THE $\mathrm{H}\mathrm{O}^{\mathrm{T}}$ STAR NEWSLETTER

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An electronic publication dedicated to O, Of, LBV and Wolf-Rayet stars and related phenomena in galaxies

No. 3

26 October 1994

editor: Philippe Eenens

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Abstracts: theory

Line-Driven Instability Growth Rates in Wolf-Rayet Winds

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We calculate the linear growth rate of small-scale radiative instabilities for Wolf-Rayet (W-R) wind models driven by multi-line scattering. Our approach involves a second-order extension of our previously developed non-isotropic diffusion treatment of the multi-line transfer. We confirm that the isotropizing effect of multiple scattering in such dense winds acts to suppress the instability, in comparison to the optically thin winds of OB stars. However, we also show that the inherent sphericity of the wind expansion leads to a significant residual instability.

Relative to the OB case, the instability growth rate in W-R winds is reduced by the ratio of the photon mean-free-path to the radius, λ/r, which is characteristically of the order of the inverse wind-momentum number, $P_{wind}^{-1} = L_*/\dot{M}v_\infty c \sim 0.1$. Even with this reduction, the level of instability is generally still strong enough for base wind perturbations to be amplified by a very large number of e-folds (typically at least 40) by the time they reach the outer wind. This can be expected to lead to extensive wind structure, including strong clumping, throughout the observable part of the wind. Such extensively clumped wind structure could provide a natural explanation for the "moving bumps" commonly observed in optical emission line spectra formed in W-R winds. It would also imply a reduction in mass-loss rates inferred from diagnostics sensitive to the square of the wind density.

Accepted by Ap. J. *For preprints, contact* gayley@bartol.bartol.udel.edu

The problem of the blue-to-red supergiant ratio in galaxies

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By summarizing the available observations, we investigate and confirm the trend that the number ratio of blue-to-red supergiants appears to be an increasing function of the metallicity. Furthermore, we

outline that virtually no assumption on stellar model physics explored so far is able to cope with this trend. We present new stellar models in the mass range $15-40M_{\odot}$, and find that the Ledoux criterion for convection plus semiconvection yields satisfying results at low Z ($Z = 0.002$), but readily fails at high Z ($Z = 0.02$). We discuss the dependence of the theoretical B/R-ratio, especially as function of the treatment of internal convective mixing, and point out the leakage of appropriate convection models. We conclude that a mixing efficiency in between the Schwarzschild and the Ledoux criterion might be most appropriate to explain the B/R-trend with Z, but argue that rotational mixing may have some contribution as well.

Accepted by Astron. Astrophys. *For preprints, contact* ntl@ipp-garching.mpg.de
electronic copies through anonymous ftp from machine 130.183.83.33 file /pub/ntl/smc.ps

Abstracts: observations

Studies of Binary Stars in the Magellanic Clouds: II. Spectroscopic Orbits of four Massive Eclipsing Binaries

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We present spectroscopic orbits of four eclipsing binaries in the Magellanic Clouds, namely HV 2241 and HV 2543 in the LMC, and HV 1620 and AzV 73 in the SMC. From our spectra and orbital analysis we find that the components of these systems are all early OB type stars with masses ranging from 14 up to 34 solar masses. The physical parameters derived for the binary components are found to be comparable with their galactic counterparts.

Accepted by Ap. J. *For preprints, contact* lbassino@fcaglp.edu.ar

A long term X-Ray variability study of the O-type stars σ Ori and ζ Ori

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X-ray emission in early-type OB stars is thought to be generated by shock-heated gas in the radiatively driven wind of these stars. Calculations of the X-ray production for such a scenario depend on the underlying shock structures, especially the occurrence rate of shocks, cooling length and cooling time which directly influence the source location of the X-rays in the stellar wind. We present a detailed variability analysis of the available ROSAT data for our two program stars σ Ori and ζ Ori. The long-term analysis of both stars covers a time range of 3 years and includes seven pointed PSPC observations, an additional pointed HRI observation for σ Ori and the ROSAT all-sky survey data of both stars. In the case of σ Ori we find no evidence for variability on all analysed time scales. Over

a long time range the timing analysis of the X-ray light curve of ζ Ori provides also no evidence for variability. Only during a period of 2 days (September 23–25 1992) we detect a moderate increase in X-ray count rate by $\approx 15\%$.
Accepted by A&A *For preprints, contact* thb@mpe-garching.mpg.de

X-ray variability in the hot supergiant ζ Orionis

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Hot massive stars represent only a small fraction of the stellar population of the Galaxy, but their enormous luminosities make them visible over large distances. Therefore, they are ideal standard candles, used to determine distances of near galaxies. Their mass loss in the form of radiation pressure driven supersonic winds contributes significantly to the interstellar medium and thus the chemical evolution of galaxies. All hot stars are soft X-ray sources; in contrast to the Sun with its highly variable X-ray flux, long time scale X-ray variability is not common among hot stars. Here we present the analysis of an unusual increase in X-ray flux observed with ROSAT during a period of 2 days for the hot supergiant ζ Orionis, the only episode of X-ray variability that we have so far found in a hot star. Our observations provide the most direct evidence obtained so far for the scenario of shock heated gas in the winds of hot stars.
Accepted by Science *For preprints, contact* thb@mpe-garching.mpg.de

Low resolution IUE spectra of Wolf - Rayet stars.

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We present uniformly reduced and measured equivalent widths, FWHM and observed line fluxes for 94 "single" WR stars (34 galactic WN, 22 galactic WC, 31 LMC WN and 7 LMC WC) based on the archive IUE spectra of WR stars gathered from different observational runs and from different epochs. The spectra are used for spectral classification in the ultraviolet region and for searching correlations among the strength and widths of emission lines of different ions. Some correlations with optical and near IR lines observed by other authors are given as well.

The set of spectra we use is almost complete to 12 magnitude and representative according to spectral subtype of WR stars.
Accepted by A&AS *For preprints, contact* aniedzi@astri.uni.torun.edu

DR 1: A WO3 Star in IC 1613 and its Surrounding Nebula, S3

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We present an analysis of the WO3 star, DR 1, which is located in the dwarf irregular galaxy IC 1613,

and is surrounded by an H II region which shows nebular He II 4686 Å in emission, a rare phenomonon in nebulae surrounding Wolf-Rayet stars. We have derived E(B–V) = 0.07 via a comparison of the observed Balmer line ratios to those predicted by theory, using the electron temperature of T_e = 17100 K derived from our nebular analysis. We find O/H = 4.99×10^{-5} by number for the nebula, in agreement with the O/H ratios found for other emission-line regions in IC 1613. We derive the following nebular mass fractions: X = 0.761, Y = 0.238 and Z = 0.00091. After allowance for the contribution by the nebular continuum, we have derived a stellar absolute magnitude of M_V = –3.6 for DR 1, a stellar effective temperature of T_* = 75000 K via a H I and He II Zanstra analysis, and a stellar luminosity of 10^6 $L_\odot$. A terminal wind velocity of v_∞ = 2850 km sec^{-1} is derived for DR 1 from the width of the strongest stellar emission lines. We also performed an abundance analysis of the stellar wind via a recombination theory analysis of the stellar emission-line features, and derive X(C) = 0.48, X(O) = 0.27 and X(He) = 0.25. These values are within the range found for other WO stars by Kingsburgh, Barlow & Storey (1994) and agree with those predicted by the Z = 0.004 massive star evolutionary models of Meynet et al. (1994), but not with their Z = 0.001 models. Our observations confirm the prediction that WO stars in low-metallicity galaxies should be much more luminous than their counterparts in higher metallicity galaxies.
Accepted by A&A *For preprints, contact* robin@bufadora.astrosen.unam.mx

Fourier-transform spectroscopy and near-IR variability of η Carinae

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We present the first Fourier Transform Spectrograph near-IR spectrum (0.95–2.5 μm) of η Car observed at CFHT in January 1987 with a resolution of 40–100 km s^{-1}. We have identified lines of H I (Paschen, Brackett series), He I, Fe II , [Fe II], [N I] with complex structures. At the time of these observations η Car was in a low excitation phase characterized by a general weakening of the hydrogen lines, and with the He I λ1082.9 nm line much weaker than in 1990–91.
Accepted by A&A. *For electronic copies (no figures), or preprints, contact* altamore@astrom.astro.it

News

The IUE MEGA project

The dates for the IUE programme of monitoring of HD 50896 (EZ CMa, WN5) + Zeta Puppis (O4f) + HD 64760 (B0.5Ib) are: 13 - 28 January 1995. The programme comprises a total of 45 IUE shifts (30 NASA + 15 VILSPA) scheduled sequentially. In each shift SWP (1150-1900 $\mathring{A}$) HIRES spectra of each star will be taken in sequence: viz (say) 50896-Z Pup-64760- 50896-etc. Exposure times are short (< 4 minutes) but with camera read time and slew overheads, we expect to get one spectrum of each star every 1.5-2 hours. With the overall 15-day run, we will therefore be able to sample and study the

time-dependent wind P-Cygni profile variabilty and wind activity over a timeframe which encompasses (at least) three stellar rotational periods either known or suspected for the target stars. The P.I. of the NASA part of this combined programme is Dr Derck Massa (Massa@achamp.gsfc.nasa.gov) and of the VILSPA part is Dr A.J.Willis (AJW@star.ucl.ac.uk). The overall IUE programme has many Co-Is from many nations.

Clearly it will be of lasting value to have (near simultaneous) coverage of these stars at other wavebands, and we therefore encourage ground-based observers/observatories to seek time to secure complementary spectroscopy/photometry/polarimetry as appropriate.

Heard at a meeting ...

CIRCUMSTELLAR MATTER 1994

(Edinburgh 29 August – 2 September 1994)

- *Session on Late Evolutionary Stages of High Mass Stars*

A Nota (STSCI):
Hubble Space Telescope imaging of the Luminous Blue Variable AG Carinae

P M Williams (Royal Observatories, Edinburgh):
Wind anisotropy revealed by dust formation around Wolf-Rayet Stars

N St-Louis (Montreal):
First Detection of Molecular Hydrogen Emission in a Wolf-Rayet Nebula

N Langer (MPI, Garching):
The Production of Circumstellar 26Al by Massive Single and Binary Stars

- *Session on Shocks in Circumstellar Winds*

I R Stevens (University of Birmingham):
Modelling Techniques for Circumstellar Winds (REVIEW TALK)

N Berruyer (Observatoire de Paris-Meudon):
Circumstellar Dynamics and Transfer

I Cherchneff (Royal Observatories, Edinburgh):
PAH Formation in Circumstellar shocks

A J Fleischer (Institut fur Astronomie und Astrophysik, TU Berlin):
Dynamical Models of Circumstellar Dust Shells around Long-Period Variables: Multi-periodicity