e-MERLIN and the COBRaS Legacy Project

Cygnus OB2 Radio Survey (COBRaS)

Luke Peck (University College London)

Principal Investigator: Prof. Raman Prinja

http://www.homepages.ucl.ac.uk/~ucapdwi/cobras

Multi-Element Radio Linked Interferometer Network

- Upgrade includes:Optical Fibre network, new receivers, analogue and digital electronics and a new correlator at JBO.
- Array of seven antennas across UK.
- Maximum baseline of 217km for VLBI.
- Observing Bands: 1.3-1.8 GHz, 4-8GHz, 22-24 GHz.
- Resolution: 10 to 150 mas
- Bandwidth: 4 GHz
- Sensitivity ~ 1μJy
- Some antenna used in EVN.

e-MERLIN LEGACY PROJECTS

- Astrophysics of Galaxy Transformation and Evolution (AGATE)
- **The e-MERLIN CYG OB2 Radio Survey: Massive and Young stars in the Galaxy**
- e-MERLIN Galaxy Evolution Survey (eMERGE)
- e-MERLIN Pulsar Interferometry Project (e-PI)
- Feedback Processes in Massive Star Formation
- Gravitational Lensing and galaxy evolution with e-MERLIN
- Legacy e-MERLIN Multi-Band Imaging of Nearby Galaxies (LeMMINGs)
- Luminous Infra-red Galaxy Inventory (LIRGI)
- Morphology and Time Evolution of Thermal Jets Associated with Low Mass Young Stars
- Planet Earth Building Blocks - a Legacy e-MERLIN Survey (PEBBLES)
- Resolving Key Questions in Extragalactic Jet Physics

Cygnus **OB**2 **Ra**dio **S**urvey (**COBRaS**)

Awarded ~ 300 hrs observing time with e-MERLIN; 252 hrs for C-band (5 GHz), 42 hrs for L-band (1.6 GHz).

Over 30 international astronomers involved in survey.

Survey the largest OB association in the northern hemisphere.

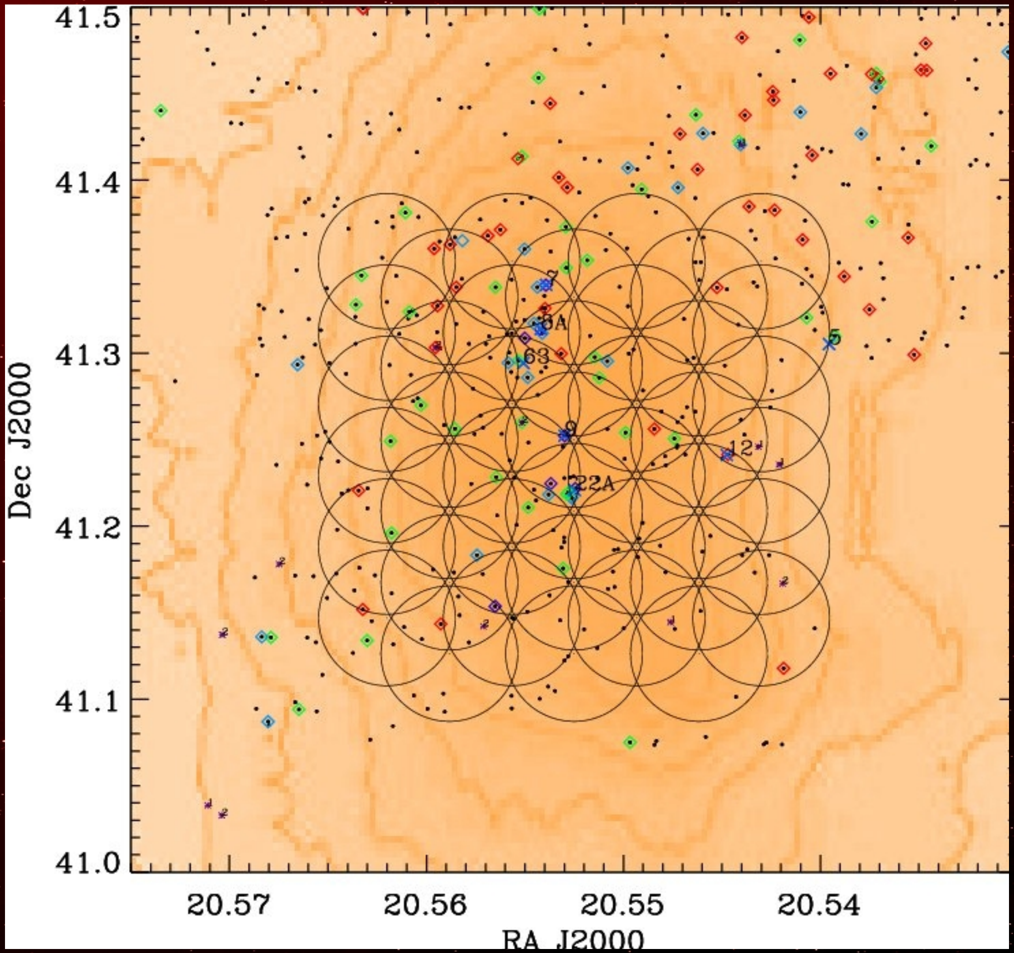
Offers comparisons to other massive clusters, young globular clusters and super star clusters.

Investigate many astrophysical problems:

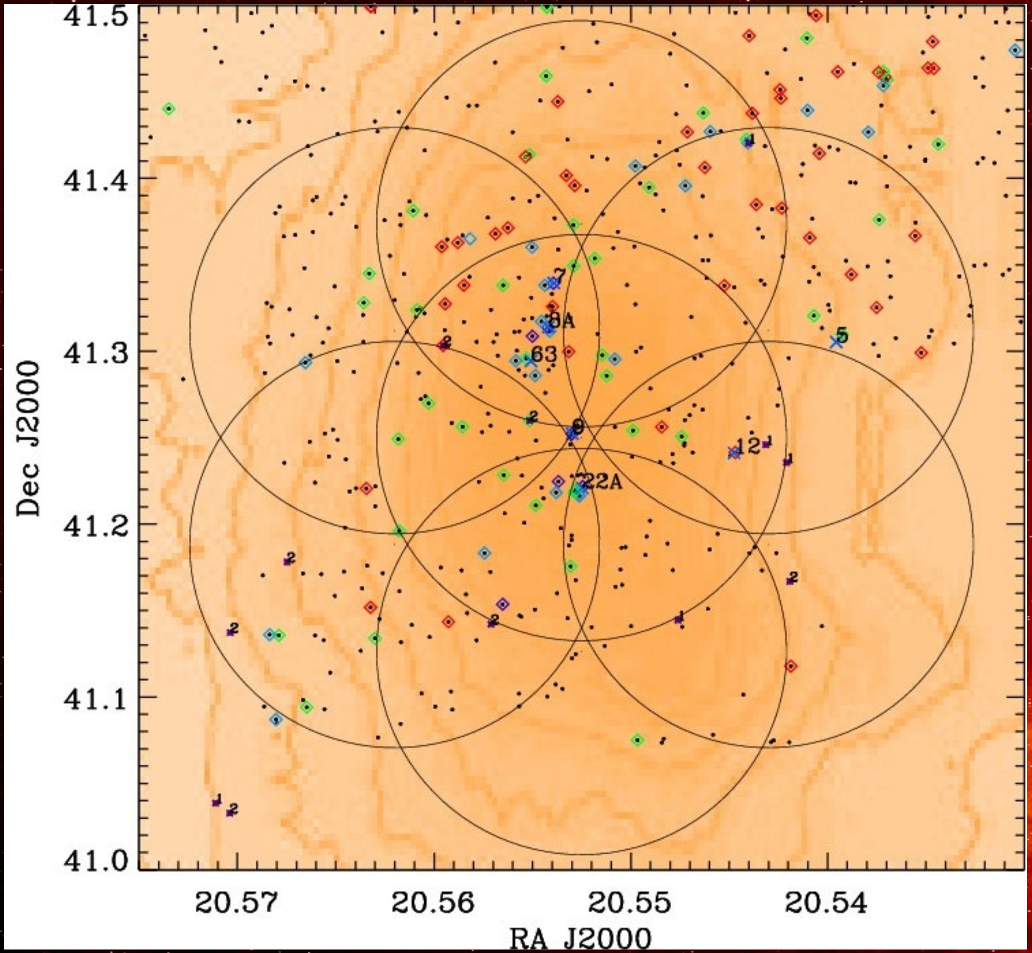
- Mass loss and evolution of massive stars
- The formation, dynamics and content of massive OB associations
- The frequency of massive binaries and the incidence of non-thermal radiation.

COBRaS Survey Regions

C-Band (5 GHz)



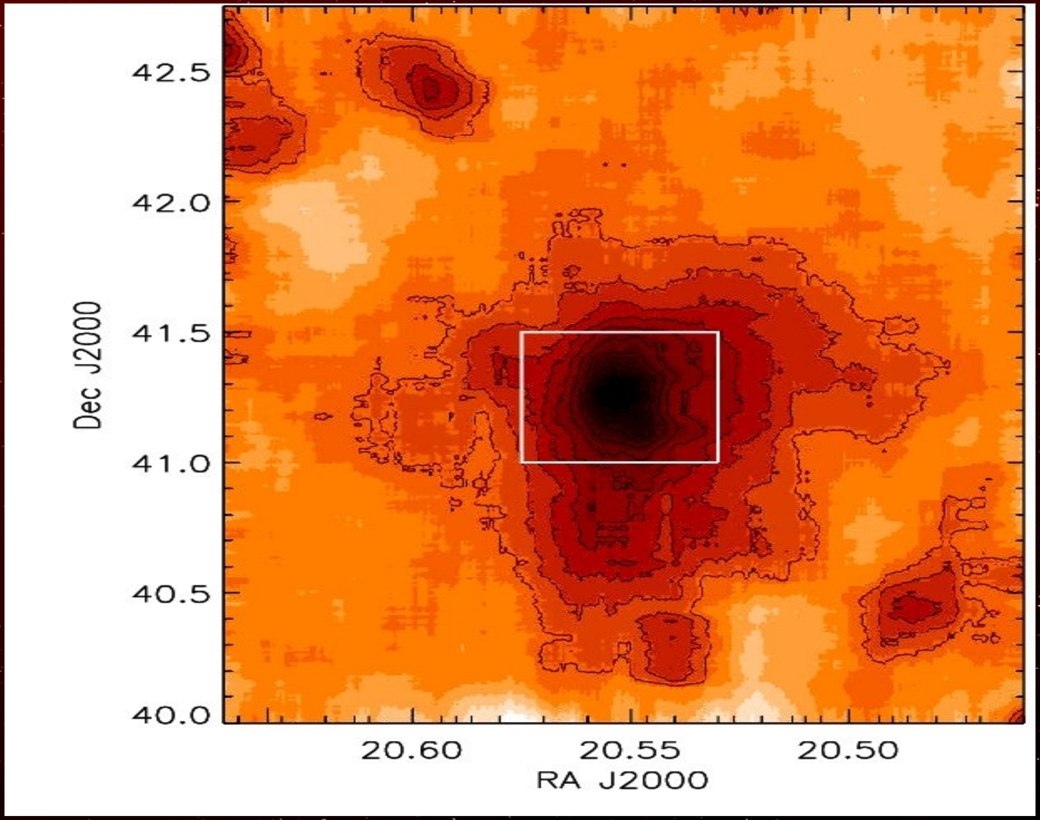
L-Band (1.6 GHz)



97 fields for C-band and 21 for L-Band

Cygnus OB2 Association

Knodlseder (2000) conducted a 2MASS survey on Cyg OB2, and suggested the re-classification from an OB association to a young globular cluster, due to it's size, mass and density.



From Knodlseder (2000)

Cyg OB2 Properties

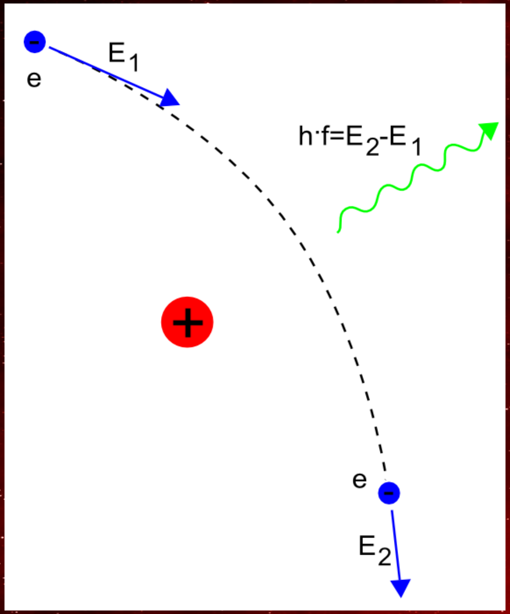
Total stellar mass:	(4 - 10) x 10^4 M_o
OB star members:	2600 ± 400
O star members:	120 ± 20
Members earlier F3V:	8600 ± 1300
Diameter:	~2º (~60 pc)
Distance:	~1.7 kpc
Extinction Av:	~ 5^m to 20^m

Core Properties

Core Radius:	29' ± 5' (14 ± 2 pc)
Central mass density:	40 – 150 M_o pc^{-3}
Centre (J2000):	$\alpha = 20^h 33^m 10^s$ $\delta = 41^o 12'$

Radio Observations of Massive Stars

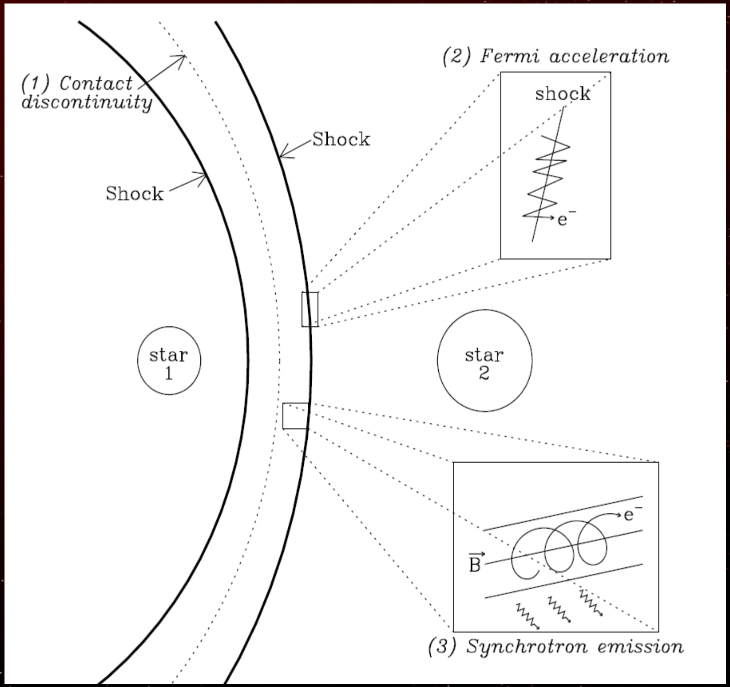
Thermal Bremsstrahlung ('braking radiation')



Stellar winds from massive stars are hot enough to ionize the material within them, producing a plasma.

Ions interact with one another, which produces emission, which can be detected at radio wavelengths.

Spectral index for thermal radiation: $\alpha \approx 0.6$ (smooth winds)



$$S \approx \nu^{\alpha}$$

Non-Thermal Radio Emission

The stellar winds from massive binaries collide to produce a shock on either side of the contact discontinuity.

At each shock, the Fermi mechanism accelerates a fraction of the electrons to relativistic speeds

These relativistic electrons spiral in the magnetic field and emit synchrotron radiation

Spectral index for non-thermal radiation: α = -0.5 to -1.0

Massive Binaries in Star Clusters

Non-thermal emission is a key indicator for binarity.

COBRaS will take advantage of e-MERLIN's wide bandwidth to observe a range of frequencies to determine the spectral index α of non-thermal radiation.

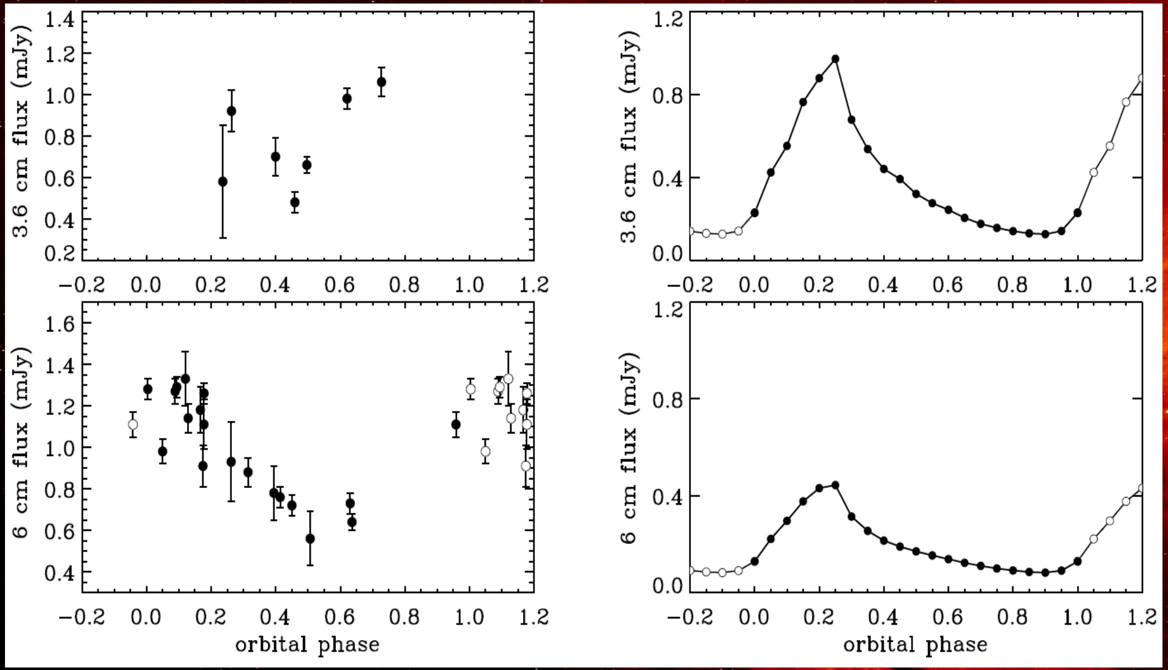
Help determine the frequency of intermediate period binaries (1 to 100 years) in massive star clusters which are thought to be very common.

At present the binary fraction is very uncertain, with estimates: more than 40% for Wolf-Rayet stars (Leitherer et al. 1997); up to 50% of detected O stars (Benaglia et al. 2001).

Not all of the synchrotron emission is detected as some is absorbed by the free-free absorption in the stellar winds.

Thus depending on the inclination to the observer and eccentricity of the binary, the non-thermal emission can be variable.

This variability is strictly dependent on the orbits of both starsl



Blomme et al. 2010

Clumping in the Winds of Massive Stars

Serious discrepancies between theoretical and observational mass losses of massive stars, sometimes by up to a magnitude.

Observational evidence suggest the presence of clumping in stellar winds: PV discrepancy, Chandra X-ray spectroscopy, electron scattering wings of WR emission lines (Crowther 2007; Puls et al. 2008), Si IV λλ1400 resonance line doublet ratios (Prinja & Massa 2010).

Theoretical models predict clumping in stellar winds due to the instabilities arising from the radiation line-driving mechanism of stellar winds from massive stars.

Many indicators are sensitive to clumping because they depend on density squared processes, such as the Hα line, infra-red, millimetre and radio continuum.

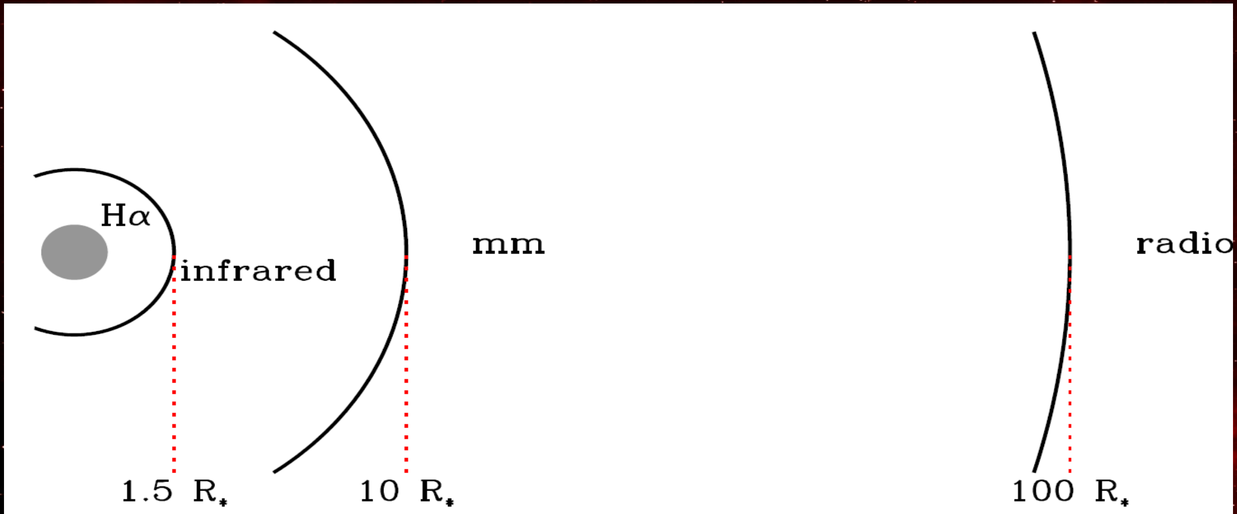


Figure from Blomme 2011

Clumping in the Winds of Massive Stars

Observing different regions of the wind, can determine whether a clumping gradient exists.

Will need to combine our radio survey with multi-wavelength studies to complete the picture.

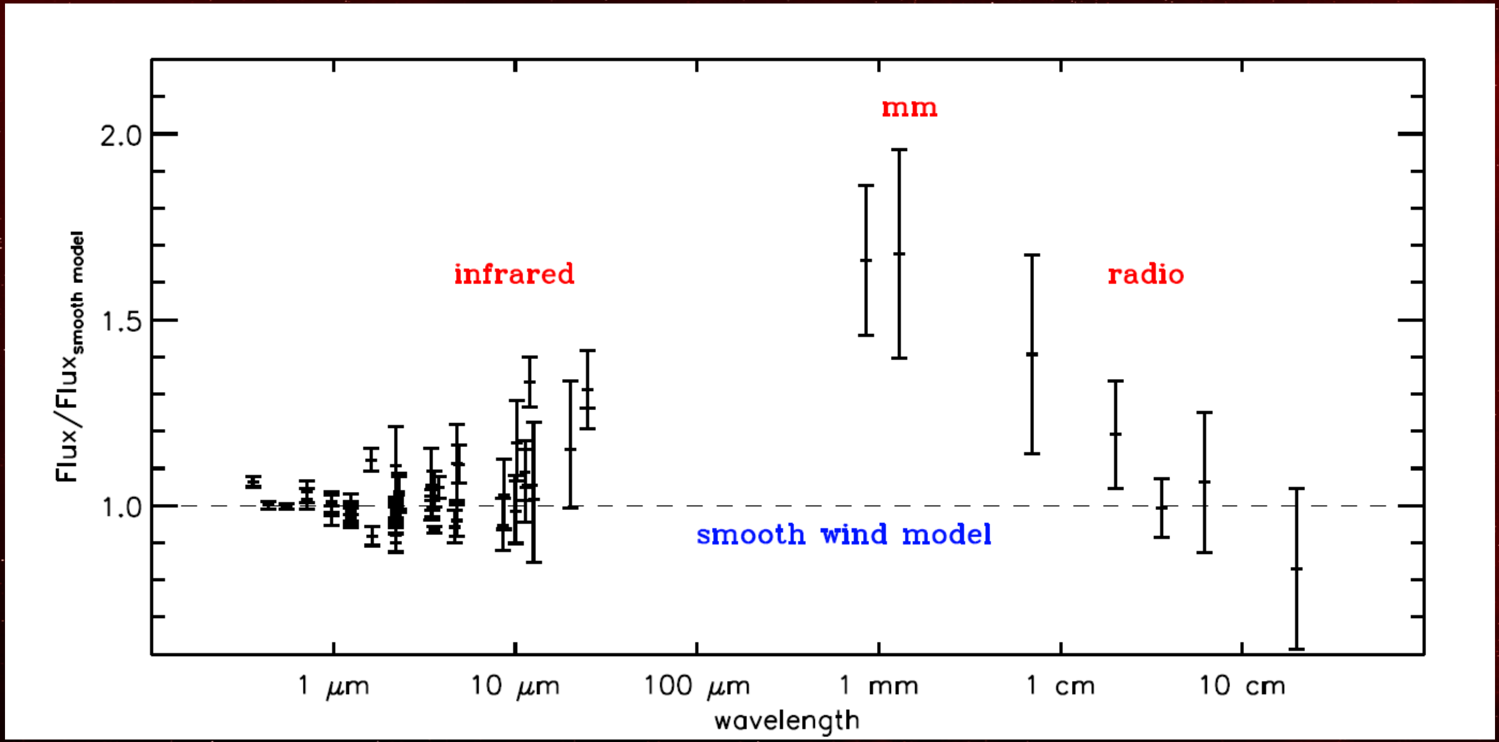


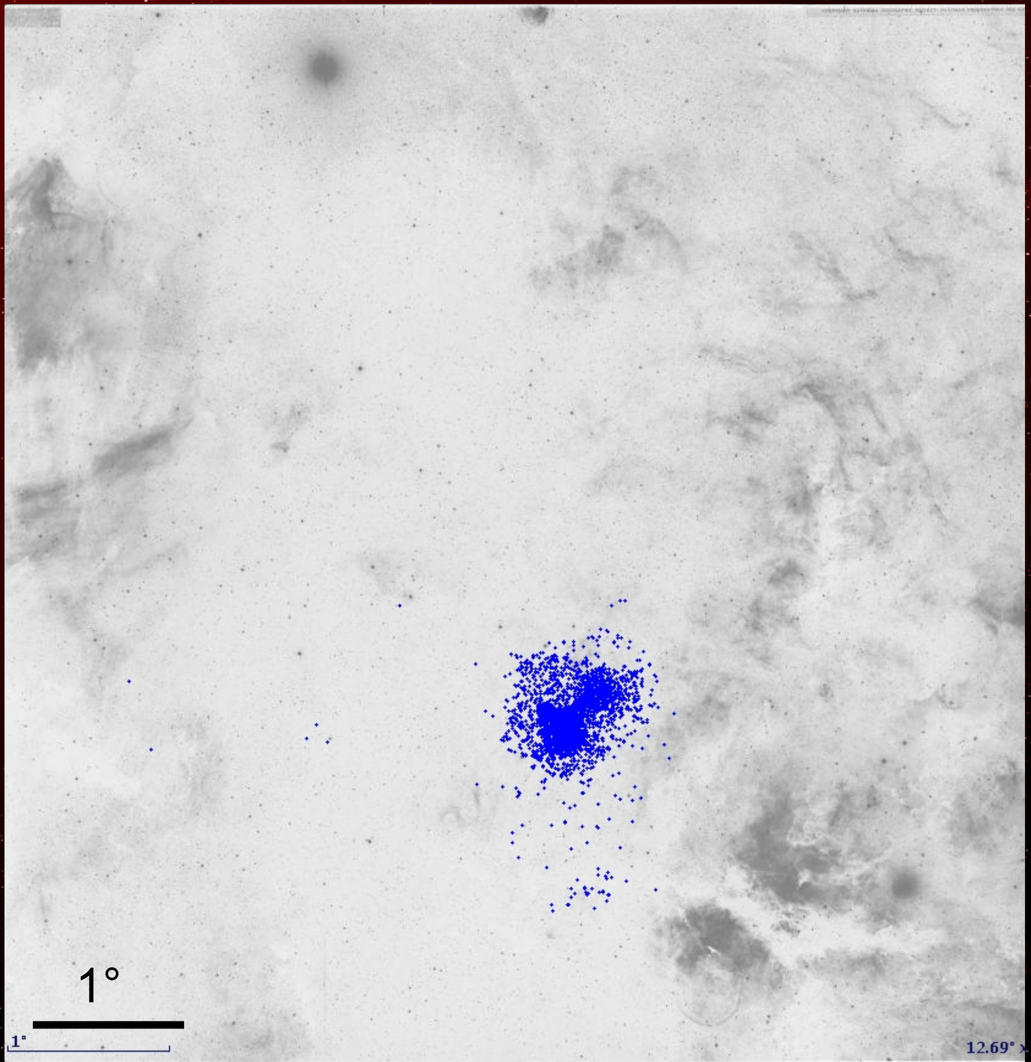
Figure from Blomme 2011

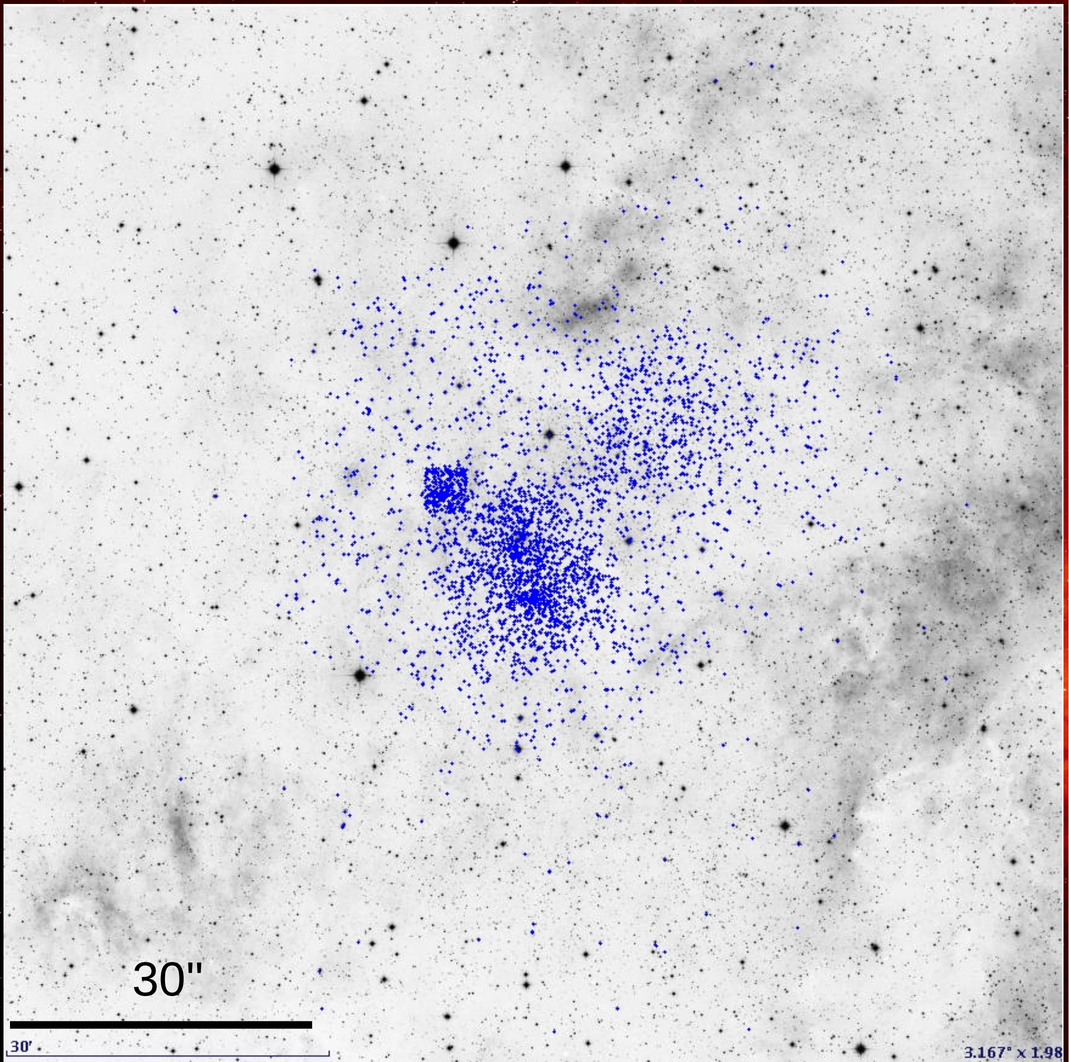
$$S_\nu = 2.24 \times 10^{11} \frac{1}{D^2} \left(\frac{\dot{M}\sqrt{f_{\rm cl}}}{\mu v_\infty} \right)^{4/3} \left(\frac{\gamma g Z^2}{\lambda} \right)^{2/3}$$

The Cyg OB2 Super Catalogue

Every survey needs a preliminary catalogue to see what we know is already there. Then we can add to this if we discover anything new.

Using the Virtual Observatory (VO) database, created a 'super catalogue' of stars within the Cyg OB2 region.

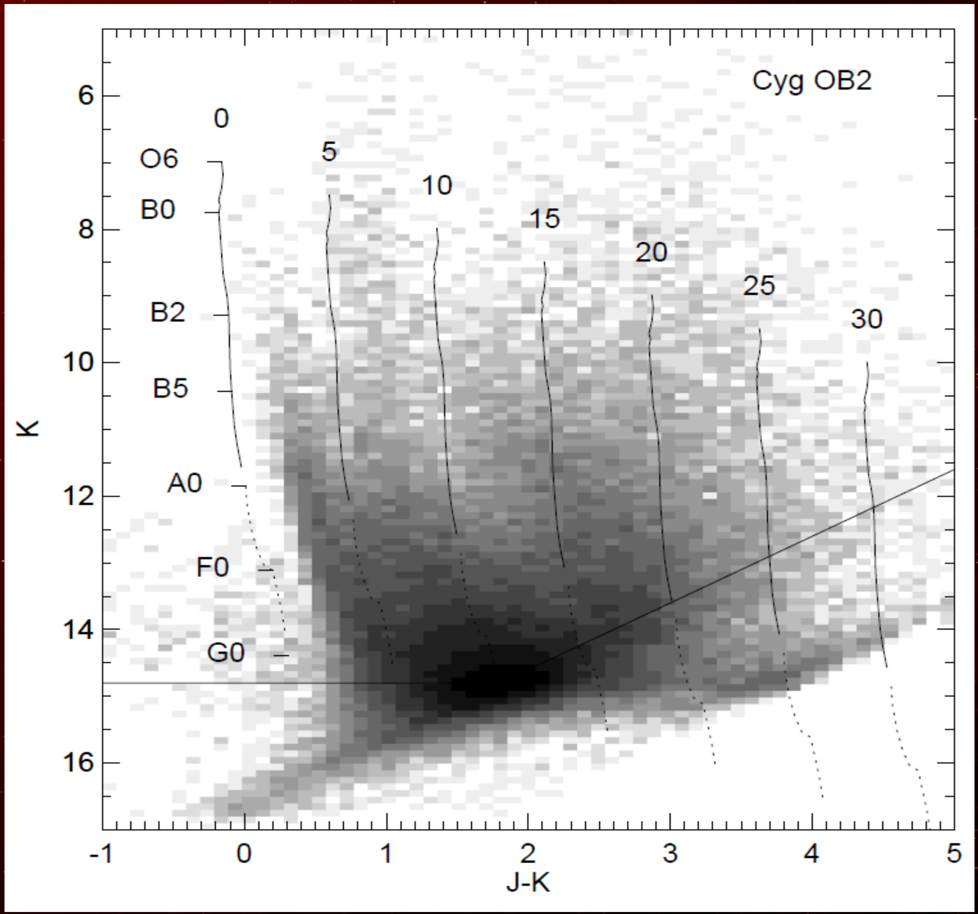




e-MERLIN and the COBRaS Legacy Project Luke Peck (UCL)

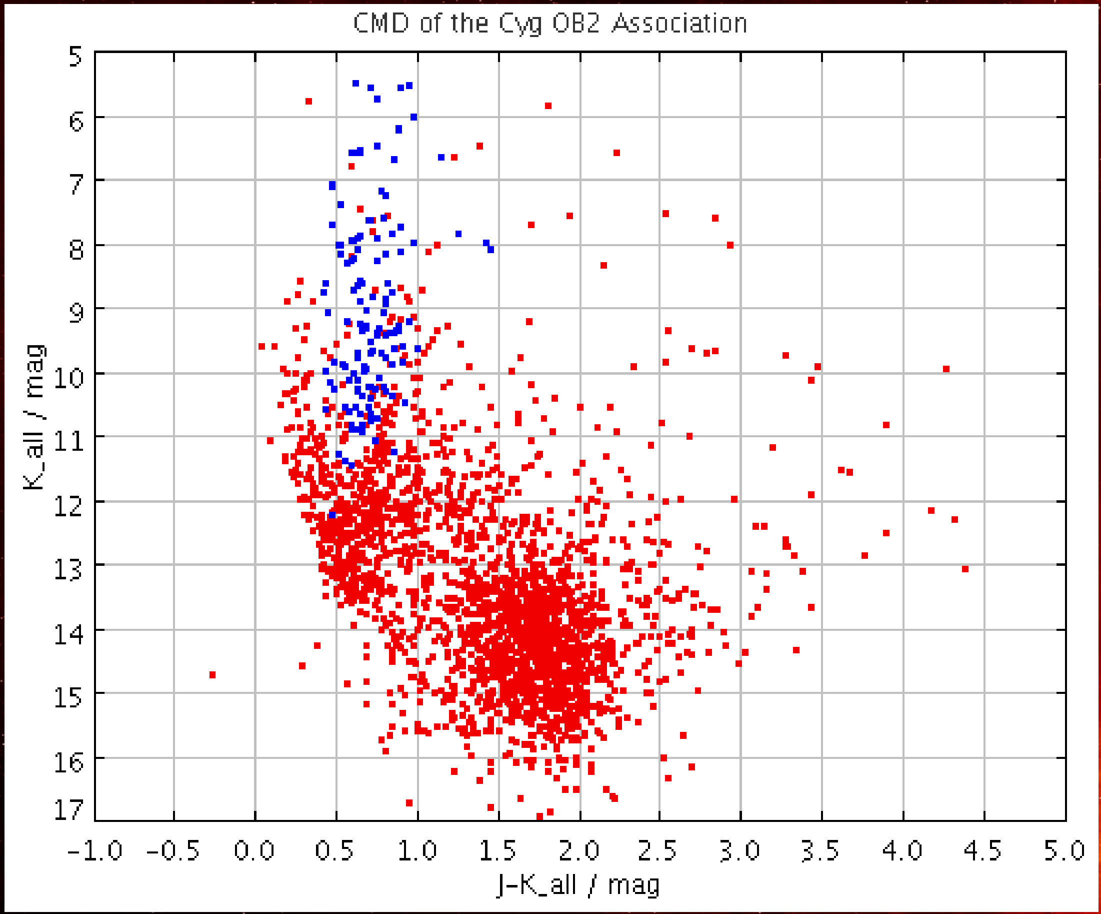
Colour Magnitude Diagrams of Cyg OB2

2MASS CMD from Knodlseder (2000)



100754 stars in a field of 3.46 degrees squared.

Super Catalogue CMD

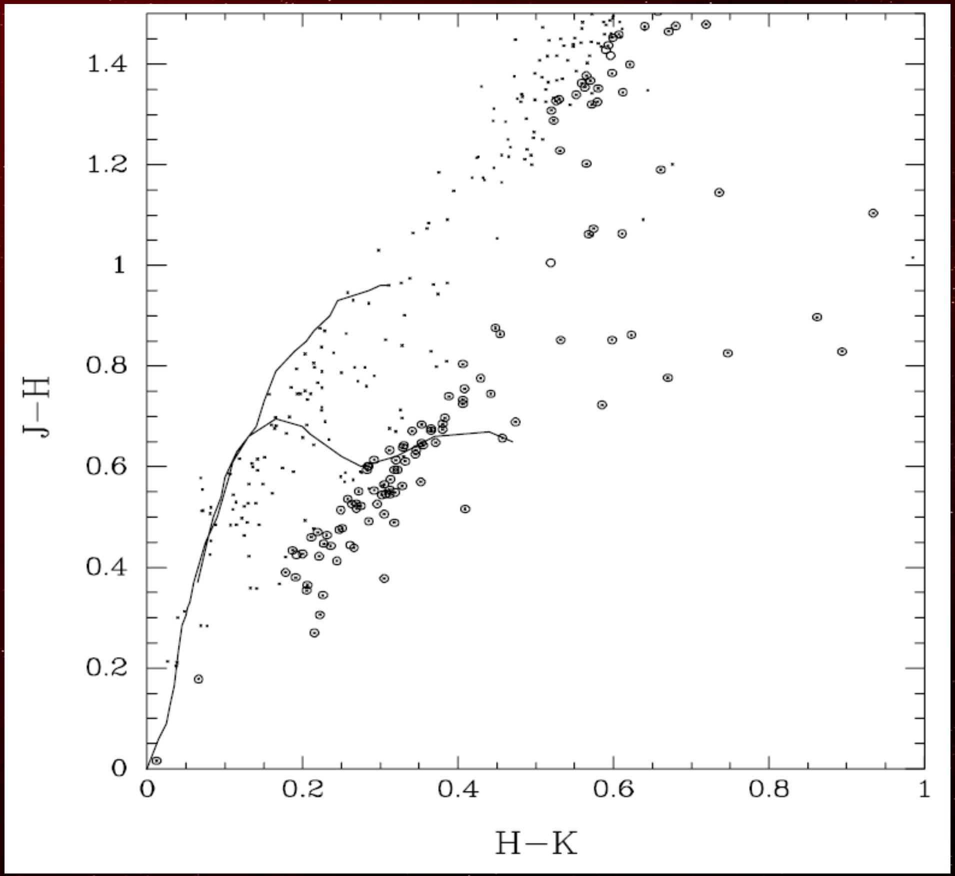


2463 stars in a field of ~ 0.5 degree squared (with some outliers) .

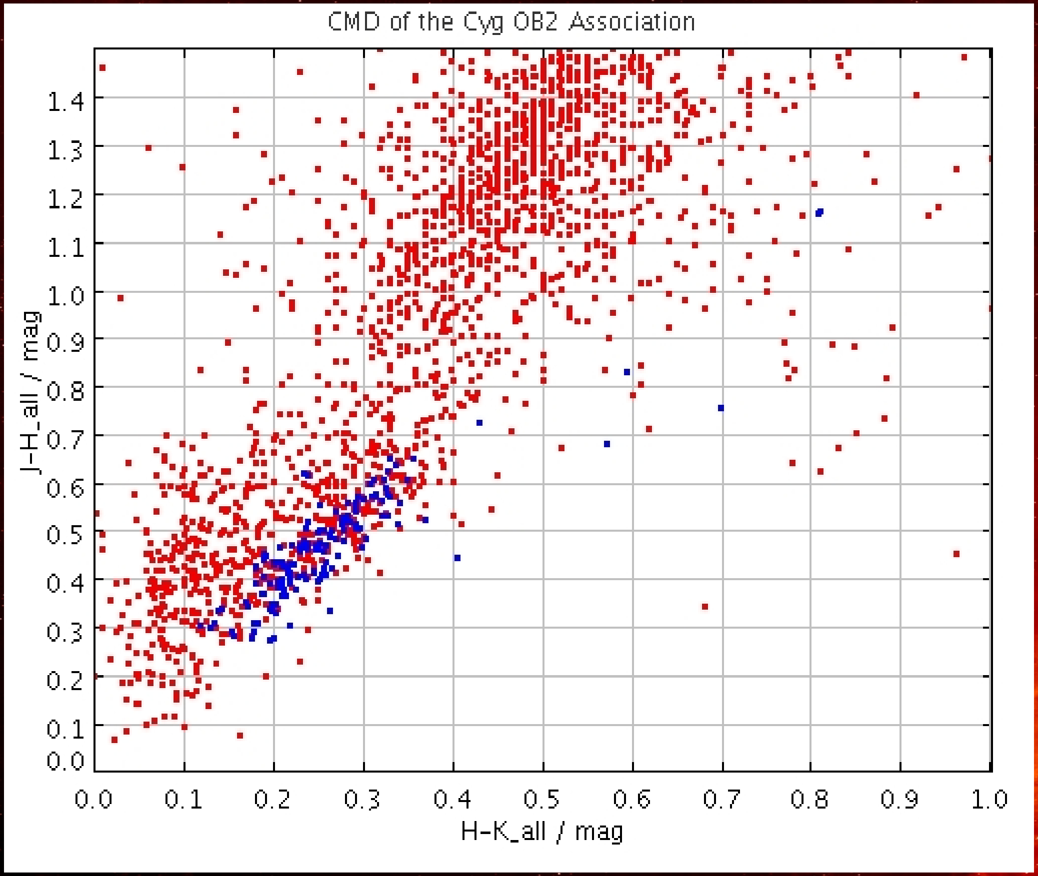
Red = All stars (with J,H, and K magnitudes)
Blue = Known OB stars

Colour Magnitude Diagrams of Cyg OB2

CMD on the Massive star contents of Cygnus OB2 (Comeron et al. 2002)



Super Catalogue CMD



Red = All stars (with J, H, and K magnitudes)
Blue = Known OB stars

e-MERLIN and COBRaS First Look

Commissioning Data:

We have 3 pointings, designed to test mosiacing.

In total we have ~ 2 days worth of observations, full stokes, 128MHz bandwidth in four IF's.