Formation, evolution, and survival of massive star clusters
Proceedings IAU Symposium No. 316, 2015
C. Charbonnel & A. Nota, eds.

doi:10.1017/S1743921315006882

e-MERLIN Radio Continuum Measurements of OB Star Winds in CYG OB2

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Abstract. Here, we report on the first results from the e-MERLIN Cyg OB2 Radio Survey (COBRaS), which is designed to exploit e-MERLIN's enhanced capabilities to conduct deep-field mapping of the tremendously rich Cyg OB2 association. The project aims to deliver the most detailed radio census of the most massive OB association in the northern hemisphere. There exists considerable evidence for clumping in the winds of hot stars, which has hugely important consequences for mass-loss determinations. The amount of mass lost from a massive star is a crucial parameter required for stellar and cluster evolution models that are paramount to our understanding of the formation and evolution of massive star clusters. Presenting some of the first 20cm (L band) detections of massive stars in Cyg OB2, both accurate mass-loss determinations and constraints upon clumping within their winds are made. These data substantially increase the observational detections of the outer wind of massive stars and in combination with other observations at different wavelengths, COBRaS will greatly advance our knowledge of clumping as a function of radial distance around massive stars.

Keywords. stars: early-type - stars: individual: CYG#12, CYG#7 & A15 - stars: winds - Galaxy: open clusters and associations: individual: Cyg OB2 - Radio: stars.

1. COBRaS: The Cyg OB2 Radio Survey

COBRaS is an e-MERLIN legacy project awarded 42 hours at L-band (1.5GHz) and 252 hours at C-band (5GHz). As an intensive radio survey, the project aims to deliver targeted, high-resolution, deep field maps covering the core of the OB rich stellar association. These observations will push the limits of the instruments capabilities in detecting sub milli-Jansky free-free radio emission from the winds of hot stars. Two leading scientific goals dominate the project. Firstly to detect the thermal free-free emission from the outer wind regions of single massive stars allowing for accurate determinations of their mass-loss rate, $\dot{M}$ from which constraints can be made upon on their small-scale wind structure. Secondly, detections of the non-thermal emission within the region will allow an investigation into T Tauri objects, Young Stellar Objects (YSOs) and the massive star binary population, providing a better estimate of the region's binary fraction.

The Cyg OB2 association is a young 'super-star' cluster ($\sim$ 2-3Myr old) located in the heart of the Cygnus X region and hosting approximately 2600$\pm$400 OB stars (Knödlseder *et al.* 2000). Due to it's 'nearby' galactic location ($\sim$ 1.4-1.7kpc away) and the fact that it suffers from a large visual extinction, $3^m \leqslant A_\nu \leqslant 8^m$ (Guarcello *et al.* 2013), make it ideally suited to studies within the radio.

2. Mass-loss from massive stars

Massive stars provide a pivotal feedback mechanism in re-cycling energy and material back into the ISM via their stellar winds. This feedback arguably provides the raw

Table 1. Positions, spectral types and predicted and observed 20cm fluxes and $\dot{M}$ for 3 stars within the COBRaS L-band pointing's from $\sim$ 35-40 minutes on source.

Object Name	RA (J2000)	DEC (J2000)	Spectral Type	Flux 20cm (μJy)		$\dot{M}$(x10^{-6}M$_{\odot}$yr^{-1})	
				Predicted	Observed	Predicted	Observed
Cyg #7	20 33 14.2	41 20 21.5	O3If	20.5	<150	1.745	<7.8
A15	20 31 36.9	40 59 09.1	O7I	16.7	<138	0.915	<4.8
Cyg #12	20 32 40.9	41 14 29.2	B3.5Ia+	1770	341	10	2.9

materials to trigger star formation and undoubtedly plays a vital role in the evolution of stellar clusters. The mass-loss parameter itself is a key determinant of a stars evolution and lifetime, and a very important parameter within stellar, cluster and galactic evolution models. Different mass-loss diagnostics have been found to be discordant with one another and Puls *et al.* 2006 suggests that previously found mass-loss rates have been over-estimated and can be attributed to the effect of wind clumping. This uncertainty in current stellar mass-loss estimates is in urgent need of clarification.

Clumping within a stellar wind is considered as 'small-scale structure' and can be described as small-scale clumps of over-dense material throughout the wind. Originating from density in-homogeneities within the inner wind that re-distribute material into enhanced density clumps, it is thought that the thermal free-free emission detected from these clumps will cause an over-estimate of the stars mass-loss rate. As a ρ^2 diagnostic, the radio thermal continuum emission is highly sensitive to any clumping and for a star of known $\dot{M}$, constraints can be put on the clumping factor, $f_{cl} = <\rho_{cl}^2>/<\rho_{sw}>^2$.

3. Pre-liminary COBRaS L-band results

The L-band (42 hours) observations were completed by April 2014 and currently $\sim$ 1/5 of the dataset has been completely reduced. The preliminary results shown below include the three stars: Cyg #7, A15 and Cyg #12 and table 1 displays information regarding their spectral types, predicted and detected 20cm fluxes and $\dot{M}$.

Unfortunately we received a null detection for both Cyg #7 and A15 and thus only have an upper limit on their 20cm flux and $\dot{M}$ value. Cyg #12 is detected with a 20cm flux of 341μJy, a significantly lower value than previously measured by Clark *et al.* 2012 who published a value of $F_{20cm} = 3270\mu$Jy. The calculated $\dot{M}$'s shown in table 1 have all been calculated through using a clumping factor $f_{cl} = 1$, however using previous $\dot{M}$ or F_{20cm} values taken from the literature we obtain a range of possible mass-loss rates for Cyg #12 giving the constraint 25 $>f_{cl}<$1. This is a loose constraint since the large variability in observed F_{20cm} suggests eruptive behaviour, it is possible that the object is in transition between the Blue Hyper-giant (BHG) and Luminous Blue Variable (LBV) evolutionary phases. It is important to stress that once the L-band dataset has been reduced in it's entirety, our sensitivity level will increase by a factor of $\sim$ 3-4 which will significantly increase the number of single star wind detections at 20cm.

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https://doi.org/10.1017/S1743921315006882 Published online by Cambridge University Press