THE HOT STAR NEWSLETTER

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and related phenomena in galaxies

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From our Readers

A Comment on LBV Terminology

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I take exception to the resolution(s?) adopted by the participants in the recent P Cygni workshop (and more generally, to astronomy by resolution in principle!). The introduction of the term "Luminous Blue Variable" was a useful development, because it embodies the unity of the previous P Cyg, S Dor, and Hubble-Sandage Variable classes, not clearly recognized before. Specialists understand what it means, and I encourage them to continue to use it; certainly I shall! In any event, a prior RSG stage of P Cyg remains hypothetical. I object even more strongly to the proposition that "S Dor-type stars that have suffered larger outbursts should preferably be called S Dor-type variables that have undergone an η Car-type outburst". Unlike any other LBV studied in detail, η Car resides in a giant H II region in association with O3 stars; its luminosity, mass, outburst amplitude, ejecta velocities, and nitrogen enrichment are all far greater than those of any other LBV, except possibly for SN 1961V and some similar "supernovae". η Car may well be a post-WN-A star, and it is not at all obvious that its evolutionary history or outburst mechanism is the same as that of other LBVs. It is also possible that the η Car phenomenon is triggered by a binary interaction; how could that represent a paradigm for other LBVs, if they should be a result of single-star evolution? Terminology is not a trivial matter. In the case of poorly understood phenomena, care should be taken that it is purely descriptive, and does not incorporate interpretational elements that may be incorrect. Otherwise, the terminology itself may bias further research detrimentally.

Meeting Report

Conference Highlights
Interacting Winds from Massive Stars

This conference was held on the Îles-de-la-Madeleine, Québec, Canada in July 2000. The proceedings will be edited by A.F.J. Moffat & N. St-Louis and published in the *ASP Conference Series*

1 Contents of the meeting

Massive stars have high luminosities that drive strong stellar winds. Although these winds constitute key factors in the ecology of the Universe and are determining factors in the evolution of massive stars, many of their properties remain elusive.

One of the principle goals of this workshop was to learn more about these strong winds by examining how they interact with: (1) the **interstellar medium** (ISM), i.e. while in the main-sequence (MS) OB star phase, their winds impinge on the ISM; (2) any **circumstellar medium** (CSM) left from previous evolutionary stages of the same star, e.g. a fast wind catching up with a slow wind; (3) **themselves**, e.g. shocks produced by internal instabilities and other intra-wind interactions. Of course, the interactions often produce various physical phenomena that are interesting in their own right (e.g. wind-blown bubbles, ring nebulae, supernova remnants, shocks...). This part of the workshop concentrated on four main successive stages: MS OB; luminous blue variable (LBV) or red supergiant (RSG), Wolf-Rayet, and supernova (SN) of type II or Ib/c. A comparison was also made with interacting winds from low-mass stars as they mount the asymptotic giant branch (AGB) on the way to becoming planetary nebulae (PNe).

The other principle goal of the workshop was devoted to winds of massive stars colliding with one another in binaries. When this occurs, a bow-shaped shock region forms around the star with the weaker wind momentum. Such bow-shocks can be highly unstable, with X-ray and non-thermal (NT) radio emission from hot (10^{6-7} K) gas near the bow head, and IR emission from hot (10^3 K) dust further downstream in some cases. Recombination line-emission from the shock regions can also be used to trace and map out the shock cone in the closer, unresolved systems.

2 Highlights

2.1 Interaction of stellar winds and the ISM

The HI (super-)shells blown by (groups of) OB stars are very common. and for individual stars their properties are very similar: $v_{exp} \sim 10\ km\ s^{-1}, t_{dyn} \sim 10^6 yrs$. What precisely determines their elongated shapes remains a mystery, although it must be a combination of the ISM, ambient density distribution, star motion, and stellar properties. Triggered star-formation at the edges of superbubbles competes with that from SNe.

2.2 Interaction of stellar winds from different evolutionary phases

Some of the most interesting points raised, going from MS through SN were: (1) The B1.5 supergiant Sher 25 in the dense, young Galactic cluster NGC 3603 has a very similar ring structure to that seen around SN 1987A, and thus merits detailed study soon – before it erupts! (2) Every WR star displaying an optical ring nebula also exhibits molecular emission as detected in CO. (3) WR stars likely explode as Ib/c SNe, e.g. Cas A, although this association is not without problems. (4) Due to the interaction of SN ejecta with the previous winds of the massive progenitor, SNRs may not evolve through all 4 classical stages; this is also complicated by copious mass-loss *just* before the SN explosion.

2.3 Intra-wind interactions of hot stellar winds

Most, if not all, hot massive stars have winds that are pervaded by multi-scale, stochastic clumping, which is likely the manifestation of supersonic, compressible turbulence. The impact of clumping was highlighted in 3 areas: (1) wind driving, which results in mass-loss rates $\sim 3\times$ less than when smooth winds are assumed; (2) shocks, accounting for the ubiquitous X-ray flux seen in hot stars; and (3) dust formation, but only in C-rich WR stars and SNe. On a larger scale, while global co-rotating interaction regions are common in OB winds, only $\sim$ 15% of WR stars show winds flattened by such action. A successful simulation was presented at the workshop to explain the ensuing spectral variations in 2 key rotating WR stars (EZ CMa and HD 191765).

2.4 Other related objects

As with ring nebulae around WR stars, PNe are thought to be created and shaped by interacting winds, but from lower-mass stars. However, unlike massive stars, the ISM plays no role in PNe due to the smaller scale of the nebulae. Other phenomena unique to PNe include: flyers, jets, concentric rings, and precessing outflows. On the other hand, there are some remarkable similarities between some PNe and some LBV nebulae (e.g. the PN Hubble 5 and the LBV nebula η Car, with their bipolar shape + skirt structure). However, while most (all?) PNe are bipolar in shape (although the kinematical studies to demonstrate that they actually reveal a bipolar ejection have not been carried out in most cases), this is not so clear for massive-star nebulae. Furthermore, strong-wind central stars of PNe with [WC] spectra have clumpy winds, much like their pop I WR counterparts.

2.5 Colliding winds in massive binaries: continuum emission

As opposed to single-star nebulae, the shock cones in massive binaries have a great advantage: they present different viewing angles as the stars revolve. Most of the emission from the wind-wind collision (WWC) zone between the two stars is produced in either continuous form (mainly radio, IR and X-rays) or spectral lines (mainly optical, UV). Besides the beautiful resolved radio images of 3 wide WR + O systems, all of which show the shock cone in non-thermal (NT) radio emission, it appears that among the larger sample of unresolved hot stars, the detection of NT radio emission implies the presence of a binary. However, recent HST/FGS observations have failed to reveal the expected resolved binaries in several cases. IR dust emitters among WR stars are all either $\sim$ WC9 or long/moderate-period WC +

O binaries of any WC subtype (although not all long/moderate-period WC + O systems are IR dust producers, e.g. γ Vel). Possibly all WC9 dust producers are also binary. In any case, while shocks in single-star winds can produce overdensities, the strongest overdensities, which are more likely to lead to dust formation (e.g. spiral pinwheels), are produced in colliding wind binaries. Most colliding wind binaries emit enhanced X-ray emission. A particularly exciting case is η Car, whose 5.5 year X-ray light curve can be modeled via WWC in a highly elliptical binary orbit. Even γ rays are predicted from the WWC zone in some systems (e.g. HD 193793) via Fermi acceleration and inverse Compton scattering, especially at preferred viewing angles.

2.6 Colliding winds in massive binaries: line emission

Spectral line radiation can provide valuable Doppler information, allowing one to map out the WWC zone, where recombination lines arise in the cooling flow along the shock surface. Line radiation has revealed considerable density fluctuations in the bow shock zone, probably a result of highly turbulent structure, as expected in the WWC zone. A large number of results have become available, a few of which are: (1) The Struve-Sahade effect in massive binaries (photospheric lines of the secondary component are stronger when it is approaching), may be the result of bow-shock X-ray heating on the secondary; (2) The possibility that clumps in the WR wind can shoot through the WWC zone and impinge on the O-star companion in the 4-day WN5 + O6 binary V444 Cygni was presented along with spectroscopic evidence; (3) Colliding wind features found from spectroscopy before the LBV eruption in the luminous WN + O SMC binary HD 5980 have been confirmed to occur in a similar fashion after the eruption - this star also reveals a 6-7 hour periodicity, which may be the result of tidal oscillations.

2.7 Colliding winds in massive binaries: theory

Advances in sophistication of numerical simulations are now allowing one to carry out more realistic models (3-D, high resolution, including proper cooling, compression, clumping, radiation, heat conduction,...) of colliding winds. Turbulence appears in all cases. Clumps in the pre-colliding wind *can* survive the collision process in some cases and be compressed in the central bow shock. With rapid cooling in metal-rich WC winds, the formation of dust appears more feasible.

2.8 Final remarks

Every meeting has its favorite buzz-words. At this one it was **clumps**, **dust** and **binaries**. Clumps are ubiquitous in winds and their interaction zones, and proper allowance must be made for them. The details of dust formation remain a mystery, although progress has been made, both in finding situations that are conducive, and in revealing the detailed chemical process. Binaries appear to occupy a bigger role than once believed and may be a crucial factor in shaping many of the ejection nebulae. On the other hand, surprisingly little was discussed about magnetic fields, which may be required to trigger large-scale wind structures and account for NT radio emission. This may be a consequence of the fact that magnetic fields are difficult to observe directly in massive stars.

Anthony F.J. Moffat & Nicole St-Louis – Université de Montréal

Accepted Papers

Differential O and Si Abundances in M33 Early B Supergiants

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We present non-LTE analyses of four M33 early B-supergiant stars and five Galactic counterparts. This is the first time that B supergiants beyond the Magellanic Clouds are analyzed by means of detailed Non-LTE techniques. Among the M33 stars, new spectroscopic observations of B38 (ob21–108) are presented and the object is classified as B1Ia. The classification of another M33 star, B133, is changed with respect to a former study. Equivalent widths of O and Si lines are measured for the M33 objects. Stellar temperatures, gravities, microturbulences and Si abundances are derived for all objects using the Si ionization equilibrium and the Balmer line wings. O abundances are then also derived. Important approximations made during the calculations are described, and their influence on the results is analyzed (namely, we set the Lyman resonance lines in detailed balance during the calculation of the atmospheric structure for stars cooler than 20 000 K, and set the SiIIIS resonance lines in detailed balance during the line formation calculations for all models). It is found that these approximations have no significant effect on the results at any microturbulence. We found a difference in the derived temperatures of the earlier Galactic stars as compared to those obtained by other authors, which we attribute to the different lines used for their derivation. A difference can also be present in the results when using the SiII/SiIII and the SiIII/SiIV ionization equilibria. We conclude that a strict differential analysis is needed to detect abundance differences. Thus we compare results line by line in M33 and Galactic stars of stellar parameters as similar as possible. Three of the four M33 stars turned out to be O deficient as compared to their Galactic counterparts, and only one, close to the center of M33 (M33 1054) is found to be moderately O enriched. From these differential analyses we find that our data are compatible with a radial O gradient in M33 as that derived from HII region data: we obtain -0.19 ± 0.13 or -0.20 ± 0.07 dex kpc^{-1}, depending on whether B133 is included or not. Our data are also consistent with other possibilities such as a steep increase of the O abundance in the inner region (at projected distances less than 9 arcmin from the center of M33), followed by a flat O abundance profile towards the outer parts of M33. Si shows the same pattern, and it is shown that Si and O correlate well, as expected for α-elements, supporting then the high value of the O abundance gradient in M33 as compared to the Milky Way and other nearby spiral galaxies. The results are compared with those of a more approximate technique, and it is concluded that this last can be used, attention being drawn to certain problems that are indicated. As an important additional point, it is shown that M33 1054 is most probably a single object, in spite of the bright absolute magnitude found in the literature.

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Modeling line profile variations of σ Ori E and θ^1 Ori C

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We analyse phase-dependent variations of the photospheric lines of the magnetic B star σ Ori E and the suspected magnetic O star θ^1 Ori C. In the framework of the oblique magnetic rotator model, the observations are interpreted as the result of inhomogeneous chemical abundances – spots – at the stellar surface. This model can at least qualitatively explain the line profile variations with two spots at the magnetic poles of both stars. In the case of σ Ori E, we find the spots to be overabundant in He and depleted in metals. For θ^1 Ori C the presumed spots would be depleted both in He and in metals. For θ^1 Ori C we also discuss an alternative model with spots of enhanced abundances at the magnetic equator. This model better fits the observations. Chemical fractionation is not expected for θ^1 Ori C and the absorption lines show indications of circumstellar absorption. Therefore, the most likely interpretation of the variations observed in the absorption lines of this star is the presence of excess absorption in a circumstellar cloud and not that of a difference in chemical abundance.

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or on the web at: `http://www.lsw.uni-heidelberg.de/∼ostahl/sigtheta.ps.gz`

Wolf–Rayet star nucleosynthesis and the isotopic composition of the Galactic Cosmic Rays

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There is now strong observational evidence that the composition of the Galactic Cosmic Rays (GCRs) exhibits some significant deviations with respect to the abundances measured in the local (solar neighbourhood) interstellar medium (ISM). Two main scenarios have been proposed in order to account for these differences ('anomalies'). The first one, referred to as the 'two–component scenario', invokes two distinct components to be accelerated to GCR energies by supernova blast waves. One of these components is just made of ISM material of 'normal' solar composition, while the other one emerges from the wind of massive mass–losing stars of the Wolf–Rayet (WR) type. The second model, referred to as the 'metallicity–gradient scenario', envisions the acceleration of ISM material whose bulk composition is different from the local one as a result of the fact that it originates from inner regions of the Galaxy, where the metallicity has not the local value. In both scenarios, massive stars, particularly of the WR type, play an important role in shaping the GCR composition.

After briefly reviewing some basic observations and predictions concerning WR stars (including s–process yields), this paper revisits the two proposed scenarios in the light of recent non–rotating or rotating WR models.

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On the origin of the O and B-type stars with high velocities II Runaway stars and pulsars ejected from the nearby young stellar groups

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We use milli-arcsecond accuracy astrometry (proper motions and parallaxes) from Hipparcos and from radio observations to retrace the orbits of 56 runaway stars and nine compact objects with distances less than 700 pc, to identify the parent stellar group. It is possible to deduce the specific formation scenario with near certainty for two cases. (i) We find that the runaway star ζ Ophiuchi and the pulsar PSR J1932+1059 originated about 1 Myr ago in a supernova explosion in a binary in the Upper Scorpius subgroup of the Sco OB2 association. The pulsar received a kick velocity of $\sim$350 km s^{-1} in this event, which dissociated the binary, and gave ζ Oph its large space velocity. (ii) Blaauw & Morgan and Gies & Bolton already postulated a common origin for the runaway-pair AE Aur and μ Col, possibly involving the massive highly-eccentric binary ι Ori, based on their equal and opposite velocities. We demonstrate that these three objects indeed occupied a very small volume $\sim$2.5 Myr ago, and show that they were ejected from the nascent Trapezium cluster.

We identify the parent group for two more pulsars: both likely originate in the $\sim$ 50 Myr old association Per OB3, which contains the open cluster α Persei. At least 21 of the 56 runaway stars in our sample can be linked to the nearby associations and young open clusters. These include the classical runaways 53 Arietis (Ori OB1), ξ Persei (Per OB2), and λ Cephei (Cep OB3), and fifteen new identifications, amongst which a pair of stars running away in opposite directions from the region containing the λ Ori cluster. Other currently nearby runaways and pulsars originated beyond 700 pc, where our knowledge of the parent groups is very incomplete.

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HST/STIS Observations of the Wolf-Rayet Star HD 5980 in the Small Magellanic Cloud: II. The Interstellar Medium Components

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Observations of the interstellar and circumstellar absorption components obtained with the Hubble Space Telescope Imaging Spectrograph (STIS) along the line-of-sight toward the WR/LBV system HD 5980 in the Small Magellanic Cloud are analyzed. Velocity components from C I, C I*, C II, C II*, C IV, N I, N V, O I, Mg II, Al II, Si II, Si II*, Si III, Si IV, S II, S III, Fe II, Ni II, Be I, Cl I, and CO are identified, and column densities estimated. The principal velocity systems in our data are: 1)

ISM components in the Galactic disk and halo (it V_{helio}= 1.1±3, 9±2 km s^{-1}); 2) ISM components in the SMC (v_{helio} =+87±6, +110±6, +132±6, +158±8, +203±15 km s^{-1}); 3) SMC supernova remnant SNR0057-7226 components (v_{helio}=+312±3, +343±3, +33, +64 km s^{-1}); 4) circumstellar (CS) velocity systems (v_{helio} =−1020,−840,−630,−530,−300 km s^{-1}); and 5) a possible system at −53±5 km s^{-1} (seen only in some of the Si II lines and marginally in Fe II) of uncertain origin. The supernova remnant SNR0057-7226 has a systemic velocity of +188 km s^{-1}, suggesting that its progenitor was a member of the NGC 346 cluster. Our data allow estimates to be made of T_e∼40,000 K, n_e∼100 cm^{-3}, N(H)∼(4-12)×10^{18} cm^{-2} and a total mass between 400 and 1000 $M_\odot$ for the SNR shell. We detect C I absorption lines primarily in the +132 and +158 km s^{-1} SMC velocity systems. As a result of the LBV-type eruptions in HD 5980, a fast-wind/slow-wind circumstellar interaction region has appeared, constituting the earliest formation stages of a wind-blown H II bubble surrounding this system. Variations over a timescale of one year in this CSM structure are detected.

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Evolutionary status of hydrogen-deficient central stars of planetary nebulae

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The observational data for the planetary nebulae with hydrogen-deficient central stars are analysed. We show that the general evolutionary sequence is: late-[WC], early-[WC], PG 1159. An analysis of the observed distributions of nebular parameters leads to a conclusion that the planetary nebulae with hydrogen-deficient nuclei are not different from the population of other planetary nebulae in the Galaxy. In particular the proportion of the H-deficient stars among young nebulae is the same as in the whole population. We have made a detailed comparison of the observed parameters with theoretical modelling of the late He-shell flash (born again AGB) scenario. Our finding is that the [WC] nuclei are not formed in a late He-shell flash. This scenario can, however, give origin to some PG 1159 objects. There are five objects known which have presumably suffered from a late He-shell flash. The observed parameters of their nebulae imply that these stars will not become typical [WC] objects. Thus most of hydrogen-deficient central stars (at least [WC]) evolve directly from the AGB as do the other planetary nebula nuclei. We discuss implications of this result.

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S Doradus variables in the Galaxy and the Magellanic Clouds

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The goal in writing this paper is five fold: (1) to summarize the scientific achievements in the 20th

century on S Dor variables (or LBVs); (2) to present an inventory of these variables in the Galaxy and the Magellanic Clouds with a description of their physical state and instability properties; (3) to emphasize the photometric achievements of the various types of instabilities. Generally this seems to be a neglected item resulting in a number of misunder- standings continuously wandering through literature; (4) to investi- gate the structure of the S Dor-area on the HR-diagram; (5) to estimate the total numbers of S Dor varibles in the three stellar systems.

The position of the strong active S Dor variables in minimum bright- ness obey the following linear relation on the HR-diagram:

$$\log L/L_{\odot} = 1.37\,\log T_{\rm eff} - 0.03$$

The relatively small dispersion of less active and supposed ex- and dormant S Dor variables with respect to this relation is twice as large at the blue side than at the red side. This might be caused by evolution to the WR stage and/or to high rotation.

S Dor variables can be subject to five types of instabilities: the very rare genuine eruptive episodes (the 'SD-eruptions'), two different brightening phases caused by slow pulsations (the 'SD- phases'): one on a time scale of years, the other on a time scale of decades at a more or less constant luminosity and two types of microvariations: one on a time scale of weeks, the other on a time scale of about 100 d.

So far, no periodicities of light curve characteristics of any of these instabilities have ever been found.

The durations of active and non-active stages are estimated for about half of the sample based on scattered magnitude estimations such as from historical records, and on monitoring campaigns. It would be a misunderstanding to believe that all S Dor variables should be always spectacular. It is estimated that most of them will be not spectacular at all for at least 70% of their lifetime as an S Dor variable.

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Gamma–ray line emission from OB associations and young open clusters: I. Evolutionary synthesis models

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We have developed a new diagnostic tool for the study of gamma–ray emission lines from radioactive isotopes (such as ^{26}Al and ^{60}Fe) in conjunction with other multi–wavelength observables of Galactic clusters, associations, and alike objects. Our evolutionary synthesis models are based on the code of Cerviño & Mas-Hesse (1994), which has been updated to include recent stellar evolution tracks, new stellar atmospheres for OB and WR stars, and nucleosynthetic yields from massive stars during hydrostatic burning phases and explosive SN II and SN Ib events.

The temporal evolution of ^{26}Al and ^{60}Fe production, the equivalent yield of ^{26}Al per ionising O7 V star ($Y_{26}^{\rm O7\ V}$), and other observables are predicted for a coeval population. The main results are:

- The emission of the ^{26}Al 1.809 MeV line is characterised by four phases: stellar wind dominated phase ($\lesssim$ 3 Myr), SN Ib dominated phase ($\sim$ 3–7 Myr), SN II dominated phase ($\sim$ 7–37 Myr), and exponential decay phase ($\gtrsim$ 37 Myr).
- The equivalent yield $Y_{26}^{\rm O7\ V}$ is an extremely sensitive age indicator for the stellar population which can be used to discriminate between Wolf–Rayet star and SN II ^{26}Al nucleosynthesis in the association.
- The ratio of the ^{60}Fe/^{26}Al emissivity is also an age indicator that constrains the contribution of explosive nucleosynthesis to the total ^{26}Al production.

We also employed our model to estimate the steady state nucleosynthesis of a population of solar metallicity. In agreement with other works, we predict the following relative contributions to the ^{26}Al production: $\sim$ 9% from stars before the WR phase, $\sim$ 33% from WR stars, $\sim$ 14% from SN Ib, and $\sim$ 44% from SN II. For ^{60}Fe we estimate that $\sim$ 39% are produced by SN Ib while $\sim$ 61% come from SN II. Normalising on the total ionising flux of the Galaxy, we predict total production rates of 1.5 $M_\odot$ Myr^{-1} and 0.8 $M_\odot$ Myr^{-1} for ^{26}Al and ^{60}Fe, respectively. This corresponds to 1.5 $M_\odot$ of ^{26}Al and 1.7 $M_\odot$ of ^{60}Fe in the present interstellar medium.

To allow for a fully quantitative analysis of existing and future multi–wavelength observations, we propose a Bayesian approach that allows the inclusion of IMF richness effects and observational uncertainties in the analysis. In particular, a Monte Carlo technique is adopted to estimate probability distributions for all observables of interest. We outline the procedure of exploiting these distributions by applying our model to a fictive massive star association. Applications to existing observations of the Cygnus and Vela regions will be discussed in companion papers.

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Submitted Papers

The Theory of Steady State Super-Eddington Winds and its Application to Novae

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We present a model for steady state winds of systems with super-Eddington luminosities. These radiatively driven winds are expected to be optically thick and clumpy as they arise from an instability driven porous atmosphere. The model is then applied to derive the mass loss observed in bright classical novae. The main results are: 1) A general relation between the mass loss rate and the total luminosity in super-Eddington systems. 2) A quantitative agreement between the observed luminosity evolution which is used to predict both the mass loss and temperature evolution, and their observations. 3) An agreement between the predicted average integrated mass loss of novae as a function of WD

mass and its observations. 4) A natural explanation for the 'transition phase' of novae. 5) Agreement with eta Carinae which was used to double check the theory. The prediction for the mass shed in the star's great eruption agrees with observations to within the measurement error.

Submitted to MNRAS

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In Proceedings

Status of the Hanle Effect for Stars

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A review of work on the Hanle effect for diagnosing magnetic fields in stars other than the Sun is presented. The use of the Hanle effect in this context is relatively new, emerging as an area of research interest only within the last 5 years. To my knowledge, the Sun is the only star for which the Hanle effect has been detected; however, stellar astrophysicists have largely been unaware of this effect until recently. To date, only limited theoretical studies of the Hanle diagnostic have been considered, especially in the context of extended stellar envelopes (winds) under rather narrow assumptions. Nonetheless, these studies do appear to be yielding promising results and have served to educate the broad stellar community about the potential of the Hanle diagnostic. A brief overview of the major results in this area is presented followed by a discussion of future theoretical and observational work to be pursued.

To appear in the proceedings of Advanced Solar Polarimetry - Theory, Observation, and Instrumentation

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Tidal Stresses and Nonconservative Mass Transfer in Close Binaries

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I suggest arguments that nonconservative mass transfer may appear as an important perturbation to standard Roche lobe overflow (RLOF) processes in massive close binaries, if radiatively driven mass-loss can be enhanced due to tidal stresses. As shown, such large enhancements would either require breaking the assumption of von Zeipel gravity darkening, so may occur for cooler envelopes with convective energy transport, or would require temperature-sensitive enhancement of the continuum opacity, also expected at lower temperatures. Thus the key issue is whether or not RLOF occurs before the evolving envelope is sufficiently cool, which depends on the degree of expansion and therefore on the binary separation. It is also possible to defeat von Zeipel gravity darkening if fast variations, induced by elliptical orbits and time-varying tidal forces, preclude thermal adjustment of the envelope. These types of processes could all lead to enhanced mass loss and nonconservative transfer that would be focused along the orbiting line of centers, with important ramifications for both binary evolution and the morphology of resulting nebulae.

A related topic, the impact of optically thin radiative forces on the secondary photosphere due to irradiation by the primary, although drastically overestimated in the past, is nevertheless of considerable diagnostic interest because of its potential for generating surface flows. Such dynamical phenomena are not necessarily expected to alter RLOF, but do offer promise for explaining the mystery of the Struve-Sahade effect. Observationally determined upper bounds on surface flows in close massive binaries are needed.

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Interacting Winds and Tidal Interactions in HD 5980

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In this paper we review the status of the wind-wind interactions in the SMC eccentric-orbit binary system HD 5980. Strong wind-wind collisions are expected, and the recent HST observations suggest that the shock cone winds tightly around the non-erupting component of the system. However, the line-profile variability leaves open the possibility that the wind structure of the erupting star may be changing as a function of orbital phase, and/or that its intrinsic wind structure is not spherically symmetric. Based on a numerical model, we suggest that stellar surface oscillations, driven by tidal forces, could be playing a role in changing the wind structure of star A, as a function of orbital phase and the question is raised as to whether such oscillations could enhance the mass-loss rates at periastron, as compared with apastron. A time-dependent wind structure (on orbital time-scales) would have implications for the modelling of the wind-wind collisions in eccentric-orbit binary systems in general.

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Improved Basic Physical Properties of the Oe-Star Binary V1007 Sco = HD 152248

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An analysis of new and published sets of spectroscopic and photometric observations of the astrophysically important eclipsing O+O binary system V1007 Sco in NGC 6231, leads to significantly improved basic physical properties of the system. We arrived at the following preliminary values for masses and

radii: $M_1 = 28.4$ M$_\odot$, $M_2 = 29.5$ M$_\odot$, $R_1 = 15.6$ R$_\odot$, $R_2 = 17.1$ R$_\odot$. These values clearly indicate log g of about 3.5 [CGS], therefore the stars are Oe giants, not Of supergiants. Similarity to Be stars follows also from the fact that the Balmer and He I emission in the spectra from the year 2000 is much stronger than in the spectra taken several years ago. We also report the discovery of apsidal motion with a period of 132 years. Our solution implies a constant of internal structure essentially in agreement with its theoretical value and with the age of NGC 6231. We suggest that the masses, which still differ from the evolutionary ones, and the observed variable Balmer and He I emission may be related to the fact that both stars come very close to their respective limits of dynamical stability near periastron, and large mass loss from the system is likely.

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