

DIVISION IV / WORKING GROUP MASSIVE STARS

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1. Background

Our Working Group studies massive, luminous stars, with historical focus on early-type (OB) stars, but extending in recent years to include massive red supergiants that evolve from hot stars. There is also emphasis on the role of massive stars in other branches of astrophysics, particularly regarding starburst galaxies, the first stars, core-collapse gamma-ray bursts, and formation of massive stars.

Before 2004, we were known as the Hot-Star Working Group, but after thorough debate, the WG Organizing Committee voted for a name change to *Massive Stars*. This name change reflects the tight interrelation of research on hot and cool stars in the upper Hertzsprung-Russell diagram.

At this time, the Organizing Committee also generated and approved a set of by-laws. These by-laws and other activities of the Working Group are posted on the web site <www.astroscu.unam.mx/massive_stars>. Our web master is Raphael Hirschi (University of Basel). Among other features, this web portal offers a discussion group page and an automatic Newsletter submission interface. This allows the members of the Working Group to submit their Newsletter abstracts and circulates newly received abstracts to registered members.

The *Massive Star Newsletter*, edited by Philippe Eenens (UNAM, Mexico City), continues to be the main means of communication and science dissemination in our Working Group. As of April 2008, 105 issues of the Newsletter have been published. Back issues are posted on the WG web site: <www.astroscu.unam.mx/massive_stars/news.php>.

2. Developments within the past triennium

Over the past three years, activities focused on co-sponsorship of IAU JD05 at the IAU XXVI GA in Prague (Czech Republic), 2006, and on the highly successful IAU Symposium No. 250 in Kauai (HI, USA). The follow gives further background on these meetings.

2.1. IAU GA2006 JD05: Calibrating the Top of the Stellar Mass-Luminosity Relation

The goal of this Joint Discussion, held 16 August 2006 at the IAU XXVI General Assembly in Prague (Czech Republic), was 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. The meeting focused 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. Major topics included:

- empirical mass determinations of the most massive single 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; and
- the role of hot massive stars during the epoch of re-ionization in the early Universe.

Further information at the website: <www.stsci.edu/science/starburst/Prague/>.

2.2. IAU Symposium No. 250: Massive Stars as Cosmic Engines

This IAU Symposium held 9-14 December 2007 on Kauai (Hawaii, USA) and hosted by the Institute for Astronomy at the University of Hawaii, focused on how massive stars shape the Universe, from the nearby Universe to high-redshift galaxies and the first generation of stars.

Massive stars form in starbursts, pollute the interstellar medium (ISM), inject energy and momentum via their stellar winds and core-collapse supernovae (SNe), drive the ISM out of galaxies, polluting the intergalactic medium. Direct detection of massive stars (via their UV continua and spectral lines) and of the products of their nucleosynthesis provides some of the most stringent constraints on the physical properties of galaxies at high redshifts, whether identified via their emission at a variety of wavelengths or by the absorption they produce in quasar spectra. Within the past few years, a direct connection has been established between certain core-collapse SNe and Gamma Ray Bursts (GRBs), supporting the collapsar model in which the GRB results from the death throes of a rapidly rotating Wolf-Rayet star.

Within the past few years, great progress has been made toward our understanding of the astrophysical role played by massive stars. From an observational perspective, temperatures of OB stars have been revised downward based on the most recent observations with *FUSE*, *HST*, and ground-based facilities. The role of clumping in stellar winds has been recognized, with potentially dramatic consequences for stellar evolution, due to its influence on derived mass-loss rates. Close binaries with masses of up to 80 M_{\odot} solar masses have been identified and studied visually and with exquisite detail using *Chandra*, *XMM*, VLA. Visibly obscured young massive clusters have been identified at our Galactic Centre, elsewhere in our own Milky Way and in external galaxies. These have been studied with *HST*, VLT, Gemini and Subaru, exploiting natural guide star Adaptive Optics (AO) techniques from the ground. Increasingly, the use of AO with laser guide stars is expected to revolutionise the study of massive star forming regions.

Quantitative spectroscopy of massive stars beyond the Local Group has been undertaken with VLT and Keck to disentangle chemical evolution of galaxies in the nearby Universe and to determine independent distances. Star formation histories have been

inferred from population/spectrum synthesis of resolved/unresolved populations of nearby star forming galaxies; nearby starbursts – templates for high-redshift counterparts – have been studied with *FUSE*, *HST*, *GALEX* and *Spitzer*. Large surveys for star forming galaxies from redshifts 1 to 6, making use of colour selection techniques at optical, infrared and sub-mm wavelengths, have provided quantitative measures of their massive stellar populations over most of the age of the Universe, including their past history of star formation, the IMF, assembled stellar masses, metallicities and chemical yields. From space, *HETE* and *SWIFT* have allowed an increasing number of GRBs to be studied in detail, with rapid follow-up from ground-based facilities permitting chemical information on their host galaxies to be obtained. These are all tremendously exciting topics, at the forefront of present-day astrophysical research and providing some of the core scientific cases for the next generation of extremely large telescopes currently under development.

Theoretically, great advances have been made toward improved evolutionary and atmospheric models for massive stars allowing for rotation and magnetic fields, and toward the evolution of massive binary systems. The impact of internal waves generated at the boundary of the convective core on the transport of angular momentum and chemical species in the stellar interior. Important developments have taken place with respect to spectral synthesis of starbursts, improved spectral energy distributions of young stellar populations, hydrodynamic simulations of GRB explosions, and notably numerical simulations of star formation at the earliest epochs, including very massive Population III stars which are thought to play the dominant role in the re-ionization of the universe at redshift $z > 6$.

The key astrophysical problems for the symposium were:

- Atmospheres of massive stars;
- Physics and evolution of massive stars;
- Massive stellar populations in the nearby Universe;
- Hydrodynamics and feedback from massive stars in galaxy evolution;
- Massive stars as probes of the early Universe.

Further information at the meeting web site <www.ifa.hawaii.edu/iau250>.

3. Future outlook

Our Working Group is a sponsor of an approved 1.5-day Joint Discussion during the IAU XXVII General Assembly in Rio de Janeiro (Brazil), 2009, entitled *Eta Carinae and Interacting Massive Binaries*, for which Ted Gull and Augusto Daminelli are SOC co-chairs.

Other meetings on massive stars include:

- *Massive Stars: A Lifetime of Influence*, 13-15 October 2008, Lowell Observatory, Flagstaff (AZ, USA), in honor of the retirement of Peter Conti.

See: <www.lowell.edu/workshops/Contifest>.

- *Hot And Cool: Bridging Gaps in Massive Star Evolution*, 10-12 November 2008, CalTech, Pasadena (CA, USA).

See: <www.ipac.caltech.edu/hotandcool/CoolAndHot.html>.

- *High-Energy Phenomena in Massive Stars*, 2-5 February 2009, Jaen, Spain.

See: <www.ujaen.es/congreso/massive.stars2009/>.

- *The Interferometric View on Hot Stars*, 2-6 March 2009, Vina del Mar, Chile.

See: <www.eso.org/sci/meetings/IHOT09/>.

In the coming years exciting new results on massive stars will be obtained by interferometry and asteroseismology. These new techniques will probe both the physics of the

surfaces and interiors of massive stars, allowing unprecedented constraints of key physical parameters like rotation, magnetic fields, and chemical composition.

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chair of the Working Group