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

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editor: Philippe Eenens

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Discussion Forum

- **World Wide Web access to this Newsletter**
  This is now possible at URL http://www.inaoep.mx/∼eenens/hot.html
  Please visit this site and let us know what you think. You will find:
  - the current issue
  - back issues
  - an index of all issues
  - catalogues and atlases
  - soon more services, just waiting for your suggestions!

- **The Working Group on Hot Luminous Stars**.
  I received only favorable responses to the suggestion to start an ad-hoc WG. Following the procedure adopted by the *Active B Star WG*, we could elect a 10-member Organizing Committee through e-mail in two steps:
  - Firstly, those working in the field send in the names of 10 people they would like to get on a list of potential OC members.
  - The actual voting is done on the basis of a merged list. Everyone could vote for three persons in priority of preference.

  Other ideas?

- **Hot news**
  This newsletter brings news about the IUE Mega-project and two meetings. Thank you for taking the time to inform us or to send your opinion!

  In this newsletter, you will find the abstracts divided into **accepted** and **submitted**. This, I hope, will help avoid confusion and save you time.

Accepted

The Stellar Content of 30 Doradus Derived from Spatially-Integrated Ultraviolet Spectra: A Test of Spectral Synthesis Models

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Using the *IUE* satellite, we have obtained spatially integrated ultraviolet spectra of three areas within the giant H II region 30 Doradus in the Large Magellanic Cloud. The spectra represent spatial integrations over areas $20'' \times 20''$, $1' \times 1'$, and $3' \times 3'$, all of which are approximately centered on R136. We have performed a spectral synthesis analysis of the spectra of the two larger regions and compared the results with the known stellar content in these regions. The spectral synthesis models are sensitive to the observed continuum levels, the P Cygni profile of the C IV λ1550 line, the absorption strength of the Si IV λ1400 line, and the emission strength of He II λ1640 line. The intrinsic continuum levels and the profiles of these stellar wind lines provide constraints on the age and duration of the starburst episode in the region, as well as on the upper cut-off mass of the initial mass function. From our analysis we find that the present day value of the upper cut-off mass has a lower limit of about $50 M_{\odot}$, a result which is in good agreement with several other recent determinations. The age of the starburst episode must be less than about 3 Myr, also in agreement with other estimates. Comparison of the observed total number of O and W-R stars with those predicted from the various models favors an instantaneous burst of star formation in the observed regions. However, the differences between the two burst scenarios we investigated (instantaneous and continuous) are small at such a young age, and distinguishing between the two is difficult. We are now confident that these spectral synthesis models can be used to determine the stellar content of more distant star forming regions.

Accepted by Ap.J. *For preprints, contact* vacca@athena.ifa.hawaii.edu

Extended wings of the UV Si IV, C IV resonance doublets and the complex [Fe II] profiles in P Cygni

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We investigate the formation and the nature of the extended wings of the UV resonance lines of Si IV 1394, 1402 Å and C IV 1548 and 1550 Å in the spectrum of the LBV P Cyg. The effects of line blending in the neighbourhood of these lines were estimated by means of a grid of theoretical synthetic spectra, computed for the P Cyg model atmosphere.. It is shown that line blending is responsible for the strong wings of these lines with photospheric origin.

Our models are next used to treat the problem of the complex structure of [Fe II] lines observed by Stahl et al. in the optical spectra of P Cygni. We find that absorption, emission and P Cygni - type

lines blending with the [Fe II] lines are responsible for their complex structure. This offers an example of how line blending can be wrongly interpreted as evidence for blobs in a stellar wind.
Accepted by Astronomy and Astrophysics *For preprints, contact* GIsrael@vub.ac.be

Chemical composition of Wolf-Rayet stars. II. Hydrogen-to-helium ratio.

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The formation of HeII, HeI and HI lines in the winds of some representative WN stars of different spectral subtypes has been modeled. Two different types of models were studied: the clumped winds and smooth winds for both of which the standard velocity law $v = v_0 + (v_\infty - v_0)(1 - R_*/r)^\beta$ with $\beta = 1$ was assumed. The smooth winds predicts about two times lower IR fluxes than observed if to determine the matter density in the winds through the observed values of radio fluxes. The increased density smooth wind models with 1.5 times higher density as compared to the radio-flux scaling are in reasonable agreement with IR fluxes and HeII and HeI line fluxes in the case of WN 5, WN 6 and WN 8 stars but for other subtypes these models predict discrepant line fluxes. The clumped wind models agree quite well with the most important observational data whereas somewhat lower mass loss rates are now derived as compared to the smooth wind models. Theoretical line fluxes were found by summing of the contributions from different layers of the wind. The level population statistical equilibria equations were solved in the Sobolev approximation by taking into account the overlap of HeII and HI lines in the expanding medium. We used 40, 20 and 52 level atomic models for HeII, HI and HeI respectively, whereas the influence of higher levels was taken into account through the correction terms. On the basis of our modelling study we derived a simple formula for the determination of hydrogen-to-helium ratios for WN stars which was used for concrete estimates for 28 stars. In all cases the hydrogen-to-helium ratios are lower than the mean cosmic value. By inspection of the line fluxes of the neighboring HeII lines of $(n-4)$, $(n-6)$ and $(n-8)$ series in the spectra of two WC stars we concluded that no hydrogen seems to be present in their winds. The hydrogen-to-helium ratio is decreasing when going from late to early WN subtypes with strong scatter existing among the stars of WN 6 and later subtypes.

Accepted by A & A *For preprints, contact* aniedzi@astri.uni.torun.pl

Terminal velocities of Wolf-Rayet stars winds from low resolution IUE spectra

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Fascinated by the simplicity of the recently published (Prinja 1994) method of determination of terminal wind velocities in hot stars from low resolution IUE spectra we investigate its application to WR stars. With a large sample of low resolution IUE spectra of WR stars (Niedzielski & Rochowicz 1994) we found even simpler (linear instead of square) empirical relation between $\Delta\lambda$ as defined in Prinja

(1994) and terminal wind velocity - v_∞. Using this new empirical relation we present v_∞ for a sample of 85 galactic and LMC stars, 19 of them determined for the first time. We almost tripled the number of terminal velocity determinations for LMC WR stars. The comparison with other determinations shows that this simple method is accurate to some 10 – 20 %.

Basing on our results we confirm the correlation between terminal velocity and WC subtype. We also show that terminal velocities of WN stars are lower than that of WCE. A comparison between galactic and LMC stars shows that the LMC WN stars have slower winds in most of WN subtypes.

Accepted by Acta Astronomica *For preprints, contact* aniedzi@astri.uni.torun.pl

A Luminous Companion to SGR 1806−20

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We have obtained infrared spectra of the star suggested to be the counterpart of the soft γ-ray repeater (SGR) 1806−20. We found strong emission lines similar to those seen in the spectra of the rare Luminous Blue Variables and B[e] stars. A He I absorption line is also seen, from which we infer a spectral type O9–B2. This classification, in combination with the minimum distance of ~ 6 kpc inferred from its extinction, makes the star one of the most luminous in the Galaxy. We infer that it is a companion to SGR 1806−20, and suggest that the presence of a companion is somehow related to the SGR phenomenon.

Accepted by Ap J (Letters). *For preprints, contact* mhvk@astro.caltech.edu

Fundamental parameters of Wolf-Rayet stars – IV. Weak-lined WNE stars

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A detailed study of 3 'weak-lined' Galactic WN3–4 stars (WR46=HD 104994, WR128=HD 187282 and WR152=HD 211564) has been carried out based on new ultraviolet, optical and infrared spectroscopy. Tailored analyses, using the WR standard model, allow determinations of stellar parameters and chemical abundances based on the observed hydrogen, helium, carbon, nitrogen and oxygen spectrum, leading to higher stellar temperatures and luminosities than previously thought. We find that the temperatures (50–90kK) and luminosities (log $L/L_\odot$=4.8–5.5) of our weak-lined WNE sample lie close to the strong-lined WNE's, but with mass-loss rates over an order of magnitude lower (log $\dot{M}/M_\odot \mathrm{yr}^{-1}\sim-5.2$) leading to smaller atmospheric extensions. Fairly low luminosities ($10^5\,L_\odot$) are found for WR128 and WR152 although hydrogen is clearly present (around 10% by mass). Such WR stars are not currently predicted by single star evolutionary theory, while close binary evolution may provide a possible explanation. For these objects, metal abundances are consistent with CNO-equilibrium values (N/He$\simeq$0.004, C/N$\simeq$0.05, C/O$\simeq$1), while an unusual oxygen abundance is found for WR46 (N/He$\simeq$0.006, O/N$\simeq$0.1, C/O$<$0.3). Our results support the Population I WR nature of WR46 (with a possible compact companion) rather than a low mass X-ray binary, as has been suggested.

Accepted by Astronomy & Astrophysics
Preprints available via anonymous ftp - please contact pac@star.ucl.ac.uk

Of–types HD 16691 and HD 190429 show WN-like spectra in infrared K band

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We present 2μm K–band spectra of two early type Of stars that have infrared emission line morphology similar to that of WN stars. Archival IUE spectra of these two Of stars indicate they appear to be Of type, rather than WN. Recently acquired optical spectra of these stars are quantitatively similar to that in the past, namely, Of stars. We suggest that these two Of stars have stellar wind characteristics closer to WN type than other Of stars. We discuss the consequences for K–band classification of highly obscured hot stars that might not otherwise be visible in optical or UV wavelengths.

Accepted by Ap. J. Letters *For preprints, contact* mhanson@wenonah.colorado.edu

Wray 977 (GX301-2): a hypergiant with pulsar companion

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Wray 977, the B supergiant companion of the X-ray pulsar GX301-2, should be classified as B1 Ia+, based on a comparison of its optical spectrum to that of ζ^1 Sco, a well-known B hypergiant and one of the brightest stars in our galaxy. The classification of Wray 977 as a hypergiant results in a new distance determination of the binary system, i.e. $d = 5.3$ kpc (previously 1.8 ± 0.4 kpc). The "average" X-ray luminosity of the pulsar is then $\sim 10^{37}$ erg s^{-1}, in good agreement with the predicted X-ray luminosity resulting from accretion of a dense, low-velocity ($v_\infty = 400$ km s^{-1}) stellar wind. A mass-loss rate of $\leq 10^{-5}$ M$_\odot$ yr^{-1} is estimated from the Hα profile. A new upper limit for the inclination of the system is derived which provides a lower limit to the (present) mass of Wray 977 (48 M$_\odot$). Regarding current binary evolution scenarios, the empirical lower mass limit for black-hole formation in a binary increases to M$_{ZAMS} \geq 50$ M$_\odot$.

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Submitted

The Lyman Continuum Fluxes and Stellar Parameters of O and Early B-Type Stars

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Using the results of the most recent stellar atmosphere models applied to a sample of hot stars, we construct calibrations of T_{eff} and $\log g$ with spectral type and luminosity class for Galactic O-type and early B-type stars. From the model results, we also derive an empirical relation between the bolometric correction and the effective temperature and gravity. Using a sample of stars with known distances, located in OB associations in the Galaxy and the Large Magellanic Cloud, we derive a new calibration of M_V with spectral class. With these new calibrations and the stellar atmosphere models of Kurucz (1992), we calculate the ionizing photon luminosities in the H^0 and He^0 continua for these types of stars. We find significant differences (more than a factor of 2) between our values of the Lyman continuum luminosity and those reported in the literature. We also discuss the significant discrepancy between O-type stellar masses derived from spectroscopic models and those derived from evolutionary tracks. We suggest that the cause of this "mass discrepancy" lies primarily in the atmospheric models, which are plane-parallel and hydrostatic and therefore do not account for an extended atmosphere and velocity fields in a stellar wind. Finally, we present a new computation of the O-star Lyman continuum production rate from 429 known O stars located within 2.5 kpc of the Sun. The total ionizing luminosity from this population, $Q_0^{\rm Tot} = 7.0 \times 10^{51}$ photons s^{-1}, is 47% higher than that derived from the Lyman continuum values tabulated by Panagia (1973).

Submitted to Ap. J. *For preprints, contact* vacca@athena.ifa.hawaii.edu

First Detection of X-ray Variability in η Carina

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Recent ROSAT observations showed a dramatic change in the hard X-ray flux from η Carina. Thus, strong variability which is a characteristic of η Carina in radio through IR and visible-band wavelengths is also observed at X-ray energies. PSPC observations of η Car separated by 4 months reveal an increase in observed hard-band ($E \geq 1.6$ keV) counting rate by about a factor of 2. The increase in hard X-ray emission could be the result of a tripling of the mass-loss rate in less than 4 months.

Submitted to ApJL *For preprints, contact* corcoran@barnegat.gsfc.nasa.gov

Spectral atlas of the Galactic Wolf-Rayet stars (WN sequence)

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Spectra of 62 (i.e. almost all) Galactic single Wolf-Rayet stars of the WN sequence are compiled. These data provided the empirical basis for our comprehensive spectral analyses of these stars published recently. The observations cover wide parts of the visual range and have a spectral resolution $\lambda/\Delta\lambda$ between 2000 and 3600 in most cases. Infrared observations around 10830 Å are included for 18 stars.

The spectra are preliminary "rectified" by division through an estimated stellar continuum. The whole material is displayed in concise plots sorted by spectral subtype in order to provide an overview. Access to the full digital data is offered via anonymous file transfer.

Submitted to A&A (Supplement Series)

Preprints available from anonymous ftp-server 134.245.66.1 alias saturn.astrophysik.uni-kiel.de (Name: *anonymous*, password: your e-mail address); PostScript File: pub/WRHamann/WN-atlas.ps (3.8 MByte, compressed 1.1 MByte)

The Massive Star Content, Reddening, and Distance of the Nearby Irregular Galaxy IC 10

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IC 10 is a nearby dwarf irregular galaxy that contains a large number of candidate Wolf-Rayet stars and has an uncertain distance modulus and an uncertain, but large, reddening. In this paper, we present spectroscopic observations of the IC 10 Wolf-Rayet candidates. In addition, CCD BV photometry of stars in IC 10 is used to construct a color-magnitude diagram in order to constrain the reddening and distance of the galaxy. Spectroscopy of the Wolf-Rayet candidates confirms 15, giving IC 10 a *galaxy-wide* surface density of massive stars that is higher by a factor of 2 than any other Local Group galaxy, and is comparable to that observed in isolated regions of recent star formation. This is in accord with suggestions that IC 10 is undergoing a star-burst. Most of the Wolf-Rayet stars are WC type, giving IC 10 a similarly anomalous ratio of WC-type to WN-type stars, contrary to predictions that this quantity simply depends on metallicity. Photometry of the Wolf-Rayet stars and the bright, blue stars lead to similar estimates of the reddening $[E(B-V) = 0.75 - 0.80]$ and distance $[(m-M)_0 = 24.9]$. Comparison with recent literature values suggests that a consensus is developing that IC 10's distance is ≈ 1 Mpc. With the additional knowledge provided by IC 10, an understanding of the variations seen in WC/WN ratio among the galaxies of the Local Group is emerging. We argue that the initial mass function and metal abundance together determine the WC/WN ratio. We speculate that IC 10's large WC/WN ratio at low metal abundance can be explained if its initial mass function has been skewed toward high-mass stars due to the very vigorous star formation that is occurring.

Submitted to AJ *For preprints, contact* massey@noao.edu

Photon loss from the helium Lyα line – the key to the acceleration of Wolf-Rayet winds?

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It is demonstrated that the ionization equilibrium of helium in non-LTE atmospheres for Wolf-Rayet stars is very sensitive to photon loss from the HeII Lyα line. A removal of 0.001% of the photons is sufficient to initiate an abruptly recombining ionization equilibrium. The assumption of photon loss allows to address the wind momentum problem of Wolf-Rayet stars. It is possible for the first time to construct a line blanketed non-LTE model of a Wolf-Rayet star that reproduces the observed spectrum and simultaneously, provides the radiation force to drive its outer velocity structure.

A method is developed to determine the free model parameters L, $R_{\rm phot}$, $\dot{M}$, v_∞, $v_{\rm phot}$, C (clumping factor), and f (photon loss factor), by an analysis of an observed Wolf-Rayet spectrum. The method is applied to the spectrum of the WN5 star HD 50896 resulting in good fits in shape and strength to the observed helium emission lines. In particular the profile of the HeI λ10830 line, which is a tracer of the outer velocity structure, is reproduced remarkably well. The hydrodynamically calculated velocity law differs significantly from the commonly adopted β-law with $\beta = 1$. The outer part can be approximated by a β-law with $\beta = 3$ (or by $\beta = 8$ if the hydrostatic radius of a stellar evolution model in the Wolf-Rayet phase is used as reference) but around the photosphere the velocity structure is flat with an expansion velocity of $v_{\rm phot} \approx 1100$ km s^{-1}. The resulting luminosity $L = 5.5 \cdot 10^5$ L$_\odot$ and terminal wind velocity $v_\infty = 2060$ km s^{-1} are found to be considerably larger than the values from previous determinations. On the other hand, the mass loss rate is lower $\dot{M} = 3.2 \cdot 10^{-5}$ M$_\odot$yr^{-1} due to an inhomogeneous wind with a clumping factor $C \approx 4$. There is evidence for a decrease of the clumping factor with distance from the star.

The wind momentum calculated by the present model exceeds the single scattering limit by a factor of 6 in contrast to previous estimates that yielded factors 50 – 100. With a momentum ratio of 6, which is probably one of the largest among the Wolf-Rayet stars, the Wolf-Rayet winds are no longer distinct from other radiation driven winds but they fit as more extreme versions to the winds of O stars.

A photon loss factor $f \approx 10^{-4}$ is required by the analysis. So far the photon loss factor is not explained theoretically. It is proposed that a Bowen resonance-fluorescence mechanism removes a small fraction of photons from the radiation field of the helium Lyα resonance line. The line FeVI λ303.70 is a candidate for this process.

Submitted to A&A main jurnal. *For preprints, contact* schmutz@astro.phys.ethz.ch

IUE Atlas of B-type Spectra from 1200 to 1900 Å

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NASA Sponsor: Theodore R. Gull[2]

[1] Space Telescope Science Institute

[2] Goddard Space Flight Center

[3] Hughes STX Corporation

[4] Computer Sciences Corporation

An Atlas of B-type spectra observed at high resolution by the International Ultraviolet Explorer is

presented. It is designed to complement the widely used O-type Atlas (NASA RP-1155). The purpose is to complete the OB natural group, i.e. to spectral type B3 on the main sequence and B8 at luminosity class Ia, in order to chart the gradual disappearance of the stellar-wind features in normal spectra as a function of spectral type and luminosity class. As in the O Atlas, the primary selection criterion is well-defined optical classifications, to derive a consistent UV reference frame of normal objects. Some peculiar categories are also included, particularly types BN/BC and super-luminous objects. Spectrograms of 86 stars are arranged in 20 spectral-type, luminosity-class, or peculiar-object sequences. The processing and presentation are similar to the O Atlas: the 1200-1900 Årange has been rectified, rebinned to a uniform resolution of 0.25 Å, and plotted at 10 Å/cm.

The conclusions from the B Atlas are similar to those from the O Atlas, namely that the ultraviolet stellar-wind features display strong systematic trends as a function of spectral type and luminosity class, and a high degree of correlation with the optical classifications as the winds decline toward the later types. A somewhat higher rate of exceptions to these correlations can be recognized among the B spectra (11%) than the O (2%), but they remain a small fraction of the total sample and do not prevent clear delineation of the normal behavior. Indeed, it is only as a result of the latter that the exceptions can be identified and described.

To be published as a NASA Reference Publication *For preprints, contact* walborn@stsci.edu

News

IUE MEGA project update

The *IUE* program to monitor wind variability in HD 50896 (EZ CMa, WN5), ζ Pup (O4f) and HD 64760 (B0.5Ib) was completed 28 January at 11:00PM EST. This was an international collaboration of more than 30 Co-Is. Derck Massa was the NASA and combined program PI, Allan Willis was the VILSPA PI and Alex Fullerton, Raman Prinja, Stan Owocki and Nicole St-Louis also contributed considerable effort to the proposal. The program spanned 16 days except for 2 shifts which went to an AGN monitoring program. In all, 446 images were obtained, 313 at GSFC and 133 at VILSPA. A debt of gratitude is owed to the staffs at both of these facilities since almost all of the observing was done in service mode.

Since proprietary data rights were waved, the data are being made available to all interested parties. As the images are processed, the MEHI and PI files (in GO format) will be placed in the anonymous ftp site

192.100.9.40
or
nebula.gsfc.nasa.gov

At this writing (30 January), there are 225 GSFC images on line and this number will grow as the remaining GSFC images are processed (there will be a few stragglers due to transmission and archiving problems). The VILSPA images should arrive within a week or two, and will also be loaded onto disk. In addition to the image files, there is an index file, MEGA.DAT, which lists, by image number, the target, exposure time, date and time that the observation began and other pertinent information. This file will be updated as data become available.

Once all of the images are in place, they will amount to 920 MB of data. We are indebted to Joy

Nichols for allowing the project to use her disk for storage. Clearly, this cannot go on indefinitely, so if you intend to pick up some or all of the data, do so as soon as possible.

In the mean time, the homepage for the project,

http://www.ari.net/MEGA/mega.html

will continue to be updated as new data arrive. So keep checking in to see how things are progressing.

Derck Massa (massa@godot.arclch.com)

Meetings

Planetary Nebulas with WR type Nuclei

Dates: August 21-25, 1995

Location: The island of Ven, Sweden (where Tycho Brahe once lived and worked)

Contact: Bjorn Stenholm
bjorn@astro.lu.se

Radio Emission from the Stars and the Sun

Dates: 1995 July 3 – 7

Location: Barcelona, Spain

Contact: radio@mizar.am.ub.es

FTP: ftp://fareb1.am.ub.es/pub/announc1.txt

URL: http://bear.ras.ucalgary.ca/announcements/conference.html

Rationale: It has been 10 years since the last meeting devoted to stellar radio emission (Radio Stars: Boulder, Colorado, 1984). Since that time there have been major observational advances in this field. The number of stars and classes of stars that are known to be sources of radio emission have increased dramatically. We are now able to image radio emission from stellar sources at resolution and sensitivity that was impossible 10 years ago. Moreover, there have been new and exciting results in both continuum and spectral line, arising from new telescopes operating at millimeter and submillimeter wavelengths. These data have revealed new phenomena associated with stars and have yielded new observational data on previously known phenomena. It is time to synthesize this rich and powerful set of new radio observations; to bring together workers in this field and to help turn this data into new theories and insights into the processes giving rise to stellar radio emission.

At the same time that major advances have been made in observations of radio stars, the study of solar radio emission has been making tremendous strides, particularly in the area of active phenomena. Solar and stellar radio astronomers have traditionally worked as two separate communities. Given the significant advances in each area, we have an excellent opportunity to foster cross-fertilization between the two disciplines. One of the goals of this meeting is to bring these two communities together to explore those areas of astrophysics in common and to study the solar-stellar connection.