THE HOT STAR NEWSLETTER

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An electronic publication dedicated to A, B, O, Of, LBV and Wolf-Rayet stars
and related phenomena in galaxies

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Accepted Papers

Line-driven winds, ionizing fluxes and UV-spectra of hot stars at extremely low metallicity. I. Very massive O-stars

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Wind models of very massive stars with metallicities in a range from 10^{-4} to 1.0 solar are calculated using a new treatment of radiation driven winds with depth dependent radiative force multipliers and a comprehensive list of more than two million of spectral lines in NLTE. The models are tested by a comparison with observed stellar wind properties of O stars in the Galaxy and the SMC. Satisfying agreement is found. The calculations yield mass-loss rates, wind velocities, wind momenta and wind energies as a function of metallicity and can be used to discuss the influence of stellar winds on the evolution of very massive stars in the early universe and on the interstellar medium in the early phases of galaxy formation. It is shown that the normal scaling laws, which predict stellar mass-loss rates and wind momenta to decrease as a power law with metal abundance break down at a certain threshold. Analytical fit formulae for mass-loss rates are provided as a function of stellar parameters and metallicity.

Ionizing fluxes of hot stars depend crucially on the strengths of their stellar winds, which modify the absorption edges of hydrogen and helium (neutral and ionized) and the line blocking in the far UV. The new wind models are therefore also applied to calculate ionizing fluxes and observable spectra of very massive stars as a function of metallicity using the new hydrodynamic, non-LTE line-blanketed flux constant model atmosphere code developed by Pauldrach et al.(2001). Numbers of ionizing photons for the crucial ionization stages are given. For a fixed effective temperature the He II ionizing emergent flux depends very strongly on metallicity but also on stellar luminosity. A strong dependencef on metallicity is also found for the C III, Ne II and O II ionizing photons, whereas the H I and He I ionizing flux is almost independent of metallicity. We also calculate UV spectra for all the models and discuss the behaviour of significant line features as a function of metallicity.

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Preprints from kudritzki@usm.uni-muenchen.de

Stellar evolution with rotation: IX. The effects of the production of asymmetric nebulae on the internal evolution

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The anisotropies of the mass loss by stellar winds, which lead to asymmetric nebulae, influence the loss of angular momentum. Polar enhanced mass loss is embarking less angular momentum than isotropic mass loss, while equatorial mass loss is removing more angular momentum. Thus, the evolution of a star and of its rotation is also influenced by the anisotropies. We give the basic equations expressing the evolution of the angular momentum for a rotating star experiencing mass loss by anisotropic stellar winds, with account for differential rotation, meridional circulation and shear diffusion. In the general case, the outer layers must be studied with a time dependent boundary conditions. However, for low enough mass loss rates, a stationary situation can be established at the stellar surface. It implies a positive Ω–gradient for polar mass loss and a negative Ω–gradient for a dominant equatorial mass loss. At the opposite, for extremely high mass loss rates (like for LBV and WR stars), the outer layers are removed before the torque associated to the anisotropies has the time to be transmitted inward.

We show that for the fastest rotating O-type stars (between 25 and 60 $M_{\odot}$ and for an average rotation velocity during the MS phase $v \geq 300$ km/s), the anisotropies of the mass loss may significantly influence the evolution of the stellar velocities and may lead the stars to break–up.

Accepted by A&A
Preprints from andre.maeder@obs.unige.ch

The evolved early-type binary HDE 228766 revisited

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We use an extensive set of spectroscopic observations to reinvestigate the properties of the massive binary HDE 228766. Conventional classification criteria suggest that HDE 228766 consists of an O7 primary and an Of^{+} secondary. However, several spectral features of the secondary, such as the simultaneous presence of N III, N IV and N V emissions, make it a rather unusual object. We find that the orbital motion of the secondary is probably best described by the radial velocities of the narrow

N III emission lines. Our orbital solution yields $m_1 \sin^3 i = 31.7$ and $m_2 \sin^3 i = 25.5\,\mathrm{M}_\odot$ for the primary and secondary respectively. The He II $\lambda\,4542$ absorption in the secondary's spectrum appears considerably blue-shifted with respect to the narrow emission lines, indicating that the absorption is probably formed in the accelerating part of the secondary's wind. We use a tomographic technique to investigate the profile variability of the broader emission lines. In addition to a strong emission from the secondary, the Hα line displays a weak emission feature that is probably associated with a wind interaction region located near the surface of the primary star. Finally, our analysis of the spectrum with a non-LTE code indicates that the secondary is an evolved object that exhibits some CNO processed material in its atmosphere and has a large mass loss rate. Assuming a distance of 3.5 kpc (which follows from adopting $M_{\mathrm{V,s}} = -6$ for the secondary) we infer $\dot{\mathrm{M}} \simeq 10^{-5}\,\mathrm{M}_\odot\,\mathrm{yr}^{-1}$ for the secondary. Our results suggest that HDE 228766 could be in a post-Roche lobe overflow stage. The secondary may be classified as WN8ha and is currently in a transition stage between a 'normal' Of star and a WNL-type Wolf-Rayet star.

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Preprints from rauw@astro.ulg.ac.be
or on the web at http://vela.astro.ulg.ac.be/Preprints/index.html

Outflow from and asymmetries in the nebula around the LBV candidate Sk-69°279

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We present and discuss new long-slit Echelle spectra of the LMC LBV candidate Sk-69°279 and put them in context with previous images and spectra. While at first glance a simple spherically expanding symmetric shell, we find a considerably more complex morphology and kinematics. The spectra indicate that morphologically identified deviations from sphericity are outflows of faster material out of the main body of Sk-69°279. The morphological as well as the kinematic similarity with other LBV nebulae makes it likely that Sk-69°279 is an LBV candidate, indeed, and poses the question in how far outflows out of expanding LBV nebulae are a general property of such nebulae—at least during some phases of their evolutions.

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Preprints from kweis@mpifr-bonn.mpg.de
or on the web at http://www.mpifr-bonn.mpg.de/staff/kweis/publications.html

Blue Variable Stars from the MACHO database I: Photometry and Spectroscopy of the LMC sample

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We present the photometric properties of 1279 blue variable stars within the LMC. Photometry is derived from the MACHO database. The lightcurves of the sample exhibit a variety of quasi-periodic and aperiodic outburst behavior. A characteristic feature of the photometric variation is that the objects are reddest when at maximum outburst. A subset of 102 objects were examined spectroscopically. Within this subset, 91% exhibited Balmer emission in at least one epoch, in some cases with spectacular spectral variability. The variability observed in the sample is consistent with the establishment and maintenance of the Be phenomenon.

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or on the web at `astro-ph/0206444`

A Magnetically Torqued Disk Model for Be Stars

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Despite extensive study, the mechanisms by which Be star disks acquire high densities and angular momentum while displaying variability on many time scales are still far from clear. In this paper, we discuss how magnetic torquing may help explain disk formation with the observed quasi-Keplerian (as opposed to expanding) velocity structure and their variability. We focus on the effects of the rapid rotation of Be stars, considering the regime where centrifugal forces provide the dominant radial support of the disk material.

Using a kinematic description of the angular velocity, $v_\phi(r)$, in the disk and a parametric model of an aligned field with a strength $B(r)$ we develop analytic expressions for the disk properties that allow us to estimate the stellar surface field strength necessary to create such a disk for a range of stars on the main-sequence. The fields required to form a disk are compared with the bounds previously derived from photospheric limiting conditions. The model explains why disks are most common for main-sequence stars at about spectral class B2 V. The earlier type stars with very fast and high density winds would require unacceptably strong surface fields ($> 10^3$ Gauss) to form torqued disks, while the late B stars (with their low mass loss rates) tend to form disks that produce only small fluxes in the dominant Be diagnostics. For stars at B2 V the average surface field required is about 300 Gauss. The predicted disks provide an intrinsic polarization and a flux at Hα comparable to observations. The radial extent of our dense quasi-Keplerian disks is compatible with typical estimates. We also discuss whether the effect on field containment of the time dependent accumulation of matter in the flux tubes/disk can help explain some of the observed variability of Be star disks.

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Preprints from `cassinelli@astro.wisc.edu`
or by anonymous ftp to `ftp.astro.wisc.edu/outgoing/joecas/MagTorqDisk.ps`
or on the web at `http://www.astro.wisc.edu/ nmiller/`

In Proceedings

Observational Constraints on Massive Star Evolution

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In this paper, I discuss the observational quantities that are useful for judging the successes and failures of current massive star evolutionary theory. The galaxies of the Local Group can s erve as important laboratories for providing these diagnostics, as their metallicties vary by a factor of 10. We find that the evolutionary tracks do a good job of matching the distribution of stars in the H-R diagram during the main-sequence phase. However, none of the models produce RSGs that are as cool and as bright as what is observed. The relative number of WC and WN stars is a strong function of metallicity, and the Padova and Geneva "normal mass-loss" models do a reasonabl y good job of matching the observations at low metallicities, but predict too fe w WCs at higher metallicity. The "enhanced" mass-loss models of the Geneva group do not match the observations at all. New data is providing excellent statistics on the number of RSGs in these nearby galaxies, and the number ratio of RSGs to WRs is also an extremely sensitive function of metallicity. None of the models reproduce the trend of the RSG/WR ratio with metallicity.

To appear in IAU212.
Preprints from `ftp://ft.lowell.edu/pub/massey/iau212massey.ps.gz`

Basic ALI in Moving Atmospheres

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The non-LTE radiative transfer problem requires the consistent solution of two sets of equations: the radiative transfer equations, which couple the spatial points, and the equations of the statistical equilibrium, which couple the frequencies. The "Accelerated Lambda Iteration" (ALI) method allows for an iterative scheme, in which both sets of equations are solved in turn.

For moving atmospheres the radiative transfer is preferably formulated in the co-moving frame-of-reference, which leads to a partial differential equation. "Classical" numerical solution methods are based on differencing schemes. For better numerical stability, we prefer "short characteristics" integration methods.

Iron line blanketing is accounted for by means of the "superlevel" concept. In contrast to static atmospheres, the frequencies can not be re-ordered in the moving case because of the frequency coupling from Doppler shifts.

One of our future aims is the coupling of elaborated radiative transfer calculations with the hydrodynamical equations in order to understand the driving of strong stellar winds, especially from Wolf-Rayet stars.

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or by anonymous ftp to `ftp.astro.physik.uni-potsdam.de`
or on the web at `www.astro.physik.uni-potsdam.de`

A spectroscopic, photometric, and astrometric Galactic O-star database

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The objective of this work is to generate a database with the spectral classification, UV-to-IR photometry, and Hipparcos astrometry of a large number of Galactic O stars. Whenever possible, a single source will be used for each type of data in order to ensure its uniformity and to allow accurate comparisons. This database could be used for several purposes, such as the testing of atmospheric models or a study of the extinction law and its spatial variations. We present here the current status of this work as well as our plans for the following months. We plan to upgrade the database in the future as more O stars are classified using the same procedure and more data are obtained from space and ground-based projects.

Conference Proceedings, IAU #212, Lanzarote, Spain
Preprints available on the web at `http://www.stsci.edu/~jmaiz`

Theses

The Effects of Magnetic Fields and Field-aligned Rotation on Line-Driven Hot-Star Winds

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There is extensive evidence that the radiatively driven stellar winds of OB-type stars are not the steady, smooth outflows envisioned in classical models, but instead exhibit extensive structure and variability on a range of temporal and spatial scales. This dissertation examines the possible role of stellar magnetic fields in forming large-scale wind structure. It is based on numerical magnetohdyrodynamic (MHD) simulations of the interaction of a line-driven flow with an assumed stellar dipole field.

The first two chapters provide a brief historical overview and a background summary of the dynamics of line-driven winds. Chapter 3 then presents initial MHD simulations of the effect of a dipole field on *isothermal* models of such line-driven outflows. Unlike previous fixed-field analyses, the MHD simulations here take full account of the dynamical competition between field and flow, and thus apply to a full range of magnetic field strength, and within both closed and open magnetic topologies. A key result is that the overall degree to which the wind is influenced by the field depends largely on a single, dimensionless, 'wind magnetic confinement parameter', η_* $(= B_{eq}^2 R_*^2/\dot{M} v_\infty)$, which characterizes the ratio between magnetic field energy density and kinetic energy density of the wind.

Chapter 4 carries out semi-analytic analyses of the properties of these numerical simulations, with focus on the effect of magnetic field tilt on the mass flux and rapid flow-tube divergence on the terminal flow speed. The results show in particular that previous expectations of a strong, factor 2-3 enhancement were a consequence of assuming a point-star approximation for the wind driving, and that in finite-disk-corrected models one obtains a much more modest 20-30% speed increase, in agreement with both the numerical MHD simulations and observational constraints.

Chapter 5 extends our MHD simulations to include field-aligned stellar rotation. The results indicate that a combination of the magnetic confinement parameter and the rotation rate as a fraction of the 'critical' rotation now determine the global properties of the wind. For models with strong magnetic confinement, rotation can limit the extent of the last closed magnetic loop, and lead to episodic mass ejections that break through the close loop and are carried outward with a slow, dense, equatorial outflow.

In contrast to these idealized isothermal models, wherein any hot gas is assumed to radiate away excess energy instantaneously, Chapter 6 carries out MHD simulations of the other extreme limit of *adiabatic* outflows, for which no energy is lost at all. The results show that adiabatic models with magnetic confinement $\eta_* < 1$ are very similar to their isothermal counterparts, but those with $\eta_* \geq 1$ are dramatically different from the isothermal case, with much greater level of equatorial confinement.

Chapter 7 summarizes the key conclusions of the thesis, and outlines directions for future work. Overall, the results here provide a dynamical groundwork for interpreting many types of observations – e.g., UV line profile variability; red-shifted absorption or emission features; enhanced density-squared emission; X-ray emission – that might be associated with perturbation of hot-star winds by surface magnetic fields.

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Preprints from asif@physics.udel.edu
or on the web at http://www.bartol.udel.edu/ asif/publications/thesis.pdf

Also Received

Hot Horizontal Branch Stars: Predictions for Mass Loss

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