different dissolution timescales. Models for a wider range of parameters and for other observables can be made on request. Please send me an e-mail if you are interested.

The model parameters of each data set are indicated by the filename, KNNNNN_NN.dat, in five directories, Z0004, Z004, Z008, Z02 and Z05.

The first number (0-4) indicates metallicity: 0 = $Z=0.0004$ ($[Fe/H]=-1.7$) 1 = $Z=0.004$ ($[Fe/H]=-0.7$) 2 = $Z=0.008$ ($[Fe/H]=-0.4$) 3 = $Z=0.02$ ($[Fe/H]=0.0$) 4 = $Z=0.05$ ($[Fe/H]=0.4$)

The second number (0-1) indicates IMF: 0 = Salpeter 1 = Kroupa

The third number (0-1) indicates whether stellar remnants are included: 0 = no remnants
1 = including remnants

The fourth number (0-1) indicates whether the preferential loss of low-mass stars is included: 0 = no preferential loss of low-mass stars 1 = including the preferential loss of low-mass stars

The last two numbers (after the underscore) indicate the dissolution timescale t_0 in Myr:
01 = $t_0=1\text{Myr}$ 03 = $t_0=3\text{Myr}$ 10 = $t_0=10\text{Myr}$

For example, file Z02/K3101_10.dat gives cluster evolution for a metallicity $Z=0.02$ ($[\text{Fe}/\text{H}]=0.0$), a Kroupa IMF, no stellar remnants, including the preferential loss of low-mass stars and a dissolution timescale $t_0=10\text{Myr}$.

In the files, columns are plotted for initial cluster masses between 10^2 and $10^7 M_{\{\text{sun}\}}$

The absolute magnitudes of the Sun that have been used to convert luminosities to magnitudes are: $[M\{\text{U,B,V,R,I,J,H,K}\}]=[5.61,5.48,4.83,4.42,4.08,3.64,3.32,3.28]$

The Age Distributions of Clusters and Field Stars in the Small Magellanic Cloud --- Implications for Star Formation Histories, [Kruijssen, J. M. D.](#); [Lamers, H. J. G. L. M.](#), Formation and Evolution of Galaxy Disks ASP Conference Series, Vol. 396, Proceedings of the conference held 1-5 October, 2007 at the Centro Convegno Matteo Ricci, Rome, Italy. Edited by José G. Funes, S.J., and Enrico Maria Corsini. San Francisco: Astronomical Society of the Pacific, 2008., p.149

Differences between the inferred star formation histories (SFHs) of star clusters and field stars seem to suggest distinct star formation processes for the two. The Small Magellanic Cloud (SMC) is an example of a galaxy where such a discrepancy is observed. We model the observed age distributions of the SMC clusters and field stars using a new population synthesis code, SPACE, that includes stellar evolution, infant mortality and cluster dissolution. We find that the two observed age distributions can be explained by a single SFH, thus eliminating the need to assume two separate mechanisms for star formation.

The photometric evolution of star clusters and the preferential loss of low-mass bodies - with an application to globular clusters, [Kruijssen, J. M. D.](#); [Lamers, H. J. G. L. M.](#), Astronomy and Astrophysics, Volume 490, Issue 1, 2008, pp.151-171

Context: To obtain an accurate description of broad-band photometric star cluster evolution, certain effects should be accounted for. Energy equipartition leads to mass segregation and the preferential loss of low-mass stars, while stellar remnants severely influence cluster mass-to-light ratios. Moreover, the stellar initial mass function and cluster metallicity affect photometry as well. Due to the continuous production of stellar

remnants, their impact on cluster photometry is strongest for old systems like globular clusters. This, in combination with their low metallicities, evidence for mass segregation, and a possibly deviating stellar initial mass function, makes globular clusters interesting test cases for cluster models. Aims: In this paper we describe cluster models that include the effects of the preferential loss of low-mass stars, stellar remnants, choice of initial mass function and metallicity. The photometric evolution of clusters is predicted, and the results are applied to Galactic globular clusters. Methods: The cluster models presented in this paper represent an analytical description of the evolution of the underlying stellar mass function due to stellar evolution and dynamical cluster dissolution. Stellar remnants are included by using initial-remnant mass relations, while cluster photometry is computed from the Padova 1999 isochrones. Results: Our study shows that the preferential loss of low-mass stars strongly affects cluster magnitude, colour and mass-to-light ratio evolution, as it increases cluster magnitudes and strongly decreases mass-to-light ratios. The effects of stellar remnants are prominent in the evolution of cluster mass, magnitude and mass-to-light ratio, while variations of the initial mass function induce similar, but smaller changes. Metallicity plays an important role for cluster magnitude, colour and mass-to-light ratio evolution. The different effects can be clearly separated with our models. We apply the models to the Galactic globular cluster population. Its properties like the magnitude, colour and mass-to-light ratio ranges are well reproduced with our models, provided that the preferential loss of low-mass stars and stellar remnants are included. We also show that the mass-to-light ratios of clusters with similar ages and metallicities cannot be assumed to be constant for all cluster luminosities due to the mass-dependence of the half-mass relaxation time. Instead, mass-to-light ratio increases with cluster luminosity and mass. Conclusions: These models underline the importance of more detailed cluster models when considering cluster photometry. By including the preferential loss of low-mass stars and the presence of stellar remnants, the magnitude, colour and mass-to-light ratio ranges of modelled globular clusters are significantly altered. With the analytic framework provided in this paper, observed cluster properties can be interpreted in a more complete perspective.

The models presented in this paper are publicly available in electronic form at the CDS via anonymous ftp to [cdsarc.u-strasbg.fr](ftp://cdsarc.u-strasbg.fr) (130.79.128.5) or via <http://cdsweb.u-strasbg.fr/cgi-bin/qcat?J/A+A/490/151> and also at <http://www.astro.uu.nl/~kruijs>.

Mass Loss and Evolution of Stars and Star Clusters: a Personal Historical Perspective, [Lamers, H. J. G. L. M.](#), Mass Loss from Stars and the Evolution of Stellar Clusters ASP Conference Series, Vol. 388, proceedings of the conference held 29 May - 1 June 2006, in Lunteren, The Netherlands. Edited by Alex de Koter, Linda J. Smith, and Laurens B. F. M. Waters. San Francisco: Astronomical Society of the Pacific, 2008., p.443

The development and progress of the studies of winds and mass loss from hot stars, from about 1965 up to now, is discussed in a personal historical perspective. The present state of knowledge about stellar winds, based on papers presented at this workshop, is described. About ten years ago the mechanisms of the winds were reasonably well understood, the mass loss rates were known, and the predictions of stellar evolution

theory with mass loss agreed with observations. However, recent studies especially those based on FUSE observations, have resulted in a significant reduction of the mass loss rates, that disagrees with predictions from radiation driven wind models. The situation is discussed and future studies that can clarify the situation are suggested. I also discuss what is known about the dissolution of star clusters in different environments. The dissolution time can be derived from the mass and age distributions of cluster samples. The resulting dissolution times of clusters in the solar neighborhood (SN) and in interacting galaxies are shorter than predicted by two-body relaxation of clusters in a tidal field. Encounters with giant molecular clouds can explain the fate of clusters in the SN and are the most likely cause of the short lifetime of clusters in interacting galaxies.

Thousands of Star Clusters in M51 with HST/ACS, [Scheepmaker, R. A.](#); [Gieles, M.](#); [Haas, M. R.](#); [Bastian, N.](#); [Lamers, H. J. G. L. M.](#), Mass Loss from Stars and the Evolution of Stellar Clusters ASP Conference Series, Vol. 388, proceedings of the conference held 29 May - 1 June 2006, in Lunteren, The Netherlands. Edited by Alex de Koter, Linda J. Smith, and Laurens B. F. M. Waters. San Francisco: Astronomical Society of the Pacific, 2008., p.417

We study the entire star cluster population in the disk of M51 by using radius measurements, and we see evidence for a universal preferred radius for both young and old cluster populations and for an increased cluster formation rate at a galactocentric distance of ~ 6 kpc, which is similar to the corotation radius.

Variation of the Cluster Luminosity Function Across the Disk of M51, [Haas, M. R.](#); [Gieles, M.](#); [Scheepmaker, R. A.](#); [Larsen, S. S.](#); [Lamers, H. J. G. L. M.](#); [Bastian, N.](#) Mass Loss from Stars and the Evolution of Stellar Clusters ASP Conference Series, Vol. 388, proceedings of the conference held 29 May - 1 June 2006, in Lunteren, The Netherlands. Edited by Alex de Koter, Linda J. Smith, and Laurens B. F. M. Waters. San Francisco: Astronomical Society of the Pacific, 2008., p.405

We study the luminosity function (LF) of the star clusters in M51. Comparing the observed LF with the LF resulting from artificial cluster populations suggests that there exists an upper mass limit for clusters and that this limit and/or the cluster disruption varies with galactocentric distance.

Star Clusters in the Solar Neighborhood: a Solution to Oort's Problem, [Lamers, H. J. G. L. M.](#); [Gieles, M.](#), Mass Loss from Stars and the Evolution of Stellar Clusters ASP Conference Series, Vol. 388, proceedings of the conference held 29 May - 1 June 2006, in Lunteren, The Netherlands. Edited by Alex de Koter, Linda J. Smith, and

Laurens B. F. M. Waters. San Francisco: Astronomical Society of the Pacific, 2008., p.367

In 1958 Jan Oort remarked that the lack of old clusters in the solar neighborhood (SN) implies that clusters are destroyed on a timescale of less than a Gyr. This is much shorter than the predicted dissolution time of clusters due to stellar evolution and two-body relaxation in the tidal field of the Galaxy. So, other (external) effects must play a dominant role in the destruction of star clusters in the solar neighborhood. We recalculated the survival time of initially bound star clusters in the solar neighborhood taking into account: (1) stellar evolution, (2) tidal stripping, (3) perturbations by spiral arms and (4) encounters with giant molecular clouds (GMCs). We find that encounters with GMCs are the most damaging to clusters. The resulting predicted dissolution time of these combined effects, $t_{\text{dis}} = 1.7 (M_i/10^4 \text{ msun})^{0.67} \text{ Gyr}$ for clusters in the mass range of $10^2 < M_i < 10^5 \text{ msun}$, is very similar to the disruption time of $t_{\text{dis}} = 1.3 \pm 0.5 (M_i/10^4 \text{ msun})^{0.62} \text{ Gyr}$ that was derived empirically from a mass limited sample of clusters in the solar neighborhood within 600 pc. The predicted shape of the age distribution of clusters agrees very well with the observed one. The comparison between observations and theory implies a surface star formation rate (SFR) near the sun of $3.5 \cdot 10^{-10} \text{ msun yr}^{-1} \text{ pc}^{-2}$ for stars in bound clusters with an initial mass in the range of 10^2 to $3 \cdot 10^4 \text{ msun}$. This can be compared to a total SFR of $7 - 10 \times 10^{-10} \text{ msun yr}^{-1} \text{ pc}^{-2}$ derived from embedded clusters or $3 - 7 \cdot 10^{-9} \text{ msun yr}^{-1} \text{ pc}^{-2}$ derived from field stars. This implies an infant mortality rate of clusters in the solar neighborhood between 50% and 95%, in agreement with the results of a study of embedded clusters.

The Impact of Selective Mass Loss on the Age Determination of Star Clusters, [Anders, P.](#); [Lamers, H. J. G. L. M.](#); [de Grijs, R.](#), Mass Loss from Stars and the Evolution of Stellar Clusters ASP Conference Series, Vol. 388, proceedings of the conference held 29 May - 1 June 2006, in Lunteren, The Netherlands. Edited by Alex de Koter, Linda J. Smith, and Laurens B. F. M. Waters. San Francisco: Astronomical Society of the Pacific, 2008., p.345

Dynamical models and observations of star cluster evolution show clear signs of mass segregation (in the sense that high-mass stars tend to be found towards the cluster center, and low-mass stars preferentially occupy the cluster outskirts). The low-mass stars in the cluster outskirts get stripped off more easily by interaction with the gravitational potential of their host galaxy. This alters the stellar mass function within the cluster, therefore changes its spectrophotometry, altering the cluster ages determined when the new spectrophotometry is compared to standard evolutionary synthesis models. These age changes can amount up to a factor of ten (in the most extreme cases).

A Spitzer IRS Survey of Wolf-Rayet Stars at 10--20 Microns, [Ignace, R.](#); [Cassinelli, J. P.](#); [Tracy, G.](#); [Lamers, H. J. G. L. M.](#); [Churchwell, E. B.](#), Mass Loss from

Stars and the Evolution of Stellar Clusters ASP Conference Series, Vol. 388, proceedings of the conference held 29 May - 1 June 2006, in Lunteren, The Netherlands. Edited by Alex de Koter, Linda J. Smith, and Laurens B. F. M. Waters. San Francisco: Astronomical Society of the Pacific, 2008., p.177

We report on a mid-infrared survey of Wolf-Rayet stars using the Spitzer IRS/SH instrument for types WN4-WN7 and WC4-WC7. Strong emission line spectra are seen, including forbidden emission lines. Surprisingly, the WN stars appear to show broad emission "bumps" that may be consistent with silicate dust grains.

Small Magellanic Cloud Be Stars: Color-magnitude Relations and Mass-Loss, [de Wit, W. J.](#); [Lamers, H. J. G. L. M.](#); [Marquette, J. B.](#); [Beaulieu, J. P.](#), Mass Loss from Stars and the Evolution of Stellar Clusters ASP Conference Series, Vol. 388, proceedings of the conference held 29 May - 1 June 2006, in Lunteren, The Netherlands. Edited by Alex de Koter, Linda J. Smith, and Laurens B. F. M. Waters. San Francisco: Astronomical Society of the Pacific, 2008., p.163

We present an analysis of optical lightcurves of Small Magellanic Cloud (SMC) Be-type stars. Observations show that (1) optical excess flux is correlated with near-IR excess flux indicating a similar mechanism and (2) the lightcurves can trace out "loops" in a colour-magnitude diagram. A simple model for the time dependence of bound-free and free-free (bf-ff) emission produced by an outflowing circumstellar disk gives reasonable fits to the observations.

The Early Mass Loss History of the Classical Nova V1974 Cyg 1992, [Cassatella, A.](#); [Lamers, H. J. G. L. M.](#), Mass Loss from Stars and the Evolution of Stellar Clusters ASP Conference Series, Vol. 388, proceedings of the conference held 29 May - 1 June 2006, in Lunteren, The Netherlands. Edited by Alex de Koter, Linda J. Smith, and Laurens B. F. M. Waters. San Francisco: Astronomical Society of the Pacific, 2008., p.153

The wind of the classical nova V1974 Cygni is studied by modeling the observed profiles of the most prominent ultraviolet doublets Mg II, C II, Al III, Si IV and C IV through the Sobolev Exact Integration (SEI) method by Lamers et al. (1997). Examples are shown for the Mg II 2800 Å doublet.

N-body Simulations of Star Clusters, [Anders, Peter](#); [Lamers, Henny J. G. L. M.](#); [Baumgardt, Holger](#), Dynamical Evolution of Dense Stellar Systems, Proceedings of the International Astronomical Union, IAU Symposium, Volume 246, p. 187-188

Two aspects of our recent N-body studies of star clusters are presented: 1) What impact does mass segregation and selective mass loss have on integrated photometry? 2) How

well do results compare from N-body simulations using NBODY4 and STARLAB/KIRA?

Star Cluster Life-times: Dependence on Mass, Radius and Environment,

[Gieles, Mark](#); [Lamers, Henny J. G. L. M.](#); [Baumgardt, Holger](#), Dynamical Evolution of Dense Stellar Systems, Proceedings of the International Astronomical Union, IAU Symposium, Volume 246, p. 171-175

The dissolution time (t_{dis}) of clusters in a tidal field does not scale with the “classical” expression for the relaxation time. First, the scaling with N , and hence cluster mass, is shallower due to the finite escape time of stars. Secondly, the cluster half-mass radius is of little importance. This is due to a balance between the relative tidal field strength and internal relaxation, which have an opposite effect on t_{dis} , but of similar magnitude. When external perturbations, such as encounters with giant molecular clouds (GMC) are important, t_{dis} for an individual cluster depends strongly on radius. The mean dissolution time for a population of clusters, however, scales in the same way with mass as for the tidal field, due to the weak dependence of radius on mass. The environmental parameters that determine t_{dis} are the tidal field strength and the density of molecular gas. We compare the empirically derived t_{dis} of clusters in six galaxies to theoretical predictions and argue that encounters with GMCs are the dominant destruction mechanism. Finally, we discuss a number of pitfalls in the derivations of t_{dis} from observations, such as incompleteness, with the cluster system of the SMC as particular example.

Dynamical mass of a star cluster in M 83: a test of fibre-fed multi-object

spectroscopy, [Moll, S. L.](#); [de Grijs, R.](#); [Anders, P.](#); [Crowther, P. A.](#); [Larsen, S. S.](#); [Smith, L. J.](#); [Portegies Zwart, S. F.](#), Astronomy and Astrophysics, Volume 490, Issue 1, 2008, pp.125-133

Aims. We obtained VLT/FLAMES+UVES high-resolution, fibre-fed spectroscopy of five young massive clusters (YMCs) in M 83 (NGC 5236). This forms the basis of a pilot study testing the feasibility of using fibre-fed spectroscopy to measure the velocity dispersions of several clusters simultaneously, in order to determine their dynamical masses. In principle, this reduces the telescope time required to obtain a statistically significant sample of dynamical cluster masses. These can be used to assess the long-term survivability of YMCs by comparing their dynamical and photometric masses, which are necessary to ascertain the potential evolution of YMCs into second-generation globular clusters. **Methods:** We adopted two methods for determining the velocity dispersion of the star clusters: cross-correlating the cluster spectrum with the template spectra and minimising a χ^2 value between the cluster spectrum and the broadened template spectra. We also considered both red giant and red supergiant template stars. Cluster 805 in M 83 (following the notation of Larsen) was chosen as a control to test the reliability of the results obtained by this observational method, through a comparison with the results obtained from a standard echelle VLT/UVES spectrum obtained by Larsen & Richtler. **Results:** We find no dependence of the velocity dispersions measured for a cluster on the choice of red giant versus red supergiant templates, nor on the method adopted. However, we do find that the standard deviation of the results obtained with only one method may

underestimate the true uncertainty. We measure a velocity dispersion of $\sigma_{\text{los}} = 10.2 \pm 1.1 \text{ km s}^{-1}$ for cluster 805 from our fibre-fed spectroscopy. This is in excellent agreement with the velocity dispersion of $\sigma_{\text{los}} = 10.6 \pm 1.4 \text{ km s}^{-1}$ determined from the standard echelle UVES spectrum of cluster 805. Our FLAMES+UVES velocity dispersion measurement gives $M_{\text{vir}} = (6.6 \pm 1.7) \times 10^5 M_{\odot}$, consistent with previous results. This value of the virial mass is a factor of ~ 3 greater than the cluster's photometric mass, indicating a lack of virial equilibrium. However, based on its effective star formation efficiency, the cluster is likely to virialise, and may survive for a Hubble time, in the absence of external disruptive forces. Unfortunately, our observations of the other M 83 star clusters have insufficient signal-to-noise ratios to determine robust cluster velocity dispersions. Conclusions: We find that reliable velocity dispersions can be determined from high-resolution, fibre-fed spectroscopy. The advantages of observing several clusters simultaneously outweighs the difficulty of accurate galaxy background subtraction, providing that the targets are chosen to provide sufficient signal-to-noise ratios, and are much brighter than the galaxy background.

Nucleosynthesis

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How Efficient is Rotational Mixing in Massive Stars ?, [Brott, I.](#); [Hunter, I.](#); [Anders, P.](#); [Langer, N.](#), FIRST STARS III: First Stars II Conference. AIP Conference Proceedings, Volume 990, pp. 273-275

The VLT-Flames Survey for Massive Stars [1, 2] provides precise measurements of rotational velocities and nitrogen surface abundances of massive stars in the Magellanic Clouds. Specifically, for the first time, such abundances have been estimated for stars with significant rotational velocities. This extraordinary data set gives us the unique possibility to calibrate rotationally and magnetically induced mixing processes. Therefore, we have computed a grid of stellar evolution models varying in mass, initial rotational velocity and chemical composition. In our models we find that although magnetic fields generated by the Spruit-Taylor dynamo are essential to understand the internal angular momentum transport (and hence the rotational behavior), the corresponding chemical mixing must be neglected to reproduce the observations. Further we show that for low metallicities detailed initial abundances are of prime importance, as solar-scaled abundances may result in significant calibration errors.

Star Clusters in the Nearby Late-Type Galaxy NGC 1311, [Eskridge, Paul B.](#); [Grijs, Richard de](#); [Anders, Peter](#); [Windhorst, Rogier A.](#); [Mager, Violet A.](#); [Jansen, Rolf A.](#) The Astronomical Journal, Volume 135, Issue 1, pp. 120-129 (2008).

Ultraviolet, optical and near-infrared images of the nearby ($D \approx 5.5$ Mpc) SBm galaxy NGC 1311, obtained with the Hubble Space Telescope, reveal a small population of 13 candidate star clusters. We identify candidate star clusters based on a combination of their luminosity, extent, and spectral energy distribution. The masses of the cluster candidates range from $\sim 10^3 M_{\text{sun}}$ up to $\sim 10^5 M_{\text{sun}}$, and show a strong positive trend of larger mass with increasing cluster age. Such a trend follows from the fading and dissolution of old, low-mass clusters, and the lack of any young super-star clusters of the sort often formed in strong starbursts. The cluster age distribution is consistent with a bursting mode of cluster formation, with active episodes of age ~ 10 Myr, ~ 100 Myr, and ~ 1 Gyr. The ranges of age and mass we probe are consistent with those of the star clusters found in quiescent Local Group dwarf galaxies.

Based on observations with the NASA/ESA Hubble Space Telescope, obtained at the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, Inc., under NASA contract no. NAS5-26555.

Division IV / Working Group Massive Stars, [Owocki, Stanley P.](#); [Crowther, Paul A.](#); [Fullerton, Alexander W.](#); [Koenigsberger, Gloria](#); [Langer, Norbert](#); [Leitherer, Claus](#); [Massey, Philip L.](#); [Meynet, Georges](#); [Puls, Joachim](#); [St-Louis, Nicole](#), Transactions IAU, Volume 4, Issue 27A, Reports on Astronomy 2006-2009. Edited by Karel van der Hucht. Cambridge: Cambridge University Press, 2008, p. 236-239

Our Working Group studies massive, luminous stars, with historical focus on early-type (OB) stars, but extending in recent years to include massive red supergiants that evolve from hot stars. There is also emphasis on the role of massive stars in other branches of astrophysics, particularly regarding starburst galaxies, the first stars, core-collapse gamma-ray bursts, and formation of massive stars.

Rotational mixing in close binaries, [de Mink, S. E.](#); [Cantiello, M.](#); [Langer, N.](#); [Yoon, S.-Ch.](#); [Brott, I.](#); [Glebbeek, E.](#); [Verkoulen, M.](#); [Pols, O. R.](#), The Art of Modeling Stars in the 21st Century, Proceedings of the International Astronomical Union, IAU Symposium, Volume 252, p. 365-370

Rotational mixing a very important but uncertain process in the evolution of massive stars. We propose to use close binaries to test its efficiency. Based on rotating single stellar models we predict nitrogen surface enhancements for tidally locked binaries. Furthermore we demonstrate the possibility of a new evolutionary scenario for very massive ($M > 40M_{\odot}$) close ($P < 3$ days) binaries: Case M, in which mixing is so efficient that the stars evolve quasi-chemically homogeneously, stay compact and avoid any Roche-lobe overflow, leading to very close (double) WR binaries.

Thermohaline mixing in low-mass giants, [Cantiello, M.](#); [Langer, N.](#), The Art of Modeling Stars in the 21st Century, Proceedings of the International Astronomical Union, IAU Symposium, Volume 252, p. 103-109

Thermohaline mixing has recently been proposed to occur in low mass red giants, with large consequences for the chemical yields of low mass stars. We investigate the role of thermohaline mixing during the evolution of stars between $1 M_{\odot}$ and $3 M_{\odot}$, in comparison to other mixing processes acting in these stars. We confirm that thermohaline mixing has the potential to destroy most of the ${}^3\text{He}$ which is produced earlier on the main sequence during the red giant stage. In our models we find that this process is working only in stars with initial mass $M \lesssim 1.5 M_{\odot}$. Moreover, we report that thermohaline mixing can be present during core helium burning and beyond in stars which still have a ${}^3\text{He}$ reservoir. While rotational and magnetic mixing is negligible compared to the thermohaline mixing in the relevant layers, the interaction of thermohaline motions with differential rotation and magnetic fields may be essential to establish the time scale of thermohaline mixing in red giants.

Multiple ring nebulae around blue supergiants, [Chita, S. M.](#); [Langer, N.](#); [van Marle, A. J.](#); [García-Segura, G.](#); [Heger, A.](#), Astronomy and Astrophysics, Volume 488, Issue 2, 2008, pp.L37-L41

Context: In the course of the life of a massive star, wind-wind interaction can give rise to the formation of circumstellar nebulae which are both predicted and observed in nature. Aims: We present generic model calculations to predict the properties of such nebulae for blue supergiants. Methods: From stellar evolution calculations including rotation, we obtain the time dependence of the stellar wind properties and of the stellar radiation field. These are used as input for hydro-calculations of the circumstellar medium throughout the star's life. Results: Here, we present the results for a rapidly rotating $12 M_{\odot}$ single star. This star forms a blue loop during its post main sequence evolution, at the onset of which its contraction spins it up close to critical rotation. Due to the consequent anisotropic mass loss, the blue supergiant wind sweeps up the preceding slow wind into an hourglass structure. Its collision with the previously formed spherical red supergiant wind shell forms a short-lived luminous nebula consisting of two polar caps and a central inner ring. With time, the polar caps evolve into mid-latitude rings which gradually move toward the equatorial plane while the central ring fades. These structures are reminiscent of the observed nebulae around the blue supergiant Sher 25 and the supernova 1987A. Conclusions: The simple model of an hourglass colliding with a spherical shell reproduces most of the intriguing nebula geometries discovered around blue supergiants, and suggests that they form an evolutionary sequence. Our results indicate that a binary system is not required to obtain them.

Evolution of Progenitor Stars of Type Ibc Supernovae and Long Gamma-Ray Bursts, [Yoon, Sung-Chul](#); [Langer, Norbert](#); [Cantiello, Matteo](#); [Woosley, Stan E.](#); [Glatzmaier, Gary A.](#), Massive Stars as Cosmic Engines, Proceedings of the International Astronomical Union, IAU Symposium, Volume 250, p. 231-236

We discuss how rotation and binary interactions may be related to the diversity of type Ibc supernovae and long gamma-ray bursts. After presenting recent evolutionary models of massive single and binary stars including rotation, the Tayler-Spruit dynamo and binary interactions, we argue that the nature of SNe Ibc progenitors from binary systems may not significantly differ from that of single star progenitors in terms of rotation, and that most long GRB progenitors may be produced via the quasi-chemically homogeneous evolution at sub-solar metallicity. We also briefly discuss the possible role of magnetic fields generated in the convective core of a massive star for the transport of angular momentum, which is potentially important for future stellar evolution models of supernova and GRB progenitors.

Rotation and Massive Close Binary Evolution, [Langer, Norbert](#); [Cantiello, Matteo](#); [Yoon, Sung-Chul](#); [Hunter, Ian](#); [Brott, Ines](#); [Lennon, Danny](#); [de Mink, Selma](#); [Verheijdt, Marcel](#), Massive Stars as Cosmic Engines, Proceedings of the International Astronomical Union, IAU Symposium, Volume 250, p. 167-178

We review the role of rotation in massive close binary systems. Rotation has been advocated as an essential ingredient in massive single star models. However, rotation clearly is most important in massive binaries where one star accretes matter from a close companion, as the resulting spin-up drives the accretor towards critical rotation. Here, we explore our understanding of this process, and its observable consequences. When accounting for these consequences, the question remains whether rotational effects in massive single stars are still needed to explain the observations.

Massive Stars, Supernovae and long GRBs, [Langer, N.](#); [van Marle, A. J.](#); [Poelarends, A. J. T.](#); [Yoon, S.-C.](#), Mass Loss from Stars and the Evolution of Stellar Clusters ASP Conference Series, Vol. 388, proceedings of the conference held 29 May - 1 June 2006, in Lunteren, The Netherlands. Edited by Alex de Koter, Linda J. Smith, and Laurens B. F. M. Waters. San Francisco: Astronomical Society of the Pacific, 2008., p.37

The evolutionary fate of massive stars in our Milky Way is thought to be reasonably well understood: stars above $\sim 8m_{\odot}$ produce neutron stars and supernovae, while those above $\sim 20\text{...}30m_{\odot}$ are presumed to form black holes. At metallicities of the SMC and below, however, our knowledge becomes poor. We show that, possibly, a type of supernova dominates in the metal-poor universe which hardly occurs at solar metallicity, and that stars of only $10m_{\odot}$ initially may form black holes and gamma-ray bursts rather than neutron stars.

Gamma-ray bursts from tidally spun-up Wolf-Rayet stars?, [Detmers, R. G.](#); [Langer, N.](#); [Podsiadlowski, Ph.](#); [Izzard, R. G.](#), Astronomy and Astrophysics, Volume 484, Issue 3, 2008, pp.831-839

Context: The collapsar model requires rapidly rotating Wolf-Rayet stars as progenitors of long gamma-ray bursts. However, Galactic Wolf-Rayet stars rapidly lose angular momentum due to their intense stellar winds. Aims: We investigate whether the tidal

interaction of a Wolf-Rayet star with a compact object in a binary system can spin up the Wolf-Rayet star enough to produce a collapsar. Methods: We compute the evolution of close Wolf-Rayet binaries, including tidal angular momentum exchange, differential rotation of the Wolf-Rayet star, internal magnetic fields, stellar wind mass loss, and mass transfer. The Wolf-Rayet companion is approximated as a point mass. We then employ a population synthesis code to infer the occurrence rates of the various relevant binary evolution channels. Results: We find that the simple scenario - i.e., the Wolf-Rayet star being tidally spun up and producing a collapsar - does not occur at solar metallicity and may only occur with low probability at low metallicity. It is limited by the widening of the binary orbit induced by the strong Wolf-Rayet wind or by the radius evolution of the Wolf-Rayet star that most often leads to a binary merger. The tidal effects enhance the merger rate of Wolf-Rayet stars with black holes such that it becomes comparable to the occurrence rate of long gamma-ray bursts.

White dwarf spins from low-mass stellar evolution models, [Suijs, M. P. L.](#); [Langer, N.](#); [Poelarends, A.-J.](#); [Yoon, S.-C.](#); [Heger, A.](#); [Herwig, F.](#), Astronomy and Astrophysics, Volume 481, Issue 3, 2008, pp.L87-L90

Context: The prediction of the spins of the compact remnants is a fundamental goal of the theory of stellar evolution. Aims: Here, we confront the predictions for white dwarf spins from evolutionary models, including rotation with observational constraints. Methods: We perform stellar evolution calculations for stars in the mass range $1 \dots 3 \{M\}_{\odot}$, including the physics of rotation, from the zero age main sequence into the TP-AGB stage. We calculate two sets of model sequences, with and without inclusion of magnetic fields. From the final computed models of each sequence, we deduce the angular momenta and rotational velocities of the emerging white dwarfs. Results: While models including magnetic torques predict white dwarf rotational velocities between 2 and 10 km s⁻¹, those from the nonmagnetic sequences are found to be one to two orders of magnitude larger, well above empirical upper limits. Conclusions: We find the situation analogous to that in the neutron star progenitor mass range, and conclude that magnetic torques may be required to understand the slow rotation of compact stellar remnants in general.

The VLT-FLAMES Survey of Massive Stars, [Evans, Chris](#); [Hunter, Ian](#); [Smartt, Stephen](#); [Lennon, Danny](#); [de Koter, Alex](#); [Mokiem, Rohied](#); [Trundle, Carrie](#); [Dufton, Philip](#); [Ryans, Robert](#); [Puls, Joachim](#); [Vink, Jorick](#); [Herrero, Artemio](#); [Simón-Díaz, Sergio](#); [Langer, Norbert](#); [Brott, Ines](#), The Messenger, vol. 131, p. 25

The VLT-FLAMES Survey of Massive Stars was an ESO Large Programme to understand rotational mixing and stellar mass loss in different metallicity environments, in order to better constrain massive star evolution. We gathered high-quality spectra of over 800 stars in the Galaxy and in the Magellanic Clouds. A sample of this size is unprecedented, enabled by the first high-resolution, wide-field, multi-object spectrograph on an 8-m telescope. We developed spectral analysis techniques that, in combination with non-LTE, line-blanketed model atmospheres, were used to quantitatively characterise every star. The large sample, combined with the theoretical developments, has produced exciting new insights into the evolution of the most massive stars.

The VLT FLAMES Survey of Massive Stars: Rotation and Nitrogen Enrichment as the Key to Understanding Massive Star Evolution, [Hunter, I.](#); [Brott, I.](#); [Lennon, D. J.](#); [Langer, N.](#); [Dufton, P. L.](#); [Trundle, C.](#); [Smartt, S. J.](#); [de Koter, A.](#); [Evans, C. J.](#); [Ryans, R. S. I.](#), *The Astrophysical Journal*, Volume 676, Issue 1, pp. L29-L32

Rotation has become an important element in evolutionary models of massive stars, specifically via the prediction of rotational mixing. Here we study a sample of stars, including rapid rotators, to constrain such models and use nitrogen enrichments as a probe of the mixing process. Chemical compositions (C, N, O, Mg, and Si) have been estimated for 135 early B-type stars in the Large Magellanic Cloud with projected rotational velocities up to $\sim 300 \text{ km s}^{-1}$ using a non-LTE TLUSTY model atmosphere grid. Evolutionary models, including rotational mixing, have been generated attempting to reproduce these observations by adjusting the overshooting and rotational mixing parameters and produce reasonable agreement with 60% of our core hydrogen burning sample. We find (excluding known binaries) a significant population of highly nitrogen-enriched intrinsic slow rotators ($v \sin i < \sim 50 \text{ km s}^{-1}$) incompatible with our models ($\sim 20\%$ of the sample). Furthermore, while we find fast rotators with enrichments in agreement with the models, the observation of evolved ($\log g < 3.7 \text{ dex}$) fast rotators that are relatively unenriched (a further $\sim 20\%$ of the sample) challenges the concept of rotational mixing. We also find that 70% of our blue supergiant sample cannot have evolved directly from the hydrogen-burning main sequence. We are left with a picture where invoking binarity and perhaps fossil magnetic fields is required to understand the surface properties of a population of massive main-sequence stars.

The Supernova Channel of Super-AGB Stars, [Poelarends, A. J. T.](#); [Herwig, F.](#); [Langer, N.](#); [Heger, A.](#), *The Astrophysical Journal*, Volume 675, Issue 1, pp. 614-625

We study the late evolution of solar metallicity stars in the transition region between white dwarf formation and core collapse. This includes the super-asymptotic giant branch (super-AGB, SAGB) stars, which ignite carbon burning and form an oxygen-neon (ONe) core. SAGB star cores may grow to the Chandrasekhar mass because of continued H- and He-shell burning, ending as core-collapse supernovae. From stellar evolution models we find that the initial mass range for SAGB evolution is $7.5\text{-}9.25 M_{\text{Solar}}$. We perform calculations with three different stellar evolution codes to judge the robustness of our results. The mass range significantly depends on the treatment of semiconvective mixing and convective overshooting. To consider the effect of a large number of thermal pulses, as expected in SAGB stars, we construct synthetic SAGB models that are calibrated through stellar evolution simulations. The synthetic model enables us to compute the evolution of the main properties of SAGB stars from the onset of thermal pulses until the core reaches the Chandrasekhar mass or is uncovered by the stellar wind. Thereby, we differentiate the stellar initial mass ranges that produce ONe WDs from that leading to electron-capture SNe. The latter is found to be $9.0\text{-}9.25 M_{\text{Solar}}$ for our fiducial model, implying that electron-capture SNe would constitute about 4% of all SNe in the local universe. The error in this determination due to uncertainties in the third dredge-up efficiency and AGB mass-loss rate could lead to about a doubling of the number of

electron-capture SNe, which provides a firm upper limit to their contribution to all supernovae of ~20%.

How Efficient is Rotational Mixing in Massive Stars ?, [Brott, I.](#); [Hunter, I.](#); [Anders, P.](#); [Langer, N.](#), FIRST STARS III: First Stars II Conference. AIP Conference Proceedings, Volume 990, pp. 273-275

The VLT-Flames Survey for Massive Stars [1, 2] provides precise measurements of rotational velocities and nitrogen surface abundances of massive stars in the Magellanic Clouds. Specifically, for the first time, such abundances have been estimated for stars with significant rotational velocities. This extraordinary data set gives us the unique possibility to calibrate rotationally and magnetically induced mixing processes. Therefore, we have computed a grid of stellar evolution models varying in mass, initial rotational velocity and chemical composition. In our models we find that although magnetic fields generated by the Spruit-Taylor dynamo are essential to understand the internal angular momentum transport (and hence the rotational behavior), the corresponding chemical mixing must be neglected to reproduce the observations. Further we show that for low metallicities detailed initial abundances are of prime importance, as solar-scaled abundances may result in significant calibration errors.

Evolution of Massive Stars at Very Low Metallicity, Including Rotation and Binary Interactions, [Yoon, S.-C.](#); [Cantiello, M.](#); [Langer, N.](#), FIRST STARS III: First Stars II Conference. AIP Conference Proceedings, Volume 990, pp. 225-229 (2008).

We discuss recent models of the evolution of massive stars at very low metallicity, including the effects of rotation, magnetic fields and binarity. Very metal poor stars lose very little mass and angular momentum during their main sequence evolution, and rotation plays a dominant role in their evolution. In rapidly rotating massive stars, the rotationally induced mixing time scale can be even shorter than the nuclear time scale throughout the main sequence. The consequent quasi-chemically homogeneous evolution greatly differs from the standard massive star evolution that leads to formation of red giants with strong chemical stratification. Interesting outcomes of such a new mode of evolution include the formation of rapidly rotating massive Wolf-Rayet stars that emit large amounts of ionizing photons, the formation of long gamma-ray bursts and hypernovae, and the production of large amounts of primary nitrogen. We show that binary interactions can further enhance the effects of rotation, as mass accretion in a close binary spins up the secondary.

The circumstellar medium around a rapidly rotating, chemically homogeneously evolving, possible gamma-ray burst progenitor, [van Marle, A. J.](#); [Langer, N.](#); [Yoon, S.-C.](#); [García-Segura, G.](#), Astronomy and Astrophysics, Volume 478, Issue 3, February II 2008, pp.769-778

Context: Rapidly rotating, chemically homogeneously evolving massive stars are considered to be progenitors of long gamma-ray bursts. Aims: We present numerical simulations of the evolution of the circumstellar medium around a rapidly rotating 20

$\{M\}_\odot$ star at a metallicity of $Z = 0.001$. Its rotation is fast enough to produce quasi-chemically homogeneous evolution. While conventionally, a star of $20 \{M\}_\odot$ would not evolve into a Wolf-Rayet stage, the considered model evolves from the main sequence directly to the helium main sequence. Methods: We use the time-dependent wind parameters, such as mass loss rate, wind velocity and rotation-induced wind anisotropy from the evolution model as input for a 2D hydrodynamical simulation. Results: While the outer edge of the pressure-driven circumstellar bubble is spherical, the circumstellar medium close to the star shows strong non-spherical features during and after the periods of near-critical rotation. Conclusions: We conclude that the circumstellar medium around rapidly rotating massive stars differs considerably from the surrounding material of non-rotating stars of similar mass. Multiple blue-shifted high velocity absorption components in gamma-ray burst afterglow spectra are predicted. As a consequence of near critical rotation and short stellar evolution time scales during the last few thousand years of the star's life, we find a strong deviation of the circumstellar density profile in the polar direction from the $1/R^2$ density profile normally associated with stellar winds close to the star.

Optical SBFs of shell galaxies, [Biscardi, I.](#); [Raimondo, G.](#); [Cantiello, M.](#); [Brocato, E.](#), 2008arXiv0812.2346B

We measure F814W Surface Brightness Fluctuations (SBFs) for a sample of distant shell galaxies observed with the Advanced Camera for Survey (ACS) on board of HST. To evaluate the distance at galaxies, theoretical SBF magnitudes for the ACS@HST filters are computed for single burst stellar populations covering a wide range of ages ($t=1.5-14$ Gyr) and metallicities ($Z=0.008-0.04$). Using these stellar population models we provide the first $M_{\text{SBF},F814W}$ versus $(F475W-F814W)_0$ calibration. The results suggest that optical SBFs can be measured at $d > 100$ Mpc using high resolution spatial optical data.

Modelling the evolution and nucleosynthesis of carbon-enhanced metal-poor stars, [Pols, O. R.](#); [Izzard, R. G.](#); [Lugaro, M.](#); [de Mink, S. E.](#), The Art of Modeling Stars in the 21st Century, Proceedings of the International Astronomical Union, IAU Symposium, Volume 252, p. 383-389

We present the results of binary population simulations of carbon-enhanced metal-poor (CEMP) stars. We show that nitrogen and fluorine are useful tracers of the origin of CEMP stars, and conclude that the observed paucity of very nitrogen-rich stars puts strong constraints on possible modifications of the initial mass function at low metallicity. The large number fraction of CEMP stars may instead require much more efficient dredge-up from low-metallicity asymptotic giant branch stars.

Evolution of stellar collision products in open clusters. II. A grid of low-mass collisions, [Glebbeek, E.](#); [Pols, O. R.](#), Astronomy and Astrophysics, Volume 488, Issue 3, 2008, pp.1017-1025

In a companion paper we studied the detailed evolution of stellar collision products that occurred in an N-body simulation of the old open cluster M 67 and compared our detailed models to simple prescriptions. In this paper we extend this work by studying the

evolution of the collision products in open clusters as a function of mass and age of the progenitor stars. We calculated a grid of head-on collisions covering the section of parameter space relevant for collisions in open clusters. We create detailed models of the merger remnants using an entropy-sorting algorithm and follow their subsequent evolution during the initial contraction phase, through the main sequence and up to the giant branch with our detailed stellar evolution code. We compare the location of our models in a colour-magnitude diagram to the observed blue straggler population of the old open clusters M 67 and NGC 188 and find that they cover the observed blue straggler region of both clusters. For M 67, collisions need to have taken place recently. Differences between the evolution tracks of the collision products and normal main sequence stars can be understood quantitatively using a simple analytic model. We present an analytic recipe that can be used in an N-body code to transform a precomputed evolution track for a normal star into an evolution track for a collision product.

Evolution of stellar collision products in open clusters. I. Blue stragglers in N-body models of M 67, [Glebbeek, E.](#); [Pols, O. R.](#); [Hurley, J. R.](#), Astronomy and Astrophysics, Volume 488, Issue 3, 2008, pp.1007-1015

Stellar collisions are an important formation channel for blue straggler stars in globular and old open clusters. Hydrodynamical simulations have shown that the remnants of such collisions are out of thermal equilibrium, are not strongly mixed and can rotate very rapidly. Detailed evolution models of collision products are needed to interpret observed blue straggler populations and to use them to probe the dynamical history of a star cluster. We expand on previous studies by presenting an efficient procedure to import the results of detailed collision simulations into a fully implicit stellar evolution code. Our code is able to evolve stellar collision products in a fairly robust manner and allows for a systematic study of their evolution. Using our code we have constructed detailed models of the collisional blue stragglers produced in the N-body simulation of M 67 performed by Hurley et al. in 2005. We assume the collisions are head-on and thus ignore the effects of rotation in this paper. Our detailed models are more luminous than normal stars of the same mass and in the same stage of evolution, but cooler than homogeneously mixed versions of the collision products. The increased luminosity and inefficient mixing decrease the remaining main-sequence lifetimes of the collision products, which are much shorter than predicted by the simple prescription commonly used in N-body simulations.

Fluorine in carbon-enhanced metal-poor stars: a binary scenario, [Lugaro, M.](#); [de Mink, S. E.](#); [Izzard, R. G.](#); [Campbell, S. W.](#); [Karakas, A. I.](#); [Cristallo, S.](#); [Pols, O. R.](#); [Lattanzio, J. C.](#); [Straniero, O.](#); [Gallino, R.](#); [Beers, T. C.](#), Astronomy and Astrophysics, Volume 484, Issue 3, 2008, pp.L27-L30

Aims. A super-solar fluorine abundance was observed in the carbon-enhanced metal-poor (CEMP) star HE 1305+0132 ($[F/Fe] = +2.90$, $[Fe/H] = -2.5$). We propose that this observation can be explained using a binary model that involve mass transfer from an asymptotic giant branch (AGB) star companion and, based on this model, we predict F

abundances in CEMP stars in general. We discuss whether F can be used to discriminate between the formation histories of most CEMP stars: via binary mass transfer or from the ejecta of fast-rotating massive stars. Methods: We compute AGB yields using different stellar evolution and nucleosynthesis codes to evaluate stellar model uncertainties. We use a simple dilution model to determine the factor by which the AGB yields should be diluted to match the abundances observed in HE 1305+0132. We further employ a binary population synthesis tool to estimate the probability of F-rich CEMP stars. Results: The abundances observed in HE 1305+0132 can be explained if this star accreted 3-11% of the mass lost by its former AGB companion. The primary AGB star should have dredged-up at least $0.2 \{M\}_{\odot}$ of material from its He-rich region into the convective envelope via third dredge-up, which corresponds to AGB models of $Z \simeq 0.0001$ and mass $\simeq 2 \{M\}_{\odot}$. Many AGB model uncertainties, such as the treatment of convective borders and mass loss, require further investigation. We find that in the binary scenario most CEMP stars should also be FEMP stars, that is, have $[F/Fe] > +1$, while fast-rotating massive stars do not appear to produce fluorine. We conclude that fluorine is a signature of low-mass AGB pollution in CEMP stars, together with elements associated with the slow neutron-capture process.

Building Blue Stragglers with Stellar Collisions, [Glebbeek, Evert](#); [Pols, Onno R.](#), Dynamical Evolution of Dense Stellar Systems, Proceedings of the International Astronomical Union, IAU Symposium, Volume 246, p. 363-364

The evolution of stellar collision products in cluster simulations has usually been modelled using simplified prescriptions. Such prescriptions either replace the collision product with an (evolved) main sequence star, or assume that the collision product was completely mixed during the collision.

It is known from hydrodynamical simulations of stellar collisions that collision products are not completely mixed, however. We have calculated the evolution of stellar collision products and find that they are brighter than normal main sequence stars of the same mass, but not as blue as models that assume that the collision product was fully mixed during the collision.

Binaries at Low Metallicity: Ranges For Case A, B and C Mass Transfer, [de Mink, S. E.](#); [Pols, O. R.](#); [Yoon, S.-C.](#), FIRST STARS III: First Stars II Conference. AIP Conference Proceedings, Volume 990, pp. 230-232 (2008)

The evolution of single stars at low metallicity has attracted great interest, while the effect of metallicity on binary evolution remains still relatively unexplored. We study the effect of metallicity on the number of binary systems that undergo different cases of mass transfer.

We find that binaries at low metallicity are more likely to start transferring mass after the onset of central helium burning, often referred to as case C mass transfer. In other words, the donor star in a metal poor binary is more likely to have formed a massive CO core before the onset of mass transfer. At solar metallicity, the range of initial binary

separations that result in case C evolution is very small for massive stars, because they do not expand much after the ignition of helium and because mass loss from the system by stellar winds causes the orbit to widen, preventing the primary star to fill its Roche lobe.

This effect is likely to have important consequences for the metallicity dependence of the formation rate of various objects through binary evolution channels, such as long GRBs, double neutron stars and double white dwarfs.

Can Low-Metallicity Binaries Avoid Merging?, [de Mink, S. E.](#); [Cottaar, M.](#); [Pols, O. R.](#), FIRST STARS III: First Stars II Conference. AIP Conference Proceedings, Volume 990, pp. 217-219 (2008).

Rapid mass transfer in a binary system can drive the accreting star out of thermal equilibrium, causing it to expand. This can lead to a contact system, strong mass loss from the system and possibly merging of the two stars. In low metallicity stars the timescale for heat transport is shorter due to the lower opacity. The accreting star can therefore restore thermal equilibrium more quickly and possibly avoid contact.

We investigate the effect of accretion onto main sequence stars with radiative envelopes with different metallicities. We find that a low metallicity ($Z < 10^{-3}$) $4M_{\text{solar}}$ star can endure a 10 to 30 times higher accretion rate before it reaches a certain radius than a star at solar metallicity. This could imply that up to two times fewer systems come into contact during rapid mass transfer when we compare low metallicity. This factor is uncertain due to the unknown distribution of binary parameters and the dependence of the mass transfer timescale on metallicity. In a forthcoming paper we will present analytic fits to models of accreting stars at various metallicities intended for the use in population synthesis models.

Orbital eccentricities of binary systems with a former AGB star, [Bonačić Marinović, A. A.](#); [Glebbeek, E.](#); [Pols, O. R.](#), Astronomy and Astrophysics, Volume 480, Issue 3, 2008, pp.797-805

Context: Many binary stellar systems in which the primary star is beyond the asymptotic giant branch (AGB) evolutionary phase show significant orbital eccentricities, whereas current binary interaction models predict that their orbits are circularised. Aims: In the search for a mechanism to counteract the circularising effect of tidal interaction, we analyse how the orbital parameters in a system are modified under mass loss and mass exchange among its binary components. Methods: We propose a model for enhanced mass loss from the AGB star due to tidal interaction with its companion, which allows a smooth transition between the wind and Roche-lobe overflow mass loss regimes. We explicitly follow its effect along the orbit on the change in eccentricity and orbital semi-major axis, as well as the effect of accretion by the companion. We calculate timescales for the variation in these orbital parameters and compare them to the tidal circularisation timescale. Results: We find that in many cases, due to the enhanced mass loss of the AGB component at orbital phases closer to the periastron, the net eccentricity growth rate in one orbit is comparable to the rate of tidal circularisation. We show that with this

eccentricity-enhancing mechanism it is possible to reproduce the orbital period and eccentricity of the Sirius system, which is expected to be circularised under the standard assumptions of binary interaction. We also show that this mechanism may provide an explanation for the eccentricities of most barium star systems, which are expected to be circularised due to tidal dissipation. Conclusions: By proposing a tidally enhanced model of mass loss from AGB stars, we find a mechanism that efficiently works against the tidal circularisation of the orbit. This mechanism can explain the significant eccentricities observed in binary systems containing a white dwarf and a less evolved companion, which are predicted to be circularised due to their proximity, such as Sirius and systems with barium stars.

Thermohaline mixing and gravitational settling in carbon-enhanced metal-poor stars, [Stancliffe, Richard J.](#); [Glebbeek, Evert](#), Monthly Notices of the Royal Astronomical Society, Volume 389, Issue 4, pp. 1828-1838

We investigate the formation of carbon-enhanced metal-poor (CEMP) stars via the scenario of mass transfer from a carbon-rich asymptotic giant branch primary to a low-mass companion in a binary system. We explore the extent to which material accreted from a companion star mixes with that of the recipient, focusing on the effects of thermohaline mixing and gravitational settling. We have created a new set of asymptotic giant branch models to determine what the composition of material being accreted in these systems will be. We then model a range of CEMP systems by evolving a grid of models of low-mass stars, varying the amount of material accreted by the star (to mimic systems with different separations), and also the composition of the accreted material (to mimic accretion from primaries of different mass). We find that with thermohaline mixing alone, the accreted material can mix with 16-88 per cent of the pristine stellar material of the accretor, depending on the mass accreted and the composition of the material. If we include the effects of gravitational settling, we find that thermohaline mixing can be inhibited and, in the case that only a small quantity of material is accreted, can be suppressed almost completely.

The Effect of Massive Binaries on Stellar Populations and Supernova Progenitors, [Eldridge, John J.](#); [Izzard, Robert G.](#); [Tout, Christopher A.](#), Massive Stars as Cosmic Engines, Proceedings of the International Astronomical Union, IAU Symposium, Volume 250, p. 179-184

We have calculated a large set of detailed binary models and used them to test the observed stellar population ratios that compare the relative populations of blue supergiants, red supergiants and Wolf-Rayet stars at different metallicities. We have also used our models to estimate the relative rate of type Ib/c to type II supernovae. We find, with an interacting binary fraction of about two thirds, that we obtain better agreement between our models and observations than with single stars. We discuss the use of models in determining the nature of supernova progenitors and show the surprising result that many type Ib/c supernova progenitors are less luminous and less massive in our models than the observed population of Wolf-Rayet stars.

The Mysterious R Stars, [Izzard, Robert G.](#); [Simon Jeffery, C.](#); [Lattanzio, John](#), IXTH TORINO WORKSHOP ON EVOLUTION AND NUCLEOSYNTHESIS IN AGB STARS AND THE IIND PERUGIA WORKSHOP ON NUCLEAR ASTROPHYSICS. AIP Conference Proceedings, Volume 1001, pp. 33-37 (2008).

The R stars are a rare class of K-type giant carbon stars. Canonical stellar evolutionary theory cannot explain their existence, yet they have been observed for more than a century. The early-R stars, the warmest in the R class, are enhanced in ^{12}C , ^{13}C and ^{14}N relative to the Sun, but not in s-processes elements or oxygen, and are all single stars. We test the idea that binary mergers lead to the formation of the early-R stars by a comparison of binary population synthesis model results with observations.

The effect of massive binaries on stellar populations and supernova progenitors, [Eldridge, John J.](#); [Izzard, Robert G.](#); [Tout, Christopher A.](#), Monthly Notices of the Royal Astronomical Society, Volume 384, Issue 3, pp. 1109-1118

We compare our latest single and binary stellar model results from the Cambridge STARS code to several sets of observations. We examine four stellar population ratios: the number of blue to red supergiants, the number of Wolf-Rayet stars to O supergiants, the number of red supergiants to Wolf-Rayet stars and the relative number of Wolf-Rayet subtypes, WC to WN stars. These four ratios provide a quantitative measure of nuclear burning lifetimes and the importance of mass loss during various stages of the stars' lifetimes. In addition, we compare our models to the relative rate of Type Ib/c to Type II supernovae to measure the amount of mass lost over the entire lives of all stars. We find reasonable agreement between the observationally inferred values and our predicted values by mixing single and binary star populations. However, there is evidence that extra mass loss is required to improve the agreement further, to reduce the number of red supergiants and increase the number of Wolf-Rayet stars.

The Role of Massive Agb Stars in the Early Solar System Composition, [Trigo-Rodriguez, Josep M.](#); [Anibal Garcia-Hernandez, Domingo](#); [Lugaro, Maria](#); [Karakas, Amanda I.](#); [van Raai, M.](#); [Garcia Lario, Pedro](#); [Manchado, Arturo](#),

We demonstrate that a massive asymptotic giant branch (AGB) star is a good candidate as the main source of short-lived radionuclides in the early solar system. Recent identification of massive (4-8 solar masses) AGB stars in the Galaxy, which are both lithium- and rubidium-rich, demonstrates that these stars experience proton captures at the base of the convective envelope (hot bottom burning), together with high-neutron density nucleosynthesis with ^{22}Ne as a neutron source in the He shell and efficient dredge-up of the processed material. A model of a 6.5 solar masses star of solar metallicity can simultaneously match the abundances of ^{26}Al , ^{41}Ca , ^{60}Fe , and ^{107}Pd inferred to have been present in the solar nebula by using a dilution factor of 1 part of AGB material per 300 parts of original solar nebula material, and taking into account a time interval between injection of the short-lived nuclides and consolidation of the first meteorites equal to 0.53 Myr. Such a polluting source does not overproduce ^{53}Mn , as supernova models do, and only marginally affects isotopic ratios of stable elements. It is

usually argued that it is unlikely that the short-lived radionuclides in the early solar system came from an AGB star because these stars are rarely found in star forming regions, however, we think that further interdisciplinary studies are needed to address the fundamental problem of the birth of our solar system.

The impact of the $^{18}\text{F}(\text{a,p})^{21}\text{Ne}$ reaction on fluorine production in AGB stars, [Karakas, Amanda I.](#); [Lee, Hye Young](#); [Lugaro, Maria](#); [Goerres, J.](#); [Wiescher, Michael](#),

The recent experimental evaluation of the $^{18}\text{F}(\text{a,p})^{21}\text{Ne}$ reaction rate, when considering its associated uncertainties, presented significant differences compared to the theoretical Hauser-Feshbach rate. This was most apparent at the low temperatures relevant for He-shell burning in asymptotic giant branch (AGB) stars. Investigations into the effect on AGB nucleosynthesis revealed that the upper limit resulted in an enhanced production of ^{19}F and ^{21}Ne in carbon-rich AGB models, but the recommended and lower limits presented no differences from using the theoretical rate. This was the case for models spanning a range in metallicity from solar to $[\text{Fe}/\text{H}] \sim -2.3$. The results of this study are relevant for observations of F and C-enriched AGB stars in the Galaxy, and to the Ne composition of mainstream silicon carbide grains, that supposedly formed in the outflows of cool, carbon-rich giant stars. We discuss the mechanism that produces the extra F and summarize our main findings.

^{26}Al and ^{60}Fe yields from AGB stars, [Lugaro, Maria](#); [Karakas, Amanda I.](#), New Astronomy Reviews, Volume 52, Issue 7-10, p. 416-418

We present yields for ^{26}Al and ^{60}Fe from asymptotic giant branch (AGB) stars. For AGB stars of masses lower than $\approx 4 M_{\odot}$ yields are of the order of only $10^{-7} M_{\odot}$, while for AGB stars of higher masses yields are up to $10^{-5} M_{\odot}$. In these massive AGB stars ^{26}Al is produced via $^{25}\text{Mg}(\text{p}, \gamma)^{26}\text{Al}$ reactions when proton captures occur at the base of the convective envelope (hot bottom burning), while ^{60}Fe is produced via the operation of the $^{59}\text{Fe}(\text{n}, \gamma)^{60}\text{Fe}$ reaction when high neutron densities result from the activation of the $^{22}\text{Ne}(\alpha, \text{n})^{25}\text{Mg}$ neutron source during thermal pulses. Large nuclear and stellar uncertainties are associated with these predictions, ranging from the rate of the $^{26}\text{Al} + \text{p}$ reaction to the amount of material carried from the He-rich shell to the convective envelope via the third dredge-up. When compared to the contribution from core-collapse supernovae, the overall contribution of AGB stars to the Galactic inventory of ^{26}Al and ^{60}Fe is insignificant. On the other hand, a massive AGB star may have polluted the early solar system with short lived radioactive nuclei since we obtain a self-consistent match for the abundances of ^{41}Ca , ^{26}Al , ^{60}Fe , and ^{107}Pd using our $6.5 M_{\odot}$ model. Finally, the interpretation of the $^{26}\text{Al}/^{27}\text{Al}$ ratios in the majority of meteoritic stellar grains from low-mass AGB stars is hindered by the three orders of magnitude error bar of the $^{26}\text{Al}(\text{p}, \gamma)^{27}\text{Si}$ reaction. Grains with very high $^{26}\text{Al}/^{27}\text{Al}$ ratios may represent evidence for extra-mixing phenomena in AGB stars or for a post-AGB origin.

New reaction rate for $\text{O}^{16}(\text{p},\gamma)\text{F}^{17}$ and its influence on the oxygen isotopic ratios in massive AGB stars, [Iliadis, C.](#); [Angulo, C.](#); [Descouvemont, P.](#); [Lugaro, M.](#); [Mohr, P.](#), Physical Review C, vol. 77, Issue 4, id. 045802

The $O16(p,\gamma)F17$ reaction rate is revisited with special emphasis on the stellar temperature range of $T=60-100$ MK, important for hot bottom burning in asymptotic giant branch (AGB) stars. We evaluate existing cross-section data that were obtained since 1958 and, if appropriate, correct published data for systematic errors that were not noticed previously, including the effects of coincidence summing and updated effective stopping powers. The data are interpreted by using two different models of nuclear reactions, that is, a potential model and R-matrix theory. A new astrophysical S factor and recommended thermonuclear reaction rates are presented. As a result of our work, the $O16(p,\gamma)F17$ reaction has now the most precisely known rate involving any target nucleus in the mass $A \leq 12$ range, with reaction rate errors of about 7% over the entire temperature region of astrophysical interest ($T=0.01-2.5$ GK). The impact of the present improved reaction rate with its significantly reduced uncertainties on the hot bottom burning in AGB stars is discussed. In contrast to earlier results we find now that there is not clear evidence to date for any stellar grain origin from massive AGB stars.

The Impact of the $^{18}F(\alpha,p)^{21}Ne$ Reaction on Asymptotic Giant Branch Nucleosynthesis, [Karakas, Amanda I.](#); [Lee, Hye Young](#); [Lugaro, Maria](#); [Görres, J.](#); [Wiescher, M.](#), The Astrophysical Journal, Volume 676, Issue 2, pp. 1254-1261

We present detailed models of low- and intermediate-mass asymptotic giant branch (AGB) stars with and without the $^{18}F(\alpha,p)^{21}Ne$ reaction included in the nuclear network, where the rate for this reaction has been recently experimentally evaluated for the first time. The lower and recommended measured rates for this reaction produce negligible changes to the stellar yields, whereas the upper limit of the rate affects the production of ^{19}F and ^{21}Ne . The stellar yields increase by $\sim 50\%$ to up to a factor of 4.5 for ^{19}F , and by factors of ~ 2 to 9.6 for ^{21}Ne . While the $^{18}F(\alpha,p)^{21}Ne$ reaction competes with ^{18}O production, the extra protons released are captured by ^{18}O to facilitate the $^{18}O(p,\alpha)^{15}N(\alpha,\gamma)^{19}F$ chain. The higher abundances of ^{19}F obtained using the upper limit of the rate helps to match the $[F/O]$ ratios observed in AGB stars, but only for large C/O ratios. Extramixing processes are proposed to help to solve this problem. Some evidence that the $^{18}F(\alpha,p)^{21}Ne$ rate might be closer to its upper limit is provided by the fact that the higher calculated $^{21}Ne/^{22}Ne$ ratios in the He intershell provide an explanation for the Ne isotopic composition of silicon-carbide grains from AGB stars. This needs to be confirmed by future experiments of the $^{18}F(\alpha,p)^{21}Ne$ reaction rate. The availability of accurate fluorine yields from AGB stars will be fundamental for interpreting observations of this element in carbon-enhanced metal-poor stars.

Rubidium and Zirconium Production in Massive AGB Stars, [van Raai, M. A.](#); [Lugaro, M.](#); [Karakas, A. I.](#); [García-Hernández, D. A.](#), IXTH TORINO WORKSHOP ON EVOLUTION AND NUCLEOSYNTHESIS IN AGB STARS AND THE IIND PERUGIA WORKSHOP ON NUCLEAR ASTROPHYSICS. AIP Conference Proceedings, Volume 1001, pp. 146-153 (2008).

A recent survey of a large sample of massive Galactic asymptotic giant branch (AGB) stars shows that significant overabundances of rubidium (up to 100 times solar), but

merely solar zirconium, are present in these stars. These observations can set constraints on our theoretical notion of the slow neutron capture process (the s process) in AGB stars, as well as on the rates of the neutron capture reactions involved in the production of Rb and Zr. We use the Monash nucleosynthesis code with a recently extended network to try to reproduce these observations. We present results for AGB stars of masses 5, 6, and 6.5 Msolar and solar metallicity. We also show results for different available choices of the neutron capture rates, as well as for the possible inclusion of a partial mixing zone (PMZ), leading to the activation of the ^{13}C neutron source. We find increasing Rb overabundances with increasing stellar mass, as observed, but we are far from matching the highest observed Rb enhancements. Inclusion of a PMZ increases the Rb abundance, but also produces an overabundance of Zr, contrary to what is observed. Only if the third dredge up efficiency remains as high as before the onset of the superwind phase during the final few pulses of a massive AGB star, can we match the highest [Rb/Fe] ratios observed by García-Hernández et al. [1]. A better understanding of the third dredge up efficiency with decreasing envelope mass for massive AGB stars is essential for further investigation of this issue.

On the solar abundance of indium, [Vitas, N.](#); [Vince, I.](#); [Lugaro, M.](#); [Andriyenko, O.](#); [Gošić, M.](#); [Rutten, R. J.](#), Monthly Notices of the Royal Astronomical Society, Volume 384, Issue 1, pp. 370-375.

The generally adopted value for the solar abundance of indium is over six times higher than the meteoritic value. We address this discrepancy through numerical synthesis of the 451.13-nm line on which all indium abundance studies are based, both for the quiet Sun and the sunspot umbra spectrum, employing standard atmosphere models and accounting for hyperfine structure and Zeeman splitting in detail. The results, as well as a re-appraisal of indium nucleosynthesis, suggest that the solar indium abundance is close to the meteoritic value, and that some unidentified ion line causes the 451.13-nm feature in the quiet-Sun spectrum.

Reaction rate uncertainties and ^{26}Al in AGB silicon carbide stardust, [van Raai, M. A.](#); [Lugaro, M.](#); [Karakas, A. I.](#); [Iliadis, C.](#), Astronomy and Astrophysics, Volume 478, Issue 2, February I 2008, pp.521-526

Context: Stardust is a class of presolar grains each of which presents an ideally uncontaminated stellar sample. Mainstream silicon carbide (SiC) stardust formed in the extended envelopes of carbon-rich asymptotic giant branch (AGB) stars and incorporated the radioactive nucleus ^{26}Al as a trace element. Aims: The aim of this paper is to analyse in detail the effect of nuclear uncertainties, in particular the large uncertainties of up to four orders of magnitude related to the $^{26}\text{Al}(p,\gamma)^{27}\text{Si}$ reaction rate, on the production of ^{26}Al in AGB stars and compare model predictions to data obtained from laboratory analysis of SiC stardust grains. Stellar uncertainties are also briefly discussed. Methods: We use a detailed nucleosynthesis postprocessing code to calculate the $^{26}\text{Al}/^{27}\text{Al}$ ratios at the surface of AGB stars of different masses ($M = 1.75, 3, \text{ and } 5 M_{\odot}$) and metallicities ($Z = 0.02, 0.012, \text{ and } 0.008$). Results: For the lower limit and recommended value of the $^{26}\text{Al}(p,\gamma)^{27}\text{Si}$ reaction rate, the predicted $^{26}\text{Al}/^{27}\text{Al}$ ratios replicate the upper values of the

range of the $^{26}\text{Al}/^{27}\text{Al}$ ratios measured in SiC grains. For the upper limit of the $^{26}\text{Al}(p,\gamma)^{27}\text{Si}$ reaction rate, instead, the predicted $^{26}\text{Al}/^{27}\text{Al}$ ratios are ≈ 100 times lower and lie below the range observed in SiC grains. When considering models of different masses and metallicities, the spread of more than an order of magnitude in the $^{26}\text{Al}/^{27}\text{Al}$ ratios measured in stellar SiC grains is not reproduced. Conclusions: We propose two scenarios to explain the spread of the $^{26}\text{Al}/^{27}\text{Al}$ ratios observed in mainstream SiC, depending on the choice of the $^{26}\text{Al} + p$ reaction rate. One involves different times of stardust formation, the other involves extra-mixing processes. Stronger conclusions on the interpretation of the Al composition of AGB stardust will be possible after more information is available from future nuclear experiments on the $^{26}\text{Al} + p$ reaction.

X-ray, Binary stars

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X-ray and optical observations of M55 and NGC 6366: evidence for primordial binaries, [Bassa, C. G.](#); [Pooley, D.](#); [Verbunt, F.](#); [Homer, L.](#); [Anderson, S. F.](#);

[Lewin, W. H. G.](#), Astronomy and Astrophysics, Volume 488, Issue 3, 2008, pp.921-933

We present Chandra X-ray Observatory ACIS-S3 X-ray imaging observations and VLT/FORS2 and Hubble Space Telescope optical observations of two low-density Galactic globular clusters; NGC 6366 and M 55. We detect 16 X-ray sources with 0.5-6.0 keV luminosities above $L_{\text{X}} = 4 \times 10^{30} \text{ erg s}^{-1}$ within the half-mass radius of M 55, of which 8 or 9 are expected to be background sources, and 5 within the half-mass radius of NGC 6366, of which 4 are expected to be background sources. Optical counterparts are identified for several X-ray sources in both clusters and from these we conclude that 3 of the X-ray sources in M 55 and 2 or 3 of the X-ray sources in NGC 6366 are probably related to the cluster. Combining these results with those for other clusters, we find the best fit for a predicted number of X-ray sources in a globular cluster $\mu_{\text{c}} = 1.2 \Gamma + 1.1 M_{\text{h}}$, where Γ is the collision number and M_{h} is (half of) the cluster mass, both normalized to the values for the globular cluster M4. Some sources tentatively classified as magnetically active binaries are more luminous in X-rays than the upper limit of $L_{\text{X}} \simeq 0.001 L_{\text{bol}}$ of such binaries in the solar neighbourhood. Comparison with XMM and ROSAT observations lead us to conclude that the brightest X-ray source in M 55, a dwarf nova, becomes fainter in X-rays during the optical outburst, in accordance with other dwarf novae. The brightest X-ray source in NGC 6366 is a point source surrounded by a slightly offset extended source. The absence of galaxies and H α emission in our optical observations argues against a cluster of galaxies and against a planetary nebula, and we suggest that the source may be an old nova.

The warm absorber in NGC 5548. The lean years, [Detmers, R. G.](#); [Kaastra, J. S.](#); [Costantini, E.](#); [McHardy, I. M.](#); [Verbunt, F.](#), Astronomy and Astrophysics, Volume 488, Issue 1, 2008, pp.67-72

We study the variability of the warm absorber and the gas responsible for the emission lines in the Seyfert 1 galaxy NGC 5548 to constrain the location and physical properties of these components. Using X-ray spectra acquired using the Chandra-LETGS in 2002 and 2005, we study the variability of the ionic column densities and line intensities. We measure a lower O VII forbidden emission line flux in 2005, while the Fe K α line flux remains constant. The warm absorber is less ionized in 2005, which enables its location to be constrained to within 7 pc of the central source. Using both the observed variability and the limit on the FWHM of the O VII f line, we constrain the location of the narrow line region to a distance of 1 pc from the central source. The apparent lack of variability in the Fe K α line flux does enable a unique explanation to be derived.

When teaching: Out with magnitudes, in with monochromatic luminosities!,
[Verbunt, Frank](#), eprint arXiv:0807.1393

The goal of this document is to illustrate that teaching the concepts of magnitudes is a needless complication in introductory astronomy courses, and that use of monochromatic luminosities, rather than arbitrarily defined magnitudes, leads to a large gain in transparency. This illustration is done through three examples: the Hertzsprung-Russell diagram, the cosmic distance ladder, and interstellar reddening. I provide conversion equations from the magnitude-based to the luminosity-based system; a brief discussion; and a reference to sample lecture notes. I suggest that we, astronomers in the 21st century, abolish magnitudes and instead use (apparent) monochromatic luminosities in non-specialist teaching. Given the large gain in transparency I further propose that we seriously consider using (apparent) monochromatic luminosities also in research papers, bringing optical astronomy in line with astronomy at other wavelengths. Comments are welcome.

An X-ray and optical study of the ultracompact X-ray binary A 1246-58,
[in't Zand, J. J. M.](#); [Bassa, C. G.](#); [Jonker, P. G.](#); [Keek, L.](#); [Verbunt, F.](#); [Méndez, M.](#);
[Markwardt, C. B.](#), Astronomy and Astrophysics, Volume 485, Issue 1, 2008, pp.183-194

Results are discussed of an X-ray and optical observation campaign of the low-mass X-ray binary A 1246-58 performed with instruments on Satellite per Astronomia X (“BeppoSAX”), the Rossi X-ray Timing Explorer (RXTE), the X-ray Multi-mirror Mission (“XMM-Newton”), the Swift mission, and the Very Large Telescope. Spectra and flux time histories are studied. The most important results are the lack of hydrogen spectral features in the optical spectrum, supporting the proposition that this is an ultracompact X-ray binary (UCXB), the determination of a 4.3 kpc distance from time-resolved spectroscopy of thermonuclear X-ray bursts, and the detection of intermediately long thermonuclear bursts as seen in a number of other UCXBs. There is evidence for a Ne/O abundance ratio in the line of sight that is higher than solar and variable. This may be due to different changes in the ionization degrees of Ne and O, which may be related to the variable irradiating flux. We discuss the spectral variability and the peculiarities of the long-term light curve.

Observational Evidence for the Origin of X-ray Sources in Globular Clusters, [Verbunt, Frank](#); [Pooley, Dave](#); [Bassa, Cees](#), Dynamical Evolution of Dense Stellar Systems, Proceedings of the International Astronomical Union, IAU Symposium, Volume 246, p. 301-310

Low-mass X-ray binaries, recycled pulsars, cataclysmic variables and magnetically active binaries are observed as X-ray sources in globular clusters. We discuss the classification of these systems, and find that some presumed active binaries are brighter than expected. We discuss a new statistical method to determine from observations how the formation of X-ray sources depends on the number of stellar encounters and/or on the cluster mass. We show that cluster mass is not a proxy for the encounter number, and that optical identifications are essential in proving the presence of primordial binaries among the low-luminosity X-ray sources.

The warm absorber in NGC 5548. The lean years, [Detmers, R. G.](#); [Kaastra, J. S.](#); [Costantini, E.](#); [McHardy, I. M.](#); [Verbunt, F.](#), Astronomy and Astrophysics, Volume 488, Issue 1, 2008, pp.67-72

We study the variability of the warm absorber and the gas responsible for the emission lines in the Seyfert 1 galaxy NGC 5548 to constrain the location and physical properties of these components. Using X-ray spectra acquired using the Chandra-LETGS in 2002 and 2005, we study the variability of the ionic column densities and line intensities. We measure a lower O VII forbidden emission line flux in 2005, while the Fe K α line flux remains constant. The warm absorber is less ionized in 2005, which enables its location to be constrained to within 7 pc of the central source. Using both the observed variability and the limit on the FWHM of the O VII f line, we constrain the location of the narrow line region to a distance of 1 pc from the central source. The apparent lack of variability in the Fe K α line flux does enable a unique explanation to be derived.

Future Instrumentation for the Study of the Warm-Hot Intergalactic Medium, [Paerels, Frits](#); [Kaastra, Jelle](#); [Ohashi, Takaya](#); [Richter, Philipp](#); [Bykov, Andrei](#); [Nevalainen, Jukka](#), Space Science Reviews, Volume 134, Issue 1-4, pp. 405-418

We briefly review capabilities and requirements for future instrumentation in UV- and X-ray astronomy that can contribute to advancing our understanding of the diffuse, highly ionised intergalactic medium.

Thermal Radiation Processes, [Kaastra, J. S.](#); [Paerels, F. B. S.](#); [Durret, F.](#); [Schindler, S.](#); [Richter, P.](#), Space Science Reviews, Volume 134, Issue 1-4, pp. 155-190

We discuss the different physical processes that are important to understand the thermal X-ray emission and absorption spectra of the diffuse gas in clusters of galaxies and the warm-hot intergalactic medium. The ionisation balance, line and continuum emission and absorption properties are reviewed and several practical examples are given that illustrate the most important diagnostic features in the X-ray spectra.

Soft X-Ray and Extreme Ultraviolet Excess Emission from Clusters of Galaxies, [Durret, F.](#); [Kaastra, J. S.](#); [Nevalainen, J.](#); [Ohashi, T.](#); [Werner, N.](#), Space Science Reviews, Volume 134, Issue 1-4, pp. 51-70

An excess over the extrapolation to the extreme ultraviolet and soft X-ray ranges of the thermal emission from the hot intracluster medium has been detected in a number of clusters of galaxies. We briefly present each of the satellites (EUVE, ROSAT PSPC and BeppoSAX, and presently XMM-Newton, Chandra and Suzaku) and their corresponding instrumental issues, which are responsible for the fact that this soft excess remains controversial in a number of cases. We then review the evidence for this soft X-ray excess and discuss the possible mechanisms (thermal and non-thermal) which could be responsible for this emission.

Clusters of Galaxies: Beyond the Thermal View, [Kaastra, J. S.](#); [Bykov, A. M.](#); [Schindler, S.](#); [Bleeker, J. A. M.](#); [Borgani, S.](#); [Diaferio, A.](#); [Dolag, K.](#); [Durret, F.](#); [Nevalainen, J.](#); [Ohashi, T.](#); [Paerels, F. B. S.](#); [Petrosian, V.](#); [Rephaeli, Y.](#); [Richter, P.](#); [Schaye, J.](#); [Werner, N.](#), Space Science Reviews, Volume 134, Issue 1-4, pp. 1-6

We present the work of an international team at the International Space Science Institute (ISSI) in Bern that worked together to review the current observational and theoretical status of the non-virialised X-ray emission components in clusters of galaxies. The subject is important for the study of large-scale hierarchical structure formation and to shed light on the “missing baryon” problem. The topics of the team work include thermal emission and absorption from the warm-hot intergalactic medium, non-thermal X-ray emission in clusters of galaxies, physical processes and chemical enrichment of this medium and clusters of galaxies, and the relationship between all these processes. One of the main goals of the team is to write and discuss a series of review papers on this subject. These reviews are intended as introductory text and reference for scientists wishing to work actively in this field. The team consists of sixteen experts in observations, theory and numerical simulations.

Non-Maxwellian electron distributions in clusters of galaxies, [Kaastra, Jelle](#); [Bykov, Andrey](#); [Werner, Norbert](#), 37th COSPAR Scientific Assembly. Held 13-20 July 2008, in Montréal, Canada., p.1418

X-ray spectra of clusters of galaxies are almost exclusively calculated assuming collisional ionisation equilibrium (CIE) and Maxwellian electron distributions. Deviations from CIE are expected to occur in the diluted cluster outskirts, where gas may still ionise and the relevant timescales are long. However, deviations from Maxwellian electron distributions are often ignored, despite the fact that these are expected to occur near the interface of hot and cold material. Although it is now known that clusters cool less strongly than predicted by the classical cooling flow models, observations still show that multiple gas phases are present in the cluster cores (e.g. optical emitting filaments within the ICM). Diffusion of electrons from the hotter to the cooler phase would over ionise the gas. In the cores of several cooling core clusters weak shocks due to the AGN/ICM interaction are observed which may accelerate electrons and produce non-

Maxwellian tails in the ICM electron distribution. In this presentation we show how these distributions affect the emerging line emission from those regions, and we investigate how the observations can help to demonstrate the presence of these electron distributions.

Constraining the neutron star equation of state using XMM-Newton, [Jonker, P. G.](#); [Kaastra, J.](#); [Méndez, M.](#); [In't Zand, J. J. M.](#), Astronomische Nachrichten, Vol.329, Issue 2, p.198

We have identified three possible ways in which future XMM-Newton observations can provide significant constraints on the equation of state of neutron stars. First, using a long observation of the neutron star X-ray transient Cen X-4 in quiescence one can use the RGS spectrum to constrain the interstellar extinction to the source. This removes this parameter from the X-ray spectral fitting of the pn and MOS spectra and allows us to investigate whether the variability observed in the quiescent X-ray spectrum of this source is due to variations in the soft thermal spectral component or variations in the power law spectral component coupled with variations in N_H . This will test whether the soft thermal spectral component can indeed be due to the hot thermal glow of the neutron star. Potentially such an observation could also reveal redshifted spectral lines from the neutron star surface. Second, XMM-Newton observations of radius expansion type I X-ray bursts might reveal redshifted absorption lines from the surface of the neutron star. Third, XMM-Newton observations of eclipsing quiescent low-mass X-ray binaries provide the eclipse duration. With this the system inclination can be determined accurately. The inclination determined from the X-ray eclipse duration in quiescence, the rotational velocity of the companion star and the semi-amplitude of the radial velocity curve determined through optical spectroscopy, yield the neutron star mass.

High spectral resolution X-ray observations of AGN, [Kaastra, J. S.](#), Astronomische Nachrichten, Vol.329, Issue 2, p.162-165

A brief overview of some highlights of high spectral resolution X-ray observations of AGN is given, mainly obtained with the RGS of XMM-Newton. Future prospects for such observations with XMM-Newton are given.

Solar Physics and Experimental Physics

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Polarimetry of Mars with SPEX, an Innovative Spectropolarimeter, [Stam, D. M.](#); [Laan, E.](#); [Snik, F.](#); [Karalidi, T.](#); [Keller, C.](#); [Ter Horst, R.](#); [Navarro, R.](#); [Aas, C.](#); [de Vries, J.](#); [Oomen, G.](#); [Hoogeveen, R.](#), Third International Workshop on The Mars Atmosphere: Modeling and Observations, held November 10-13, 2008 in Williamsburg, Virginia. LPI Contribution No. 1447, p.9078

We present SPEX, an innovative, compact, and robust spectropolarimeter that measures fluxes and polarization of sunlight reflected by Mars from 400 to 800 nm. With simulations we'll show how with SPEX atmospheric dust and the surface can be studied.

Diversity among other worlds: characterization of exoplanets by direct detection [Schneider, J.](#); [Boccaletti, A.](#); [Aylward, A.](#); [Baudoz, P.](#); [Beuzit, J. -L.](#); [Brown, R.](#); [Cho, J.](#); [Dohlen, K.](#); [Ferrari, M.](#); [Galicher, R.](#); [Grasset, O.](#); [Grenfell, L.](#); [Griessmeier, J. -M.](#); [Guyon, O.](#); [Hough, J.](#); [Kasper, M.](#); [Keller, Ch.](#); [Longmore, A.](#); [Lopez, B.](#); [Martin, E.](#); [Mawet, D.](#); [Menard, F.](#); [Merin, B.](#); [Palle, E.](#); [Perrin, G.](#); [Pinfield, D.](#); [Sein, E.](#); [Shore, P.](#); [Sotin, Ch.](#); [Sozzetti, A.](#); [Stam, D.](#); [Surdej, J.](#); [Tamburini, F.](#); [Tinetti, G.](#); [Udry, S.](#); [Verinaud, C.](#); [Walker, D.](#), eprint arXiv:0811.2496

The physical characterization of exoplanets will require to take spectra at several orbital positions. For that purpose, a direct imaging capability is necessary. Direct imaging requires an efficient stellar suppression mechanism, associated with an ultrasmooth telescope. We show that before future large space missions (interferometer, 4-8 m class coronagraph, external occulter or Fresnel imager), direct imaging of giant planets and close-by super-Earth are at the cross-road of a high scientific interest and a reasonable feasibility. The scientific interest lies in the fact that super-Earths share common geophysical attributes with Earths. They already begin to be detected by radial velocity (RV) and, together with giant planets, they have a larger area than Earths, making them detectable with a 1.5-2 m class telescope in reflected light. We propose such a (space) telescope be a first step before large direct imaging missions.

Design of a laboratory simulator to test exoplanet imaging polarimetry, [Jeffers, S. V.](#); [Miesen, N.](#); [Rodenhuis, M.](#); [Keller, C. U.](#), Ground-based and Airborne Instrumentation for Astronomy II. Edited by McLean, Ian S.; Casali, Mark M. Proceedings of the SPIE, Volume 7014, pp. 70147B-70147B-8

Research on extrasolar planets is one of the most rapidly advancing fields of astrophysics. In just over a decade since the discovery of the first extra-solar planet orbiting around 51 Pegasi, 289 extrasolar planets have been discovered. This breakthrough is the result of the development of a wide range of new observational techniques and facilities for the detection and characterisation of extrasolar planets. In Utrecht we are building the Extreme Polarimeter (ExPo) to image extra-solar planets and circumstellar environments using polarimetry at contrast ratio of 10^{-9} . To test and calibrate ExPo, we have built a laboratory-based simulator that mimics a star with a Jupiter-like exoplanet as seen by the 4.2m William Herschel Telescope. The star and planet are simulated using two single-mode fibres in close proximity that are fed with a broadband arc lamp with a contrast ratio down to 10^{-9} . The planet is partially linearly polarized. The telescope is simulated with two lenses, and seeing can be included with a rotating glass plate covered with hairspray. In this paper we present the scientific requirements and the simulator design.

The Extreme Polarimeter (ExPo): design of a sensitive imaging polarimeter, [Rodenhuis, M.](#); [Canovas, H.](#); [Jeffers, S. V.](#); [Keller, C. U.](#), Ground-based and Airborne Instrumentation for Astronomy II. Edited by McLean, Ian S.; Casali, Mark M. Proceedings of the SPIE, Volume 7014, pp. 70146T-70146T-9

The Extreme Polarimeter (ExPo) is approaching its first deployment at the 4.2 m William Herschel Telescope at La Palma. This imaging polarimeter, developed at the Astronomical Institute of Utrecht University, aims to study circumstellar material at a contrast ratio with the central star of 10^{-9} . Working at visible wavelengths, it will provide an inner working angle down to 0.5 arcsec and a field of view of 20 arcsec diameter. ExPo employs a dual beam-exchange technique based on polarimeter designs for solar studies. A partially transmitting coronagraph mask placed in the first focus reduces the light of the star. The beam is modulated using three ferro-electric liquid crystals in a Pancharatnam configuration, then split in a polarizing beamsplitter. Both beams are re-imaged onto the same Electron-Multiplying CCD camera. We present the design of the ExPo instrument, highlighting the elements that are critical to the polarimetric performance. Some prototype laboratory experiments demonstrating the instrument concept are discussed. These have been performed using our realistic exoplanet laboratory simulator.

SPHERE ZIMPOL: overview and performance simulation, [Thalmann, Christian](#); [Schmid, Hans M.](#); [Boccaletti, Anthony](#); [Mouillet, David](#); [Dohlen, Kjetil](#); [Roelfsema, Ronald](#); [Carbillet, Marcel](#); [Gisler, Daniel](#); [Beuzit, Jean-Luc](#); [Feldt, Markus](#); [Gratton, Raffaele](#); [Joos, Franco](#); [Keller, Christoph U.](#); [Kragt, Jan](#); [Pragt, Johan H.](#); [Puget, Pascal](#); [Rigal, Florence](#); [Snik, Frans](#); [Waters, Rens](#); [Wildi, François](#), Ground-based and Airborne Instrumentation for Astronomy II. Edited by McLean, Ian S.; Casali, Mark M. Proceedings of the SPIE, Volume 7014, pp. 70143F-70143F-12

The ESO planet finder instrument SPHERE will search for the polarimetric signature of the reflected light from extrasolar planets, using a VLT telescope, an extreme AO system (SAXO), a stellar coronagraph, and an imaging polarimeter (ZIMPOL). We present the design concept of the ZIMPOL instrument, a single-beam polarimeter that achieves very high polarimetric accuracy using fast polarization modulation and demodulating CCD detectors. Furthermore, we describe comprehensive performance simulations made with the CAOS problem-solving environment. We conclude that direct detection of Jupiter-sized planets in close orbit around the brightest nearby stars is achievable with imaging polarimetry, signal-switching calibration, and angular differential imaging.

The upgrade of HARPS to a full-Stokes high-resolution spectropolarimeter, [Snik, Frans](#); [Jeffers, Sandra](#); [Keller, Christoph](#); [Piskunov, Nikolai](#); [Kochukhov, Oleg](#); [Valenti, Jeff](#); [Johns-Krull, Christopher](#), Ground-based and Airborne Instrumentation for Astronomy II. Edited by McLean, Ian S.; Casali, Mark M. Proceedings of the SPIE, Volume 7014, pp. 70140O-70140O-10

We present the design of a compact module that converts the HARPS instrument at the 3.6-m telescope at La Silla to a full-Stokes high-resolution spectropolarimeter. The polarimeter will replace the obsolete Iodine cell inside the HARPS Cassegrain adapter. Utilizing the two fibers going into the spectrograph, two dual-beam systems can be positioned in the beam: one with a rotating superachromatic quarter-wave plate for circular polarimetry and one with a rotating superachromatic half-wave plate for linear polarimetry. A large polarimetric precision is ensured by the beam-exchange technique and a minimal amount of instrumental polarization. The polarimeter, in combination with the ultra-precise HARPS spectrograph, enables unprecedented observations of stellar magnetic fields and circumstellar material without compromising the successful planet-finding program.

SPEX: an in-orbit spectropolarimeter for planetary exploration, [Snik, Frans](#); [Karalidi, Theodora](#); [Keller, Christoph](#); [Laan, Erik](#); [ter Horst, Rik](#); [Navarro, Ramon](#); [Stam, Daphne](#); [Aas, Christina](#); [de Vries, Johan](#); [Oomen, Gijs](#); [Hoogeveen, Ruud](#), Space Telescopes and Instrumentation 2008: Optical, Infrared, and Millimeter. Edited by Oschmann, Jacobus M., Jr.; de Graauw, Mattheus W. M.; MacEwen, Howard A. Proceedings of the SPIE, Volume 7010, pp. 701015-701015-10

SPEX (Spectropolarimeter for Planetary EXploration) is an innovative, compact remote-sensing instrument for detecting and characterizing aerosols. With its 1-liter volume it is capable of full linear spectropolarimetry, without moving parts. High precision polarimetry is performed through encoding the degree and angle of linear polarization of the incoming light in a sinusoidal modulation of the intensity spectrum. This is achieved by using an achromatic quarter-wave retarder, an athermal multiple-order retarder and a polarizing beamsplitter behind each entrance pupil. Measuring a single intensity spectrum thus provides the spectral dependence of the degree and angle of linear polarization. Polarimetry has proven to be an excellent tool to study microphysical properties (size, shape, composition) of atmospheric particles. Such information is essential to better

understand the weather and climate of a planet. Although SPEX can be used to study any planetary atmosphere, including the Earth's, the current design of SPEX is tailored to study Martian dust and ice clouds from an orbiting platform: a compact module with 9 entrance pupils to simultaneously measure intensity spectra from 350 to 800 nm, in different directions along the flight direction (including two limb viewing directions). This way, both the intensity and polarization scattering phase functions of dust and cloud particles within a ground pixel are sampled while flying over it. In the absence of significant amounts of dust and clouds, the surface properties can be studied. SPEX provides synergy with instruments on rovers and landers, as it provides a global view of spatial and temporal variations of the planet.

New Observations of the Magnetic Vector Field across the Solar Disk, [Keller, C. U.](#); [Harvey, J. W.](#); [Henney, C. J.](#), 14th Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun ASP Conference Series, Vol. 384, proceedings of the conference held 5-10 November, 2006, at the Spitzer Science Center and Michelson Science Center, Pasadena, California, USA. Edited by Gerard van Belle., p.166

Full disk solar magnetograms have been available for more than three decades. However, those maps only show the line-of-sight magnetic flux. The physical quantity we really want to know is the magnetic field vector along with the filling factor, i.e. the fractional area of the resolution element that is occupied by the magnetic field. Since August 2003, the SOLIS Vector-SpectroMagnetograph has been recording the photospheric magnetic field vector across the full solar disk with high sensitivity and resolution. Some of the data are now becoming available for beta testing, and the first science results are emerging. Here we provide a brief introduction to the instrument and its data products and then present some of the data from the first three years of operation.

DOT Tomography of the Solar Atmosphere VII. Chromospheric Response to Acoustic Events, [Rutten, R. J.](#); [van Veelen, B.](#); [Sütterlin, P.](#), Solar Physics, Volume 251, Issue 1-2, pp. 533-547

We use synchronous movies from the Dutch Open Telescope sampling the G band, Ca ii H, and H α with five-wavelength profile sampling to study the response of the chromosphere to acoustic events in the underlying photosphere. We first compare the visibility of the chromosphere in Ca ii H and H α , demonstrate that studying the chromosphere requires H α data, and summarize recent developments in understanding why this is so. We construct divergence and vorticity maps of the photospheric flow field from the G-band images and locate specific events through the appearance of bright Ca ii H grains. The reaction of the H α chromosphere is diagnosed in terms of brightness and Doppler shift. We show and discuss three particular cases in detail: a regular acoustic grain marking shock excitation by granular dynamics, a persistent flasher, which probably marks magnetic-field concentration, and an exploding granule. All three appear to buffet overlying fibrils, most clearly in Dopplergrams. Although our diagnostic displays to dissect these phenomena are unprecedentedly comprehensive, adding even more information (photospheric Doppler tomography and magnetograms along with chromospheric imaging and Doppler mapping in the ultraviolet) is warranted.

H α as a Chromospheric Diagnostic, [Rutten, R. J.](#), First Results From Hinode ASP Conference Series, Vol. 397, Proceedings of the conference held 20-24 August, 2007, at Trinity College Dublin, Dublin, Ireland. Edited by Sarah A. Matthews, John M. Davis, and Louise K. Harra. San Francisco: Astronomical Society of the Pacific, 2008., p.54

I first illustrate with images from the Dutch Open Telescope (DOT) that H α is the principal diagnostic of the solar chromosphere. The DOT movies at <http://dot.astro.uu.nl> demonstrate this fact even more vividly.

I then summarize, on the basis of the recent numerical simulations by Leenaarts et al. (2007), why H α is such an omnipresent diagnostic of the chromosphere. The ubiquity of H α fibrils in both hot and cool gas is due to (i)- the presence of shocks everywhere, guided by the magnetic field into dynamic fibrils near the network and pushing the canopy and transition region upward in weaker-field internetwork regions, (ii)- the large rate difference between the fast hydrogen ionization/recombination balancing in hot shocks and the slow balancing in cool post-shock gas, and (iii)- the large excitation energy of H α 's n=2 lower level, causing strong coupling to the ion population. These three facts combine to cause appreciable H α opacity throughout the chromosphere, enormously in excess of instantaneous Saha-Boltzmann partitioning in cool post-shock gas. Thus, sluggish post-shock recombination causes H α to be visible everywhere.

Finally, I address H α observing. Since Hinode's H α imaging is affected by bubbles and limited in cadence, the DOT may serve as a complementary facility furnishing profile-sampling H α image sequences at the same 0.3 arcsec angular resolution as Hinode whenever the La Palma seeing is good. However, imminent loss of DOT funding requires outside financing of an on-site observer for DOT utilization in co-pointed joint observing.

Dynamic Ly alpha jets, [Koza, J.](#); [Rutten, R. J.](#); [Vourlidas, A.](#), eprint arXiv:0807.4889

The solar chromosphere and transition region are highly structured and complex regimes. A recent breakthrough has been the identification of dynamic fibrils observed in H alpha as caused by field-aligned magnetoacoustic shocks. We seek to find whether such dynamic fibrils are also observed in Ly alpha. We used a brief sequence of four high-resolution Ly alpha images of the solar limb taken by the Very high Angular resolution ULtraviolet Telescope (VAULT), which displays many extending and retracting Ly alpha jets. We measured their top trajectories and fitted parabolas to the 30 best-defined ones. Most jet tops move supersonically. Half of them decelerate, sometimes superballistically, the others accelerate. This bifurcation may arise from incomplete sampling of recurrent jets. The similarities between dynamic Ly alpha jets and H alpha fibrils suggest that the magnetoacoustic shocks causing dynamic H alpha fibrils also affect dynamic Ly alpha jets.

High levels of surface differential rotation on the young G0 dwarf HD171488, [Jeffers, S. V.](#); [Donati, J.-F.](#), Monthly Notices of the Royal Astronomical Society, Volume 390, Issue 2, pp. 635-644

We present high-resolution images of the young, rapidly rotating G0 dwarf HD171488, using both Stokes I and Stokes V data. The observations were secured with the MuSiCoS spectropolarimeter at Telescope Bernard Lyot from 2005 May 31 to June 10. The photospheric surface brightness distributions show a strong and slightly decentred polar cap that dominates over weak high- and low-latitude spot features. The large-scale magnetic field topology shows a strong ring of anticlockwise azimuthal field with a latitudinal dependence on polarity and large regions of radial field with negative polarity at all latitudes. Using the good phase coverage of our data, we measure the differential rotation on HD171488. The results indicate that the equator laps the pole every 12 days for brightness data and 13 days for magnetic data, which is the highest measurement of differential rotation obtained using Zeeman-Doppler imaging techniques.

Spectropolarimetric observations were obtained, from 2005 May 31 to June 10, with the MuSiCoS echelle spectropolarimeter at the Telescope Bernard Lyot (Observatoire du Pic du Midi, France).

The intensity contrast of solar granulation: comparing Hinode SP results with MHD simulations, [Danilovic, S.](#); [Gandorfer, A.](#); [Lagg, A.](#); [Schüssler, M.](#); [Solanki, S. K.](#); [Vögler, A.](#); [Katsukawa, Y.](#); [Tsuneta, S.](#), Astronomy and Astrophysics, Volume 484, Issue 3, 2008, pp.L17-L20

Context: The contrast of granulation is an important quantity characterizing solar surface convection. Aims: We compare the intensity contrast at 630 nm, observed using the Spectro-Polarimeter (SP) aboard the Hinode satellite, with the 3D radiative MHD simulations of Vögler & Schüssler (2007, A&A, 465, L43). Methods: A synthetic image from the simulation is degraded using a theoretical point-spread function of the optical system, and by considering other important effects. Results: The telescope aperture and the obscuration by the secondary mirror and its attachment spider, reduce the simulated contrast from 14.4% to 8.5%. A slight effective defocus of the instrument brings the simulated contrast down to 7.5%, close to the observed value of 7.0%. Conclusions: A proper consideration of the effects of the optical system and a slight defocus, lead to sufficient degradation of the synthetic image from the MHD simulation, such that the contrast reaches almost the observed value. The remaining small discrepancy can be ascribed to straylight and slight imperfections of the instrument, which are difficult to model. Hence, Hinode SP data are consistent with a granulation contrast which is predicted by 3D radiation MHD simulations.

Strong horizontal photospheric magnetic field in a surface dynamo simulation, [Schüssler, M.](#); [Vögler, A.](#), Astronomy and Astrophysics, Volume 481, Issue 1, 2008, pp.L5-L8

Context: Observations with the Hinode spectro-polarimeter have revealed strong horizontal internetwork magnetic fields in the quiet solar photosphere. Aims: We aim to interpret the observations with results from numerical simulations. Methods: Radiative MHD simulations of dynamo action by near-surface convection are analyzed with respect

to the relation between vertical and horizontal magnetic field components.
Results: The dynamo-generated fields show a clear dominance of the horizontal field in the height range where the spectral lines used for the Hinode observations are formed. The ratio between the averaged horizontal and vertical field components is consistent with the values derived from the observations. This behavior results from the intermittent nature of the dynamo field with polarity mixing on small scales in the surface layers.
Conclusions: Our results provide further evidence that local near-surface dynamo action contributes significantly to the solar internetwork fields.

Evidence of Relentless Reconnections at Boundaries of Supergranular Network Lanes in Quiet Sun and Coronal Hole, [Aiouaz, T.](#), The Astrophysical Journal, Volume 674, Issue 2, pp. 1144-1152

Doppler-shift properties of the solar transition region (TR) and low corona are investigated in relation to the underlying chromospheric supergranular network, with particular regard to the role of the magnetic field. EUV line properties were obtained from a large raster scan of the solar chromosphere, transition region, and corona acquired by the SUMER spectrometer on board SOHO. The observed region includes an equatorial coronal hole, as well as surrounding quiet-Sun areas. The chromospheric supergranular network pattern is enhanced using a filter defined previously by Aiouaz and coworkers applied to a Lyman continuum image. The filtered continuum image and Dopplergrams are used to produce dispersion plots. We find correlations between the chromospheric network, and the N IV (765.15 Å), O IV (790.19 Å), S V (786.50 Å), O V (760.45 Å) Doppler shifts in quiet Sun and coronal hole. It is established that the maximum inflow (redshift) at transition region temperatures appears statistically toward the center of the network lanes in the quiet-Sun areas and toward the boundary of the network lanes in the coronal hole. Furthermore, while the strong redshifts in the TR lines complement spatially blueshifts from the low corona (Ne VIII 770.41 Å) in a puzzle-like pattern, bidirectional flows (i.e., cospatial strong red- and blueshifts in the TR/Corona) appear predominantly in the coronal hole. The bidirectional flows congregate almost systematically at boundaries of magnetic field concentrations seen in SOHO MDI magnetograms. These results support a coherent interpretation of almost 30 years of unexplained statistical Doppler-shift variations in the transition region and corona for quiet Sun and coronal hole. The proposed scenario involves reconnections between the strong network magnetic field and continuously advected weak field from the supergranular cell interior.

Role of Magneto-Convection in Plasma Dynamic and Energy Balance Above the Supergranular Network, [Aiouaz, T.](#), Subsurface and Atmospheric Influences on Solar Activity ASP Conference Series, Vol. 383, proceedings of the conference held 16-20 April 2007 at the National Solar Observatory, Sacramento Peak, Sunspot, New Mexico, USA. Edited by R. Howe, R. W. Komm, K. S. Balasubramaniam and G. J. D. Petrie. San Francisco: Astronomical Society of the Pacific, 2008, p.173

The current project aims to model the upper solar atmosphere taking in account the magnetic complexity of the supergranulation pattern. The result of a potential field

extrapolation is used as the initial condition for the magnetic field in the framework of a forward 3D MHD model including the calculation of EUV emission lines.

The MHD model describes the solar atmosphere from the high chromosphere to the lower solar corona above a synthetic supergranular cell. I present preliminary results on the relation between the magnetic topology, the thermodynamic properties of the plasma (e.g., flow, temperature, density) and the EUV intensity as calculated from the synthetic emission lines. Signatures of the magnetic field concentration is to be found in the corona in the density and temperature structure, and thus in emissivity and intensity, while the magnetic field is almost homogeneous. This model succeeds in reproducing for the first time the supergranular pattern as observed with a spectrometer in the EUV.

Open Principle for Large High-Resolution Solar Telescopes,

[Hammerschlag, Robert H.](#); [Bettonvil, Felix C. M.](#); [Jägers, Aswin P. L.](#); [Sliepen, Guus](#), Earth, Moon, and Planets, Volume 104, Issue 1-4, pp. 83-86

Vacuum solar telescopes solve the problem of image deterioration inside the telescope due to refractive index fluctuations of the air heated by the solar light. However, such telescopes have a practical diameter limit somewhat over 1 m. The Dutch Open Telescope (DOT) was the pioneering demonstrator of the open-telescope technology without need of vacuum, now pursued in the German GREGOR. Important ingredients for this technology are primary beam completely open to natural wind flow, stiff but still open design by principal stiff overall geometries in combination with carefully designed joints and completely open-foldable dome constructions based on tensioned strong cloth. Further developments to large sizes are made within the framework of the design study for a European Solar Telescope (EST).

Cornelis Zwaan, open principle, and the future of high-resolution solar telescopes,

[Hammerschlag, Robert H.](#); [Bettonvil, Felix C. M.](#); [Jägers, Aswin P. L.](#); [Sliepen, Guus](#), Ground-based and Airborne Telescopes II. Edited by Stepp, Larry M.; Gilmozzi, Roberto. Proceedings of the SPIE, Volume 7012, pp. 70120M-70120M-12 (2008)

It was in the years around 1970 that during site-test campaigns for JOSO masts were erected up till 30 m height with sensors at several heights for the measurement of temperature fluctuations. Cornelis (Kees) Zwaan discovered that the fluctuations decrease drastically at heights from about 15 m and upward when there is some wind. The conclusion from this experience was the open telescope principle: the telescope should be completely free in the air 15 m or more above the ground. The Dutch Open Telescope (DOT) was the pioneering demonstrator of the open-telescope technology. Now that larger high-resolution telescopes come in view, it is time to analyze again the principle: (i) the essentials for proper working of the open principle; (ii) the differences with nighttime observations particularly concerning the seeing; (iii) the design consequences for the new generation of high-resolution solar telescopes.

Fast foldable tent domes, [Jägers, Aswin P. L.](#); [Sliepen, Guus](#); [Bettonvil, Felix C. M.](#); [Hammerschlag, Robert H.](#), Advanced Optical and Mechanical Technologies in

Telescopes and Instrumentation. Edited by Atad-Ettinger, Eli; Lemke, Dietrich. Proceedings of the SPIE, Volume 7018, pp. 70181R-70181R-11 (2008).

In the near future ELTs (Extreme Large Telescopes) will be built. Preferably these telescopes should operate without obstructions in the near surrounding to reach optimal seeing conditions and avoid large turbulences with wind-gust accelerations around large obstacles. This applies also to future large solar telescopes. At present two foldable dome prototypes have been built on the Canary Islands: the Dutch Open Telescope (DOT, La Palma) and the GREGOR Telescope (Tenerife), having a diameter of 7 and 9 meter, respectively. The domes are usually fully retracted during observations. The research consists of measurements on the two domes. New camera systems are developed and placed inside the domes for precise dome deformation measurements within 0.1 mm over the whole dome size. Simultaneously, a variety of wind-speed and -direction sensors measure the wind field around the dome. In addition, fast sensitive air-pressure sensors placed on the supporting bows measure the wind pressure. The aim is to predict accurately the expected forces and deformations on up-scaled, fully retractable domes to make their construction more economically. The dimensions of 7 and 9 meter are large enough for realistic on-site tests in gusty wind and will give much more information than wind tunnel experiments.

Large fully retractable telescope enclosures still closable in strong wind, [Bettonvil, Felix C. M.](#); [Hammerschlag, Robert H.](#); [Jägers, Aswin P. L.](#); [Sliepen, Guus](#), Advanced Optical and Mechanical Technologies in Telescopes and Instrumentation. Edited by Atad-Ettinger, Eli; Lemke, Dietrich. Proceedings of the SPIE, Volume 7018, pp. 70181N-70181N-9 (2008).

Two prototypes of fully retractable enclosures with diameters of 7 and 9 m have been built for the high-resolution solar telescopes DOT (Dutch Open Telescope) and GREGOR, both located at the Canary Islands. These enclosures protect the instruments for bad weather and are fully open when the telescopes are in operation. The telescopes and enclosures also operate in hard wind. The prototypes are based on tensioned membrane between movable but stiff bows, which fold together to a ring when opened. The height of the ring is small. The prototypes already survived several storms, with often snow and ice, without any damage, including hurricane Delta with wind speeds up to 68 m/s. The enclosures can still be closed and opened with wind speeds of 20 m/s without any problems or restrictions. The DOT successfully demonstrated the open, wind-flushing concept for astronomical telescopes. It is now widely recognized that also large future telescopes benefit from wind-flushing and retractable enclosures. These telescopes require enclosures with diameters of 30 m until roughly 100 m, the largest sizes for the ELTs (Extreme Large Telescopes), which will be built in the near future. We discuss developments and required technology for the realization of these large sizes.

Contactless sub-millimeter displacement measurements, [Sliepen, Guus](#); [Jägers, Aswin P. L.](#); [Bettonvil, Felix C. M.](#); [Hammerschlag, Robert H.](#), Advanced Optical and Mechanical Technologies in Telescopes and Instrumentation. Edited by Atad-

Ettegui, Eli; Lemke, Dietrich. Proceedings of the SPIE, Volume 7018, pp. 70181C-70181C-9 (2008).

Weather effects on foldable domes, as used at the DOT and GREGOR, are investigated, in particular the correlation between the wind field and the stresses caused to both metal framework and tent clothing. Camera systems measure contactless the displacement of several dome points. The stresses follow from the measured deformation pattern. The cameras placed near the dome floor do not disturb telescope operations. In the set-ups of DOT and GREGOR, these cameras are up to 8 meters away from the measured points and must be able to detect displacements of less than 0.1 mm. The cameras have a FireWire (IEEE1394) interface to eliminate the need for frame grabbers. Each camera captures 15 images of 640×480 pixels per second. All data is processed on-site in real-time. In order to get the best estimate for the displacement within the constraints of available processing power, all image processing is done in Fourier-space, with all convolution operations being pre-computed once. A sub-pixel estimate of the peak of the correlation function is made. This enables to process the images of four cameras using only one commodity PC with a dual-core processor, and achieve an effective sensitivity of up to 0.01 mm. The deformation measurements are well correlated to the simultaneous wind measurements. The results are of high interest to upscaling the dome design (ELTs and solar telescopes).

The meteor year of the Meteor Research Group of the European Space Agency's Research and Scientific Support Department, [Koschny, D. V.](#); [Mc Auliffe, J.](#); [Barentsen, G.](#); [Bettonvil, F. C. M.](#); [Hatton, J. P.](#); [Lowiessen, F.](#); [Zender, J. J.](#), WGN, Journal of the International Meteor Organization, vol. 36, no. 6, p. 131-138

A lot of activities took place in 2007 at the Meteor Research Group (MRG) of the European Space Agency's (ESA) Research and Scientific Support Department (RSSD). Both special observing campaigns as well as continuous observations were performed, mainly with intensified video cameras, but also with still CCD cameras. Over 1400 meteors were observed; about 150 meteors were observed from more than one station allowing orbit computations. In addition to collecting observational data, ESA/RSSD further pursued the idea of setting up standards for a 'Virtual Meteor Observatory'. The activities are summarized here to allow referencing for more detailed, scientific papers.

Determination of the Velocity of Meteors Based on Sinodial Modulation and Frequency Analysis, [Bettonvil, Felix](#), Earth, Moon, and Planets, Volume 102, Issue 1-4, pp. 205-208

In meteor photography the velocity of meteors is generally obtained from a chopper which blocks periodically the incident light beam in front of the camera lens. In this paper I examine modulation of the meteor trail instead with a sinodial function and use frequency analysis to compute accurately the mean atmospheric velocity.