THE HOT STAR NEWSLETTER

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and related phenomena in galaxies

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Contents of this newsletter

From the editor

This newsletter cannot reach its aim (of keeping us up to date of the recent developments in our field) without the kind collaboration of authors. Thank you to all those who regularly send the abstract of their newly written papers.

However many papers of interest are published without being announced in this newsletter. We would like to encourage each of you to send the abstracts of your papers related to our field. It should not take much time to cut the LaTeX version from your manuscript and e-mail it to us. Many thanks in advance!

The VIIth Catalogue of Galactic Wolf-Rayet Stars (van der Hucht, K.A. 2001, New Astronomy Reviews 45, 135) is now available on the WWW at
ftp://saturn.sron.nl/pub/karelh/UPLOADS/VIIWRCAT.pdf
Thank you Karel.

The nature of Sk -67°18 in the Large Magellanic Cloud: a multiple system with an O3f* component

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We present the results of photometric and spectroscopic observations obtained between 1980 and 1996, which show that the bright star Sk -67°18 in the Large Magellanic Cloud (LMC) is a multiple star which contains an eclipsing binary system. Our spectra show that this is an Of + O type binary, where the primary is probably of type O3f*. The orbital period of the eclipsing binary is almost exactly 2 days, which considerably compromises the obtaining of data with suitable phase coverage. Furthermore, from our radial velocity analysis of the spectral lines, Sk -67°18 appears to be a multiple system consisting of at least two pairs of short-period binaries.

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Non-LTE line formation for Mg I/II: abundances and stellar parameters

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An extensive model atom for non-LTE line-formation calculations for neutral and singly-ionized magnesium is presented, taking into account recent improvements in the atomic data. As a test and first application of the model, stellar parameters and magnesium abundances are determined on the basis of line-blanketed LTE model atmospheres for three stars: Vega (A0 V), η Leo (A0 Ib) and HD 92207 (A0 Iae) using high S/N and high resolution spectra at visual and near-IR wavelengths. The ionization equilibrium of Mg I/II proves to be a sensible temperature indicator for early A-type stars at all luminosities. Evidence is given that in late A and early F-type supergiants ($T_{\rm eff} \lesssim 8000$ K) the determination of accurate stellar parameters is hampered by the presence of a pressure inversion region in the model atmospheres at line-formation depths. The Mg I/II lines in the observations are reproduced simultaneously by the calculated line profiles with high accuracy. For Vega spectral synthesis in the UV region of the Mg I/II resonance lines also proves excellent consistency with the results from the visual. The dependence of the non-LTE effects on the atmospheric parameters is discussed with special emphasis on the supergiants where a strong radiation field at low particle densities favours deviations from LTE, especially in the minor ionic species of neutral magnesium. Non-LTE corrections turn out to be small in Mg I – typically $\lesssim$ 0.3 dex – even in supergiants, but are essential for an accurate

effective temperature determination. From the Mg II spectrum, only the features at $\lambda\lambda$ 4481 and 7877-96 Å react sensitively to non-LTE effects. Furthermore, the influence of microturbulence on the statistical-equilibrium calculations is investigated. The line strengths are found to be systematically affected.

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Mass-loss predictions for O and B stars as a function of metallicity

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We have calculated a grid of massive star wind models and mass-loss rates for a wide range of metal abundances between $1/100 \leq Z/Z_{\odot} \leq 10$.

The calculation of this grid completes the Vink et al. (2000) mass-loss recipe with an additional parameter Z. We have found that the exponent of the power law dependence of mass loss vs. metallicity is constant in the range between $1/30 \leq Z/Z_{\odot} \leq 3$. The mass-loss rate scales as $\dot{M} \propto Z^{0.85} {v_{\infty}}^{p}$ with $p = -1.23$ for stars with $T_{\rm eff} \gtrsim 25\ 000$ K, and $p = -1.60$ for the B supergiants with $T_{\rm eff} \lesssim 25\ 000$ K. Taking also into account the metallicity dependence of v_{∞}, using the power law dependence $v_{\infty} \propto Z^{0.13}$ from Leitherer et al. (1992), the overall result of mass loss as a function of metallicity can be represented by $\dot{M} \propto Z^{0.69}$ for stars with $T_{\rm eff} \gtrsim 25\ 000$ K, and $\dot{M} \propto Z^{0.64}$ for B supergiants with $T_{\rm eff} \lesssim 25\ 000$ K.

Although it is derived that the exponent of the mass loss vs. metallicity dependence is constant over a large range in Z, one should be aware of the presence of bi-stability jumps at specific temperatures. Here the character of the line driving changes drastically due to recombinations of dominant metal species resulting in jumps in the mass loss. We have investigated the physical origins of these jumps and have derived formulae that combine mass loss recipes for both sides of such jumps. As observations of different galaxies show that the ratio Fe/O varies with metallicity, we make a distinction between the metal abundance Z derived on the basis of iron or oxygen lines.

Our mass-loss predictions are successful in explaining the observed mass-loss rates for Galactic and Small Magellanic Cloud O-type stars, as well as in predicting the observed Galactic bi-stability jump. Hence, we believe that our predictions are reliable and suggest that our mass-loss recipe be used in future evolutionary calculations of massive stars at different metal abundance. A computer routine to calculate mass loss is publicly available.

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Preprints from j.vink@ic.ac.uk
or on the web at http://astro.ic.ac.uk/∼jvink/

The origin of the runaway high-mass X-ray binary HD153919/4U1700-37

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Based on its *Hipparcos* proper motion, we propose that the high-mass X-ray binary HD153919/4U1700-37 originates in the OB association Sco OB1. At a distance of 1.9 kpc the space velocity of 4U1700-37 with respect to Sco OB1 is 75 $\mathrm{km\,s^{-1}}$. This runaway velocity indicates that the progenitor of the compact X-ray source lost about 7 $M_\odot$ during the (assumed symmetric) supernova explosion. The system's kinematical age is about 2 ± 0.5 million years which marks the date of the supernova explosion forming the compact object. The present age of Sco OB1 is $\lesssim$8 Myr; its suggested core, NGC 6231, seems to be somewhat younger ($\sim$ 5 Myr). If HD153919/4U1700-37 was born as a member of Sco OB1, this implies that the initially most massive star in the system terminated its evolution within $\lesssim$6 million years, corresponding to an initial mass $\gtrsim$ 30 $M_\odot$. With these parameters the evolution of the binary system can be constrained. **Accepted by Astronomy & Astrophysics**
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The strange case of the massive binary HD 149404

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We report the analysis of an extensive set of high-resolution spectroscopic observations of the massive binary system HD 149404. We compare different techniques to measure the radial velocities of the heavily blended absorption lines and we derive a new orbital solution. The absorption lines display strong variability that slightly affects the orbital solution and the determination of the spectral types of the components of the binary. We find that the primary is probably of spectral type O7.5 I(f), while the secondary is most likely an ON9.7 I supergiant.
The secondary seems to be the most evolved component of the system and its current evolutionary status could best be explained if the system has undergone a Roche lobe overflow episode during the past. The secondary could actually still be rather close to filling its critical volume and this could lead to an enhanced mass loss of the secondary.
The spectrum of HD 149404 displays many emission lines some of which show phase-locked line profile variations. In particular, the Hα line displays a double-peaked morphology at orbital phases near conjunction. We investigate the radial velocity behaviour of the emission lines and we find that some of them must be formed in an interaction region. We propose a simple model where some of the optical emission lines arise in a heavily bended shock region.

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HD 152248: evidences for a colliding wind interaction.

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We present the results of a four year spectroscopic campaign on the early-type binary system HD 152248. Our analysis yields a new classification as O7.5III(f) + O7III(f) in contradiction with previous classifications of the components as supergiants. We derive improved orbital elements and the corresponding masses ($M_1 = 29.6\,\mathrm{M}_\odot$ and $M_2 = 29.9\,\mathrm{M}_\odot$) are somewhat larger than previously reported in the literature, though they are still significantly lower than the ones expected from evolutionary tracks. Both components of the system are rather close to fill their Roche lobe at periastron passage. We also investigate the equivalent width variations of the lines of the two components and we discuss their relation to the *Struve-Sahade* effect. Finally, we show that the line profile variability of the He II $\lambda4686$ and H α lines is consistent with a strong wind interaction between the two stars very much as predicted by current colliding wind models.

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Chemical abundances and winds of massive stars in M31: a B-type supergiant and a WC star in OB 10

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We present high quality spectroscopic data for two massive stars in the OB 10 association of M31, OB 10–64 (B0 Ia) and OB 10-WR1 (WC6). Medium resolution spectra of both stars were obtained using the ISIS spectrograph on the William Hershel Telescope. This is supplemented with HST-STIS UV spectroscopy and Keck I HIRES data for OB 10–64. A non-LTE model atmosphere and abundance analysis for OB 10–64 is presented indicating that this star has similar photospheric CNO, Mg and Si abundances as solar neighbourhood massive stars. A wind analysis of this early B-type supergiant reveals a mass-loss rate of $\dot{M} = 1.6 \times 10^{-6} M_\odot \mathrm{yr}^{-1}$, and $v_\infty = 1650\ \mathrm{km\,s}^{-1}$. The corresponding wind momentum is in good agreement with the wind momentum – luminosity relationship found for Galactic early B supergiants.

Observations of OB 10-WR1 are analysed using a non-LTE, line-blanketed code, to reveal approximate stellar parameters of $\log L/L_\odot \sim 5.7$, $T_* \sim 75$ kK, $v_\infty \sim 3000\ \mathrm{km\,s}^{-1}$, $\dot{M}/(M_\odot \mathrm{yr}^{-1}) \sim 10^{-4.3}$ adopting a clumped wind with a filling factor of 10%. Quantitative comparisons are made with the Galactic WC6 star HD 92809 (WR23) revealing that OB 10-WR1 is 0.4 dex more luminous, though it has a much lower C/He ratio (∼0.1 versus 0.3 for HD 92809). Our study represents the first detailed, chemical model atmosphere analysis for either a B-type supergiant or a WR star in Andromeda, and shows the potential of how such studies can provide new information on the chemical evolution of galaxies and the evolution of massive stars in the local Universe.

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Turbulent outflows from [WC]-type nuclei of planetary nebulae: II. The [WC 8] central star of NGC 40

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Using spectroscopic observations taken at the Observatoire de Haute-Provence (France) and the Observatoire du mont Mégantic (Canada), we describe wind fluctuations in the [WC 8]-type central star of the planetary nebula NGC 40, HD 826, which was observed intensively during 22 nights. Moving features seen on the top of the CIIIλ5696 and CIV$\lambda\lambda$5801/12 (+CIIIλ5826) emission lines are interpreted as outflowing "blobs" which are radially accelerated outwards in the Wolf-Rayet wind. The amplitudes of the variations range up to 25–30% of the adjacent continuum flux, over timescales of hours. The variabilities of both lines are quite well correlated, although they are somewhat weaker for the CIV complex. Subpeaks (or gaps) on the top of the CIII line generally move towards the nearest line edge in a symmetric fashion in the blue and the red. Kinematic parameters of the blobs have been derived and compared to those observed for massive and other low-mass Wolf-Rayet stars. Especially impressive are the significantly larger observed maximum radial acceleration values of the blobs, compared to those already reported for massive WC 5–9, or low-mass [WC 9] stars. This is attributed to the very small stellar radius of HD 826. In addition the β velocity field is found to possibly underestimate the true gradient within the stellar wind flow. On the whole, the wind of HD 826 is highly stochastically variable on a very short time-scale. This supports a turbulent origin.

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CO observations of NGC2359: the molecular clouds revisited

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Based on CO(2-1) observations obtained with the SEST telescope, the distribution of molecular material associated with the Wolf-Rayet ring nebula NGC 2359 has been determined. The angular resolution is 22" and the velocity resolution, 0.33 km s^{-1}. Three molecular components are detected in the direction of the nebula. The bulk of the molecular gas is observed at 54 km s^{-1} and follows the SE border of the nebula. Adopting for NGC 2359 a distance $d = 5$ kpc, an H_2 mass of about 1200±500 $M_\odot$ appears to be related to the southern part of the nebula, while 140±50 $M_\odot$ are linked to the filamentary wind blown bubble. The volume density of the molecular gas related to the southern *bar* is $\geq 10^3$ H_2 molecules cm^{-3}, while lower densities were estimated for the material associated with the filamentary wind blown bubble. From the present data, it is not clear if the molecular gas at 37 km s^{-1} ($\simeq$ 380±120 $M_\odot$, $d = 5$ kpc) is associated with the nebula, while the molecular material observed at 67 km s^{-1} ($\simeq$ 70±25 $M_\odot$, $d = 5$ kpc) seems to be unconnected. The comparison between ionized, HI and molecular distributions indicates that the HI filament detected with the VLA is located at the interface between the ionized and molecular material and that the HI filament at 54 km s^{-1} has originated in the photodissociation of the H_2. Most of the molecular gas associated with the filamentary bubble seems to be interstellar in origin. The dynamics of the nebula is reanalyzed based on these new molecular results. It is consistent with momentum conservation or with an intermediate stage between energy and momentum conservation.

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In Proceedings

Confidence Limits: SNr, E_k and $^{14}N/^{12}C$

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When evolutionary synthesis models take into account the stochastic nature of the IMF together with the discrete number of stars in real stellar clusters, typical output turns to dispersion band (where real data can be placed) instead of narrow lines. We present here a *qualitative* analysis of such dispersion in the SN rate, the kinetic energy and the $^{14}N/^{12}C$ ratio for different amounts of mass transformed into stars. A *quantitative* analysis will be presented in a forecoming paper.

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On the Effect of Binarity and Metallicity in WC/WO Stars

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Extensive measurements of WC and WO stars were used to investigate on a quantitative ground the influence of (i) binarity and (ii) metallicity of the parent galaxy, on the emission line strengths. We found that fairly accurate (±0.1/0.2 dex) emission–line *median values* can be determined for single–spectrum stars, and that in the WC4 stars of the LMC, the C IV 581 nm line is on the average 1.9 times stronger than in MW stars. Much larger differences are observed between non–galactic and galactic WO stars. This '*C IV anomaly*' is attributed to a mass–loss effect and/or to a different initial stellar mass. A good match is instead found between the strengths of the O V 559 nm line in both the galactic and non–galactic WO and WC4 stars, indicating that the 559 nm line is a good temperature tracer for the hotter stars. We have also derived from the large emission lowering with respect to the median values of the composite–spectrum stars (WR+OB), an OB/WR continuum ratio as large as one dex, which is an observational confirmation of the large luminosity decrease of the WR component following the O–supergiant phase.

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Analysis of Stellar Spectra with Enhanced Emission Lines

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Starting from the analysis of the main spectral features in the prototype of the luminous emission line stars, P Cyg, we discuss the main processes of level excitation and the self–asborption effects in the envelopes of emission line stars. We present the results of the semiempirical analysis of the optical spectra of a variety of emission line sources, which allows the quantitative measure of line opacities and population anomalies related, for instance, to fluorescence effects.

To appear in ' Eta Carinae and other mysterious stars. The hidden opportunities of emission spectroscopy', ASP Conf. Series

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The AURELIE 1μ Spectrum of P Cygni at High Resolution

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We present the high resolution (R=60 000) NIR spectrum of P Cyg in the spectral range 996–1015 nm. The main spectral features are described, with special emphasis on the high excitation Fe II 999.7 nm emission line. We analyse the velocity field of the different features in the light of possible forming regions. We briefly review the appearence and variability of the 999.7 nm line in early type stars and discuss possible excitation mechanisms.

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The SARG Very High Resolution Spectrum of P Cygni

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We present the results of a preliminary analysis of the very high resolution spectrograms (R=86 000) of P Cyg obtained with the new SARG spectrograph attached to the Italian National Telescope (TNG). A marked change in the Hα profile is noticed with respect to the May 1996 observations of Gäng (2000). We also analyse the effect of the telluric lines on the spectral appearence by comparison with lower resolution observations, and find that it can simulate weak line variability.

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The 5.52 Year Cycle of Eta Carinae: BeppoSAX Detection of Variable Hard (> 10 keV) X-Ray Emission

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BeppoSAX observed the superluminous star η Car in 1996–2000, during four different phases of its 5.52 yr variability cycle. A high–energy tail in excess of the hard (4.6 keV) X–ray source is discovered which extends to $\geq$50 keV. During the observations, the 4–10 keV spectrum appeared steady, both in flux and in temperature. A profound flux deficit near 1.5–4 keV in March 1998, just after the deep 1997.9–1998.2 eclipse, is attributed to a 4$\times$ larger absorption. At that time no PDS flux was detected, while the Fe–k line was 40% stronger. The results are discussed in the framework of occultation in a binary system.

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Theses

Spectroscopic Analysis of Galactic OB stars

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The analysis of stellar spectra gives us precise information on the atmospheres in which they are created, as well as on the stellar interior. Such analyses aim to determine the parameters that describe the conditions in the stellar atmosphere (effective temperatures, surface gravities, element abundances, the parameters characterizing winds in the case of massive stars, etc.), as well as other less significant features, such as microturbulence.

To perform these analyses we make use of model atmospheres that simulate the physical processes taking place in the star and reproduce the stellar spectra that finally emerge from it. We need to improve such analyses in order to obtain a better and more realistic description of the atmospheres of OB stars in our Galaxy. This way we shall be able to answer several pending questions about these objects, especially whether the *He discrepancy* can be explained by mixing processes within the stellar interior induced by rotation.

Our improvements in the analysis with plane–parallel and hydrostatic models (pph models) consist in considering the effect of *line blocking* and microturbulence in the spectral synthesis, and in establishing the systematic problems found in the reproduction of the H/He spectra in the O and early B range. We show that the use of *line blocking* is necessary for reproducing the earlier spectra, hotter than 35 000 K, and that for temperatures around 50 000 and hotter it is impossible to reproduce the observed spectra with pph models.

All these improvements lead to lower He abundances, making the overabundance less important in some stars, and disappear completely in some others. Nevertheless, we still find stars with an He abundance higher than solar, and we think that this is definitely a real effect of the composition of the stellar atmosphere, not an artefact produced by deficiencies in the atmospheric models. We also see that analysis with unified models (those accounting for the stellar wind) reproduce the results of the pph models in the case of a moderate wind, so that our pph analyses prove to be useful in such cases.

If the overabundance of helium is real and is caused by mixing processes with the nucleus of the star, it must be correlated with CNO contamination. The abundances of these elements are modified by the CNO cycle in the nuclei of these stars. The CNO abundances of an O9 fast rotator with a slight He overabundance, when compared to those obtained for other three O9 stars with normal compositions, show indications of such contamination. This result supports the idea of mixing processes induced by rotation being responsible for the surface exposure of the CNO processed material.

We have also seen that the best way to study stellar compositions and their relation with stellar evolution is to study members of a certain OB association. In the case of 11 stars in the Cyg OB2 association, we have found that the low rotational velocities and the youth of the stars could be the explanation for not having found any *He discrepancy.* This forms another proof of the relation between rotation and mixing.

Thesis defended at the IAC, Spain, 2001 January 11

Meetings

The Evolution of Galaxies. II. Basic Building Blocks

Ile de la Réunion, France, Oct. 16-21 2001

The evolution of galaxies has become an observational fact mainly after recent sky surveys (e.g. the HST deep field survey, the Canada-France redshift survey, or ISO deep surveys), which have shown that the properties of distant galaxies, formed early in the life of the Universe, differ from those of nearby ones. New observational windows at X-ray, ultraviolet, infrared and millimetric wavelengths (ROSAT, IUE, IRAS, ISO, IRAM) have revealed that galaxies contain a wealth of components (very hot gas, atomic hydrogen, molecules, dust, dark matter).

However, theoretical modeling has not progressed as fast as the census of the content of galaxies. So far, most models are very empirical or semi-empirical. A real understanding of galaxy evolution requires a proper physical description of the galaxy components as well as of the coupling and feedback between them: stars and gas, cold and hot phases of the interstellar medium, large scale and small scale phenomena.

A significant advance is expected in the near future mostly due to the conjunction of two circumstances. On the one hand, the exploration of the most distant Universe will be possible with the new facilities from ground and space (e.g. VLT, FIRST, XMM, etc..). On the other hand, the rapidly developing computing facilities will permit, for the first time, to provide self-consistent models of galaxy evolution. During the next decade, we can expect a breakthrough in galaxy modeling, in which all the relevant large and small scale processes will be taken into account in a coherent way. It will be possible to test this new generation of models against strong observational constraints.

We have started a cycle of three Euroconferences on the evolution of galaxies. The first conference, devoted to the observational clues, took place in May 2000 in Grenada (Spain). The second will take place in October 2001 in the Island of La Reunion (France) in the Indian Ocean and will address the interplay between the different components of a galaxy: interstellar matter, star formation, stellar evolution and death, role of dynamics and environment. The last one will take place in July 2002 in Kiel (Germany) and will address the detailed modeling of galaxy evolution.

Specialists in various fields of Astronomy, observers and theoreticians are expected to participate.

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Important Dates

January 15, 2001 - April 2, 2001	Pre-registration
April 2, 2001	Dead line for final abstract submission
May 2, 2001	Final list of participants and second announcement
October 16-21 2001	Conference

Chemical Composition of Stars

Seattle, September 19 – 22, 2001.

In commemoration of the 50th anniversary of the paper by Chamberlain and Aller that showed that the subdwarfs are metal-poor, and the discovery of technetium in stars, The Astronomy department of the University of Washington is pleased to announce a conference on the Chemical Composition of Stars to be held in Seattle on September 19, 20, 21, 22, 2001.

Specific subtopics that we would like covered include:
– Li, Be, B, in stars
– C, N, O, Na, Al, alphas
– Hot Stars (types O, B, A)
– Supernova Nucleosynthesis
– Extremely metal-poor stars
– AGB and post-AGB stars
– Stars with planets
– L and T stars
– Atmospheric modeling and NLTE

Specific social events will include a salmon bake and a Seattle Mariners baseball game.

To receive further information and to help us estimate the number of attendees please send an email to George Wallerstein – **wall@astro.washington.edu** – if it is likely that you will attend.

A web site will be created within a month or so.

The Scientific Organizing Committee consist of Lawrence Aller and Jesse Greenstein (Honorary Chairmen), W.D. Arnett, A.M. Boesgaard, C. Charbonnel, M. Carlsson, G. Gonzalez, W. Haxton, R.P.Kraft, J. Lutz, C.A. Pilachowski, V.V. Smith, C. Sneden, K. Venn, G. Wallerstein (Chair).