THE $\mathrm{H}\,\mathrm{O}^{\mathrm{T}}$ 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

Discovery of a Little Homunculus within the Homunculus Nebula of Eta Carinae

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We report long-slit spectroscopic mapping of the η Carinae Nebula obtained using the Space Telescope Imaging Spectrograph (*HST*/STIS). The observations reveal the presence of a previously unknown bipolar emission nebula ($\sim \pm 2''$ along its major axis) embedded within the well-known and larger Homunculus Nebula. A preliminary analysis suggests that this embedded nebula may have originated from a minor eruption event circa 1890, 50 years after the formation of the larger Homunculus.

Accepted by Astronomical Journal

Preprints from `bish@space.mit.edu`

X-ray Emission Line Profile Modeling of O Stars: Fitting a Spherically-Symmetric Analytic Wind-Shock Model to the *Chandra* Spectrum of ζ Puppis

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X-ray emission line profiles provide the most direct insight into the dynamics and spatial distribution of the hot, X-ray-emitting plasma above the surfaces of OB stars. The O supergiant ζ Pup shows broad, blueshifted, and asymmetric line profiles, generally consistent with the wind-shock picture of OB star X-ray production. We model the profiles of eight lines in the *Chandra* HETGS spectrum of this prototypical hot star. The fitted lines indicate that the plasma is distributed throughout the wind starting close to the photosphere, that there is significantly less attenuation of the X-rays by the overlying wind than is generally supposed, and that there is not a strong trend in wind absorption with wavelength.

Accepted by The Astrophysical Journal

Preprints from roban@sccs.swarthmore.edu

or on the web at http://astro.swarthmore.edu/∼cohen/Papers/KCO_final_astro-ph.pdf

or http://arxiv.org/abs/astro-ph/0211550

Discovery of Highly Dynamic Matter Enhancements Along the Polar Axis and Equatorial Plane in the LBV Binary HD 5980

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HD 5980 is a WR+O eclipsing binary in the SMC that has attracted considerable attention since it underwent an LBV-type outburst in 1994. Since then, intense spectroscopic and photometric monitoring have revealed the presence of periodic variability on a timescale of 6-7 hours that cannot be explained by our current understanding of the system. In this paper, we present the first results from our polarimetric observations around secondary eclipse when the assumed WR star passes in front of the assumed LBV component (phase $\phi = 0.36$). These data confirm the presence of stochastic polarimetric variability on a typical time scale of $\sim$ 30 minutes, reaching a very high amplitude of almost 1% on our last of 5 nights. At that time, we also found that the mass loss, which is responsible for the polarimetric variability, presented fluctuations in axial symmetry ranging from very rapid density enhancements along the orbital plane to polar ejections. We propose that either a fast rotator model for the WR star or the presence of a close orbiting neutron star could qualitatively explain the observed polarimetric, spectroscopic and photometric behavior. The evidence presented in this paper is crucial for an understanding of the erratic behavior of this important binary and should be taken into account in any consistent model of the system.

Accepted by The Astrophysical Journal

Preprints from alfredo@astro.umontreal.ca

Spectroscopy of early-type star candidates in M 33 and NGC 6822. II

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We present ground-based spectra of early-type star candidates in the Local Group galaxies M 33 and NGC 6822 taken at the 4.2 m *William Herschel Telescope* (La Palma, Spain). Photospheric parameters $T_{\rm eff}$ and $\log g$ were derived by LTE modeling of the Balmer lines. When possible, mass-loss rates were calculated from the H_α profiles computing emission and scattering in the wind with the method of Scuderi et al. (1992). Five hot star candidates were found in M 33, out of seven stars analyzed, and two out of three in NGC 6822.

Accepted by Astronomy and Astophysics
Preprints from `gca@ct.astro.it`
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Identification of the ionizing source of NGC 2024

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We propose the late-O, early-B star IRS2b as the ionizing source of the Flame Nebula (NGC 2024). It has been clear that such a hot, massive star must be present in this heavily obscured region, and now it has been identified. New near-infrared photometry shows that IRS2b is the most luminous and hottest star in the young star cluster embedded in the center of NGC 2024. The near-infrared observations ($5' \times 5'$) cover $\sim$90 % of the H II region detected in radio continuum radiation, making the probability very low that the ionizing star is not present in the field. A K-band spectrum of IRS2b obtained with ISAAC on the *Very Large Telescope* indicates that the spectral type of IRS2b is in the range O8 V – B2 V. Additional arguments indicate that its spectral type is likely closer to O8 than to B2. The corresponding amount of ionizing radiation is consistent with published radio continuum and recombination line observations.

Accepted by Astronomy & Astrophysics
Preprints from `bik@science.uva.nl`
or on the web at `http://xxx.lanl.gov/abs/astro-ph/0303029`

Detectibility of Mixed Unburnt C+O in Type Ia Supernova Spectra

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Motivated by recent 3-D calculations of the explosion of Type Ia supernova via a pure deflagration we calculate the observed spectra at 15–25 days past maximum light of a parameterized model which has a considerable fraction of unburnt C+O in the central regions. Rather than attempting a self consistent 3-D calculation, which is beyond the scope of current computer codes, we modify the composition structure of the 1-D deflagration model W7. In our exploratory parameterized calculations, we find that a central concentration of C+O is not ruled out by observations for the epochs we study. We briefly examine whether nebular phase spectra could be incompatible with observations.

Accepted by ApJ (Letters) May 1, 2003
Preprints from `baron@nhn.ou.edu`
or on the web at `http://arxiv.org/archive/astro-ph/0303627`

Asymptotic expressions for the angular dependence of low-frequency pulsation modes in rotating stars

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Through the solution of Laplace's tidal equations, approximated to describe equatorially-trapped wave propagation, analytical expressions are obtained for the angular dependence of pulsation modes in uniformly-rotating stars. As the ratio between rotation and pulsation frequencies becomes large, these expressions approach the exact solutions of the governing low-frequency pulsation equations.

Four classes of asymptotic solution are found, corresponding to g (gravito-inertial), r (Rossby), Kelvin and Yanai modes. The Kelvin modes arise through the conservation of specific vorticity, much like the r modes, but propagate in the same sense as the rotation; they are found to be the equivalents of prograde sectoral modes. The prograde Yanai modes behave like g modes, as do the retrograde ones if the rotation is sufficiently rapid; otherwise, the latter exhibit the character of r modes.

Comparison between asymptotic and numerical solutions to the tidal equations reveals that, for g and Yanai modes, the former converge rapidly towards the latter. The convergence is slower for Kelvin and r modes, since these modes become equatorially trapped only when the rotation is very rapid. It is argued that the utility of the asymptotic solutions does not rest on their accuracy alone, but also on the valuable physical insights which they are capable of providing.

Accepted by MNRAS
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or on the web at `http://www.star.ucl.ac.uk/~rhdt/publications/`

A semi-analytical formula for the light variations due to low-frequency g modes in rotating stars

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Through the adoption of the so-called 'traditional approximation', a new semi-analytical formula is derived for the light variations produced by low-frequency g modes in uniformly-rotating stars. The formula is used to examine the influence of rotation on the variability produced by stellar model representative of the slowly-pulsating B-type class.

It is found that, for all apart from prograde sectoral modes, the Coriolis force acts to trap pulsation within an equatorial waveguide. Toward rapid rotation and/or low pulsation frequency, this waveguide becomes so narrow that only a thin band around the stellar equator makes any appreciable contribution toward flux changes. As a result, unless viewed from near the poles, the variability exhibited by the star becomes very small, possibly explaining why recent photometric observations of rapidly-rotating stars have failed to find much evidence for the presence of low-frequency modes.

It is further demonstrated that the ratio between the variability amplitude in pairs of passbands depends, with the introduction of rotation, both on the azimuthal order of a mode, and on the location of the observer in relation to the star's rotation axis. This means that the standard photometric techniques used to identify modes in non-rotating stars cannot easily be applied to systems where rotation is significant.

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In Proceedings

Magnetic Spin-Up of Line-Driven Stellar Winds

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We summarize recent 2D MHD simulations of line-driven stellar winds from rotating hot-stars with a dipole magnetic field aligned to the star's rotation axis. For moderate to strong fields, much wind outflow is initially along closed magnetic loops that nearly corotate as a solid body with the underlying star, thus providing a torque that results in an effective angular momentum spin-up of the outflowing material. But instead of forming the "magnetically torqued disk" postulated in previous phenemenological analyses, the dynamical simulations here show that material trapped near the tops of such closed loops tends either to fall back or break out, depending on whether it is below or above the Keplerian corotation radius. Overall the results raise serious questions about whether magnetic torquing of a wind outflow could naturally result in a Keplerian circumstellar disk. However, for very strong fields, it does still seem possible to form a centrifugally supported, "magnetically rigid disk", in which the field not only forces material to maintain a rigid-body rotation, but for some extended period also holds it down against the outward centrifugal force at the loop tops. We argue that such

rigid-body disks seem ill-suited to explain the disk emission from Be stars, but could provide a quite attractive paradigm for circumstellar emission from the magnetically strong Bp and Ap stars.

Submitted to Proceedings of International Conference on Magnetic Fields in O, B, and A Stars, ASP Conf. Ser., Vol. 216, L. Balona, H. Henrichs, & T. Medupe, eds.
Preprints from owocki@bartol.udel.edu
or on the web at www.bartol.udel.edu/õwocki/preprints/Owocki-SA.ps.gz

Analysis of Doppler-Broadened X-ray Emission Line Profiles from Hot Stars

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We show how X-ray emission arising within an accelerating, expanding medium that also contains a source of continuum absorption generates line profiles of a characteristic shape. A simple, spherical wind model based on this picture provides good fits to the *Chandra* HETGS spectrum of the prototypical O star, ζ Pup. We discuss the model, the fitting procedure, and the determination of confidence limits on the model parameters, and our initial results for this star. The derived fit parameters are consistent with a generic wind-shock scenario for ζ Pup, but there are several surprising aspects of the results, including a lower-than-expected mean wind optical depth and a nearly complete lack of wavelength dependence of the results.

Note that this paper contains more information about the modeling, including five color figures, than does the accepted Ap.J. paper listed in this newsletter by the same authors.

To appear in the Proceedings of the MSSL Workshop on High-Resolution X-ray Spectroscopy, Dorking, Surrey, UK, October 2002
Preprints from dcohen1@swarthmore.edu
or on the web at http://astro.swarthmore.edu/∼cohen/Papers/dcohen_mssl.ps.gz

The extreme Of-Supergiant HD 15570 (O4If+)

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Spectroscopic monitoring of the very massive O4If+ star HD 15570 in IC 1805, performed at the Loiano and San Pedro Martir telescopes from 1990 and 2002 combined with data from the literature, reveal substantial Hα variability of HD 15570, while the He II and the feature *f* appear less variable. The possibility of instrumental effects is ruled out by the constancy of the nearby diffuse interstellar bands and of the He II 6683 Å absorption line. The Hα equivalent width seems to follow a secular trend, as far as observed, and reached the maximum observed value, 11.3 Å in 1996.69. However Conti (1974) reports a higher value of 11.7 sometime between 1967 and 1970. The minimum observed value (3.33 Å) occured in 1990 and then increased to a new maximum value in 1996 with an inversion

of tendency during 1992. In hot stars, the equivalent width of the Hα line is related to the mass loss. We have worked out the variation in mass loss that corresponds to the observed EW variation, using the formula by Puls et al. (1996; Equation 43). If, following Markova et al (2001), we adopt the hypothesis that on a time scale of a few decades neither the star's radius nor the wind terminal velocity changes significantly, the variation of mass loss with respect to an average value comes out to be $\sim \pm 40\%$. Such variability may reflect underlying wind instabilities, which are relevant for the problem of magnetic fields in young massive objects and for the evolutionary connections between O/Of stars, LBVs and Wolf-Rayet stars.

To appear in: " International Conference on Magnetic Fields in O, B and A Stars: Origin and Connection to Pulsation, Rotation and Mass Loss ", PASP Conf. Proceedings, in press
Preprints from `polcaro@rm.iasf.cnr.it`

Theses

Pulsation, rotation, wind and magnetic field in early B-type stars

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In this PhD thesis I have concentrated on the pulsation and magnetic properties of three different kinds of early B-type stars: Be, β Cephei and Slowly Pulsating B (SPB) stars. I present in-depth studies of a few carefully chosen targets, which are representative for the variety of phenomena associated with these massive stars. In all studied stars new non-radial pulsation modes are found. By studying the UV stellar wind variations I could derive the rotational period of these stars very precisely, which allowed me to search for the presence of a magnetic field. Magnetic fields were indeed found in these stars, which I have modeled as simple dipole fields with a typical strength of a few hundred Gauss, inclined with the stellar rotation axis. With present-day instrumentation this is about the weakest field that can be detected in such stars. With no exception, abundance anomalies are found to be associated with these magnetic stars, for which I carried out a quantitative analysis.

PhD thesis defended on October 23, 2002
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