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The e-Merlin Cyg OB2 Radio Survey (COBRaS): Massive and Young Stars in the Galaxy

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Abstract: The e-Merlin Cyg OB2 Radio Survey (COBRaS) will provide targetted deep–field mapping of this extremely rich association in the Galaxy detecting at least 1000 sources. Inter-related core themes of the COBRaS programme include: (i) mass loss and evolution of massive stars, (ii) the formation, dynamics and content of massive OB associations, (iii) frequency of massive binaries and non-thermal radiation and (iv) ongoing and triggered star formation

1 The COBRaS SURVEY

The upcoming enhanced UK radio facility e-Merlin will provide greatly increased sensitivity (about 3 micro-Jy) and high spatial reolution (milli-arcsec) observations at 5 GHz (C-band) and 1.6 GHz (L-band) with bandwiths of 2 GHz and 0.4 GHz respectively. More details of the e-Merlin facility and the COBRaS programme can be found on the website www.homepage.ucl.ac.uk/ ucapwi/cobras. The large bandwidths and size of the e-Merlin network provide for a greatly increased sensitivity over previous radio surveys (eg VLA) which will allow for a huge increase in the numbers of early-type, massive stars with actual radio flux measurements. We are planning a major survey of the tremendously rich Cyg OB2 association using targetted, deep-field mapping of this region to deliver the most detailed radio census for the most massive OB association in the northern hemisphere, offering direct comparison to not only young massive clusters in general, but also young globular clusters and super star clusters. We have been allocated 242 hours at C-band and 42 hours at L-band to conduct this e-Merlin legacy programme, allowing for about 100 pointings at 5 GHz and 20 pointings at 1.6 GHz. We estimate that at least 1000 sources will be detected which will complement other, multi-wavelength surveys of the Cyg-X region (IPHAS, Spitzer, Chandra and JWST). An outline of the major science programmes that will be addressed using this new dataset is given below.

2 Massive Stars: mass loss rates

The mass loss rates for OB (and WR) stars are currently in question at the order of magnitude level (see Fig. 1, Fullerton, Massa & Prinja 2006) with profound implications for stellar evolution, mass loss processes across the HR diagram, and the injection of energy and enriched gas into the ISM. The recognition of clumped and/or porous radiation-driven stellar winds has led to reduced mass loss rate estimates from spectroscopic UV and optical data compared to inferences from past (and very limited) radio observations. To produce WR stars and neutron stars we may be forced to appeal to episodic mass loss perhaps through numerous LBV stages (eg. Smith & Owocki 2006) rather than continual stellar winds, with major differences in the nature of the energy and enriched gas injected into the ISM.

Radio free-free fluxes from massive stars occur at large radii in the winds where the terminal velocity has been reached and their interpretation is not strongly dependent on details of the velocity law, ionisation conditions, inner velocity field of the photospheric profile etc., which complicates the interpretation of UV P-Cygni profile and H-alpha data. However, the greater geometric region in the radio and density-squared dependence of the free-free flux makes radio data extremely sensitive to clumping in the wind. Thus radio data can be used to constrain wind-clumping and, coupled with H-alpha, near-IR and mm-wave data we can determine the run of clumping as a function of geometrical region in the wind for individual stars.

Based on 2MASS data (Knödlseder 2000) Cyg OB2 contains about 120 O stars and 2600 B stars. We expect the COBRaS survey to increase the number of OB stars detected in the radio by about a factor of 50, including radio mass loss rates for low luminosity stars for the first time. It is anticipated that over 100 OB stars will be detected with sufficient quality to obtain estimates of their mass loss rates. Our e-Merlin data will permit us to: (i) understand how clumping changes as a function of radial distance in the wind, thus providing reliable mass loss rates, (ii) study for the first time how clumping changes as a function of effective temperature, luminosity and rotation in superiants, giants and main-sequence stars. The high quality of the imaging capabilities of e-Merlin will match the 50 mas angular scales marked by the radio ”photospheres” of massive stars, which will yield direct evidence of large scale wind structures for OB stars and later evolution stages like LBV and red supregiants.

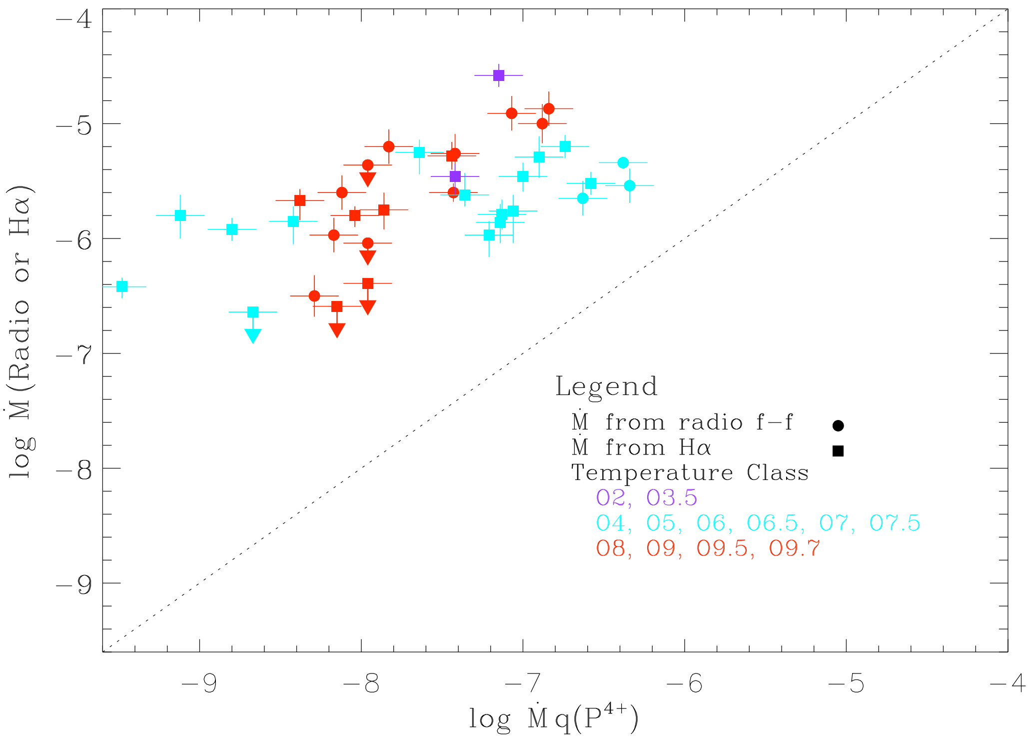

Figure 1: Radio vs. UV mass loss rates for O stars.

3 Cluster Dynamics

We will use e-Merlin to secure milliarcsec accuracy astrometric observations of radio stars in Cyg OB2 at multiple epochs to determine proper motions. Coupled with optical radial velocities this will provide a full 3–D picture of the kinematics of the Cyg OB2 association, its IMF and total mass, and constrain models of cluster formation, together with the star formation history of the region. As part of our consortium we have an ongoing programme of high resolution spectroscopic observations of the massive stellar populations within Cyg OB2 to identify and characterise massive binaries, which provide radial velocity measurements of comparable accuracy. Taken together, these complementary datasets will allow a full 3D picture of the kinematics of Cyg OB2 to be constructed.

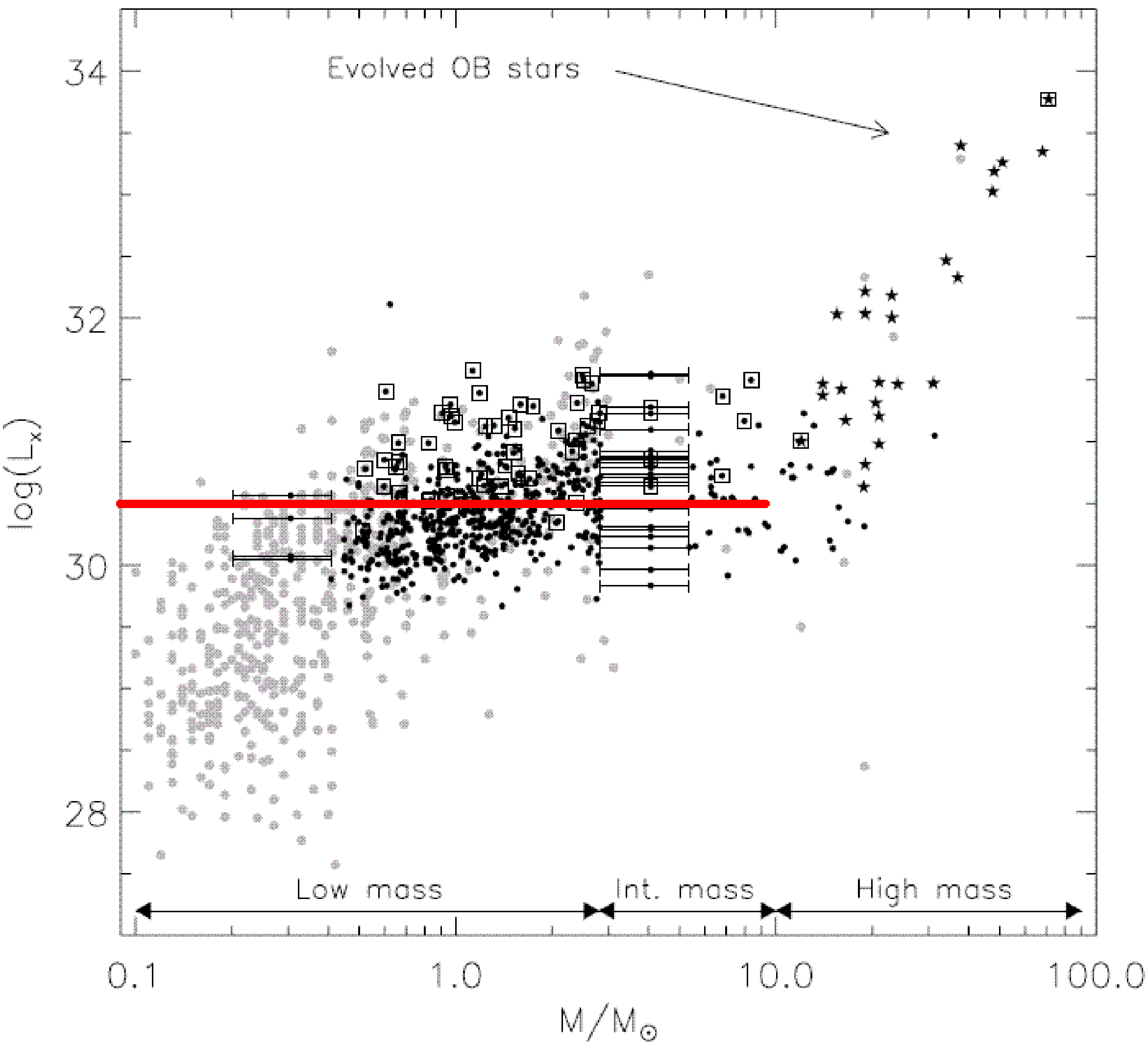

Figure 2: X-ray luminosity vs. Mass for the core of Cyg OB2. The red line is the 3 sigma e-Merlin detection limit.

4 Binarity and non-thermal radiation

In a early-type binary system (e.g. O+O) the two stellar winds collide and electrons are accelerated to relativistic velocities around the shocks in the colliding-wind region. The resulting emission of synchrotron radiation can be detected at radio wavelengths (Dougherty & Williams 2000), with a characteristic non-thermal radio spectral index. Although at present only a fraction of early-type binaries are quoted as non-thermal radio emitters (De Becker 2007, Benaglia 2010), the COBRaS survey will provide a deeper and more accurate census of the radio emission from massive binaries and provide valuable information on the frequency of non-thermal radio emission amongst colliding-wind binaries which is poorly constrained at present. The broad bandwith of the 5 GHz data will allow us to discriminate between thermal and non-thermal sources and thus identify likely colliding wind binary systems and constrain binary statistics. The e-Merlin data from this project will allow us to: (i) provide a better determined binary frequency in Cyg OB2 which is an important constraint for evolutionary population synthesis models, and hence have a broad impact on our understanding of galactic chemical evolution, (ii) study statistically the colliding-wind phenomenon and better understand its dependence on stellar and binary parameters, and (iii) improve our understanding of the first-order Fermi mechanism responsible for particle acceleration.

5 On-going and Triggered star formation

Until now most pre-main sequence T Tauri ($\sim$ 1 solar mass) and their intermediate ($\sim$ 2-10 solar mass) Herbig Ae/Be counterparts have been found in relatively isolated star-forming regions in the Gould's belt. So far we lack the full picture of star formation in more extreme environments such as in and around the Cyg OB2 association. Recently, Vink et al. (2008) reported the discovery of 50 new PMS candidates towards Cyg OB2, found via their strong H-alpha emission using the IPHAS survey of the northern Galactic Plane. Reipurth & Schneider (2008) discuss current knowledge of the star formation in Cyg OB2. T Tauri stars are traditionally divided into Classical T Tauri stars (CTTS) and Weak line T Tauri stars(WTTS) discriminated by their H-alpha emission equivalent width being greater/lower that 10 Å. The latter population presents a major, perhaps dominant, component of the PMS population in most star forming regions, but it is difficult to find the WTTS population with the H-alpha method alone. However, VLA studies at 5 GHz have shown that WTTS stars have radio emissions a hundred times stronger than that of the Sun, indicating that magnetic activity is much stronger during the PMS phase than at later phases in their evolution. Further, it is known that for low mass stars there is a good correlation between X-ray and radio luminosity (Güdel 2002). Fig. 2 shows the X-ray luminosity vs. mass for the Albacete Colombo et al. (2007) X-ray sources in the core of Cyg OB2 (their Fig. 10) embracing their coverage of T Tauri, Herbig Ae/Be and higher mass stars. Also shown is the 3-sigma e-Merlin detection limit. This shows that we will clearly detect large numbers of T Tauri, Herbig Ae/Be stars. Flaring during the observations will make even more stars detectable, and note also that we plan coverage of Cyg OB2 that is three times larger than that attempted by Albacete Colombo et al. (2007). This will allow us to investigate the Pre-Main-Sequence population in detail and the potential environmental effect of OB stars in the star formation history of the association.

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References

Albacete Colombo, J.F., Caramazza, M., Flaccomio, E., Micela, G. & Sciortino, S. 2007, A&A, 474, 495
Benaglia, P. 2010, ASP Conf. Ser., Vol. 422, 111
De Becker, M. 2007, A&ARev, 14, 171
Dougherty, S.M., & Williams, P.M. 2000, MNRAS, 319, 1005
Fullerton, A.W., Massa, D.L., & Prinja, R.K. 2006, ApJ, 637, 1025
Güdel, M. 2002 ARA&A, 40, 217
Knödlseder, J. 2000, A&A, 360, 539
Reipurth, B. & Schneider, N. 2008, *Handbook of Star Forming Regions*, Vol. 1, 36
Smith, N. & Owocki, S.P. 2006, ApJ, 645, L45
Vink, J.S., Drew, J.E., Steeghs, D., Wright, N. J., Martin, E. L., Gänsicke, B. T., Greimel, R. & Drake, J. 2008, MNRAS, 387, 308