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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Contents of this newsletter

Forum

Long-awaited book on Stellar Winds

The book ‘‘`Introduction to Stellar Winds`’’ by Henny Lamers and Joe Csssinelli will be launched in June. A brief table of contents is given in the last page of this newsletter.

Advance praise:

1. This is an enlightening book, full of vivid physics. It fills a longstanding gap in the astrophysical literature and will stand as the foundation of the rapidly growing field of stellar winds.
(Norbert Langer, University of Potsdam)

2. This badly needed book by two well-known researchers brings together theory and observation to provide an excellent, integrated treatment of a fascinating subject.
(Hollis Johnson, Indiana University)

Meetings for 1999

Several meetings will gather the hot massive star community in the near future (for further details see inside this newsletter page 19).

• “The Be Phenomenon in Early-Type Stars”, IAU Colloquium No. 175, 28 June – 2 July, 1999, Alicante, Spain

• "The Interplay Between Massive Stars and the ISM", Parallel Session I of JENAM99 (European Astronomical Society and the French Astronomical Society), September 10 - 11, 1999, Toulouse, France

Other Meetings

If you are in the early stages of planning a meeting related to hot massive stars, please contact our Working Group in order to bring some coordination and avoid overlaps and clashes. We have already been informed of two proposals.

• A one-day Joint Discussion on "Massive Star Birth", to take place during the year 2000 IAU General Assembly, has been proposed to the IAU Executive Committee. The Scientific Organizing Committee, chaired by Peter Conti and Edward Churchwell, also counts with the participation of John Dyson, Tom Hartquist, Ewine van Dishoeck, Malcolm Walmsley, Karl Menten and Guido Garay.

• A workshop on "Colliding Winds of Hot, Luminous Stars" is being proposed for July 2000 by Tony Moffat and Nicole St-Louis (Université de Montréal). They write:

> A lot of exciting things are going on in the area of colliding hot winds these days: eta Carina, WR104, WR137, WR140, etc., etc.... We feel that it is time for a dedicated but informal workshop to discuss intensively two aspects:
>
> – Wind-wind interactions in single luminous hot stars (e.g. WR ring nebulae);
>
> – Wind-wind collisions in binary hot stars.
>
> We are currently looking for a suitable venue in Eastern Canada, but do not exclude Western Canada either. We are aiming for July 2000 (thus non-IAU sponsored). We will form an SOC soon. Comments welcome!

News

• Peter Tuthill draws our attention to the most unusual high-resolution images he has obtained of the streams of dust around the interacting wind system WR 104. The images and movie are available on the WWW at `http://isi.ssl.berkeley.edu/wr104.html`

• Stan Owocki writes:

> Just a brief note to call your attention to two items of potential interest. The first is a general article on "Radiatively Driven Stellar Winds from Hot-Stars" written for the new Encyclopedia of Astronomy and Astrophysics being published by MacMillan. You can download the postscript file for this by either anonymous ftp or web browser to:
> www.bartol.udel.edu/∼owocki/preprints/encyc_hsw.ps
>
> The second item regards the 100th anniversary meeting in Atlanta of the American Physical Society. For special session touting the "Great Discoveries of Astronomy", I have prespared a poster on "Solar and Stellar Winds". You can access links to either the full (34"x34") color poster, or to slide show versions of this via my web page:
>
> www.bartol.udel.edu/∼owocki
>
> Regards, Stan Owocki, owocki@bartol.udel.edu

Accepted Papers

Differences in the fractions of Be stars in galaxies

André Maeder[1] and Eva K. Grebel[2,3,] and Jean–Claude Mermilliod[4]

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The number ratios $Be/(B+Be)$ of Be to B–type stars in young, well studied clusters of the Galaxy, the LMC and SMC are examined. In order to disentangle age and metallicity effects we choose clusters in the same age interval and for which reliable photometric and spectroscopic data are available. Number counts are made for various magnitude intervals, and the results are found to be stable with respect to this choice. In the magnitude interval $M_V = -5$ to -1.4 (i.e. O9 to B3) we obtained a ratio $Be/(B+Be) = 0.11, 0.19, 0.23, 0.39$ for 21 clusters located in the interior of the Galaxy, the exterior of the Galaxy, the LMC and the SMC, respectively.

Various hypotheses for these differences are examined. An interesting possibility is that the average rotation is faster at low metallicities as a result of star formation processes. The much higher relative N–enrichment found by Venn et al. in A–type supergiants of the SMC, compared to galactic supergiants, also strongly supports the presence of more rotational mixing at low metallicities. We discuss whether high rotational mixing may be the source of primary nitrogen in the early chemical evolution of galaxies.

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Preprints from `Andre.Maeder@obs.unige.ch`
or by anonymous ftp to obsftp.unige.ch cd /ftpanonymous/pub/maeder

Spectroscopic Monitoring of the Be/X-ray Pulsar X Persei/4U0352+309 with ORFEUS-2 and the IUE

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We present phase-resolved spectra of the Be/X-ray pulsar system X Persei/4U0352+309 obtained with the Tübingen far-UV echelle spectrometer of ORFEUS/SPAS-2. Data were obtained in November 1996 and folded on the ∼837.5 sec pulsar period derived from contemporaneous X-ray observations. Contrary to optical results by several groups, we find no evidence for periodic modulation in our FUV line profile data. The limits we can place on the presence of any periodic signal are ∼1% of the continuum level in the Si IV λ1394 line and ∼1.6% in N V λ1238. We have also combined these ORFEUS spectra with newly reprocessed IUE data to discover radial velocity variations in X Per which are consistent with a period of the order of 20–30 years and a binary separation of ∼20 AU. Even with a wide separation for this system, we argue that certain types of reported rapid variability

as well as long-term X-ray enhancements could be caused by the residue of expanding Be discs falling onto the neutron star. The UV resonance lines appear to be typical for a classical Be star, showing variability on timescales of a day and also a few hours.

Accepted by Astrophysical Journal
Preprints from msmith@stsci.edu
or by anonymous ftp to nobel.stsci.edu ("cd pub/paul/paper")

On the origin of [OIV] emission in Wolf-Rayet galaxies

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We propose that the emission of the high excitation [OIV] line observed with ISO in NGC 5253 and II Zw 40 is due to the presence of hot Wolf-Rayet (WR) stars in these objects. We construct a consistent evolutionary synthesis and photoionization model which successfully reproduces the constraints on their massive star content and the relevant optical and IR emission lines including [OIV] 25.9 μm. Our explanation for the origin of [OIV] is supported empirically by: *1)* the simultaneous presence of nebular He II and [OIV] in these objects, and *2)* the close relation between nebular He II and WR stars in extragalactic H II regions. Photoionization by hot WR stars is mainly expected to be of importance in young low metallicity galaxies. Alternate mechanisms are likely at the origin of [OIV] emission in other objects.

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Preprints from schaerer@obs-mip.fr
Also on the web at http://www.obs-mip.fr/omp/astro/people/schaerer/

Infrared spectroscopic variability of Cygnus X-3 in outburst and quiescence

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We present four epochs of high-resolution infrared spectroscopy of the peculiar X-ray binary Cygnus X-3. The observations cover quiescent, small flaring and outburst states of the system as defined by radio and X-ray monitoring. The underlying infrared spectrum of the source, as observed during radio and X-ray quiescence and small flaring states, is one of broad, weak He II and N V emission. Spectral variability in this state is dominated by modulation at the 4.8 hr orbital period of the system. H-band spectra confirm the significant hydrogen depletion of the mass donor. The closest spectral match to the quiescent infrared spectrum of Cyg X-3 is an early-type WN Wolf-Rayet star.

In outburst, the infrared spectrum is dramatically different, with the appearance of very strong twin-peaked He I emission displaying both day-to-day variability and V(iolet)/R(ed) variations with orbital phase. We argue that the twin-peaked emission cannot arise in relativistic jets or, unless the distance

to Cyg X-3 is severely overestimated, an accretion disc. The most likely explanation appears to be an enhanced stellar wind from the companion. Thus X-ray and radio outbursts in this system are likely to originate in mass-transfer, and not disc, instabilities, and the lengthening of the orbital period will not be smooth but will be accelerated during these outbursts. Furthermore, the appearance of these lines is suggestive of an asymmetric emitting region. We propose that the wind in Cyg X-3 is significantly flattened in the plane of the binary orbit. This may explain the observed twin-peaked He I features as well as reconciling a massive Wolf-Rayet secondary with the relatively small optical depth to X-rays, if the disc wind is inclined at some angle to the line of sight. A small set of observations following outburst, when the system was returning to a more quiescent X-ray and radio state, reveal strong He I 2.058 μm absorption with a clear P-Cygni profile, at the same time as the more common weak He II and N V features. In a disc-wind geometry this can be interpreted as absorption in the densest, accelerating regions of the wind which can be viewed directly if the disc is inclined at some angle to the line of sight.

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Preprints from rpf@astro.uva.nl

The Fourth Catalogue of Population I Wolf-Rayet Stars in the Large Magellanic Cloud

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The catalogue provides for each of the 134 W-R stars of Population I presently known in the Large Magellanic Cloud, accurate equatorial coordinates, photometric data, spectral classification, binary status, correlation with OB associations and HII regions. The miscellaneous designations of the stars are also listed. Although completeness is not pretended, results published during the last decade are highlighted in the notes given for each individual star. A uniform set of finding charts is presented.

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Preprints from jbreysac@eso.org

Dust formation in the hot massive binary HD 192641 = WR 137 (WC7 + OB)

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of the episodic dust-forming, long-period ($\sim 13\,yrs$) WC7+OB binary WR 137 were obtained with the NICMOS-2 camera of HST during periastron passage in 1997-1998. We have resolved, for the first time in any WR+OB binary, IR-emitting dust in the close environment of this system. The dust emission occurs in a few clumps within about $0.5''$ of the star, as well as in a jet-like structure with

total extension $\sim 0.25''$. The dust is likely either created or enhanced in the zone of gas shocked by wind-wind collision. We estimate the total mass of the resolved dust features during the 1997-1998 outburst to be $\sim 2 \times 10^{-7}\, M_\odot$ ($\sim 0.1 M_\oplus$), within a factor of three.

Accepted by ApJ
Preprints from `sergey@astro.umontreal.ca`
or by anonymous ftp to `ftp ftp.astro.umontreal.ca, cd incoming/sergey/wr137`

Spectropolarimetry of the WR+O binary Gamma-2 Velorum during periastron passage

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We present low resolution (~ 6 Å), high signal-to noise spectropolarimetric observations obtained with the new William-Wehlau spectropolarimeter for the apparently brightest Wolf-Rayet star in the sky, the 78.5 d WR+O binary γ^2 Velorum. Quasi-simultaneous monitoring of all four Stokes parameters $I(\lambda)$, $q(\lambda)$, $u(\lambda)$ and $v(\lambda)$ was carried out over an interval of 31 nights centered on periastron. All emission lines in our observed wavelength interval (5200 – 6000 Å) show highly stochastic variations over the whole run. The phase-dependent behavior of the excess emission in the C 3 5696 line can be related to the wind-wind collision phenomenon.

Varying features of Stokes q and u are seen across the strong lines, probably as a result of variable electron scattering of mainly continuum light. The spherical symmetry of the WR wind is thus broken by the presence of the O companion and clumping in the WR wind. Similar features in the extended red wing of the C 3 5696 emission line remain unexplained. No obvious circular line polarization features are seen across any emission line above the $3\sigma \sim 0.03\%$ instrumental level.

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or by anonymous ftp to `ftp ftp.astro.umontreal.ca, "cd incoming/sergey/g_vel`

ICCD Speckle Observations of Binary Stars. XXII. A Survey of Wolf-Rayet Stars for Close Visual Companions

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We present the results of a speckle interferometric survey for close visual companions mainly among

29 of the apparently brightest Wolf-Rayet stars. Only one target, WR 48 = θ Mus, was resolved as a close astrometric binary (with a separation of 46 ± 9 milliarcseconds). This system is probably a triple comprised of a short-period WR binary plus a distant O-supergiant companion. Although our binary detection fraction is low, it is not an unexpected result given the selection effects that militate against easy detection of binaries. New, higher resolution observations will almost certainly increase the fraction of binaries. There are four known binaries among the six WR stars in our sample which have non-thermal radio emission, and this connection supports the idea that the non-thermal emission originates in the wind-wind collision between components.

Accepted by AJ
Preprints from `hartkopf@chara.gsu.edu`

Revised mass determination of the super massive Wolf-Rayet star WR 22

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We analyze the orbital motion of the WN7+abs + O binary WR 22 based on 88 high resolution optical spectra obtained in 1996. By combining our data with values from the literature a period $P = 80.336 \pm 0.0013$ d was found. We determine a radial velocity semi-amplitude $K_{\rm WR} = 70.6 \pm 0.3$ km s^{-1} for the Wolf-Rayet star. By averaging six He I lines it was possible to detect clearly the weak absorptions of the O companion. We determine its spectral class to be O9 III but the luminosity class is uncertain and brightness arguments indicate a luminosity class V. For the orbit of the O companion we derive $K_{\rm O} = 190 \pm 10$ km s^{-1}. This leads to a mass ratio $q = M_{\rm WR}/M_{\rm O} = 2.69 \pm 0.14$. Because the system is eclipsing we assume $\sin i = 1$ and we obtain the masses of 55.3 ± 7.2 M$_\odot$ and 20.6 ± 1.6 M$_\odot$ for the WR and for the O star, respectively. Our mass determination revises down considerably the last published value for the mass of the Wolf-Rayet component but even with the new mass WR 22 remains "the most massive Wolf-Rayet star ever weighed".

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Preprints from `J.Schweickhardt@lsw.uni-heidelberg.de`

NaSt1: A Wolf-Rayet star cloaked by an η Car–like nebula?

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We present a study of the peculiar Galactic emission line object NaSt1 (WR122, IRAS 18497+0056) which has previously been classified as a Wolf-Rayet (WR) star. Our spectroscopic dataset comprises Keck I-HIRES, WHT-ISIS and UKIRT-CGS4 observations which show that NaSt1 has a highly reddened nebular spectrum with extremely strong permitted and forbidden lines covering a wide range

in excitation (H I, He I-II, N I-III, [N II], [Ne III-IV], Mg I-II, Si II, [S II-III], [Ar III-V], [Ca V-VII], [Fe II-VII], [Ni II-III]). [O II-III] is unusually weak, with He I-II and [N II] very strong, and carbon absent, suggestive of chemical peculiarities. Narrow-band WHT imaging reveals an elliptical nebula with an average diameter of 6.8 arcsec. We measure an interstellar extinction of $E_{B-V}\sim 2.1$ mag and estimate a distance of 1–3 kpc, suggesting that NaSt1 is a luminous object, with $4 \leq \log(L/L_{\odot}) \leq 6.5$. We determine the physical parameters and abundances from the nebular forbidden lines. For $T_e = 13\,000$ K and $N_e = 3.10^6\,\mathrm{cm}^{-3}$, we obtain He/H> 0.64, N enhanced by a factor of 20, O deficient by a factor of 140, while Ne, Ar and S are normal compared to average H II region abundances. This unusual abundance pattern suggests that the nebula consists of fully CNO-processed material. We compare the spectral appearance of NaSt1 with other luminous emission objects, and conclude that it is not an Ofpe/WN9, B[e] star or symbiotic nova although it does share several characteristics of these systems. We suggest instead that NaSt1 contains a massive evolved star that ejected its heavily CNO-processed outer layers a few thousand years ago. Although the stellar remnant is completely hidden from view by the dense nebula, we argue that the star must be an early-type WR star. The only object that shares some of the peculiarities of NaSt1 is η Carinae. Whatever its true nature, NaSt1 should no longer be considered as a late-WN classification standard in the near-IR.

To appear in *Monthly Notices of the RAS*
Preprints from `pac@star.ucl.ac.uk`
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or on the web at `http://xxx.lanl.gov/abs/astro-ph/9903410`

On the decoupling and reaccretion of low density, line-driven winds

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The flow generated by low-density radiatively driven winds which decouple their gas and radiation fields is discussed. In particular we concentrate on flow which is still bound to the star and can therefore reaccrete. The wind decelerates after decoupling and eventually stalls. A shell of gas is generated, and we find that this shell is unstable and contracts back to the star with periods of hours to days.

We find that the pulsating shells may be difficult to observe, as their emission is variable and the maximum emission at H_α (of $\sim 1\%$ of the continuum) occurs over a small fraction of the shell cycle.

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Preprints from `jmp@astro.livjm.ac.uk`
or on the web at `http://cwis.livjm.ac.uk/astro/research/papers99.html`

Differences in the fractions of Be stars in galaxies

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The number ratios $Be/(B+Be)$ of Be to B–type stars in young, well studied clusters of the Galaxy, the LMC and SMC are examined. In order to disentangle age and metallicity effects we choose clusters in the same age interval and for which reliable photometric and spectroscopic data are available. Number counts are made for various magnitude intervals, and the results are found to be stable with respect to this choice. In the magnitude interval $M_V = -5$ to -1.4 (i.e. O9 to B3) we obtained a ratio $Be/(B+Be) = 0.11, 0.19, 0.23, 0.39$ for 21 clusters located in the interior of the Galaxy, the exterior of the Galaxy, the LMC and the SMC, respectively.

Various hypotheses for these differences are examined. An interesting possibility is that the average rotation is faster at low metallicities as a result of star formation processes. The much higher relative N–enrichment found by Venn et al. in A–type supergiants of the SMC, compared to galactic supergiants, also strongly supports the presence of more rotational mixing at low metallicities. We discuss whether high rotational mixing may be the source of primary nitrogen in the early chemical evolution of galaxies.

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On the 4640 Å Feature in Wolf-Rayet Galaxies

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Several Wolf-Rayet galaxies exhibit broad emission features around 4640 Å in their optical spectra. These features are usually identified as N III and C III/C IV emission lines from WR stars. In a few WR galaxies the flux in this feature has been measured to be as large or larger than that in the corresponding He II λ4686 stellar emission line. We demonstrate that a 4640/4686 flux ratio larger than unity cannot be produced by any known population of WR stars. In particular, we show that the enhanced ratio cannot be explained by the presence of carbon lines from WC stars. We examine the possible origins of the broad λ4640 feature and offer several possible explanations for the enhanced strength in this emission feature. The most plausible explanations involve the presence of large numbers of Of stars in the starburst regions and/or the contamination of the stellar lines by nebular emission features. We discuss the implications that both possibilities have for the interpretation of the star formation histories in WR galaxies, as derived from their massive star content. We find that the instantaneous burst scenario cannot be correct for any metal-rich region whose optical spectrum exhibits both an enhanced 4640/4686 flux ratio and C IV 5808 emission from WC stars. These regions must have experienced a "multiple-burst" star-formation event, composed of several instantaneous bursts separated by short time intervals (a few Myr).

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Preprints from `schmutz@astro.phys.ethz.ch`
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A dusty pinwheel nebula around the massive star WR 104

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Wolf-Rayet (WR) stars are luminous massive blue stars thought to be immediate precursors to the supernova terminating their brief lives. The existence of dust shells around such stars has been enigmatic since their discovery some 30 years ago; the intense radiation field from the star should be inimical to dust survival. Although dust-creation models, including those involving interacting stellar winds from a companion star, have been put forward, high-resolution observations are required to understand this phenomena. Here we present resolved images of the dust outflow around Wolf-Rayet WR 104, obtained with novel imaging techniques, revealing detail on scales corresponding to about 40 AU at the star. Our maps show that the dust forms a spatially confined stream following precisely a linear (or Archimedian) spiral trajectory. Images taken at two separate epochs show a clear rotation with a period of 220 ± 30 days. Taken together, these findings prove that a binary star is responsible for the creation of the circumstellar dust, while the spiral plume makes WR 104 the prototype of a new class of circumstellar nebulae unique to interacting wind systems.

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For preprints, contact `Peter Tuthill: gekko@ssl.berkeley.edu`

We have a "movie" of this star! Look on our web page: http://isi.ssl.berkeley.edu/wr104.html

Long-Term Coherent Variations in the WR System EZ CMa: The Binary Scenario Revisited

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An analysis of seven different spectroscopic and eight photometric sets of observations of the WN5 star HD 50896=EZ CMa, distributed over more than 15 years is used to refine the known 3.76 days period. The value of $P = 3.7650 \pm 0.0001d$ yields variations which have coherent phase-dependence. Although not conclusive, this coherence in the 3.7650 day periodic variations over such a long time revives scenarios in which HD 50896 consists of a binary system, a hypothesis that had been nearly completely discarded over the past few years. A binary scenario is not in contradiction with the presence of a non-spherically symmetric wind distribution or instabilities in the WR star's wind and, in fact, mechanisms such as these are probably responsible for the difficulty in having until now obtained a period which yields coherent variations. The low X-ray fluxes suggest that the possible companion may not be a collapsed object, or that the accretion process is inhibited.

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Preprints from `georgiev@astroscu.unam.mx`

HST Observations of the very young SMC "blob" N 88A

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High-resolution *Hubble Space Telescope* images have allowed us for the first time to resolve the compact SMC ionized "blob" N 88A (diameter $\sim 3''.5$ or 1 pc). This very young H II region, which is hatching from its natal molecular cloud, is heavily affected by absorbing dust associated with the cloud. The interstellar reddening towards N 88A is on average $A_V \sim 1.5$ mag and strikingly rises to more than 3.5 mag in a narrow dust band crossing the core of the H II region. Such a high extinction is unprecedented for an H II region in the metal-poor SMC. We present the photometry of some 70 stars lying towards the OB association at the center of which lies N 88A. The exciting star(s) of N 88A is not detected, due to the heavy extinction. The chronology of star formation is discussed for the whole region.

Accepted by Astronony & Astrophysics

Preprints from heydari@obspm.fr

Paper also available on the web at http://wwwusr.obspm.fr/ heydari/projects/N88/

The Geometry of HD 165763: A Polarization Study of a WC Star

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We have obtained spectropolarimetric data of HD 165763 (WR 111, WC5) with a spectral resolution of 1.24 Å covering the wavelength range from 4950 Å to 6200 Å. The continuum is polarized at a level of 0.39% at 5805 Å, but there is no polarization variation across the emission lines. The latter indicates that most of the polarization arises from the interstellar medium. It further suggests that any global deviation of the atmosphere from spherical symmetry, if it exists, is small.

Radiative transfer calculations of axisymmetric stellar wind models are used to predict polarization changes across the very strong C 4 (λ5805) emission line. We fit the observational data with the models by using the continuum polarization as a constraint and by treating the interstellar polarization as a free parameter instead of using unreliable values of interstellar polarization estimated from analysis of field stars. The results from the χ^2 testing of the model suggest that the global deviation from spherical symmetry of this object is no larger than 20%, and it is probably less than 10%. In our formulation, the ratio of the equatorial density and the polar density (ρ_{eq}/ρ_{pole}) corresponding to the 20% upper limit is about 1.25. A similar conclusion is obtained from comparison of "continuum-minus-line" polarization of the observations with that of our models.

None of the single WC stars (except for WR 103) with spectropolarimetric data shows a variation in polarization across emission lines. Therefore global deviations from spherical symmetry of WC stars are expected to be small in general. The relatively low value of the upper limit for WR 111 indicates that mass-loss enhancement due to rotation is unlikely to explain the difference between the observed and the predicted WC mass-loss rates. It also suggests that a significant amount of angular momentum is removed by mass loss during the pre-WC star stage of stellar evolution. A low value for

the upper limit of deviation from spherical geometry is important since it validates the assumption of spherical symmetry used in many current evolutionary and atmospheric models of single WC stars.

Accepted by Astronomical Journal
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Stellar evolution with rotation IV: von Zeipel's theorem and anisotropic losses of mass and angular momentum.

André Maeder

Geneva Observatory

The von Zeipel theorem is generalised to account for differential rotation in the case of a "shellular" rotation law (cf. Zahn 1992). We write this law in the form $\Omega = \Omega(r)$, a simplification which does not apply to fast rotation. We find that von Zeipel's relation contains a small additional term, generally further increasing the radiative flux at the pole and decreasing it at the equator. We also examine the local Eddington factor in rotating stars and notice some significant differences with respect to current expressions.

We examine the latitudinal dependence of the mass loss rates $\dot{M}(\vartheta)$ in rotating stars and find two main source of wind anisotropies: 1) the "$g_{\rm eff}$" effect which enhances the polar ejection; 2) the "opacity effect" (or "κ–effect"), which favours equatorial ejection. In O–stars the $g_{\rm eff}$ effect is expected to largely dominate. In B– and later type stars the opacity effect should favour equatorial ejection and the formation of equatorial rings. We also examine the behaviour of the wind density and notice a strong enhancement at the equator of B– and later type stars. Possible relations with the polar ejections and the skirt of η Carinae and with the inner and outer rings of SN 1987 A are mentioned. If $\dot{M}(\vartheta)$ has sharp extrema due to some peaks in the opacity law, non equatorial and symmetrical rings may be produced.

We also show that the global mass loss rate of a star at a given location in the HR diagram is rapidly increasing with rotation, which is in good agreement with the numerical models by Friend & Abbott (1986).

Anisotropic stellar winds remove selectively the angular momentum. For example, winds passing through polar caps in O–stars remove very little angular momentum, an excess of angular momentum is thus retained and rapidly redistributed by horizontal turbulence. These excesses may lead some Wolf–Rayet stars, those resulting directly from O–stars, to be fast spinning objects, while we predict that the WR–stars which have passed through the red supergiant phase will have lower rotation velocities on the average. We also show how anisotropic ejection can be treated in numerical models by properly modifying the outer boundary conditions for the transport of angular momentum. Finally, in an Appendix the equation of the surface for stars with shellular rotation is discussed.

Accepted by Astronomy and Astrophysics
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Submitted Papers

Title Dynamics of Line-Driven Winds from Disks in Cataclysmic Variables. I. Solution Topology and Wind Geometry

Achim Feldmeier[1] **and Isaac Shlosman**[1]

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We analyze the dynamics of 2-D stationary, line-driven winds from accretion disks in cataclysmic variable stars. The driving force is that of line radiation pressure, in the formalism developed by Castor, Abbott, & Klein for O stars. Our main assumption is that wind helical streamlines lie on straight cones.

We find that the Euler equation for the disk wind has two eigenvalues, the mass loss rate and the flow tilt angle with the disk. Both are calculated self-consistently. The wind is characterized by two distinct regions, an *outer* wind launched beyond four white dwarf radii from the rotation axis, and an *inner* wind launched within this radius. The inner wind is very steep, up to 80 degree with the disk plane, while the outer wind has a typical tilt of 60 degree. In both cases the ray dispersion is small. We, therefore, confirm the bi-conical geometry of disk winds as suggested by observations and kinematical modeling. The wind collimation angle appears to be robust and depends only on the disk temperature stratification. The flow critical points lie high above the disk for the inner wind, but close to the disk photosphere for the outer wind. Comparison with existing kinematical and dynamical models is provided. Mass loss rates from the disk as well as wind velocity laws are discussed in a subsequent paper.

Submitted to ApJ
Preprints from `achim@pa.uky.edu`
or on the web at `http://www.pa.uky.edu/ achim`

Title Dynamics of Line-Driven Winds from Disks in Cataclysmic Variables. II. Mass Loss Rates and Velocity Laws

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We analyze the dynamics of 2-D stationary, line-driven winds from accretion disks in cataclysmic variable (CV) stars, by generalizing the Castor, Abbott and Klein (CAK) theory. In the first paper, we have solved the wind Euler equation, derived its two eigenvalues, and addressed the solution topology and wind geometry. Here, we focus on mass loss rates and velocity laws of the wind.

We find that disk winds, even in luminous novalike variables, have low optical depth, even in the strongest driving resonance lines. This suggests that thick-to-thin transitions in these lines occur in the wind. For disks with a realistic radial temperature law, the mass loss is dominated by gas emanating from the inner decade in radius. The total mass loss rate associated with the wind from a disk of luminosity $10L_{\odot}$ is $\sim 10^{-12}M_{\odot}\,\mathrm{yr}^{-1}$, or 10^{-4} of the mass accretion rate. This is one order of magnitude below the lower limit obtained from fitting P Cygni line profiles using kinematical wind

models, when the ionizing flux shortwards of the Lyman edge is supressed. The difficulties associated with such small mass loss rates for line-driven winds from disks in CVs are principal, and confirm our previous work on this subject. We conjecture that this issue may be resolved by detailed non-LTE calculations of the CAK line force within the context of CV disk winds, and/or better accounting for the disk energy distribution and wind ionization structure.

We find that the wind velocity profile is well approximated by the empirical law used in kinematical modeling. The acceleration length scale is given by the footpoint radius of the wind streamline in the disk. This suggests an upper limit of ~ 10 rwd to the acceleration scale, which is smaller by factors of a few as compared to values derived from line fitting.

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Radiation driven winds of hot luminous stars: XIV. Line statistics and radiative driving

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This paper analyzes the inter-relation between line-statistics and radiative driving in massive stars with winds (excluding Wolf-Rayets) and provides insight into the qualitative behaviour of the well-known force-multiplier parameters $k_{\rm CAK}$, α and δ, with special emphasis on α.

After recapitulating some basic properties of radiative line driving, the correspondence of the local exponent of (almost) arbitrary line-strength distribution functions and α, which is the ratio of optically thick to total line-force, is discussed. Both quantities are found to be roughly equal as long as the local exponent is not too steep.

The central part of this paper considers the question concerning the shape of the line-strength distribution function, with line-strength k_L as approximate depth independent ratio of line and Thomson opacity. We derive the analytic result that for hydrogenic ions the exponent of the differential distribution is -4/3 corresponding to $\alpha = 2/3$, as the final consequence of the underlying oscillator strength distribution. Furthermore, it is shown that for *trace* ions the equality $\alpha + \delta \approx 1$ is valid throughout the wind.

For the majority of non-hydrogenic ions, we follow the statistical approach suggested by Allen (1966), refined in a number of ways which allow, as a useful by-product, the validity of the underlying data bases to be checked. Per ion, it turns out that the typical line-strength distribution consists of two parts, where the first, steeper one is dominated by excitation effects and the second one follows the oscillator strength distribution of the specific ion.

By summing up the contributions of all participating ions, this *direct* influence of the oscillator strength distribution almost vanishes. It turns out, however, that there is a second, indirect influence controlling the absolute line numbers and thus $k_{\rm CAK}$. From the actual numbers, we find an average exponent of order $-1.2 \ldots -1.3$, similar to the value for hydrogen.

Most important for the actual shape is the difference between iron group vs. light ions line-strength distributions, resulting from the larger number of lines and the influence from meta-stable levels in

the first group. On the whole, the line numbers from iron group elements increase with decreasing temperature, whereas those from light ions remain rather constant. Secondly, the specific (mean) abundance ratio controls the horizontal offset (in a log-log representation) between both groups, leading to a much more constant slope for (relative) solar abundances, compared to the case if they are equal.

As a final result, we find (for relative solar abundances) that iron group elements control the distribution for low and intermediate values of line-strength (corresponding to the acceleration in the inner wind part), whereas light ions (including hydrogen under A-star conditions) dominate the high k_L end (outer wind). Generally then, α becomes a decreasing function of decreasing $T_{\rm eff}$, increasing $k_1 = {\rm dv/dr}/\rho$ and decreasing *global* metallicity z, consistent with the findings of earlier theoretical investigations and observations.

As an application, we discuss some scaling relations with respect to global metallicity z, and compare our results with the so-called $\bar{Q}$-formalism introduced by Gayley (1995).

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Preprints from `uh101aw@usm.uni-muenchen.de`
or on the web at `http://www.usm.uni-muenchen.de/people/puls`

HST Observations of the very young SMC "blob" N 88A

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High-resolution *Hubble Space Telescope* images have allowed us for the first time to resolve the compact SMC ionized "blob" N 88A (diameter $\sim 3''.5$ or 1 pc). This very young H II region, which is hatching from its natal molecular cloud, is heavily affected by absorbing dust associated with the cloud. The interstellar reddening towards N 88A is on average $A_V \sim 1.5$ mag and strikingly rises to more than 3.5 mag in a narrow dust band crossing the core of the H II region. Such a high extinction is unprecedented for an H II region in the metal-poor SMC. We present the photometry of some 70 stars lying towards the OB association at the center of which lies N 88A. The exciting star(s) of N 88A is not detected, due to the heavy extinction. The chronology of star formation is discussed for the whole region.

Submitted to Astronony & Astrophysics
Preprints from `heydari@obspm.fr`

In Proceedings

Resolving X-ray Spectral Variations in η Carinae

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We discuss the characteristics of the spatially-resolved X-ray spectrum of η Car using data from *EINSTEIN*, *ROSAT* and *ASCA*, paying particular attention to spatial and temporal variations. We review the discovery of the temporal variability of the hard central source and, using newer data from *ASCA* show that the subsequent variation in the X-ray spectrum is either confined to a change in the emission measure of the source, or represents a surprising variation in the temperature distribution of the hot gas. We compare our results to expectations based on simple colliding wind binary models and show that while the observed spectral variations are consistent with the binary model, the variation in the intrinsic X-ray luminosity requires a substantial change in the temperature distribution of the hot plasma if the colliding wind model is correct.

To appear in the *Eta Carinae at the Millenium* **Proceedings, ed. Jon Morse, Roberta Humphreys, and Augusto Damineli, ASP. Conf. Ser., in press**

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or on the web at http://lheawww.gsfc.nasa.gov/users/corcoran/eta_car/corcoranmf_1.ps.gz

Spectral Variability of η Car in the XXth Century

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We show that the intensity of the high excitation lines ([Ne] III, [Fe] III, [N] II) in η Car - once the 5.52 year cyclic variation is taken off - has been gradually increasing since the beginning of the XXth century. The low excitation lines (Fe II, [Fe] II, [Ni] II), however, remained constant. This indicates a double source of excitation, like expected in a binary system where the two companion stars have different temperatures. We suggest that the long-term spectroscopic and photometric behavior of η Car is due to a combination of dust dissipation plus intrinsic stellar variability of one of the binary companions.

Conference proceedings of Eta Carinae at the Millenium - Montana (USA) July/1998

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or on the web at http://www.iagusp.usp.br/~damineli/PAPERS/ETACAR/100years.ps.gz

The Historical Evidence for the 5.52-Year Cycle

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We describe how the 5.52 year cycle in η Carinae was discovered, what are the main characteristics of the spectroscopic events and how this periodicity opened important roads to understand the nature of this massive star.

Conference proceedings of Eta Carinae at the Millenium - Montana (USA) July/1998
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η Car Binarity After the 1998 Event

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[2] Observatório Nacional do Rio de Janiero - Brazil

[3] JILA-NIST, University of Colorado - USA

We review the status of the binary model for η Carinae proposed by Damineli, Conti and Lopes (1997) on the light of new data. The true periodicity, the repeatability of line intensities and radial velocities from cycle to cycle give a strong support to the binary scenario and restricts the possibility of shell ejection as the mechanism regulating the spectroscopic events in η Car. Updated orbital parameters for the system are presented.

Conference proceedings of Eta Carinae at the Millenium - Montana (USA) July/1998
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or on the web at http://www.iagusp.usp.br/∼damineli/PAPERS/ETACAR/binarity.ps.gz

Theses

Contribution to the study of high-velocity early-type stars observed by Hipparcos

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In this thesis work, the origin of early-type stars with high velocity and/or large distance away from the galactic plane is studied, using Hipparcos satellite data.

First, the influence of stellar rotation on absolute magnitudes computed using trigonometric parallaxes is analysed with a sample of normal main-sequence A-type stars. No significant effect is detected.

A method for radial velocity determination is developed from the spectra observed with the =C9lodie spectrograph (OHP). It allows the calculation of the radial velocity with a precision of about 1–2 $\mathrm{km\,s^{-1}}$ without limitation due to the $v \sin i$ of the observed star.

In a second part, a sample of 35 000 B–A–F type stars from the Hipparcos catalogue is analysed. 316 high velocity stars are identified and the various assumptions explaining their origin are discussed. In particular, the contribution of the blue stragglers is studied using a population synthesis model. It is shown that thin disc blue stragglers represent a source of high velocity stars primarily in B and early A-type stars whereas thick disc blue stragglers contribute to late A-type and F stars.

Thesis done under the direction of A.E. Gómez at Paris Observatory and accepted in March 1999
Copies from `frederic.royer@obspm.fr`

The astrophysics of energetic X-ray binaries

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This thesis is a study of the X-ray binary Cygnus X-3, and related objects, using primarily observations at radio, sub-mm and infrared wavelengths. I find the emission mechanism to be synchrotron in the radio and sub-mm, while the infrared emission is thermal from the hot wind. The upper limit to the synchrotron emission is interpreted as being due to spectral ageing and implies a magnetic field strength of 7 T at a distance of 700 $\mathrm{R_\odot}$ from the centre of the system.

The nature of the companion star in Cyg X-3 was investigated by mid-infrared observations using the *ISO* satellite. I find that the spectrum shows a steady decrease and flattening at longer wavelengths which is consistant with a standard wind emission. Thus the complete quiescent spectrum from Cyg X-3 shows two different emission mechanisms and covers a full 5 decades of frequency.

High sensitivity and high time resolution radio photometry, taken during a minor flare period, reveal rapid (10 minute) increases and decreases in intensity which severely constrain the size of plasmons. Brightness temperatures of typically 10^{10} K are found.

I also consider models for the superluminal expansion and contraction of the Cyg X-3 source, observed on a milli-arcsecond scale by (Newell et al. 1998). The elliptical shape and the superluminal contraction are particularly hard to explain. Models involving photon beams illuminating shells, or propagating photon patterns are the most plausible.

A thorough survey for maser emission from these sources has produced strong upper limits and improved our understanding of the circumstellar environment of Cyg X-3.

This thesis has probed the radio-jet X-ray binaries, and made significant advances, opening up more questions about the nature of these sources and new areas of research.

Thesis defended at the Open University in January 1999 (supervisor Prof. S.J. Bell Burnell)
Preprints from `ogley@discovery.saclay.cea.fr`
or by anonymous ftp to `physics.open.ac.uk/pub/astro/rno`

Meetings

SECOND ANNOUNCEMENT:

IAUC No. 175: "The Be Phenomenon in Early-Type Stars"

28 June – 2 July, 1999
Alicante, Spain

Scientific Rationale:
Although Be stars have been recognized for over a century, the cause of their irregular episodes of enhanced mass loss, "the Be phenomenon," remains mysterious. These stars show varying degrees of similarities to the Oe, Wolf-Rayet, B supergiant, Bp, and B[e] variables. The origin of variability on practically every timescale for Be and related stars remains elusive. Evidence is accumulating that no single cause is capable of producing the emission in all or even most Be stars. Thus, an understanding of the observed phenomena necessitates the merging of several subdisciplines in observations (multi-wavelength and coverage in time) and theory (radiative transfer, hydrodynamics, theory of pulsations and magnetic field generation, evolution of binary systems). The Alicante conference will bring together experts in all of these areas. We seek to place the Be phenomenon into a broad context of stellar activity and so will include experts from the cool-star, high energy, and interacting binaries.

The topics for this colloquium include:
• definitions and background of the Be phenomenon
• new relevant missions and technologies
• temporal variability (periodic and nonperiodic)
• winds and circumstellar environment
• interacting Be binary sars

SPECIAL NOTICE:
Special Splinter session on the JPL Deep Space-3 (interferometry) mission **in honour of Profs. A. Slettebak and M. Jaschek**

Registration: about $110
SOC Contact: Myron Smith (msmith@nebula.gsfc.nasa.gov)
LOC Contact: Juan Fabregat (juan@pleione.uv.es)

Deadlines:
Abstracts (proposed oral papers): 31 March
Abstracts (posters) 15 May
Registration: 15 May

Please contact the LOC at http://www.bestars.ua.es/be99/ for further details.

http://www.ua.es/sri/stars.htm

The Interplay Between Massive Stars and the ISM

Parallel Session I of JENAM99 (Joint European and National Astronomical Meeting) of the European Astronomical Society and the French Astronomical Society

JENAM99: September 7-11, 1999, Toulouse, France
Session I on September 10-11, 1999.

Scope of the session:
The interplay between massive stars and the ISM plays a fundamental role in the formation and evolution of galaxies. In addition to providing ionizing photons and newly synthesized elements, massive stars inject copious amounts of kinetic energy and momentum to their surrounding gas through stellar winds and supernovae. Considerable progress has been made in the recent years on our understanding of the nature and physics of these feedback mechanisms and their importance. The aim of this session is to gather specialists from different fields which allow to contribute to a consistent picture of these phenomena.

Scientific program and contributions:
The scientific program includes three main topics:

- Stellar content and physics of massive star-forming regions (giant HII regions, starbursts)
- Chemical enrichment by massive stars
- The dynamical impact of star formation on the ISM from small to large scales

Some review talks will be invited. Oral contributions and posters are welcome.

REGISTRATION ETC.:
Informations on registration, accommodation, etc. are found on the central JENAM99 page:
`http://www.omp.obs-mip.fr/omp/astro/JENAM99/`
This page also includes the scientific program of the plenary session and all parallel sessions. *All registrations are handled centrally through this page.*
May 31, 1999: Registration and hotel reservation deadline

Additional information regarding Session I is found on:
`http://www.obs-mip.fr/omp/astro/people/schaerer/jenam99/`

Scientific Organizing committee of Session I: F. Ferrini (Italy), R. Gonzalez-Delgado (Spain, co-chair), M. Heydari-Malayeri (France), D. Lutz (Germany), A. Maeder (Switzerland), D. Schaerer (France, chair), R. Terlevich (United Kingdom)

Books

Introduction to Stellar Winds

Henny J.G.L.M. Lamers and Joseph P. Cassinelli

Content: 460 pages, 112 figures, 70 problems with answers

Chapters:

1. Historical overview
2. Observations of stellar winds
3. Basic concepts: isothermal winds
4. Basic concepts: non-isothermal winds
5. Coronal winds
6. Sound wave driven winds
7. Dust driven winds
8. Line driven winds
9. Magnetic rotator theory
10. Alfven wave driven winds
11. Outflowing disks from rotating stars
12. Winds colliding with the interstellar medium
13. The effects of mass loss on stellar evolution
14. Bibliography
15. Problems and solutions
16. Appendices
17. Subject index, Keyword index

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