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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This issue of the Hot Star Newsletter is dominated by X-rays, both from XMM-Newton and Chandra. X-rays will probably not spare the meeting on η Car. Enjoy the reading!

Contents of this newsletter

Accepted Papers

Phase-resolved X-ray and optical spectroscopy of the massive binary HD 93403

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We report the first results of a campaign aimed at the study of early-type binaries with the *XMM-Newton* observatory. Phase-resolved EPIC spectroscopy of the eccentric binary HD 93403 reveals a clear orbital modulation of the X-ray luminosity as a function of the orbital phase. Below 1.0 keV, the observed X-ray flux is modulated by the opacity of the primary wind. Above 1.0 keV, the observed variation of the X-ray flux is roughly consistent with a $1/r$ dependence expected for an adiabatic

colliding wind interaction. HD 93403 appears less overluminuous in X-rays than previously thought and a significant fraction of the total X-ray emission arises probably within the winds of the individual components of the binary.
Optical monitoring of the system reveals strong variability of the He II λ 4686 and Hα line profiles. The He II λ 4686 line displays a broad asymmetrical emission component which is found to be significantly stronger between phases 0.80 and 0.15 than around apastron. This suggests that part of the emission arises in the interaction region and most probably in the trailing arm of a shock cone wrapped around the secondary. Some absorption lines of the secondary's spectrum display equivalent width variations reminiscent of the so-called Struve-Sahade effect. The differences in behaviour between individual lines suggest that the temperature may not be the only relevant parameter that controls this effect.

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or on the web at `http://vela.astro.ulg.ac.be/Preprints/P70/index.html`

Galactic Starburst NGC 3603 from X-rays to Radio

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NGC 3603 is the most massive and luminous visible starburst region in the Galaxy. We present the first Chandra/ACIS-I X-ray image and spectra of this dense, exotic object, accompanied by a deep cm-wavelength ATCA radio image at similar $<\sim 1''$ spatial resolution, and HST/ground-based optical data. At the S/N > 3 level, Chandra detects several hundred X-ray point sources (compared to the 3 distinct sources seen by ROSAT). At least 40 of these sources are definitely associated with optically identified cluster O and WR type members, but most are not. A diffuse X-ray component is also seen out to $\sim 2'$ (4 pc) from the center, probably arising mainly from the large number of merging/colliding hot stellar winds and/or numerous faint cluster sources. The point-source X-ray fluxes generally increase with increasing bolometric brightnesses of the member O/WR stars, but with very large scatter. Some exceptionally bright stellar X-ray sources may be colliding wind binaries. The radio image shows (1) two resolved sources, one definitely non-thermal, in the cluster core near where the X-ray/optically brightest stars with the strongest stellar winds are located, (2) emission from all three known proplyd-like objects (with thermal and non-thermal components), and (3) many thermal sources in the peripheral regions of triggered star-formation. Overall, NGC 3603 appears to be a somewhat younger and hotter, scaled-down version of typical starbursts found in other galaxies.

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High-Resolution X-ray Imaging of the Colliding Wind Shock in WR 147

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We analyze new high-resolution *Chandra* X-ray images of the Wolf-Rayet binary system WR147. This system contains a WN8 star with an early-type companion located 0.6" to its north, and is the only known early-type binary with a separation on the sky large enough for the wind-wind collision between the stars to currently be resolved at X-ray energies. The 5 ksec *Chandra* HRC-I image provides the first direct evidence for spatially extended X-ray emission in an early-type binary system. The X-ray emission peaks close to the position of the radio bow shock and north of the WN8 star. A deeper X-ray image is needed to accurately determine the degree of spatial extension, to exactly align the X-ray and optical/radio frames, and to determine whether part of the detected X-ray emission arises in the individual stellar winds. Simulated X-ray images of the wind-wind collision have a FWHM consistent with the data, and maximum likelihood fits suggest that a deeper observation may also constrain the inclination and wind momentum ratio of this system. However, as the WR wind dominates the colliding wind X-ray emission it appears unlikely that $\dot{M}_{\rm OB}$ and $v_{\infty_{\rm OB}}$ can be separately determined from X-ray observations. We also note an inconsistency between numerical and analytical estimates of the X-ray luminosity ratio of the stronger and weaker wind components, and conclude that the analytical results are in error.

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or on the web at http://ast.leeds.ac.uk/∼jmp/jmp_published.html

The dominant X-ray wind in massive star binaries

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We investigate which shocked wind is responsible for the majority of the X-ray emission in colliding wind binaries, an issue where there is some confusion in the literature, and which we show is more complicated than has been assumed. We find that where both winds rapidly cool (typically close binaries), the ratio of the wind speeds is often more important than the momentum ratio, because

it controls the energy flux ratio, and the *faster* wind is generally the dominant emitter. When both winds are largely adiabatic (typically long-period binaries), the slower and denser wind will cool faster and the *stronger* wind generally dominates the X-ray luminosity.

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In Hot Pursuit of the Hidden Companion of η Carinae: An X-ray Determination of the Wind Parameters

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We present X-ray spectral fits to a recently obtained *Chandra* grating spectrum of η Carinae, one of the most massive and powerful stars in the Galaxy and which is strongly suspected to be a colliding wind binary system. Hydrodynamic models of colliding winds are used to generate synthetic X-ray spectra for a range of mass-loss rates and wind velocities. They are then fitted against newly acquired *Chandra* grating data. We find that due to the low velocity of the primary wind ($\approx$ 500km/s^{-1}), most of the observed X-ray emission appears to arise from the shocked wind of the companion star. We use the duration of the lightcurve minimum to fix the wind momentum ratio at $\eta = 0.2$. We are then able to obtain a good fit to the data by varying the mass-loss rate of the companion and the terminal velocity of its wind. We find that $\dot{M}_2 \approx 10^{-5}$ M$_\odot$/yr^{-1} and $v_{\infty_2} \approx 3000$ km/s^{-1}. With observationally determined values of $\approx 500 - 700$ km/s^{-1} for the velocity of the primary wind, our fit implies a primary mass-loss rate of $\dot{M}_1 \approx 2.5 \times 10^{-4}$ M$_\odot$/yr^{-1}. This value is smaller than commonly inferred, although we note that a lower mass-loss rate can reduce some of the problems noted by Hillier et al. (2001) when a value as high as 10^{-3} M$_\odot$/yr^{-1} is used. The wind parameters of the companion are indicative of a massive star which may or may not be evolved. The line strengths appear to show slightly sub-solar abundances, although this needs further confirmation. Based on the over-estimation of the X-ray line strengths in our model, and re-interpretation of the HST/FOS results, it appears that the homunculus nebula was produced by the primary star.

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Chemical composition of Galactic OB stars I. CNO abundances in O9 stars

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We present NLTE abundances of CNO for a sample of four O9 stars in the Galaxy, together with

new determinations of their stellar parameters, $T_{\rm eff}$, $\log g$, ϵ(He) and microturbulence. These new analyses take into account the effect of *line–blocking* in the spectral synthesis with our classical NLTE, plane–parallel and hydrostatic model atmospheres.
The sample includes three O9 He normal stars: two dwarfs, HD 214680 and HD 34078, and one supergiant, HD 209975, and one fast rotating giant with a preliminary high He overabundance, HD 191423 with ϵ(He)=0.20.
We find first that the consideration of microturbulence in the spectral synthesis for the fast rotator leads to a considerably lower He abundance, ϵ(He)=0.12.
The CNO abundances of the three He normal stars are in good agreement with the values in the literature for Galactic B dwarfs with no evidence of mixing, and show that they all have the same chemical composition. We also discuss however the possible CNO contamination of the supergiant HD 209975. For the fast rotator we find that the abundances show the trend of the CNO contamination: a N overabundance together with C and O depletion. The N/C and N/O ratios of our stars as a function of their projected rotational velocities are consistent with the predictions of the recent evolutionary models of Meynet & Maeder.

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Suspected Wolf-Rayet Galaxies UM 456 and UM 594.

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First results of an on-going search for Wolf-Rayet galaxies, based on new observations obtained with the Hobby Eberly Telescope (HET) and the Marcario Low Resolution Spectrograph (LORES), are presented. UM 456 and UM 594 have been found to be normal HII galaxies. New determinations of radial velocities have been given: UM 456 - V_r=1702±48 km s^{-1} UM 594 - V_r=6540±45 km s^{-1}. Independent estimates of distances, WR/(WR+O) ratios and oxygen to helium abundances ratios have been obtained.

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On the massive star contents of Cygnus OB2

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We present a near-infrared spectroscopic survey of a large area centered on the Cygnus OB2 association aiming at constraining its massive star contents. Our goal is to establish a nearly complete list of O-type members of the association, both to examine recent claims based on starcounts that suggest a richer contents than previously thought, and to provide a suitable database for further studies of the entire high-mass end of one of the richest associations of the Galaxy. The target selection is based on the JHK photometry published in the 2MASS all-sky survey. We identify 46 new early-type candidates, most of them expected to be O-type stars, plus 16 new stars with emission in Brγ and often in other lines as well, characteristic of evolved massive stars undergoing intense mass loss. We also present spectra of three luminous stars with CO overtone emission, one of them having also intense H_2 emission and being associated with compact nebulosity. By considering our findings, those of other authors, and plausible completeness corrections, we estimate the number of O-type stars or stars having evolved from a O-type progenitor to be 90-100, slightly below, but compatible with, most recent starcounts estimates by Knödlseder (2000, A&A, 360, 539). These results support the notion that Cygnus OB2 may be considered as a young globular cluster. The lists of new members that we provide, in particular those with emission lines, should be a useful resource for future investigations of Cygnus OB2 itself, as well as of very massive stellar evolution by providing a nearby, abundant sample of stars sharing a common environment.

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The mass-loss rates of Wolf–Rayet stars explained by optically thick radiation driven wind models

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Observed, clumping-corrected mass-loss rates of Galactic Wolf–Rayet (WR) stars are compared with predictions of the optically thick radiation driven wind models. We did not develop models for the whole wind, but we studied the conditions at the sonic point that would explain the observed high mass-loss rates of WR-stars. We find that optically thick wind models can explain the observed values of the mass-loss rates only if two conditions are satisfied:
(a) The sonic point (where $v_{\rm flow} = v_{\rm sound}$) lies deep in the wind where the temperature is either near 160 000 K, or in the range of 40 000 to 70 000 K.
(b) The flux-mean opacity must increase outward at the sonic point.
With these conditions a simple approximate formula for the mass-loss rates of WR-stars can be derived. The first condition implies that the sonic point is at an optical depth between about 3 and 30. Such large optical depths require a slowly increasing velocity law in the supersonic region, with a velocity-law index of $\beta \simeq 5$ for WR-stars, compared to $\beta \simeq 1$ for O-stars. The OPAL-opacity tables for the chemical composition of the WR-stars show that the opacity indeed increases outward at the temperature range near 1.6×10^5 K, and between about 4×10^7 and 7×10^4 K, as required for the optically thick wind models. The opacity at the sonic points of the models is very similar to the OPAL-opacity at the sonic point temperature and density. The radius of the sonic point is about half

as large as the inner boundaries of the "standard" models for early type WR-winds. Observational evidence, derived from line profile variations and from the light-curves of WR-stars in eclipsing binary systems, support the derived large values of β and the small values of the sonic point radius. The models presented here show that the high mass-loss rates of WR-stars might be the result of optically thick radiation driven winds. The presence of two very distinct temperature regimes for the sonic point implies a bifurcation in the wind models of WR-stars.

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or by anonymous ftp to `ftp://ftp.aai.ee/pub/publications/astro/H3332.ps.gz`

The eclipsing hypergiant R 81 (B2.5Ia-O) in the Large Magellanic Cloud

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The eclipsing P Cygni-type star R 81 (HDE 269128, HIP 24080) of spectral type B2.5 Ia-0 in the Large Magellanic Cloud was studied on the basis of a long continuous time series with simultaneous high-resolution FEROS spectra and photometric measurements in the Strömgren system. The stellar parameters derived for the primary are $T_{\rm eff} = 19\,500$ K and $R = 96$ R$_\odot$. The orbital period of the binary is 74.566 days. The mean light curve shows two eclipses, a brightness maximum just after the eclipse of the hypergiant and a slow decline of brightness between the two minima. For the first time, the orbital motion of the primary has been detected. The system is close and eccentric ($e = 0.569$) and both components nearly fill their Roche volumes. A spectral signature of the companion of the hypergiant has not been found. We suspect that the secondary is embedded in a shell or disk of material accreted from the primary. In addition, line profile variations with a period of about 11 days, probably caused by non-radial pulsation, were observed. The line profiles indicate a strong wind from the primary with an outflow velocity of about 150 km sec^{-1}. Near primary eclipse strong absorptions in low excitation lines emerge abruptly which point to an outflow of enhanced density and higher velocity in the direction towards and beyond the secondary.

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Submitted Papers

The effect of binaries on the evolution of WR-type spectral features in massive starbursts

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In the present paper we investigate in detail the effects of binaries with initial period between 1 day and 10 years on theoretical simulation of WR-type spectral features in massive starbursts. We focus on the evolution of the nebular Balmer b (Hb) line in starburst in general, on the intensity ratios I(He II l4686 nebular)/I(Hb), I(blue bump)/I(Hb) and I(red bump)/I(Hb) as function of W(Hb) of WR galaxies in particular.

The binary evolutionary processes that dominate the evolution of the considered spectral features are the Roche lobe overflow in Case Br systems, the mass transfer rate and the merger rate. Furthermore we show that the results are critically affected by uncertainties in theoretical WR atmospheres and not in the least by uncertainties in the subsonic velocity region of the WR wind.

The observations of low Z starbursts are best reproduced by a theoretical model with a significant number of binaries and with a Z-dependent WR wind.

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The effects of binaries on the evolution of UV spectral features in massive starbursts

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In this paper we investigate the effects of binaries with initial period between 1 day and 10 years on the theoretical simulation of the evolution of UV spectral features in massive starbursts. The binary evolutionary processes that dominate the evolution of the considered spectral features are the Roche lobe overflow in Case Br systems, the mass transfer rate and the merger rate. They cause UV spectral 'rejuvenation' in starbursts which are older than 5 Myr.

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In Proceedings

An XMM-Newton study of 9 Sgr and the Lagoon Nebula

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We report preliminary results of an XMM-Newton observation of the O4 V star 9 Sgr (= HD 164794). 9 Sgr is one of a few single OB stars that display a non-thermal radio emission attributed to synchrotron emission by relativistic electrons. Inverse Compton scattering of photospheric UV photons by these relativistic electrons is a priori expected to generate a non-thermal power-law tail in the X-ray spectrum. Our EPIC and RGS spectra of 9 Sgr suggest a more complex situation than expected from this 'simple' theoretical picture.
Furthermore, soft-band EPIC images of the region around 9 Sgr reveal a number of point sources inside the Lagoon Nebula (M 8). Most of these sources have optical counterparts inside the very young open cluster NGC 6530 and several X-ray sources are associated with low and intermediate mass pre-main sequence stars. Finally, we also detect (probably) diffuse X-ray emission from the Hourglass Region that might reveal a hot bubble blown by the stellar wind of Herschel 36, the ionizing star of the HG region.

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Monitoring the wind interaction in HD 93403 with XMM-Newton

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We report the first results of a campaign aimed at the study of early-type binaries with the XMM-Newton observatory. Phase resolved EPIC spectroscopy of the eccentric binary HD 93403 reveals a clear modulation of the X-ray flux as a function of the orbital phase. We find that the variations of the EPIC count rates in the 1.0 – 2.5 keV band are consistent with a colliding wind scenario.
Beside some diffuse emission from the Carina Nebula, the EPIC images centered on HD 93403 reveal also X-ray emission from the open cluster Trumpler 15 as well as a number of discrete sources. We briefly discuss the properties of one of these sources.

To appear in: Proc. Symposium *'New Visions of the X-ray Universe in the XMM-Newton and*

Meetings

η Carinae: Reading the Legend

July 11 - 13 , 2002

Crystal Mountain Ski Lodge, Mt. Rainier, Washington

The fourth workshop on η Car is intended to unite observers and theoreticians in a quest to exchange ideas, understandings, and perspectives on the past, present, and future of this extraordinary object (which is also a subject!). There are two scientific foci for the 2002 meeting. One is to probe the origin and evolution of the homunculus from both observational or theoretical perspectives. The second is to focus and coordinate a campaign for the upcoming scheduled light minimum in 2003, when the "Celestial Thunderbird" once again will enter its periodic anxious, unstable state. The venue and agenda are intended to foster a sense of community among new and experienced members of the "η Community", at the same time, invite the active participation of astronomers from related disciplines.

Members of the SOC are: Bruce Balick (University of Washington, Chair), Mike Corcoran (USRA & Goddard Space Flight Center), Pierre Cox (Institut d'Astrophysique Spatiale), Augusto Damineli (Universidade de São Paulo), Kris Davidson (University of Minnesota), Mike Dopita (Australian National University), Adam Frank (University of Rochester), Ted Gull (Goddard Space Flight Center), Roberta Humphreys (University of Minnesota), Norbert Langer (Utrecht University), Garrelt Mellema (Sterrewacht Leiden), Jon Morse (University of Colorado, Boulder), Nathan Smith (University of Minnesota), Kerstin Weis (Max-Planck-Institut für Radioastronomie)

Because we expect this to be a relatively small, topical meeting, we are planning a more informal format organized around discussions of the outstanding questions and problems in these major areas of investigation:

I. The Structure and Origin of the Homunculus

II. The Inner and Outer Ejecta

III. Symmetrical Nebula around Evolved Stars

IV. Developments Since 1997 Across the Spectrum

V. The Next Event

There will be a limited number of review talks plus posters with an emphasis on topical discussions and future advances in observations and theory.

Deadlines: The deadline for registration is 1 June 2002, while reservations for accommodations must be made by 15 June 2002.

A web page is now ready for registration and with general meeting information:
http://www.astro.washington.edu/balick/eta_conf/

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