The RMS Survey
Testing models of massive star formation

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Introduction

Although massive stars (> 8 $M_\odot$ and 10^3 $L_\odot$) make up only a few per cent of the stellar population they play a hugely important role in many astrophysical processes from the formation of the first solid material in the early Universe (Dunne et al. 2003, Nature 424, 285); to their substantial influence upon the evolution of their host galaxies and future generations of star formation. However, despite decades of research relatively little is known about the underlying physical processes involved in the formation of massive stars. This lack places a major hurdle in the way of studies of galaxy formation and evolution (e.g. Silk 2003, Where Cosmology & Fundamental Physics Meet).

Recent theoretical 3D hydrodynamic simulations suggest that massive stars are formed through disk accretion (e.g., Krumholtz et al., 2009, Science, 323, 754), in a scaled-up version of low-mass star formation. We plan to exploit a newly developed sample of massive young stellar objects (MYSOs) and two new cutting edge facilities; the Atacama Large Millimetre Array (ALMA) and the *Herschel Space Observatory*. The Red MSX Source (RMS) survey provides a large and unbiased foundation for the large scale high resolution investigations that are permitted for the first time by the exquisite sensitivity and angular resolution of ALMA.

The RMS survey

The RMS survey (Urquhart et al. 2008, ASPCS, 387, 381) has identified a large well-selected and well-characterised sample of young massive stars (e.g., distance and luminosity; www.ast.leeds.ac.uk/cgi-bin/RMS/RMS_DATABASE.cgi). By combining infrared, millimetre and radio wavelength observations with complementary archival data we have identified ~1300 MYSOs and ultra-compact HII regions located throughout the Galactic plane (b < 5°; see Fig. 1) — an order of magnitude larger than previously available.

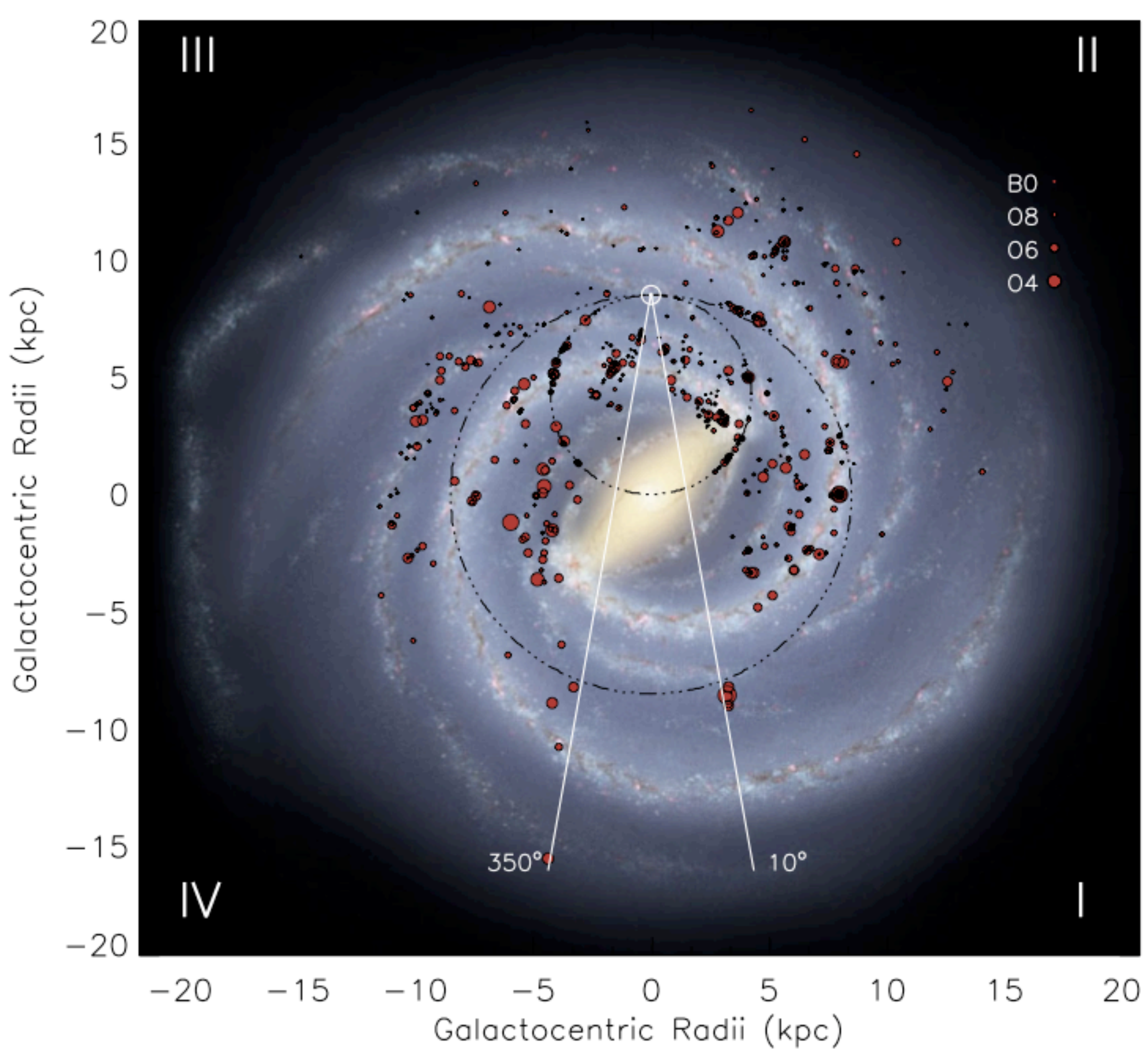

Figure 1: Galactic distribution of the complete RMS sample of MYSOs and UC HII regions with bolometric luminosites >10^4 $L_\odot$. The RMS distribution is superimposed over a sketch of how the Galaxy is thought to appear if viewed face-on. This image has been produced by Robert Hurt of the Spitzer Science Center in consultation with Robert Benjamin and attempts to synthesise many of the key elements of Galactic structure using the best data currently available.

The RMS sample has a number of advantages over current samples, most of which are based on lower resolution data obtained by the IRAS satellite (~25 times lower than MSX at 25 μm) and are therefore biased towards bright, isolated sources and tend to avoid dense clustered environments and the Galactic mid-plane where the majority of MYSOs are expected to be found. The RMS survey provides a well-selected sample with sufficient numbers of sources in each luminosity bin to allow statistical studies as a function of luminosity (see Fig. 2 for luminosity distribution).

We will also extend the RMS to longer wavelengths, in particular to encompass the 70 - 500 μm Herschel Hi-Gal survey (Molinari et al, 2010, PASP 122, 314) and data from the SCUBA2 legacy surveys. When combined the HiGal, SCUBA2 and archival Spitzer

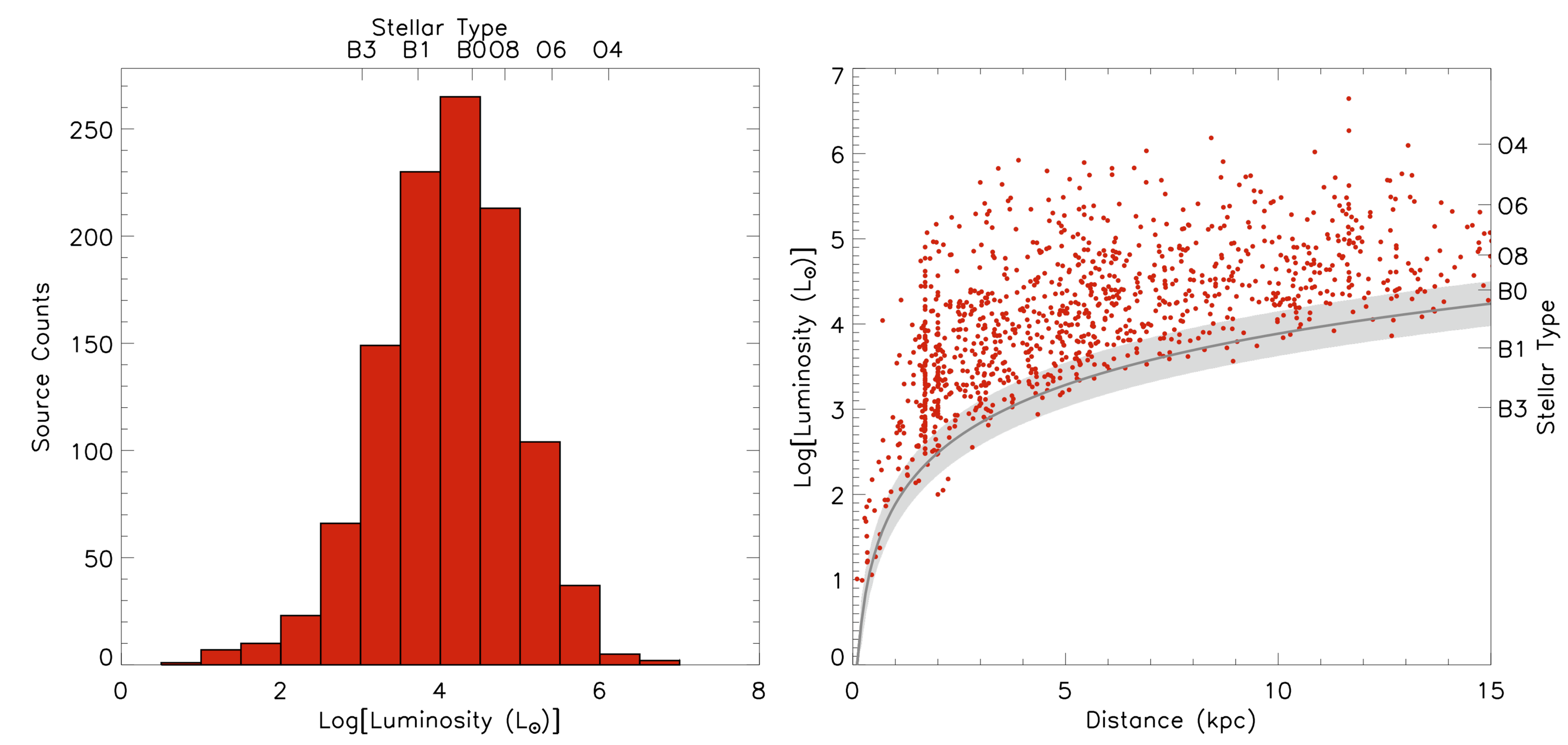

Figure 2: Left panel: Histogram of the distribution of RMS sources as a function of luminosity (bin size used is 0.5 dex). Right panel: Luminosity distribution as a function of heliocentric distance. The dark grey line and light grey shading indicates the limiting sensitivity of RMS and its associated uncertainty.

data provide complete coverage from the mid-infrared to the submillimetre wavelengths with comparable angular resolution at the longer wavelengths. These data sets will complement the data already complied for the RMS sample and will be used to improve model fits to source spectral energy distributions (SEDs), allowing the dust temperatures, masses and luminosities to be better constrained (see Fig. 3 for schematic of wavelength coverage).

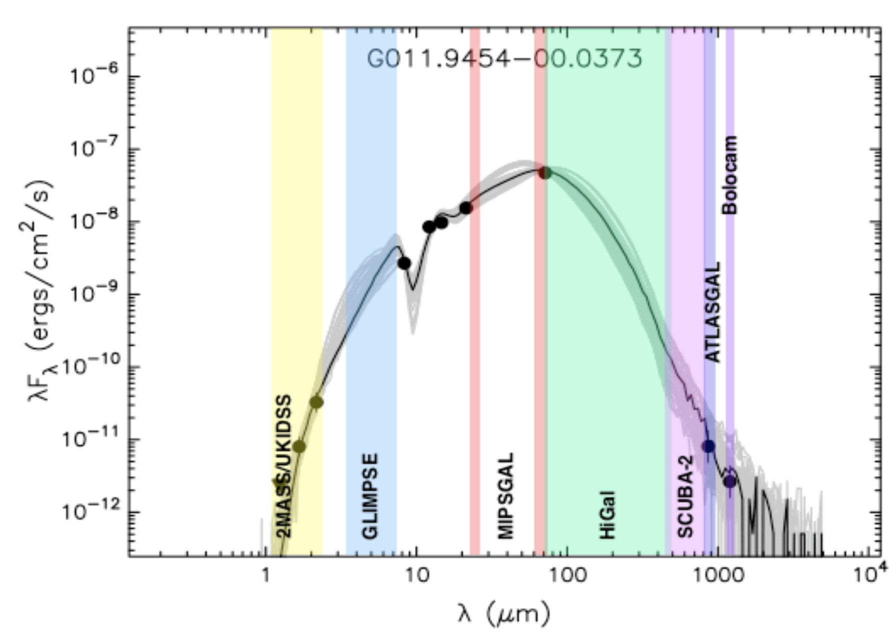

Figure 3: Spectral energy distribution for the RMS source G011.9454-00.0373. The SED has been fit using the 2MASS, MSX, MIPS 70 μm, SCUBA 850 μm and MAMBO 1.1 mm which are shown as filled circles. The coloured bands show the wavelength coverage of a number of the Galactic Plane surveys that have recently been completed, are underway or are due to begin.

Research outline and goals

A key prediction of the monolithic collapse and competitive accretion models is the presence of a circumstellar disk, a common feature of low-mass star formation (e.g. Lada 1999, OSPS, 143). While the detection of disks around massive young stars would confirm the accretion scenario, relatively few high mass disk candidates have been found to date (Cesaroni et al. 2008, ApSS, 313, 23), and none have been found towards O-type stars.

To test these models for the most massive O-type stars, where radiation pressure and photoevaporation of the accretion disk and protostellar envelope may play a significant role in the formation process, requires an increase in sensitivity and angular resolution of an order of magnitude than is currently available — ALMA will provide the sensitivity and angular resolution necessary. We plan to use ALMA to conduct a systematic study of circumstellar disks towards a large luminosity selected sample of the most massive O-type stars. These data will not only be used to measure the frequency of MYSO circumstellar accretion disks, but will also correlate disk properties with those of their MYSO hosts, providing stringent observational tests of massive star formation theories. In particular, we will test the following predictions of the massive star formation models:

1) Disk mass to stellar mass ratio, disk radius and spiral strength are all proportional to stellar mass, and hence luminosity (Krumholz et al. 2007, ApJ 665, 478).
2) Disk frequency should be a strong function of whether competitive accretion or monolithic collapse is the dominant process (Bonnell & Bate 2007, MNRAS 370, 488; Krumholz et al. 2007, ApJ 665, 478).
3) Monolithic collapse models predict a high degree of collimation in molecular outflows (Arce et al.2007, *Protostars & Planets V, 245).*

Summary

High-resolution and sensitive observations of a well-selected sample of young massive stars will provide crucial information on the frequency and properties of accretion disks, and molecular outflows, as a function of luminosity and provide a wealth of addition information with which to investigate the influence of environment on the formation of massive stars. This project will leave a high quality legacy data set with clearly defined source parameters against which theoretical models can be tested.

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Further information

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