THE HOT ⋆ STAR NEWSLETTER

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and related phenomena in galaxies

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From the editor

This issue contains what we hope to be the first of a series of short commentaries. This one is on the *photospheric connection*. It would be useful to hear your comments, critics and complementary views. If you wish to write a commentary on another topic, please contact the newsletter editor.

The news this month include plans for an X-ray observing campaign, notice of the launch of a newsletter on the Magellanic Clouds and information on the Liege colloquium (July) and on a colloquium on LBV stars (October).

Best season wishes!

Contents of this newsletter

Commentary

Variability in the Photospheres and Stellar Winds of Hot Stars: The "Photospheric Connection" At Last?

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It has been slightly more than 10 years since a seminal workshop on "The Connection Between Nonradial Pulsations and Stellar Winds in Massive Stars" was hosted by JILA and the University of Colorado (Abbott et al. 1986). At that time (see, e.g., the pivotal review by Henrichs 1984), there was a great deal of excitement in the OB- and Be-star communities owing to the recognition that photospheric variability (probably due to one or more modes of nonradial pulsation) coexisted with stellar wind variability (as diagnosed by the discrete absorption components [DACs] in the absorption troughs of UV P Cygni profiles). Since then, the search for observational evidence connecting variations in these two atmospheric regions has been the focus of intense effort, as has been the search for theoretical explanations for the origin of the coupling required to mediate such a connection. From the observational side, the evidence for a connection has proven to be much more elusive than originally anticipated. However, as amply demonstrated by abstracts in recent editions of the *Hot-Star Newsletter* (HSN), observational evidence supporting the existence of a photospheric connection has been mounting, to the point that we may be on the verge of developing a new paradigm for the atmospheres of OB stars. In this commentary, we provide a brief (and necessarily incomplete) overview of our interpretation of these developments.

The new observational evidence comes from spectroscopic time series observations of a wide range of early-type stars that have been painstakingly collected from ground- and space-based observatories, particularly the stalwart *IUE* satellite. In the UV, the long-term monitoring program of 10 bright O stars conceived by Henrichs (Kaper et al. 1996a; HSN 13) shows that the recurrence time between repetitions of patterns of DACs and the acceleration of a given component is longer for stars with smaller projected rotational velocities, but that for a given object the pattern of variability seems to remain fixed over at least 6 years. This behaviour suggests that the DACs are related to the underlying rotation rate of the star. Rotation also seems to govern the time scales associated with variability in optical wind lines of BA supergiants (Kaufer et al. 1996; HSN 10), which very often resemble the UV DACs seen in O stars. Indeed, analogs of the UV DACs are also seen at quite small velocities in optical P Cygni profiles of O stars (e.g., Prinja et al. 1996; HSN 14) which, together with the synchronous variability observed between subordinate UV lines and stronger resonance lines (Kaper et al. 1996a) and covariability between DACs and Hα wind profiles (Kaper et al. 1996b) implies that the variability originates deep in the wind. The widespread occurrence of optical line profile variations among the O stars (Fullerton, Gies, & Bolton 1996; HSN 13) and the agreement between the distribution of O-type variables in the H-R diagram and the domain of strange-mode oscillations leave open the possibility that pulsational activity triggers variations in the stellar wind.

Direct evidence in favour of a connection comes from the *IUE* MEGA campaign (Massa et al. 1995; HSN 11), which provided an unprecedented look at stellar wind variability over an interval of $\sim$16 days (i.e., several consecutive rotational periods) for 3 key objects: HD 50896 (WN5; St Louis et al.

1995; HSN 11); HD 64760 (B0.5 Ib; Prinja, Massa, & Fullerton 1995; HSN 11); and ζ Puppis (O4 I(n)f; Howarth, Prinja, & Massa 1995; HSN 11). The repeatability of the variations in the winds of these stars is astonishing. For ζ Pup and HD 64760 (and perhaps also HD 50896), some – though not all – aspects of the variability repeat at intervals that are compatible with the rotational period of the star (ζ Pup) or an integral submultiple of the rotation period (HD 64760).

The detection of wind variability that is tied to the underlying star can only mean that the variations originate in the photosphere. Presumably, the wind responds to boundary conditions that vary as a function of position on the stellar surface. Both heuristic, kinematical models (Owocki, Cranmer, & Fullerton 1995; HSN 10) and dynamical simulations (Cranmer & Owocki 1996; HSN 11) of radiation-driven winds that incorporate large-scale basal perturbations of unspecified origin (but neglect the strong, small-scale line-driven instability) produce large-scale, spiral patterns of enhanced density in the wind. These are the "corotating interaction regions" (CIRs) first considered for hot stars by Mullan (1984); their presence introduces significant deviations from spherical symmetry in the azimuthal density distribution of the stellar wind. Synthetic spectra generated from these simulations reproduce several aspects of the observed variability.

The results from the MEGA campaign lead to a second, startling inference: in order to have different boundary conditions for the wind at different positions on the star, the photosphere cannot be uniform. Thus, the time-dependent behavior of the stellar winds of at least some OB (and WR?) stars tells us that large-scale inhomogeneities must be present in their photospheres. The prime candidates for the origin of these nonuniformities are nonradial pulsations or magnetic fields, or some combination of both. By themselves, the wind variations do not provide many additional clues to the nature of these photospheric processes, so tests to distinguish between them will have to come from time-series spectroscopy of photospheric lines. Unfortunately, some of these tests may have to be indirect, particularly since extremely small ($\sim$10 G; i.e., probably undetectable) magnetic fields might still have a measurable effect on the emergence of the stellar wind.

Both processes may be at work in ζ Puppis, the perennial "archetypical O star" for stationary models of hot-star atmospheres, which has also emerged as an important object for variability studies. Its new prominence may be viewed as another legacy from the 1985 workshop, since it was there that Dietrich Baade announced the detection of line-profile variations in its C IV $\lambda\lambda$5801, 5812 doublet, which he interpreted as signatures of nonradial pulsation. This interpretation has now been substantially confirmed by Reid & Howarth (1995; HSN 12), who also detected the pulsation period (8.54 hours) in the near-star wind (as diagnosed by the Hα emission feature). This period was not evident in the MEGA campaign observations of the high-velocity wind, which was instead dominated by two periodic components, one of which probably reflects the rotational period of the star (5.2 days). Howarth et al. (1995) suggest that a magnetic field inclined to the rotation axis of the star (i.e, an oblique rotator model) may cause this modulation. The second period (19.2 hours) reflects the recurrence time of the DACs during the MEGA campaign, and may be related to the 16.7-hour period reported by Berghöfer et al. (1995; HSN 10) in simultaneous observations of Hα and X-ray emission made at an earlier epoch. The periodic nature of these X-ray variations is truly remarkable, and might also be attributable to corotating structures in the wind.

These results paint a new, dynamic picture of hot-star atmospheres, one in which time-dependent phenomena in their deep photospheric layers provide shape and structure to their line-driven outflows, much as had been anticipated by the 1985 workshop. At a very basic level, we think that there are two conclusions to be drawn. First, the usual assumption that hot-star winds are uniform and spherically symmetric will probably have to be done away with, once and for all. There needs to be a concerted effort to determine the extent to which the asphericity of the wind's density distribution in the (r, θ) plane (see, e.g., Ignace, Bjorkman, & Cassinelli 1996; HSN 10) and the presence of CIRs in the (r, ϕ)

plane will alter spectroscopically derived mass-loss rates, particularly those from diagnostics that are sensitive to ρ^2. Petrenz & Puls (1996; HSN 14) have taken the first steps in making this assessment for Hα by accounting for the presence of wind-compressed zones in the (r, θ) plane. Second, there is evidently an additional physical process (or processes) at work in the atmospheres of hot stars whose influence has largely been ignored in modelling efforts to date. Pulsation is an obvious candidate; surface magnetic fields might also play a role. Whatever their origin, a more complete understanding of the photospheric variations promises new diagnostic probes of the interior structure of early-type stars.

In view of these developments, we think that Conti's (1986) description of hot-star research at the time of the 1985 workshop is equally apt now: "It is an exciting time for observations and a stimulating period for theoretical advances." Watch these pages for all the latest news!

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Accepted Papers

A Three Dimensional Classification for WN stars

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A three dimensional classification for WN stars is presented using: 1) the HeII 5411/HeI 5875 ratio as primary indicator of ionisation; 2) FWHM 4686 and EW 5411 as indicators of line width and strength; and 3) an oscillating Pickering decrement as indicator of hydrogen presence. All WN stars in the Galaxy and two thirds of the LMC stars are classified on the new system. Almost all spectra inspected fall smoothly into categories within which the spectra are very similar. All ionisation subclasses show a tight correlation between line strength and width, with stars containing hydrogen at the weak narrow end and WN/C stars near the strong broad end. H^+/He^{++} correlates with strength and width with a cut-off for presence of hydrogen, which is slightly dependent on ionisation subclass, at about FWHM 4686 = 30 Å and EW 5411 = 25 Å.

The correlations found indicate that high (initial) mass stars evolve as narrow line stars from late to early ionisation subclass. Lower (initial) mass stars evolve with increasing line strength and width, probably changing to earlier ionisation subclass. The HeII 4686/NV III 4604-40 ratio shows a clear correlation with Galactocentric radius, presumably an effect of the Z gradient. CIV 5808/HeII 5411 shows no such correlation. LMC WN stars can be classified without difficulty by the criteria established for Galactic WN stars. While individual spectra of a given subtype are similar in the two galaxies, the frequency distributions over ionisation subclass, over EW and FWHM in subclasses WN4 and 5, and hydrogen content in subclasses WN6-8 are different. The effects are presumably due to metallicity, but the causal connection is unclear.

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UBV Photometry of OB Associations within Superbubbles of the Large Magellanic Cloud

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This work presents *UBV* photometry of the stellar populations associated with 7 superbubble nebulae and 5 classical H II regions in the Large Magellanic Cloud. Although the nebular morphology of the superbubbles appears to be substantially evolved compared to the classical nebulae, the color-magnitude diagrams do not reveal any noticeable correlation between the resident stellar population and nebular morphology. The photometry presented here will be used in a forthcoming paper to examine further the stellar content and dynamics of these superbubbles.

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The Stellar Content of Superbubble H II Regions in the Large Magellanic Cloud

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I examine the stellar population enclosed within a sample of 6 LMC superbubbles and compare these clusters with previously studied OB associations in classical H II regions. The H-R diagrams, constructed with spectral classifications of the most massive stars, do not reveal any systematic differences between OB associations resident within superbubbles and classical nebulae: the main-sequence turnoffs show stars as massive and luminous as those in classical H II regions. Assuming the superbubble structures result from the stellar winds and/or supernovae of the associations, the similarity of the stellar populations to those of classical H II regions implies that the shell formation timescale is somewhat shorter than the cluster evolutionary timescale for these objects. The stellar winds and/or supernovae of the one or two most massive stars must therefore dominate the formation of the superbubbles. The star-forming events for the superbubble associations are also no more extended in duration than that of other OB associations. Finally, the IMF slopes are not systematically different from those previously found. Since the OB associations within superbubbles appear normal, the shell structures must be the result of normal OB stellar influences. I also present a few spectrograms of interesting massive stars, including S149, a probable new B[e] supergiant.

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On the nature of the blue giants in NGC 330

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The young SMC cluster NGC 330 contains a number of blue stars that lie above the main-sequence turnoff found from our isochrone fitting and below the position of the blue supergiants. We used our own, new spectroscopy and published data on these stars to investigate their possible nature. Problems in interpreting the evolutionary status of the blue giants have been found in several preceding studies. In theoretical HRDs, these stars lie in the rapidly traversed post main-sequence gap, similar to the unexpected concentration found by Fitzpatrick & Garmany (1990) in the HRD of the LMC.

We argue that these stars probably are core H burning main-sequence stars that appear as blue stragglers resulting from binary evolution as described in the simulations of Pols & Marinus (1994) and effects of rapid rotation. Many of the blue stragglers are Be stars and likely rapid rotators. We suggest that there is evidence for the presence of blue stragglers also in NGC 1818, NGC 2004, and NGC 2100. We point out that blue stragglers may be a general phenomenon in the CMDs of young clusters in the Magellanic Clouds and discuss the implications for IMF and age determinations.

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The Atmospheric variations of the peculiar B[e] star HD 45677 (FS CAm)

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We have studied spectra of the peculiar B[e] star HD 45677. Examination of the Balmer wings enabled us to determine a value of $\log g = 3.9$ indicating a possibly luminosity class V. The weak He I lines together with the Si II 4128 and 4130 Å doublet indicate a low rotation velocity in the order of 70 km s^{-1}, which is much lower than the previously claimed value of 200 km s^{-1} by Swings & Allen (1971). We have examined high-resolution profiles of the strong He I line at 5876 Å and found on one hand that we can explain the variation of the profile by the motions of clouds, some of which accreted. The Balmer lines on the other hand show the presence of an accelerated wind plus absorption by a disk seen edge-on.

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Linear spectropolarimetry of the Hα emission line of ζ Puppis

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We present high-S/N spectropolarimetry of the Hα emission line of ζ Puppis. We discuss, and successfully remove, a high-frequency instrumental signature. The corrected data show polarization structure through the emission line, which we attribute to an equatorial density enhancement of the wind. We employ simple (core-halo) numerical models to derive a lower limit of a factor of 1.3 to the implied equator-to-pole density ratio, and to demonstrate that the wind structure predicted by wind-compression theory is capable of reproducing the gross characteristics of the polarization spectrum.

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or URL http://star-www.st-and.ac.uk/astronomy/preprints.html

Toward Resolving the "Mass Discrepancy" in O-type Stars

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We show that metal line blanketing has an important effect on the atmospheres of hot stars, and we argue that the omission of metal line blanketing in previous non-LTE model atmospheres of O-type stars has led to underestimates of surface gravity and stellar mass. In addition to wind emission, metal line blanketing contributes to solve the long-standing discrepancy between spectroscopic and evolutionary masses for O-type stars.

To support our argument, we calculated a series of NLTE stellar atmospheres for O and Of-type stars. We compared the predicted profiles of hydrogen and helium lines produced by (*i*) a static plane-parallel H-He model, (*ii*) a metal line-blanketed static model, and (*iii*) an extended expanding model atmosphere. We find that simple H-He models produce stronger lines than do our metal line-blanketed models. Consequently, they lead to underestimated gravities. Wind emission is more effective in filling in the wings of H or He lines in the case of large mass-loss rates, typical of extreme Of stars. These findings apply equally to young, massive O-type stars and to highly evolved stars, i.e. central stars of planetary nebulae. The lower gravities derived from H-He models yield underestimated masses for young O-type stars, and overestimated masses for highly evolved stars.

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Spectroscopic observations of AB supergiants in M33

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We have observed 10 luminous blue stars in M33 at intermediate dispersion and have determined spectral types and luminosity classes from the blue and red spectrograms by comparing with galactic and SMC stars. Hα profiles have proved to be very useful in dissentangling luminosity and metallicity effects, and constitute a valuable diagnostic when comparing spectral classifications in galaxies with different metallicities. We derive qualitative estimates of the stellar metallicities which range from solar to SMC-like and are broadly consistent with abundance gradient results obtained for M33 from H II region studies. Comparison of the new data for B324 with previous work shows that there is evidence for significant spectral variability strongly suggesting an LBV nature for this star.

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also available via anonymous ftp as /scratch1/ftp/pub/papers/m33.ps from suncc.ll.iac.es

Vela X–1: how to produce asymmetric eclipses

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Light curves of the X-ray pulsar Vela X–1 obtained with the ASCA satellite show a strong asymmetry in the hard energy band during the eclipse of the X-ray source: a steep drop at ingress is followed by a gradual decline, whereas only a steep increase is observed at egress. X-ray scattering off the dense accretion wake trailing the neutron star cannot explain the gradual decline because of the long persistence of the latter ($\Delta\phi = 0.11$). Instead we propose that scattering in an extended photoionization wake is responsible. This wake is caused by the switch-off of the radiative force that drives the B supergiant wind during the passage through the highly ionized Strömgren region surrounding the X-ray source. The stalled gas then trails the neutron star, which moves relative to the B star surface (no corotation). A model for the Vela X–1 system which assumes that the B star does not rotate gives too large a phase extent for the dense wake and can be ruled out. Including the B star rotation in an approximate way, the relative azimuthal motion of the neutron star is slower and the wake covers a smaller phase interval. Finally, we assume that the Strömgren sphere does not reach too deep into the wind accelerating region. The wind can then reach a certain fraction of the terminal velocity before the radiative force is switched off. This elongates the photoionization wake further and both its phase extent and its scattering efficiency match the observations.

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http://www.usm.uni-muenchen.de:8001/people/feld/vela.ps.Z

The 5.52-Year Cycle of Eta Car

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I have discovered line variations, strongly correlated with the NIR light-curve of Whitelock et al. (1994). There are continuous variability from high to low excitation states, in which the luminosity of the HeI λ10830 Å line varies from 1500 $L_\odot$ to 15 $L_\odot$. This behavior is very different from that of episodic "shell events" or "bursts", frequently referred in the literature. The continuum and line variations are opposite in phase, like in the S Dor variables. This brings Eta Car to a normality inside the LBV class rather than a special case.

This fundamental character of Eta Car remained unknown, in spite of the great amount of observations in the past, because the variations are pronounced only in a few emission lines and it lacked long term, homogeneous coverage.

We found also, that the historical bursts of 1827, 1838 and 1843 occurred quite close in phase with the presently ongoing variations, suggesting that the giant bursts are connected with the S Dor variability. I have predicted a new minimum excitation event, to occur in the closing 1997. The line excitation is now decreasing, what seems to be a confirmation of a fortcoming "shell event".

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preprint available via anonymous ftp from beatriz.lna.br – dir /pub/etacar – file etacar.ps (140 kbytes).

Submitted Papers

The enigmatic flarings of HR 2517

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We report the discovery of strong flaring of the B3 II-III star HR 2517. The evidence is based on Strömgren differential *uvby* photometry spanning more than a decade. We discuss the behaviour of HR 2517 in terms of two models, viz. a rooted bright spot suddenly appearing and developing with modulation in photospheric temperature producing periodic light and profile variations as the star rotates, or that HR 2517 is a Be star in an eccentric ($P \sim 33-34$d) high-mass X-ray binary (HMXB) with neutron star companion—one of the brightest such systems known.

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Variability of the extreme P Cygni star HDE 326823

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On the basis of *uvby* and visual photometry, and spectrography in the optical region collected over a time span of 10 years, we report large amplitude photometric and spectroscopic variations, and the onset of a sudden brightening event in the system of the extreme supergiant HDE 326823. The event fits the picture that the H-deficient N-rich star is on its way towards becoming a WN star.

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Phase-locked photospheric and stellar-wind variations of θ^1 Ori C

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We have obtained a long series of optical spectra and new IUE spectra of θ^1 Ori C, the brightest star in the Orion Trapezium and the main source of ionization of the Orion nebula (M 42). With these data, we have improved the accuracy of the period of the optical emission line variations and the UV

stellar-wind absorption-line variations. We find a period of 15.422 ± 0.002 days. The high accuracy of the period makes it possible to phase correctly our new data and archival IUE data obtained more than fifteen years ago. The stellar wind absorption is weakest when the emission lines have maximum strength. In addition, we have detected periodic variations in the strength of photospheric spectral lines. Lines from HeI, HeII, CIV and OIII all vary in phase. The absorption of these lines is strongest when the emission is at its maximum. These variations appear to be due to a rotating surface feature which spatially coincides with the emission region.

Submitted to A & A*For preprints, contact*
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manuscript available by anonymous ftp
ftp://ftp.lsw.uni-heidelberg.de/incoming/ostahl/thetaOri.ps.gz
and by WWW http://www.lsw.uni-heidelberg.de/˜ostahl/thetaOri.ps.gz

Long-term spectroscopic monitoring of BA-type supergiants II: High-velocity absorptions in β Ori and HD 96919

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During our extended monitoring campaigns on late B and early A-type supergiants (Kaufer et al. 1996, Paper I) we have observed extraordinarily deep and highly blue-shifted absorption events in the Hα-line. In this work, new time-series observations showing the most extreme cases of such events observed so far are presented for two objects, β Ori (B8 Ia) and HD 96919 (B9 Ia).

The development of these high-velocity absorption (HVA) events in velocity and time are discussed: the HVAs show *no* signs of spherically symmetric mass-loss events with subsequent accelerated propagation into the wind. The absence of unshifted line emission in connection with the HVAs is especially indicative of the non-sphericity of the active circumstellar regions. Simultaneously with the blue-shifted absorption, red-shifted absorption is found in Balmer and metallic lines, primarily during the onset of the developing event, which clearly reveals the complex structure of the involved velocity fields. Mass outflow and mass infall are present in the envelope.

As a picture for the circumstellar structures that cause the sudden appearance of the HVAs over a large velocity range, localized regions of enhanced mass loss on the stellar surface, which build up extended, rotating streak lines in the equatorial plane are suggested.

Finally, the role of a critical ionization structure in the condensed structures is discussed.

Submitted to A & A *For preprints, contact* A.Kaufer@lsw.uni-heidelberg.de
Preprints are available from the anonymous ftp-server ftp.lsw.uni-heidelberg.de
– directory /incoming/akaufer/Asupergiants/ – file highvelAbs.ps.gz – size 160kB
or via WWW http://www.lsw.uni-heidelberg.de/∼akaufer.
Preprints of Paper I, which is still in press, are available there, too.

A coupled hydrodynamic-ionisation model for the clumpy Wolf-Rayet ring nebula RCW 58

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We present a time-dependent hydrodynamic model for the Wolf-Rayet ring nebula RCW 58 that includes a self-consistent treatment of the nonequilibrium evolution of the ionisation state of the gas. We investigate the feasibility that hydrodynamic ablation from embedded dense clumps in the nebula is responsible for the high-velocity ultraviolet absorption features observed towards the central star. It is found that the observed correlation between the velocity of these features and the ionisation potential of the absorbing ion can be qualitatively reproduced by such a model. The calculated velocity range depends strongly on the adopted wind velocity.

Submitted to A & A *For preprints, contact* jane@astroscu.unam.mx
also available as gzipped postscript file at http://caifan.astroscu.unam.mx:80/ will/papers/rcw58.ps.gz

In Proceedings

Discovery of X–ray emission from the Wolf-Rayet star in Westerlund 2

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The young star cluster Westerlund 2 is located at the center of the giant HII region RCW 49, and is the likely energy source for this extended radio/optical/X–ray nebula. We report the results of a ROSAT HRI observation showing that part of the diffuse X–ray emission from Westerlund 2 can be spatially resolved into three point sources. One of these sources can be identified with the only Wolf-Rayet star known in this cluster.

To appear in the Proceedings of the International Conference on X–ray Astronomy and Astrophysics "Roentgenstrahlung from the Universe", September 25–29, 1995, Wurzburg, Germany.
For preprints, contact sandro@ifctr.mi.cnr.it

Ionization Stratification in [WR] Winds

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Department of Physics & Astronomy, University of Pittsburgh

We summarize currently available evidence for ionization stratification in the winds of [WR] stars and point out that ionization stratification may be important to explain with radiation-driven wind theory the winds of [WR] stars, while also providing an empirical tool to investigate [WR] wind structures.

To appear in the proceedings of the Ven workshop on "Planetary Nebulas with WR Type Nuclei". *For preprints, contact* rsl@binar.phyast.pitt.edu

Sudden Radiative Braking in Colliding Hot-Star Winds

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When two hot-star winds collide, their interaction occurs where the momentum fluxes balance. However, in WR/O systems, the imbalance in the momentum fluxes may be extreme enough to preclude a standard head-on wind/wind collision. Previous studies of the interaction layer have included only the corporeal momentum fluxes, but an important component of the total momentum flux in radiatively driven winds is carried by photons. Thus if the wind interaction region has sufficient scattering opacity, it can reflect stellar photons and cause important radiative terms to enter the momentum balance. In Sobolev theory, a self-consistent picture emerges in which the steep velocity gradient in such a "braking" layer Doppler-shifts wind spectral lines enough to reflect the fraction of the stellar spectrum required to support this braking.

We use a radiative-hydrodynamics calculation to show that such radiative braking can be an important effect in many types of colliding hot-star winds. Characterized by sudden deceleration of the stronger wind in the vicinity of the weak-wind star, it can allow a wind ram balance that would otherwise be impossible in many WR/O systems with separations less than a few hundred solar radii. It also greatly weakens the shock strength and the encumbent X-ray production. We demonstrate the significant features of this effect using V444 Cygni as a characteristic example. We also derive a general analytic theory that applies to a wide class of binaries, yielding simple, testable predictions for when radiative braking should play an important role in the wind interaction.

To appear in the conference series of Rev. Mex. de Astr. y Astrof. (Proceedings of the La Plata colloquium on Colliding Winds) *For preprints, contact* gayley@bartol.udel.edu

Theses

The Stellar Content and Dynamics of Superbubbles in the Large Magellanic Cloud

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The interaction between massive stars and the interstellar medium (ISM) is a fundamental process determining the structure and composition of the ISM. This work examines the stellar content and resulting dynamics of superbubbles in the Large Magellanic Cloud (LMC).

In work with P. Massey, I first show analytically that for 2 single-O star bubbles in M33, the evolution of wind power as the stars evolve is important in the bubble evolution. In a second prototype study, we find that the LMC superbubble DEM 152 shows evidence for sequential star formation, based on

differing ages between the stars interior and exterior to the shell. We construct a numerical form of the standard Weaver *et al.* (1977) evolutionary model for wind-driven bubbles, and use the stellar census to compare the predicted shell evolution with the observed kinematics. There is a substantial discrepancy: the shell's observed expansion velocity is too large relative to its radius.

I then find that the color-magnitude diagrams of the associations within 7 LMC superbubbles and 5 classical H II regions are indistinguishable. The H-R diagrams, constructed with spectral types for 6 superbubble clusters, also appear similar to those in classical H II regions, implying that the shell formation timescale is shorter than the cluster evolutionary timescale. The stellar winds of the 1–2 most massive stars must therefore dominate the shell formation. The star-forming events for the superbubble associations are also no more extended in duration than that of other OB associations. The slopes of the initial mass functions appear normal.

Numerical modeling of the 6 superbubbles shows results falling into two distinct categories: "high-velocity" objects showing anomalous kinematics like DEM 152 and "low-velocity" objects which appear fairly consistent with the model. X-ray evidence suggests that the high-velocity objects have been accelerated by supernova remnant (SNR) impacts. Results for both categories imply an overestimate in the growth rate equivalent to an effective input power of up to an order of magnitude too large. I suggest that the superbubbles are likely to be struck and "burst" by such SNR impacts if the prior stellar wind power is $\log L_w \lesssim 37.8$ erg s^{-1}. The interior coronal gas is then expelled by the pressure differential with the environment, which could greatly enhance the dispersal and distribution of the hot ionized medium. A minority of superbubbles with stellar wind power above the threshold are more likely to grow to the sizes of supergiant shells.

Ph.D. Thesis completed at the University of Arizona, 1995 October (awarded in December), under the direction of Robert C. Kennicutt, Jr.

For copies, contact oey@ast.cam.ac.uk

News

Preliminary Announcement: Massive Star X-ray Observing Campaign

M. Corcoran, T. Moffat, & A. Pollock

At the November La Plata Workshop on Colliding Winds there was considerable interest from workshop participants for a large program of X-ray observations of massive stars, along the lines of the IUE "MEGA" campaign. This preliminary announcement is to alert any interested parties who were not at the workshop about this program and to lay out some of the initial discussion generated at the workshop.

Rationale

The Einstein, ROSAT and ASCA X-ray observatories have made (and in the case of ROSAT and ASCA continue to make) substantial progress in the understanding of X-ray emission from massive stars, having established for example that the observed X-ray luminosity is proportional to stellar bolometric luminosity for the OB stars, or that X-ray variability is relatively rare among massive stars, or that Wolf-Rayet stars show unexpectedly large amounts of scatter in their Lx/Lbol relation, or that binary systems like WR 140 and Gamma Vel show evidence of X-ray emitting gas produced by the collision of stellar winds. These observations have also raised many unresolved questions: why are some binaries X-ray variables and some not? What causes the scatter in Lx/Lbol for the WR stars? Why are LBVs weak X-ray sources? When is X-ray emission from colliding winds important, and what does that tell us about the nature of the stellar winds in binaries? In addition, modern X-ray observatories raise the exciting possibility to use X-ray emission as a tool to address fundamental questions about the dynamics and chemistry of stellar winds. The time has come to build on the initial inroads with a dedicated program of X-ray observations which can address these issues.

Science Objectives:

There are a number of possible science objectives. During a brief brainstorming session at the workshop we came up with the following non-exhaustive list:
a) Detailed X-ray lightcurves/spectra of well-known binary systems which show variable X-ray emission;
b) observations of suspected colliding wind systems (eg WR 137);
c) X-ray spectral analysis to measure shock temperatures, absorbing columns, wind densities, and wind chemistry;
d) detailed observations of colliding wind systems to determine the geometry and physics of the interaction region;
e) examining correlations between X-ray emissivity and stellar rotation, age, or binarity

Available Facilities

Currently the ROSAT and ASCA X-ray observatories are in operation, although the ROSAT Position Sensitive Proportional Counter is no longer functioning and observations with ROSAT are limited to use of the High Resolution Imager (HRI). The X-ray Timing Explorer is set for launch in Dec 95 but is not well suited for studies of massive stars due to its hard spectral response and large point response. The Italian X-ray observatory SAX is scheduled for launch in the spring but we are not sure how much guest observer time there will be. Thus for present purposes we should probably restrict consideration to use of either ROSAT or ASCA.

Observing Strategies:

At the La Plata meeting, 2 complementary strategies were discussed: a) dedicated pointings with ASCA at known X-ray variable(s) to generate a high S/N X-ray lightcurve and phase-resolved X-ray spectra. Possible targets mentioned were Gamma Vel, V444 Cyg and/or EZ CMa.
b) deep pointings with the ROSAT HRI at an OB association or young open cluster to determine luminosity functions and test for variability. The Carina Nebula region (containing the OB associations Tr 14, Tr 16 & Co 228) was suggested as a good candidate.

Timescale

The next ROSAT AO (AO 7) will probably come out sometime in Mar 96 with proposals due in May 96. The next AO for ASCA (AO 5) will probably come out in Jun 96 with proposals due in Sep 96.

Action Items

The basic idea would be to generate a list of participants, develop a consensus on targets and observing strategy, and produce the proposal. The questions we need to address immediately are:

a) who's interested in participating?
b) what target or targets are of interest?
c) how should we shape the observing strategy?
d) how best to involve coordinated/contemporaneous ground based (and IUE and HST) observations?

For further information

To express interest in this program or for further information please contact
Mike Corcoran, Code 660.2, GSFC, Greenbelt MD 20771.
corcoran@barnegat.gsfc.nasa.gov

The Magellanic Clouds Newsletter

The first issue of the Magellanic Clouds Newsletter (edited by: You-Hua Chu and Dominik J. Bomans) has appeared. It can be obtained from MCnews@astro.uiuc.edu or on the WWW at URL http://www.astro.uiuc.edu/mcnews/MCnews.html

In their first issue, they announce the availability of the Bonn Magellanic Clouds Catalogue (13.1 MB) via anonymous ftp from ftp.astro.uni-bonn.de (dir pub/macs).

The format to submit abstracts is identical to that of the Hot Star Newsletter (coincidence!), so authors can send abstracts to both newsletters without effort.

Meetings

33rd Liège International Astrophysical Colloquium "Wolf-Rayet Stars in the Framework of Stellar Evolution"

The colloquium will be held at Institut d'Astrophysique (Université de Liège) from July 1–3, 1996. The first announcement with the preliminary programme was sent by e-mail to the subscribers of the Hot Star Newsletter. It can also be found on the WWW: http://www.inaoep.mx/~eenens/hot/ulg/ or http://webhead.com/~sergio/hot/hot/ulg/

The deadline for abstracts and early registration is May 15, 1996. All mail should be sent to:
Denise Fraipont, Institut d'Astrophysique, Avenue de Cointe 5, B-4000 Liege, Belgium
E-mail: astrocol@vm1.ulg.ac.be

Luminous Blue Variables: Massive Stars in Transition

To be held at the Royal Kona Resort in Kona Hawaii, on 6-11 october, 1996.

Scientific Organizing Committee: Antonella Nota (chair), Bruce Bohannan, Mark Clampin, Peter Conti, Henny Lamers, Norbert Langer, Claus Leitherer, Mario Livio, Tony Moffat, Werner Schmutz, Regina Schulte-Ladbeck, Linda Smith, Nolan Walborn.

Contact: Antonella Nota (e-mail: nota@stsci.edu)