COBRaS

The e-MERLIN Cyg OB2 Radio Survey

P.I. Raman Prinja

Outline

- COBRaS is an e-MERLIN legacy project awarded ~300 hrs of observing time
- Intensive radio survey of the core of the Cygnus OB2 association in our Galaxy.
- Conduct a uniquely probing, targeted deep-field mapping of the young massive cluster.
- Offer direct comparison to not only massive clusters in general, but also young globular clusters and super star clusters.

Cygnus OB2

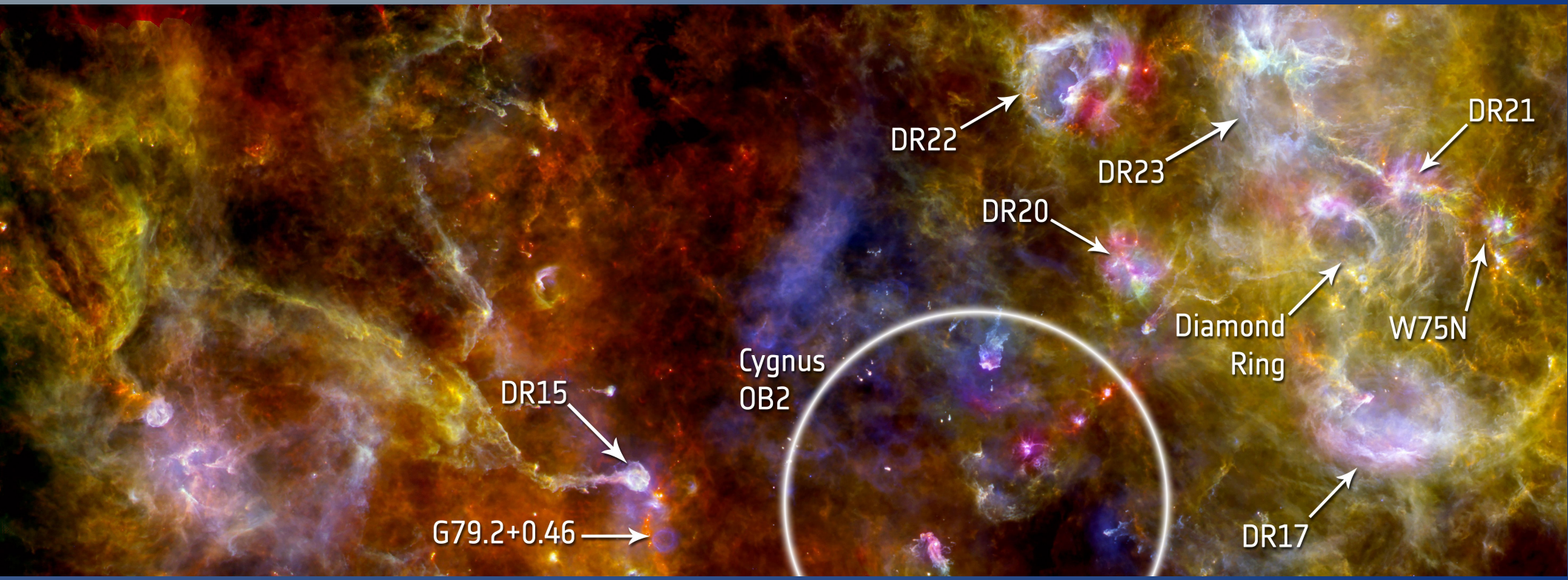
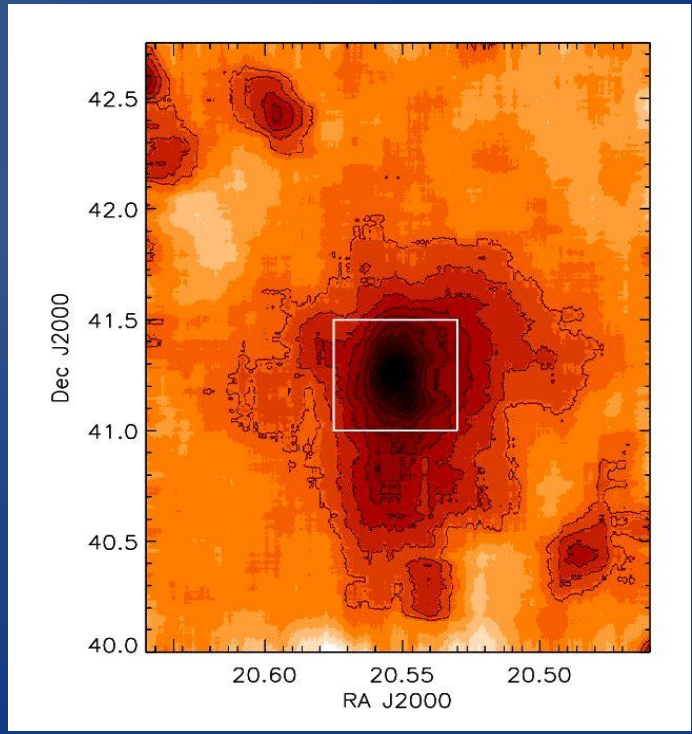


Image: ESA/Herschel/PACS/SPIRE/HOBYS Consortium.

What is Cygnus OB2?

- Located in the core of the Cygnus X region.
- Approximately 1.4 kpc away
- Heavily obscured – ideal for radio studies.
- Estimated cluster mass 4-10 x 10^4 M_o
- Estimated age 2-3 Myr



Knodlseder (2000) 2MASS distribution density

Why Cygnus OB2?

- 120 ± 20 O-type, 2600 ± 400 OB-type stars (Knödlseder 2000)
- WR stars (WR145, 146)
- Candidate LBV (G79.29+0.46)
- HII regions (DR 15, DR 18)
- High energy gamma ray source (TeV J2032+4130)
- Young Stellar Objects
- B[e] star – MWC 349

Why study massive stars?

- Massive stars are important:
  - Return mass, momentum and energy to ISM
  - Important for ionisation, heating and turbulence
  - Have strong effect on star and planet formation
  - As well as galaxy evolution
- Achieve this through various stages in stellar evolution
- Mass-loss and eventual supernova explosion

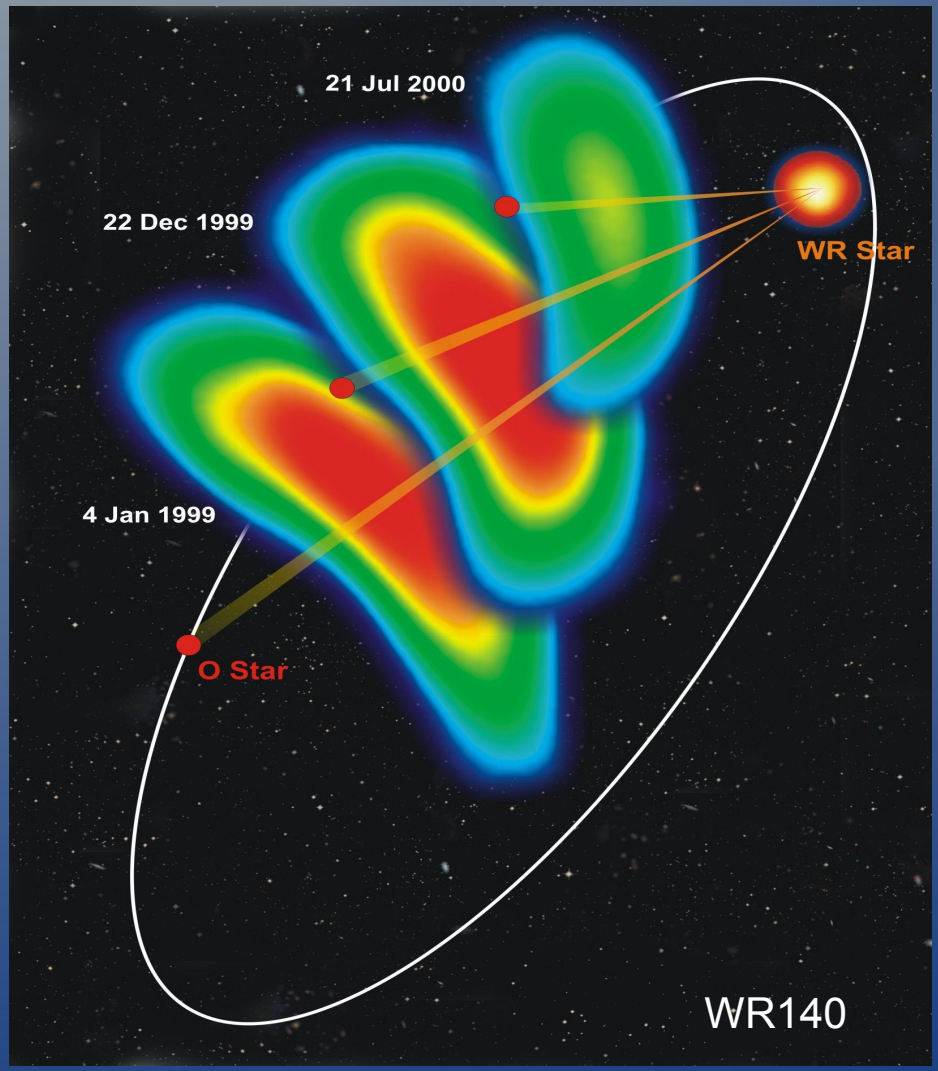
Key science goals

- Study the binary population
- Mass-loss, clumping and stellar evolution

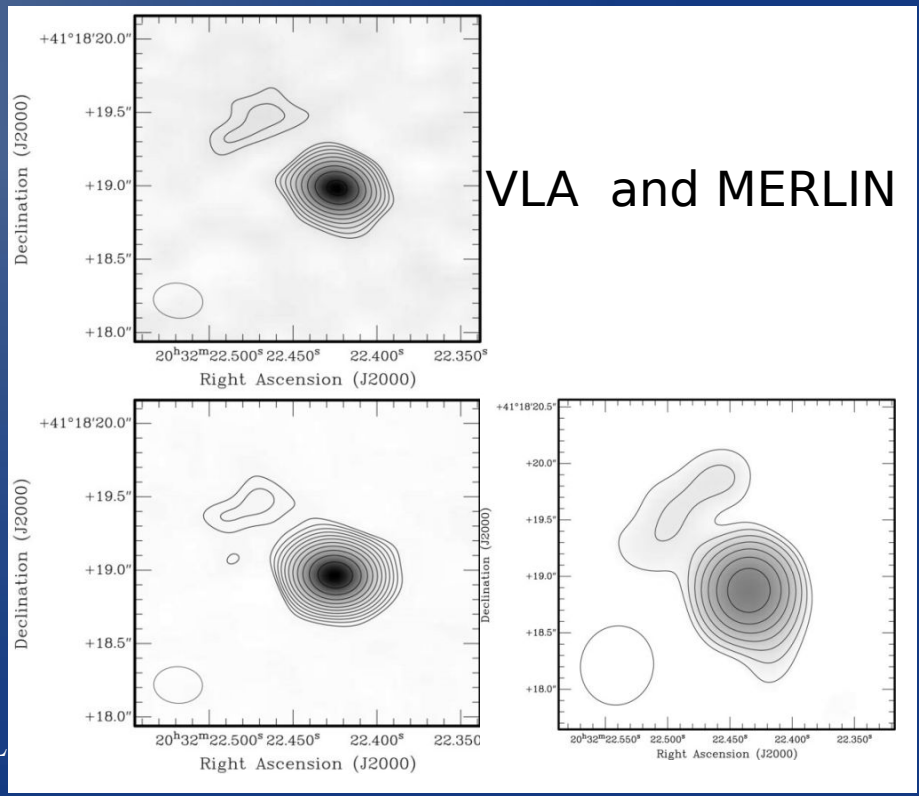
Binary populations in Cyg OB2

- Colliding wind regions from massive star binaries gives rise to non-thermal emission.
- Shock fronts in collision region produce synchrotron emission.
- Differentiate from thermal radio emission using wide bandwidths.
- Study wind collision regions, individual binary systems and binary population.
- Single epoch confirmation of binary source
- No chance alignments

Binary interactions



- Example wind collision region Cyg OB2 #5 – O+O binary
- Distinguish components via wide-band spectral information
- As-well as multiple bands

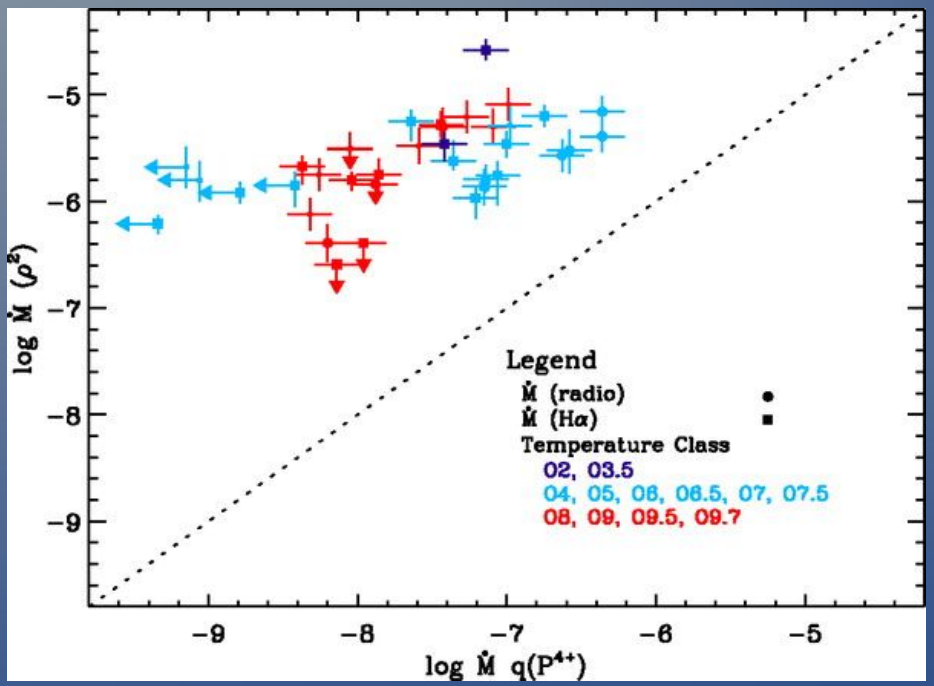


VLA and MERLIN

Binary population

- Binary frequencies are currently quite uncertain
- Direct observation of binary frequency
- Cover a wide range of binary periods
- Pivotal for understanding evolution of stellar populations
- Population synthesis codes require knowledge of binary systems e.g. binary fraction, distribution of masses etc.
- Binary properties also important for constraining models of massive star formation.

Mass-loss and massive stars



Fullerton, Massa & Prinja 2006, ApJ 637, 1025

- Different mass-loss diagnostics disagree.
- Factors of order-of-magnitude.
- Three main diagnostics:
  - Thermal radio – ρ^2
  - Hα - ρ^2
  - UV resonance line – ρ
- ρ^2 affected by inhomogeneities in wind - i.e. clumping

Mass-loss and massive stars

- Radio emission – thermal free-free
- Emission arises at large radii – terminal velocity reached
- Radio flux interpretation not dependent on details of
    - Velocity field
    - Ionisation conditions
    - Photospheric profile
- But, very sensitive to clumping

Mass-loss and massive stars

- COBRaS – flux density information constrain clumping.
- Will cover range of stellar parameters e.g. temperature, luminosity etc.
- Combine with other datasets to study clumping as function of radial distance.
- Hence provide revisions to mass-loss rates and inputs for wind theory

Triggered star formation

- JVLA observations to study DR15 for evidence of triggered SF
- Observe PMS stellar population
- Study distribution as function of evolutionary sequence
- Determine if triggered SF from Cyg OB2

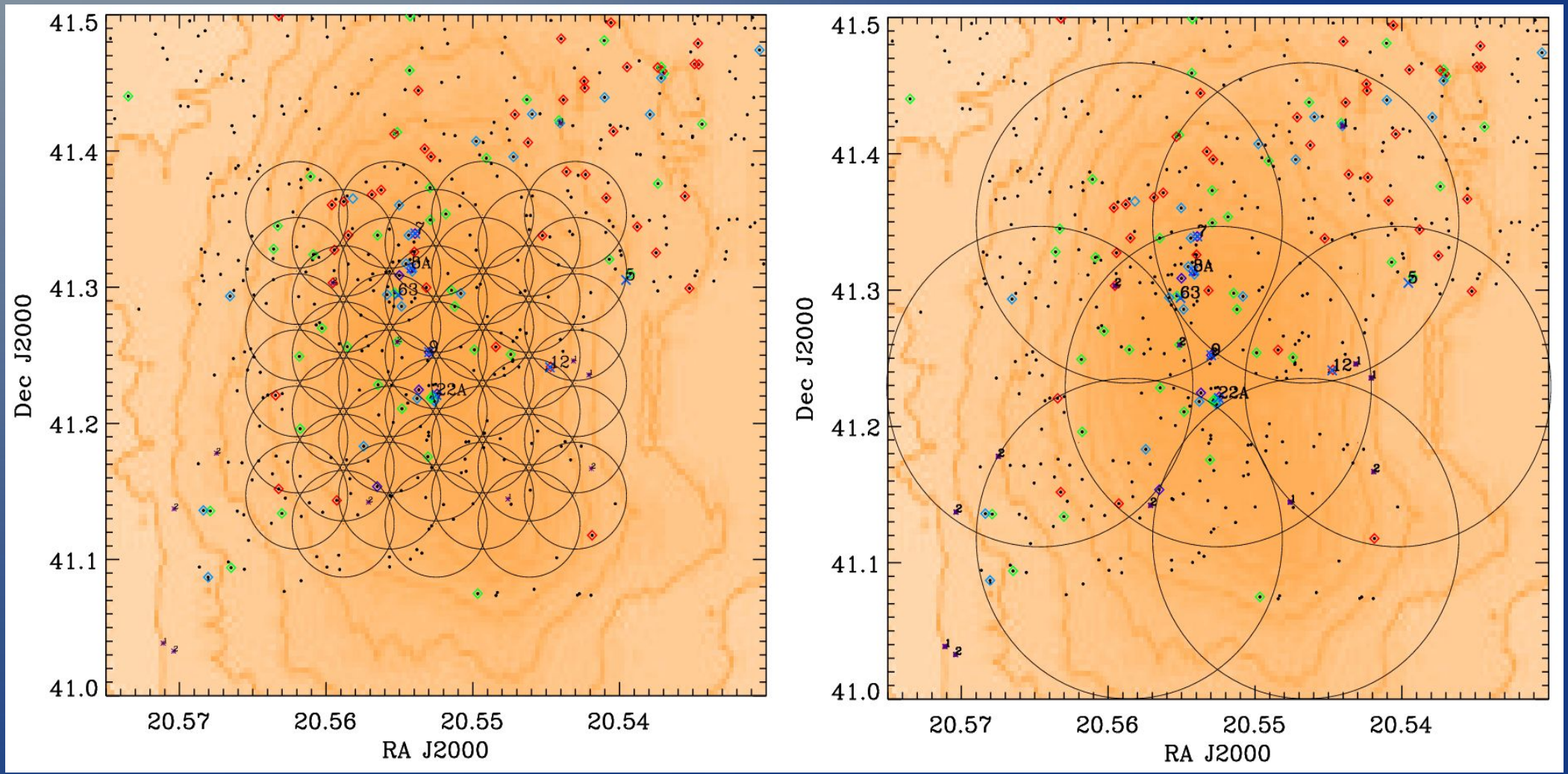
More Complimentary datasets

- Hα and near-IR – Cygnus radial velocity survey
- IPHAS (Hα), NIR 2MASS, MIR Spitzer photometry
- Chandra survey – 16’x16’ - Luke O-stars and WR
  - Rauw 2014 ApJS Special Issue
- Anticipated
  - Follow-up SCUBA-2 data
  - Herschel
  - Hα survey (proposed)

COBRaS legacy observations

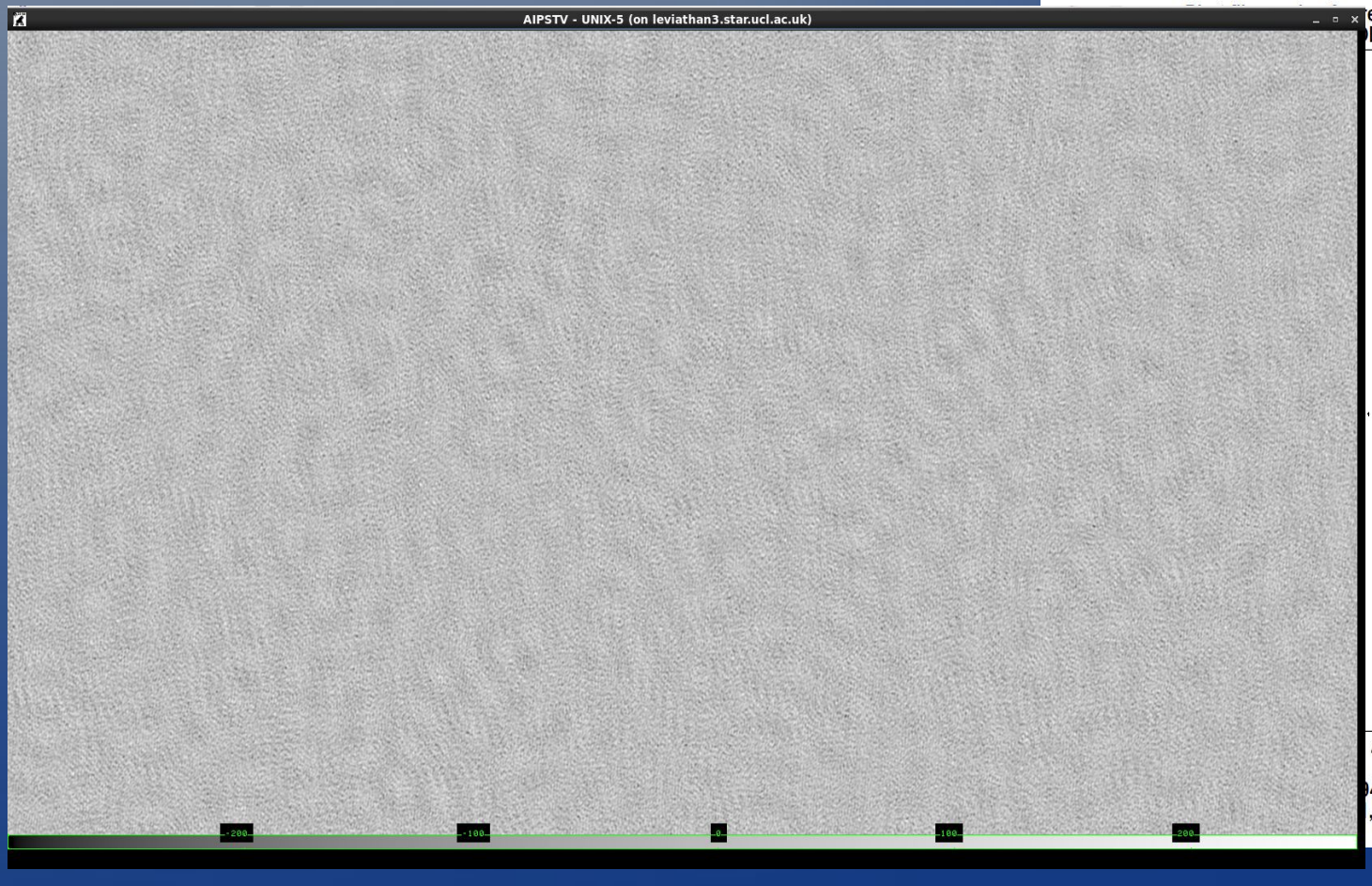
- Mosaiced observations of central region of cluster
- 252 hrs C- band
  - 6hrs/pointing
  - Expected rms ~3-4 μJy
- 42 hrs L-band
  - 6hrs/pointing
  - Expected rms ~7-8 μJy

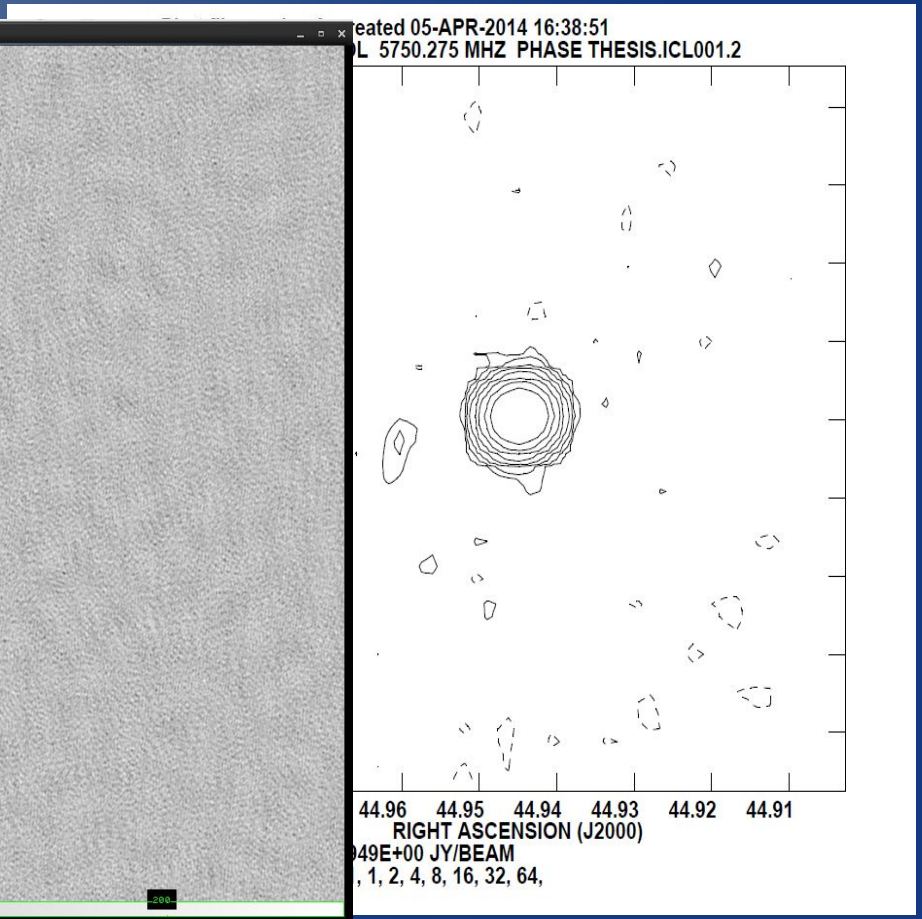
COBRaS legacy observations



C-band commissioning

- Two pointings near central region
- Noise level ~ 50 μJy





C-band commissioning

- From catalogue field should contain ~ 49 sources
- 1 O-star supergiant, predicted flux ~ 50-100 μJy
- 1 B-star supergiant, predicted flux ~ 250 μJy
- But fluxes heavily dependent on parameters used
- We don't see either of them...

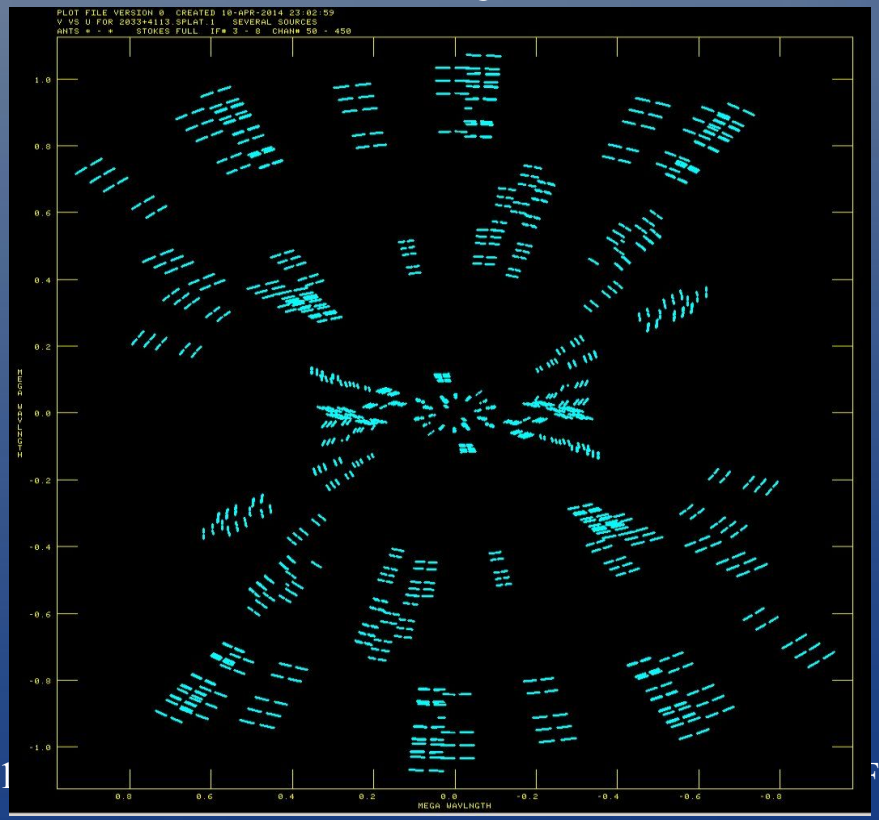
L band observations

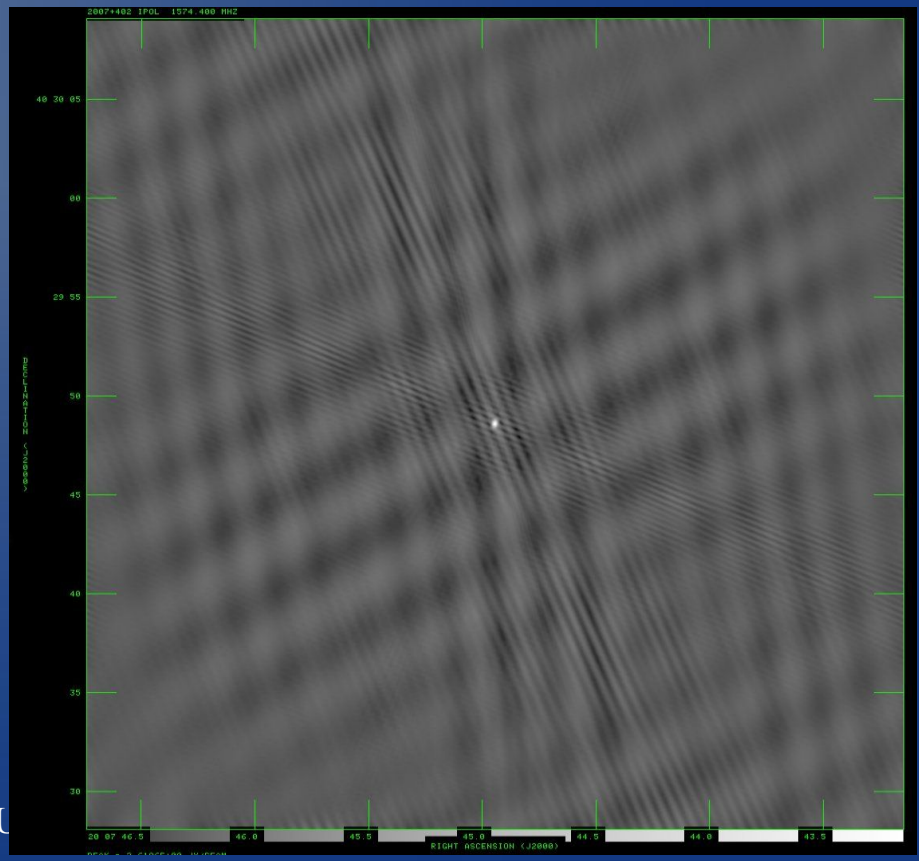
- Two sets of L-band observations
  - 2013
  - 2014
- Multiple pointings - cyclic observations with phase cal.
- Still calibrating...

L-band observations 2013

- ~ 50 mins on source
- RFI major problem
- IFs 3-8 only

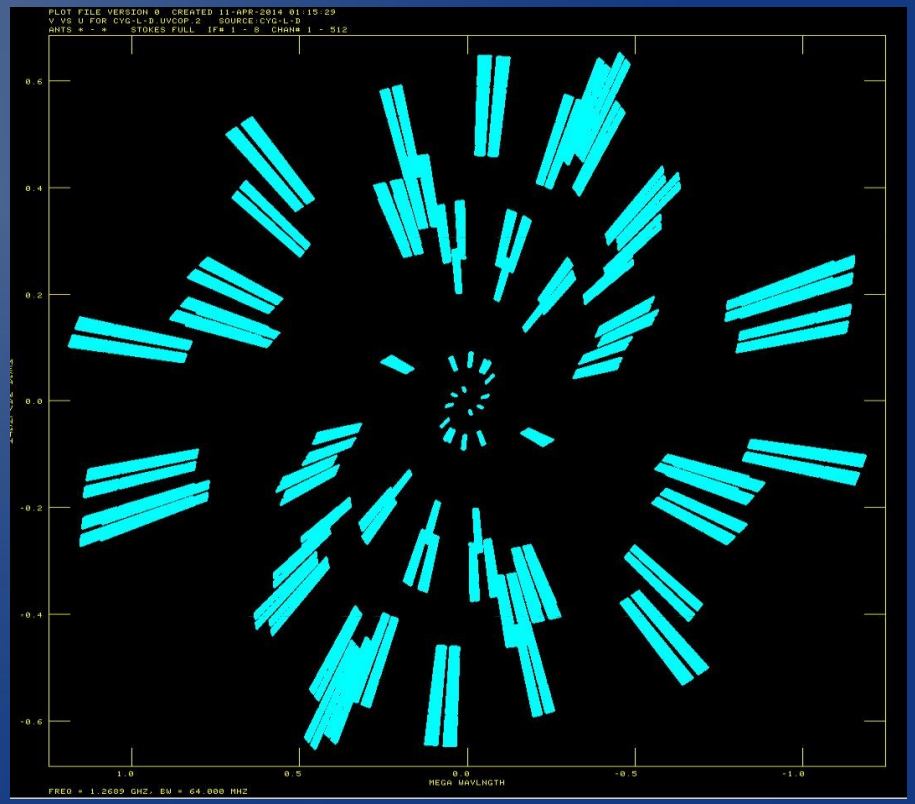
- First point of call – phase cal...





L-band observations

- Almost but not quite there...
- Still data editing really
- RFI, multiple pointing pattern – little sensitivity in short time
- ~ 40 mins on source per pointing (raw)
- Theoretical noise level sub-mJy
- Brightest known sources in field ~ few mJy



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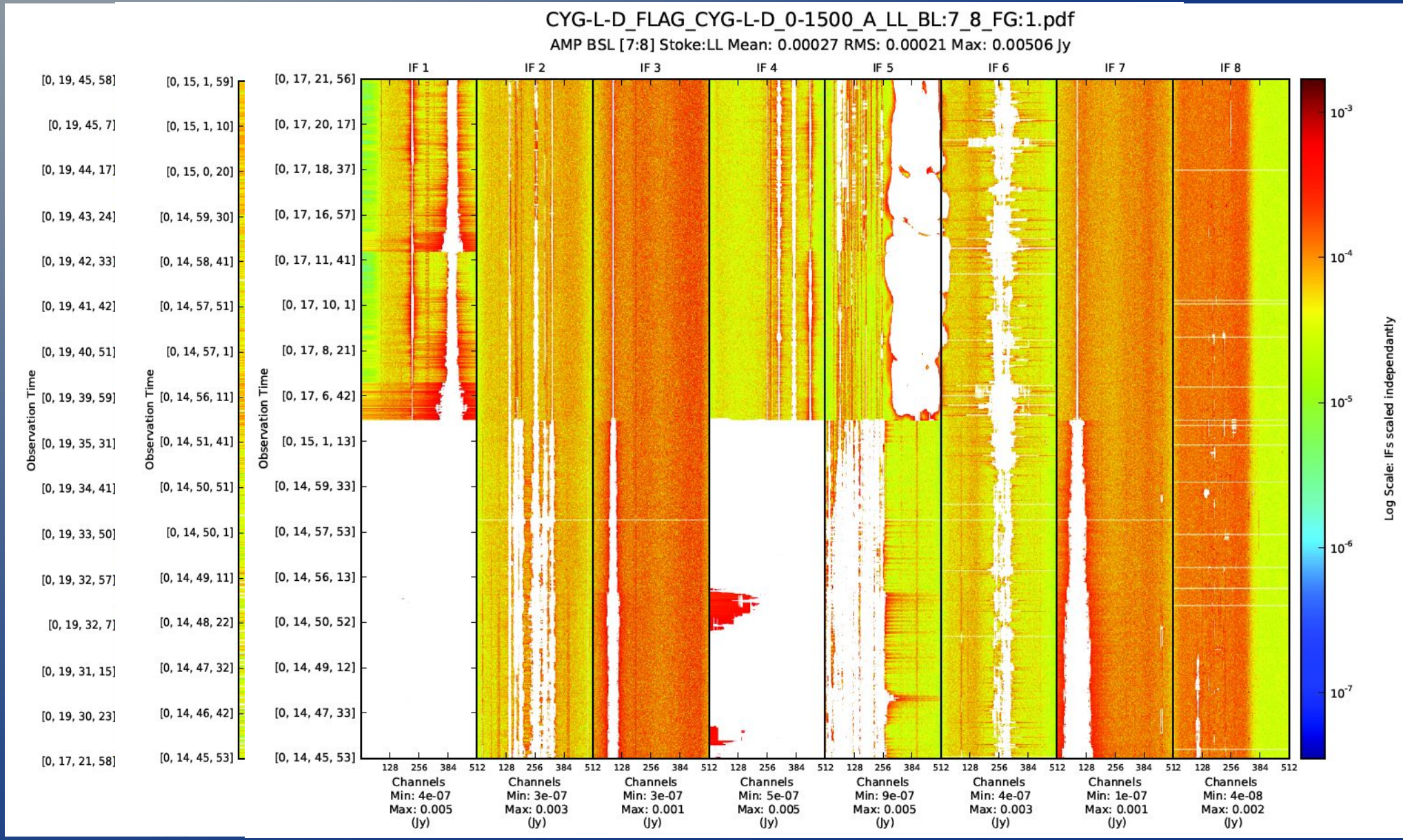
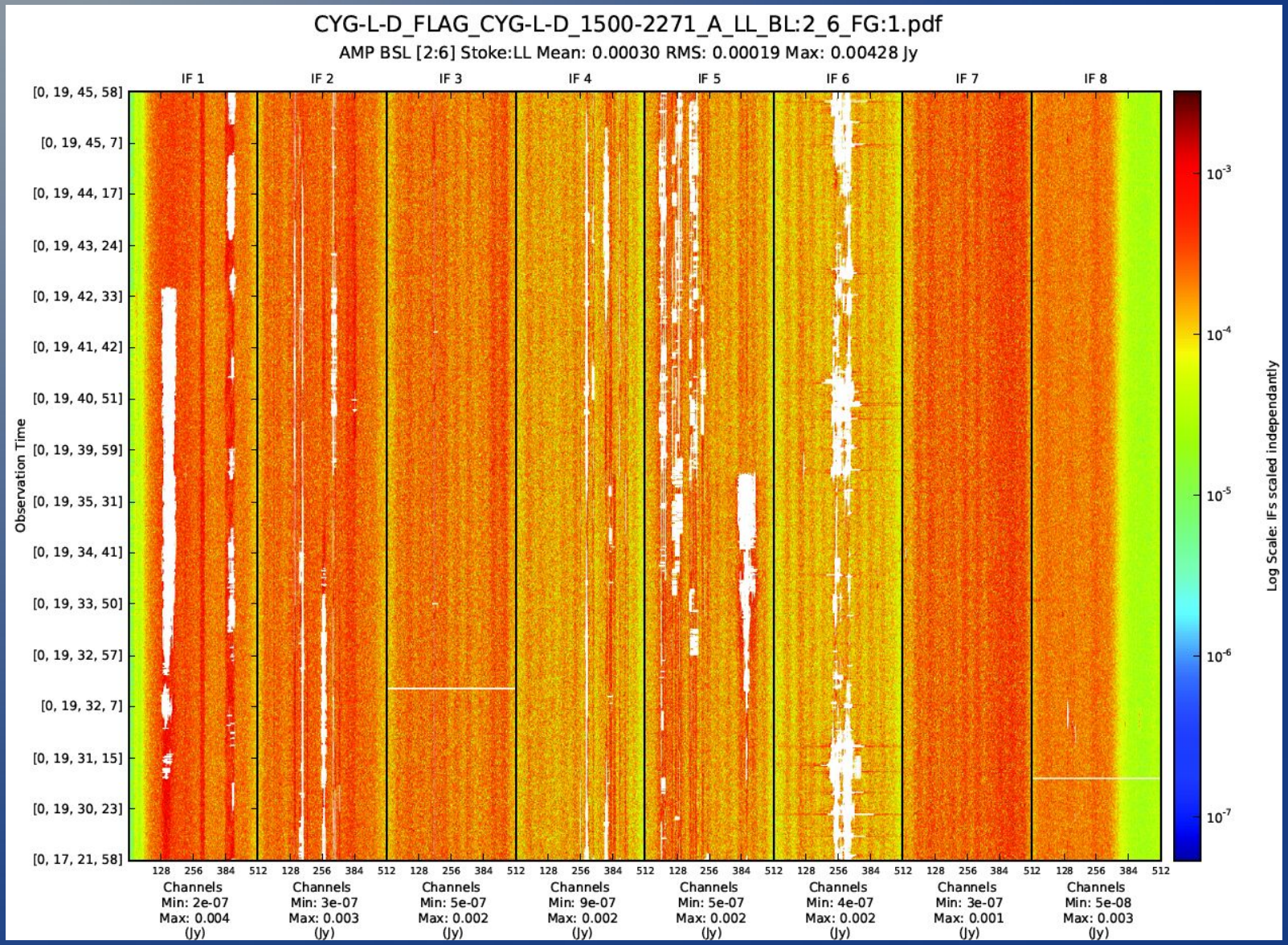


L-band observations



Summary

- Observations of the most massive cluster in the northern hemisphere.
- C and L-band mosaiced observations.
- Requires e-MERLIN sensitivity, resolution and wide-band capabilities.
- Early science doable

Consortia and further information

Website: **http://www.ucl.ac.uk/star/research/stars_galaxies/cobras**

- Ronny Blomme (Royal Observatory of Belgium)
- Simon Clark (Open University, UK
- Phil Diamond (JBCA, Manchester, UK)
- Jeremy Drake (Harvard-Smithsonian CfA, USA)
- Stewart Eyres (Univ. of Central Lancashire, UK)
- Simon Goodwin (University of Sheffield, UK)
- Ian Howarth (University College London, UK)
- Chip Kobulnicky (Univ. of Wyoming , USA)
- Julian Pittard (University of Leeds, UK)
- Salvo Scuderi (Astronom. Observatory, Catania)
- Ian Stevens (University of Birmingham, UK)
- Jacco Van Loon (University of Keele, UK)
- Martin Ward (University of Durham, UK)
- Dugan Witherick (Univ. College London, UK)
- Jeremy Yates (University College London, UK)
- Ishwara Chandra (GMRT, Tata Institute, India)
- Paul Crowther (University of Sheffield, UK)
- Sean Dougherty (NRC, Canada)
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- Jorick Vink (Armagh Observatory, UK)
- Allan Willis (University College London, UK)
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- Luke Peck (University College London, UK)
- Jack Morford (University College London, UK)