THE HOT STAR NEWSLETTER

⋆

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

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http://www.astro.ugto.mx/∼eenens/hot/
http://www.star.ucl.ac.uk/∼hsn/index.html

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From the editor

This issue starts with a letter from Tony Moffat to the editor and a suggestion for a special session at the next AAS meeting. We received quite a few abstracts, including one of an interesting thesis. We close this issue with the table of contents of the proceedings of the recent Munich workshop.

In the Hot Stars WWW pages a link was added to the recently published paper on the binary properties of Galactic O-type stars (Mason et al. 1998, AJ, 115, 821),
`http://www.chara.gsu.edu/DoubleStars/Ostars/ostars.html`
and its Table 1, which lists information on the spectroscopic and astrometric binary propoerties of over 200 O stars. The authors plan to keep this Table current as new results come in.

Letter to the editor

Dear Philippe:

This being the 4th anniversary of the Hot Star Newsletter, it is a good time to thank you for the splendid job you have been doing, not only in having created the HSN, but also in making it grow and serve an ever more active community. No doubt, the good health of the HSN reflects also the strength of the HS community. I also welcome your new initiatives....

It would also be good for the HS community if more HS specialists would apply for time on big telescopes, groundbased or in space. More and more, it seems that TAC panels are being created in several pre-selected areas, one being "Hot Stars". What's more, the time allocated to a HS panel (as for any other panel) is normally proportional to the amount of time requested. So, if more apply, they'll get more, too! There's nothing wrong with good healthy competition amongst ourselves (avoided to some extent by working in teams). There's nowhere that this might apply more, than for the Hubble Space Telescope. During the last HST competition (NICMOS extended cycle 7, Nov. 1997, when I had the dubious honour of chairing the HS panel), the relative number of HS proposals was down (about half of most other panels), so as a result, the HS community naturally got (proportionately) less time. I hope this was merely an "IR glitch" and will change in the future, so that we can retain (regain?) our vitality.

Amitiés, Tony Moffat

P.S. Just a little remark about the scope of the HSN. I would say we should include CSPN when relevant, but normally not. I would not eliminate pre-main sequence stars that are massive!

Meetings

AAS Session proposal: "Shells in the Global ISM"

As the stellar populations in galaxies return mass and energy to the ISM, interstellar shells are evidently a principal interface structure. In recent years, feedback processes, especially from massive stars, have been recognized as an essential influence on galaxy formation and evolution. However, there have been no meetings on shells as a phenomenon in their own right. We therefore propose a one-day Topical Session at the 1999 June meeting of the AAS in Chicago, on this subject.

A great variety of objects can be classified as shells: supergiant shells (kpc-scale); OB superbubbles (10s–100s of pc); supernova remnants; massive-star circumstellar bubbles from OB, WR, LBV, and RSG stars; PNe; PMS outflows; impacts from high-velocity clouds; bow shocks; and other objects. Clearly, these cannot be comprehensively addressed in a one-day workshop. We therefore request input from the community in narrowing the focus.

Our initial suggestion is a view toward the influence of shells in the global ISM. How do shells mediate and/or regulate the interaction of hot and cool gas, and the dispersion of heavy elements? What are the relative roles of the different types of shells in the global ISM of various galactic types? What is the origin of supergiant shells? The following is a preliminary list of possible relevant topics:

- shell evolution—early, intermediate, late; timescales

- energy budget, heating/cooling
- energy sources, relation to stellar populations
- hot/cool gas interaction, role in multi-phase ISM
- relation to/effect on different modes of star formation
- ISM structure: determinant and probe, interactions
- ISM enrichment, mixing

Is there enough interest in these sorts of subjects to warrant a Topical Session at the AAS? Please let us know if you favor this concept. We'd also like to know which topics have the widest interest, as well as any additional comments or suggestions on the scientific content. What are the most pressing related issues and why?

Thanks for your input,
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Accepted Papers

Compact HII regions in the Large Magellanic Cloud observed by ISO

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We present ISOCAM observations of five fields in the Large Magellanic Cloud centered on IRAS point sources with colors of ultracompact HII regions. Three bright sources of parsec or subparsec size, with luminosities consistent with being embedded O stars, are detected at 15 μm in two fields belonging to the HII region N 159. Using published high resolution radio observations, it is found that two of these sources may be ultracompact HII regions with a turnover frequency above 2.4 GHz, while the other is identified with a known compact HII region. If their nature as true ultracompact HII regions is confirmed by follow-up observations, these objects can provide a first sample useful for future studies of early massive star evolution in a low metallicity environment.

Accepted by Astronomy and Astrophysics (Letters)

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or on the web at `http://www.eso.org/~fcomeron/publicat.html`

The relationship between the WR classification and stellar models. II. The WN stars without hydrogen.

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We consider the relationships between the classification parameters of WN stars in the new 3-dimensional classification of Smith et al. (1996) and the corresponding and related parameters that define stellar

atmosphere models. Specifically, we consider: FWHM of HeII 4686 vs. v_∞; hydrogen content by direct inspection vs. hydrogen content by modelling and vs. colour $(b\text{–}v)_0$; ionisation subclass and M_v vs. effective temperature. From these data we argue that the WN b and *only* the WN b stars (i.e. stars with EW 5411 $>$ 40 Å or FWHM 4686 $>$ 30 Å) are entirely free of hydrogen.

For the WN b stars, we consider the relationships of EW 5411 and FWHM 4686 to the derived temperature T_*; the mass loss rate; and the surface mass flux. It appears that, to first approximation, the stars are a one–parameter family and the spectral classification criteria are sufficient to give an indication of the intrinsic colour, absolute magnitude (not very accurately), effective temperature T_* and terminal velocity.

Theoretical models suggest that the critical parameter defining most of the properties of a WN b star is its present mass. However, the behaviour of FWHM 4686 suggests the presence of a second parameter that affects the mass loss rate and terminal velocity of the wind. We suggest that the second parameter may be either (or a combination of) the internal mean molecular weight or the rotation rate of the star.

We further compare the relationships predicted by evolutionary models with those found for observed stars (using atmosphere models), highlighting the present difficulties in these comparisons.

Accepted by Astronomy and Astrophysics Main Journal
Preprints from `Andre.Maeder@obs.unige.ch`

A Multi-Wavelength Campaign on γ Cas. II. The Case for Co-rotating, Circumstellar Clouds

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Simultaneous X-ray/UV observations over a full day on 14–15 March 1996 have been made of the prototypical B0.5e star γ Cas using the *RXTE* satellite and the *Goddard High Resolution Spectrograph (GHRS)* on board the *Hubble Space Telescope.* The *GHRS* spectra, taken in the region of the Si IV $\lambda\lambda$1394–1403 doublet, also permitted the construction of an extremely precise light curve from a nearby "pseudo-continuum" region. The continuum UV and X-ray light curves reveal a pair of X-ray maxima $\sim$10 hours apart which coincide in time with UV continuum flux "dips" of $\sim$1%. In Paper I of this series we attributed the long-term X-ray variations to magnetic activity sites on the star's surface which undergo rotational modulation on a $\sim$1.125 day period. In the current study we find that flux and color curves generated from a 33-hour sequence of *IUE* echellograms obtained in January 1996 display dip features similar to those in the *GHRS* data. Comparing the timings of the continuum flux dips and the Si IV line strength variations in both the *GHRS* and *IUE* datasets gives a slightly revised period of 1.123 days for both the UV and X-ray activities. This strengthens the argument that high-energy activity on γ Cas is modulated by rotation of long-lived structures close to its surface.

Analysis of the pseudo-continuum light curves constructed from the *GHRS* and *IUE* light curves shows at least two surprising characteristics for the flux dips: (1) the dips last only $\sim$0.3 cycles, which is too brief for rotation modulation of surface features, and (2) their amplitudes increase from long to short wavelengths, attaining a maximum near 1206 Å. The character of the variations of the photospheric

Si IV line profiles is unexpected in that the equivalent width fluctuations do not correlate with the slow undulations of the continuum flux. Moreover, the profile variations do not show an expected blue-to-red migration of microfeatures.

We show that the continuum characteristics and absence of migration of features in the Si IV lines can be explained by the presence of very cool, optically thin clouds which co-rotate with the star. Assuming a tilt of the rotational axis of 45^o to the observer's line of sight, our model simulations of the two major dips in the UV light curves indicate that the clouds have radii of a few tenths of a stellar radius and are attached to points on the surface at low- to mid-latitudes on the near hemisphere. These findings support Paper I's conclusion that γ Cas is a member of a small group of OB stars which have magnetospheres associated with X-ray activity.

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Radiative Steady State Colliding Stellar Winds Models: Are they correct ?

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The properties of radiative steady-state colliding stellar winds in binary systems are studied. It is shown that the presence of a singularity at the stagnation point has a big influence on the structure of these flows. This problem is of great importance if their stability properties are considered. None of the existing models treats properly this mathematical problem and special efforts must be undertaken in the future in order to have a firm conclusion about the physical nature of possible instabilities. At the moment, both numerical and analytical models cannot be considered of acceptable accuracy in the case of highly radiative steady-state colliding stellar winds.

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Preprints from szhekov@bgearn.acad.bg; szhekov@space.acad.bg

Tomographic Analysis of Hα Profiles in HDE 226868/Cygnus X-1

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We present high quality Hα spectra of the massive X-ray binary, HDE 226868 = Cyg X-1, that were made in 1985 and 1986. We measured radial velocities using the He I λ6678 line, and we use the resulting orbital solution together with an *Hipparcos* light curve of the ellipsoidal variation to arrive at a revised period estimate of $P = 5.59977 \pm 0.00002$ d. We analyze the orbital phase-related variations in Hα emission using a Doppler tomography algorithm, and we show that the profile variations are well matched by a linear combination of two components: a P Cygni profile that moves with the motion of the supergiant star and an emission component that follows an anti-phase but phase-shifted velocity curve (semiamplitude $K_{\rm em} = 68$ km s^{-1} and radial velocity maximum at $\phi_0 = 0.86$; these parameters are similar to those for the He 2 λ4686 emission line). We use a vector decomposition of this motion to argue that the latter emission component forms between the stars in a focused wind flow from the supergiant to the unseen companion. We searched for but found no clear evidence of Hα emission from the accretion disk surrounding the companion (any such emission contributes less than 3% of the continuum intensity). The results demonstrate that the Hα line provides an important probe of the mass transfer process that eventually fuels the X-ray source.

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Searching for WR stars in I Zw 18 – The origin of HeII emission

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I Zw 18 is the most metal poor star-forming galaxy known and is an ideal laboratory to probe stellar evolution theory at low metallicities. Using archival HST WFPC2 imaging and FOS spectroscopy we were able to improve previous studies. We constructed a continuum free HeII λ4686 map, which was used to identify Wolf-Rayet (WR) stars recently found by ground-based spectroscopy and to locate diffuse nebular emission. Most of the HeII λ4686 emission is associated with the NW stellar cluster, clearly displaced from the surrounding shell-like [OIII] and Hα emission. We found evidence for HeII λ4686 sources, compatible with 5–9 WNL stars and/or compact nebular HeII λ4686 emission, as well as residual diffuse emission. Only one of them is outside the NW cluster. We have done an extensive comparison between our results and the recent ground-based data used by Izotov et al. (1997) and Legrand et al. (1997) to identify WN and WC stars in I Zw 18. The differences between the various data may be understood in terms of varying slit locations, continuum fits, and contamination by nebular lines. We have calculated evolutionary tracks for massive stars and synthesis models at the appropriate metallicity ($Z \sim 0.02$ Z$_\odot$). These single star models predict a mass limit $M_{\rm WR} \approx 90$ M$_\odot$ for WR stars to become WN and WC/WO. For an instantaneous burst model with a Salpeter IMF extending up to $M_{\rm up} \sim$ 120-150 M$_\odot$ our model predictions are in reasonable agreement with the observed equivalent widths. Our model is also able to fully reproduce the observed equivalent widths of nebular HeII λ4686 emission due to the presence of WC/WO stars. This quantitative agreement and the spatial correlation of nebular HeII λ4686 with the stellar cluster and the position of WR stars shown from the ground-based spectra further supports the hypothesis that WR stars are responsible for nebular HeII emission in extra-galactic HII regions.

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Paper also available on the web at http://www.obs-mip.fr/omp/astro/people/schaerer/

Bipolar Outflows and the Evolution of Stars

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Hypersonic bipolar outflows are a ubiquitous phenomena associated with both young and highly evolved stars. Observations of Planetary Nebulae, the nebulae surrounding Luminous Blue Variables such as η Carinae, Wolf Rayet bubbles, the circumstellar environment of SN 1987A and Young Stellar Objects all revealed high velocity outflows with a wide range of shapes. In this paper I review the current state of our theoretical understanding of these outflows.

Beginning with Planetary Nebulae considerable progress has been made in understanding bipolar outflows as the result of stellar winds interacting with the circumstellar environment. In what has been called the "Generalized Wind Blown Bubble" (GWBB) scenario, a fast tenuous wind from the central star expands into an ambient medium with an aspherical (toroidal) density distribution. Inertial gradients due to the gaseous torus quickly lead to an expanding prolate or bipolar shell of swept-up gas bounded by strong shock waves. Numerical simulations of the GWBB scenario show a surprisingly rich variety of gasdynamical behavior, allowing models to recover many of the observed properties of stellar bipolar outflows including the development of collimated supersonic jets.

In this paper we review the physics behind the GWBB scenario in detail and consider its strengths and weakness. Alternative models involving MHD processes are also examined. Applications of these models to each of the principle classes of stellar bipolar outflow (YSO, PNe, LBV, SN87A) are then reviewed. Outstanding issues in the study of bipolar outflows are considered as are those questions which arise when the outflows are viewed as a single class of phenomena occuring across the HR diagram.

Accepted by New Astronomy Reviews

Preprints from `afrank@alethea.pas.rochester.edu`

The Development and Behavior of an Active Region On/Near the Photosphere of the B2e Star μ Centauri

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An unusual mass loss event observed in the B2e star μ Cen during the course of 5 days in 1994 April is described and discussed within the framework of contemporary ideas on the Be phenomenon. The onset of the activity occurred in less than 1^d and was characterized by variable emission in He I $\lambda6678$ that displayed a distinctive character. Unlike the transient microemission in He I that frequently occurs in μ Cen and other Be stars, the emission line variations seen in this event took place more slowly in *three discrete velocity intervals*. On two occasions, violet (v) and red (r)-shifted emission components declined on a time scale of < 2 hr, while the emission at/near the line center *increased*. The short time scale and observed velocity behavior suggest the site of the activity was near the photosphere. The possible importance of nonradial pulsations and magnetic fields in precipitating the event is discussed. A scenario is suggested to explain the observations in which material originating from an active site on the photosphere is injected into a slab. Layers in the active region become visible in He I $\lambda6678$ as the prevailing density builds to values favorable for the production of this emission line. It is estimated that the slab covered $\sim$30% of the star. A 22% increase in the Hα emission

strength by the final day of the observations indicates that the activity did indeed add material to the circumstellar disk.

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Preprints from gjpeters@mucen.usc.edu

Star formation and shell formation in superbubble DEM 192

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Was star formation in the OB associations, LH 51 and LH 54, triggered by the growth of the superbubble DEM 192? To examine this possibility, we investigate the stellar contents and star formation history, and model the evolution of the shell. H-R diagrams constructed from UBV photometry and spectral classifications indicate highly coeval star formation, with the entire massive star population having an age of $\lesssim$ 2–3 Myr. However, LH 54 is constrained to an age of $\sim$ 3 Myr by the presence of a WR star, and the IMF for LH 51 suggests a lower-mass limit implying an age of 1–2 Myr. There is no evidence of an earlier stellar population to create the superbubble, but the modeled shell kinematics are consistent with an origin due to the strongest stellar winds of LH 54. It might therefore be possible that LH 54 created the superbubble, which in turn may have triggered the creation of LH 51. Within the errors, the spatial distribution of stellar masses and IMF appear uniform within the associations.

We reinvestigate the estimates for stellar wind power $L_w(t)$, during the H-burning phase, and note that revised mass-loss rates yield a significantly different form for $L_w(t)$, and may affect stellar evolution timescales. We also model superbubble expansion into an ambient medium with a sudden, discontinuous drop in density, and find that this can easily reproduce the anomalously high shell expansion velocities seen in many superbubbles.

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and http://xxx.lanl.gov/abs/astro-ph/9806009 *and mirrors.*

In Proceedings

A search for the cause of the cyclical variability in O star winds: a multiwavelength approach

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The more than 18 years of UV high-resolution spectroscopy of OB stars with the IUE satellite have convincingly shown that hot star winds are significantly variable. Time resolved spectra made it possible to follow large-scale stellar wind variations at timescales as short as an hour. In spite of these observational successes, which inspired a large theoretical effort, the physical cause of these variations is still not known. It is not doubted that rotation plays a key role.

A number of worldwide multiwavelength campaigns have been conducted to search for the presence of non-radial pulsations as well as of small surface magnetic fields embedded in the photosphere; these being the two most likely candidates for causing the observed time variability. We report here the main results of such a campaign for the bright O 7.5 giant ξ Persei, and conclude that for this star non-radial pulsations are unlikely responsible for the strongest periodicity found in the wind. A preliminary upper limit to the magnetic field strength has been derived. The presence of magnetic patches on the stellar surface remains the most promising candidate to give rise to the structures in the stellar wind. New efforts to find the cause of hot-star wind variability should concentrate on photospheric phenomena, which makes simultaneous UV and groundbased observations indispensable.

As a spin-off of this work we report the discovery of a new class of wind-variable B stars which resemble well-known magnetic rotators, but for which no magnetic field has yet been measured.

Proc. UV Astrophysics beyond the IUE Final Archive, Sevilla, November 1997, ESA SP
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First results of the November 1996 MUSICOS Campaign on the O7.5III star ξ Persei

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A. Collier Cameron[13], N. Morrison[8], L. Kaper[12], T. Kennelly[14], J. Neff[15], T. Simon[16], E. ten Kulve[1], I. Tuominen[9], Y. Unruh[17], N. Walton[6]

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We present the first results of the MUSICOS campaign on the O7.5III star ξ Persei, held in November 1996, which was aimed to study its wind variability, rotation, pulsation and magnetic field in order to study their mutual effects. During 10 days at 8 observatories around the globe we obtained more than 300 high-resolution optical spectra between 4100 and 8000 Å, as well as magnetic field measurements from Hawaii and La Palma. So far we analysed the spectral lines of Hα, He I λ5875 and O III λ5592. CLEANed Fourier transforms of the three studied lines yield a complicated multiperiod behaviour and indicate that the most likely rotation period is about 4 days. Combining these data with data from earlier campaigns, we find strong evidence in the photospheric lines for prograde non-radial pulsations with a period of 3.5 h. Since the pulsation period is much shorter than the dominant cyclic period in the stellar wind features (as found in the UV lines, recorded in an earlier campaign including the IUE satellite), we can conclude that pulsation is very unlikely the driving agent for the cyclic wind variations, at least for ξ Per. The analysis of the magnetic field measurements is still in progress. Whether magnetic fields are responsible for the observed wind modulation can therefore not be answered at the present stage, but remains still the most likely option.

Proc. ESO workshop on Cyclical Variability in Stellar Winds, Graching, October 1997
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Theses

Galaxies with strong stellar formation: Binary systems and X-ray emission

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Star Forming galaxies (SFG) are characterized by a high star formation rate that produces a large number of massive stars that dominate, directly or indirectly, the energetic emission of the galaxy. Those stars (especially the hottest and most massive) emit most of their output in the ultraviolet (UV) and optical wavelength regions. However, starburst also contain significant amounts of gas and dust that absorb the high energy radiation and re-emit it at longer wavelengths. The high mass stars generate an ionizing continuum that excites and ionizes the interstellar medium (ISM) gas producing emission lines and a nebular emission continuum covering wavelengths from the UV to the radio.

The evolution of the most massive stars also produces supernovae that will heat up the gas that consequently will emit in X-ray and radio wavelengths. They also dump kinetic energy into the ISM that together with stellar winds can lead to the onset of galactic winds. The process of star formation will most likely produce some multiple stellar systems that can also radiate in X-rays contributing as well to the ionizing radiation.

Starburst evolutionary synthesis models predict different stages in the early evolution of SFGs according to their dominant stellar population. The duration and strength of such stages depend on the initial mass function (IMF) and metallicity of the burst of star formation and can help to determine the age and properties of the star forming region. However, the evolutionary stage of the SFG can also be critically influenced by the presence of binary systems.

The objectives of this work were first to investigate the effect on the evolution of the cluster of the presence of stars in binary systems, and second, to synthesize the emission in the high energy ranges (soft and hard X-rays).

The evolution of binary systems is determined by the mass and separation of their components. As these bound stars evolve, they increase their radii. In the case of close binaries, the Roche lobe can be filled and most of the primary star's envelope can be transferred. One of the principal results obtained is that this process can yield to the formation of WR stars at ages were no such stars should be present in the cluster according to isolated stars evolutionary tracks. Indeed, a significant population of WR and Red Supergiant Stars could be co-eval during few Million years. As a side effect, these stars will increase the ionizing continuum strongly modifying the evolution of some *classical* age indicators as the Hβ equivalent width.

Binary systems having undergone mass transfer will develop into X-ray emitting systems. Observational estimates suggest that a 0.5% of the OB stars formed in a burst will evolve into these type of systems in agree with models results. The X-ray emission from these binary systems can be estimated from their mass accretion rate. The resulting spectrum, determined by the properties of accretion onto compact systems, can be characterized by a multi-color blackbody emission of effective temperature ~ 1 keV. In that case, more than 50% of the emission will be produced at energies higher than 3.5 keV.

Besides the X-ray emission due to binary systems, we had considered an additional component due to the heating of the ISM by the kinetic energy dumped by stellar winds and SNe. These high energy processes will be responsible for the super winds observed in SFGs and for a diffuse soft X-ray emission.

The synthesized ionizing spectrum (i.e. $\lambda < 912\AA$) including the high energy contribution has been used as input in the photoionizing code *CLOUDY* in order to obtain the emission intensity of the nebular He II line at 4686 $\AA$. The observational value of the ratio He II/Hβ can be reproduced by the models if it is assumed that a large fraction of the kinetic energy produced by the star formation processes is reprocessed by the ISM as X-rays radiation.

We have finally used the synthesis models for determine the contribution of circumnuclear star forming regions to the multiwavelength energy distribution in Active Galactic Nuclei, finding that the UV to soft X-ray continuum in a significant fraction of Seyfert 2 galaxies seems to be dominated by star formation processes.

Ph.D. Thesis completed at LAEFF, April 24 1998, under the supervision of J.M. Mas-Hesse.
For copies (in spanish), contact `mcs@laeff.esa.es`
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Book

ESO workshop on Cyclical Variability in Stellar Winds

October 14-17, 1994

Eds. Lex Kaper & Alex Fullerton.

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(R) = Review paper

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