Calibrating the Top of the Stellar M-L Relation

Meeting Format: One-day Joint Discussion.

Venue: IAU General Assembly in Prague, August 2006.

Scientific Organizing Committee: Claus Leitherer (Baltimore; Chair), Norbert Langer (Utrecht), Anthony Moffat (Montreal), Stanley Owocki (Delaware), and Joachim Puls (Munich).

Coordinating Division: Division IV (Stars).

Supporting Divisions: Division V (Variable Stars), Division VI (Interstellar Matter), Division VII (Galactic System), Division VIII (Galaxies and the Universe).

Supporting Commissions: Commission 26, 28, 29, 34, 35, 36, 37, 42, 45, 47.

Main Topics:

- Empirical mass determinations of the most massive stars.
- Models for massive stars on and off the main sequence.
- Stability near the Eddington limit with and without rotation.
- Comparisons of atmospheric and evolutionary masses.
- Observational efforts to detect, monitor, and analyze massive binaries.
- Mass and energy return to the interstellar medium from massive stars.
- Extrapolations to the first generation of stars with ultra-high masses.
- The role of hot massive stars during the epoch of reionization in the early universe.

Rationale:
The goal is to bring together theorists and observers from the stellar and extragalactic communities to discuss the properties of the most massive stars and the implications for cosmological studies. We will focus on a set of themes that follow from fundamental stellar astronomy, such as mass determinations in binary stars, to recent modeling of atmospheres and evolution, to the significance of massive stars for the ecology of the host galaxy, and finally to a critical assessment of the properties of the first generation of stars in the universe.
Until now, few efforts have been devoted to aggressively searching for the most massive stars. Massey et al. have looked at the most luminous O-type stars on the main sequence, with mass estimates for several O3-type stars in the surprisingly broad, low range from some 35 – 60 $M_\odot$. Rauw and collaborators have concentrated on luminous WR stars in the van der Hucht catalogue (2001), and recent light curve measurements for the WN6ha + WN6ha system WR20a lead to component masses close to 83 and 82 $M_\odot$, the highest binary-inferred masses to date. Moffat et al. are concentrating on the most luminous, H-rich WNL stars mainly in the LMC and NGC 3603 in the Galaxy. It thus remains an open issue how much above the binary-inferred maximum 80 $M_\odot$ the most massive stars may actually be.

Optical interferometry is entering a new age with several ground-based long-baseline observatories now making observations of unprecedented resolution. Interferometers bring a new level of resolution to bear on massive spectroscopic binaries, enabling the full extraction of the physical parameters for the component stars with high accuracy. This will be an opportunity to determine hundreds of fully three-dimensional orbits in absolute units, when interferometric results are combined with spectroscopic orbits, thus accurately determining masses, diameters, and distances (hence luminosities) of tens of massive binary stars through their orbital parallaxes.

In contrast to such direct observations of masses, based on Keplerian orbits in binaries, which have never yielded values above 85 $M_{\odot}$, less direct techniques based on spectroscopic analyses tend to give a fairly large spread of masses. For extremely luminous stars like η Carinae and the Pistol Star, keeping within the Eddington limit requires masses near 100 $M_{\odot}$. Up-to-date atmospheric models accounting for mass-loss and line-blanketing seem to indicate that the long-standing mass discrepancy (i.e., the problem that atmospheric masses were systematically lower than the evolutionary ones) has still not been fully resolved. Since mass is the most fundamental stellar parameter, such a discrepancy is intolerable, and its theoretical origin needs to be explored.

While determining the mass of the most massive stars and calibrating the top of the mass-luminosity relation are meritorious in their own right, stellar masses are a central theme in current extragalactic astronomy as well. The top end of the stellar initial mass function is imprinted in the observed spectra of distant populations, and our knowledge of the stellar content relies on local calibrations. The subject has received particular interest from research aimed at understanding and predicting the properties of distant stellar populations, which are thought to be the powering sources of Lyman-break or SCUBA galaxies.

A common theme of contemporary cosmology is the quest for the first generation of stars formed in the universe. Such stars are thought to be the supermassive cousins of the massive stars studied locally. Local calibrations of the fundamental stellar parameters will provide much sought guidance for cosmological models. Modeling massive metal-free stars poses major challenges due to yet unexplored phenomena such as rotation and mass loss in such extreme environments. A particularly important issue regards the importance of episodes of super-Eddington, continuum-driven mass loss (such as occurs in η Carinae and other Luminous Blue Variable stars), which can reduce the evolutionary mass even in the absence of a substantial metal-line-driven stellar wind. With rapid rotation a bipolar shaping of the mass ejection (such as seen in the Homunculus nebula of ηCarinae) can reduce the associated angular momentum loss, with potentially important consequences for leaving the rapidly rotating core central to the collapsar model for gamma-ray bursts.

We believe a JD on these topics is timely and of broad interest, not only to members of the commissions in Division IV, which we propose as the coordinating division. We envision significant overlap with the scientific interests of IAU members in Divisions V, VI, VII, and VIII.

Prospective Speakers:

- Spectroscopic binaries: Massey, Rauw, Moffat.
- Optical interferometry: Gies, Mason.

- Models: Herrero, Puls, Maeder, Meynet, Najarro.
- Eddington limit: Owocki, Langer.
- Stellar populations, pop III: Bromm, Leitherer, Abel, El Eid.

Recipients of this proposal:

- President of IAU Division IV (Stars):
  D. Dravins *(dainis@astro.lu.se)*
- President of IAU Division V (Variable Stars):
  J. Christensen-Dalsgaard *(jcd@phys.au.dk)*
- President of IAU Division VI (Interstellar Matter):
  John Dyson *(jed@ast.leeds.ac.uk)*
- President of IAU Division VII (Galactic System):
  Patricia Whitelock *(paw@saao.ac.za)*
- President of IAU Division VIII (Galaxies and the Universe):
  Francesco Bertola *(bertola@pd.astro.it)*
- Assistant General Secretary:
  K. van der Hucht *(K.A.van.der.Hucht@sron.nl)*

With copies to:

- Commission 26 – Double and Multiple Stars (Div IV)
  W. Hartkopf *(wih@crux.usno.navy.mil)*
  C. Allen *(chris@astroscu.unam.mx)*
- Commission 28 – Galaxies (Div VIII)
  E. Sadler *(ems@physics.usyd.edu.au)*
  F. Combes *(francoise.combes@obspm.fr)*
- Commission 29 – Stellar Spectra (Div IV)
  C. Sneden *(chris@astro.as.utexas.edu)*
  M. Parthasarathy *(krp@isid.isid.ac.in)*
- Commission 34 – Interstellar Matter (Div VI)
  J. Dyson *(jed@ast.leeds.ac.uk)*
  T. Millar *(tom.millar@umist.ac.uk)*
- Commission 35 – Stellar Constitution (Div IV)
  W. Dziembowski *(wd@astrouw.edu.pl)*
  F. D'Antona *(dantona@mporzio.astro.it)*
- Commission 36 – Theory of Stellar Atmospheres (Div IV)
  D. Dravins *(dainis@astro.lu.se)*
  M. Spite *(Monique.Spite@obspm.fr)*
- Commission 37 – Star Clusters and Associations (Div VII)
  A. Sarajedini *(ata@astro.ufl.edu)*
  R. Spurzem *(spurzem@ari.uni-heidelberg.de)*
- Commission 42 – Close Binary Stars (Div V)
  A. Gimenez *(agimenez@rssd.esa.int)*
  S. Rucinski *(rucinski@astro.utoronto.ca)*

- Commission 45 – Stellar Classification (Div IV)
  - T. Lloyd Evans *(tle@nottingham.ac.uk)*
  - C. Corbally *(corbally@as.arizona.edu)*
- Commission 47 – Cosmology (Div VIII)
  - S. Lilly *(simon.lilly@phys.ethz.ch)*
  - R. Webster *(rwebster@isis.ph.unimelb.edu.au)*