

The Mopra CO Galactic Plane Survey

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Synopsis

- CO Survey of the southern Galactic plane
 - i.e. the parts invisible from northern telescopes
 - Range in b : -1 to +1
 - Range in l : 260 – 10 (110 deg)
 - 220 Square degrees
- All 4 isotopomers: ^{12}CO , ^{13}CO , C^{18}O , C^{17}O
 - Simultaneous observations
- Resolution: 0.5 arcmin, ~ 0.1 km/s
- > 3 Mpix, each with many spectral data points

Purpose

- Mapping the Milky Way Galaxy in Molecular Gas at subarcminute resolution
- CO is the basic tracer of dense gas
 - Easily thermalised ($>\sim 1000 \text{ cm}^{-3}$)
 - Energy levels fit ISM temperatures well; even cool gas has CO up to $J=4$
- Complementary to ASKAP
 - HI/continuum
 - Good extended source sensitivity
- Complementary to Cherenkov Telescope Array, CTA
 - High-energy Gamma-rays
 - Trace the interaction of cosmic rays with protons
- Complementary to moderate-size THz telescope
 - $>1 \text{ m}$ aperture at C+ 1.9 THz (e.g. DATE5!)
 - 5m aperture at CI 0.5 THz (e.g. NANTEN2, DATE5)
 - Maps of most major cooling lines of the Milky Way Galaxy at high resolution

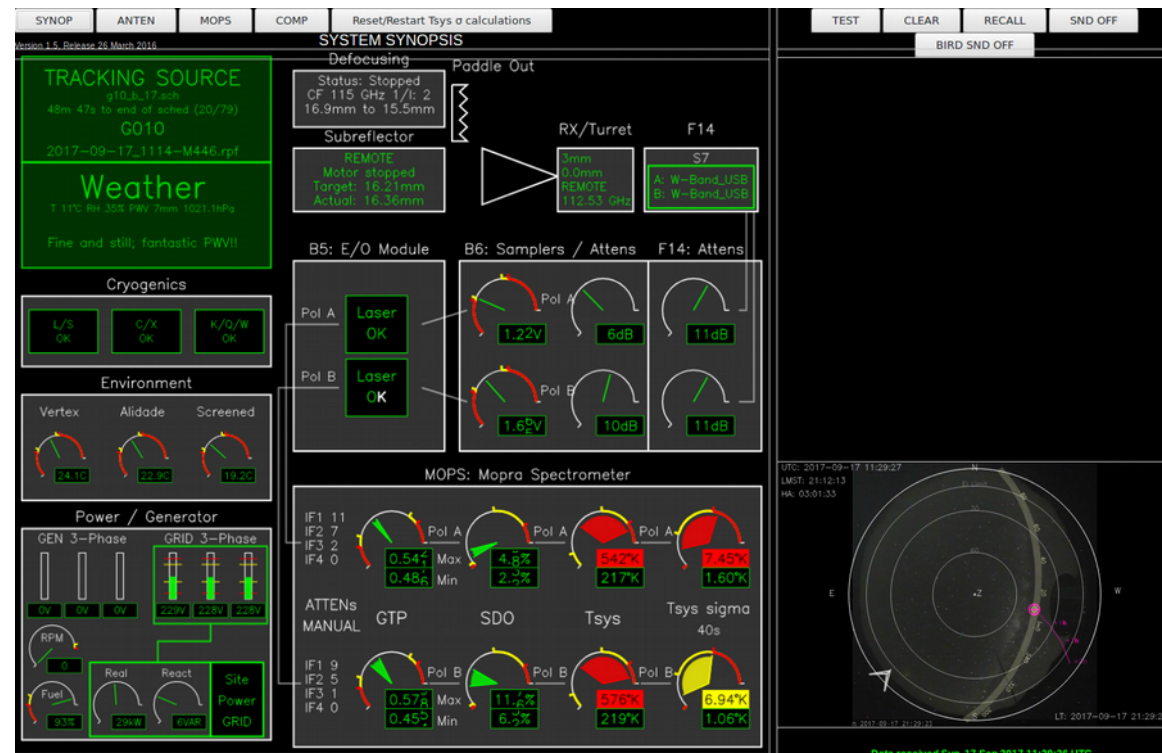
Mopra Telescope

22m single dish
1 – 115 GHz
Spectroscopy and VLBI
AUD405k pa (direct)
Fire resistant!



Observing Techniques

- Fast on-the-fly (FOTF)
 - Uses 256ms pulsar mode to yield fast integration times, and hence fast scanning speeds
- Fully-remote observations
 - Observing from your phone!*
 - VNC, queue mode
 - TOAD
 - *full observations from a phone are non-trivial



Science – Find the Protons!

- Combine molecular (CO), atomic (HI) and ionic (C⁺, N⁺) tracers
- Trace all states of the baryonic ISM
 - Gamma rays trace the interactions of cosmic rays with protons
 - Understanding the structure of the ISM allows the physics of cosmic rays to be understood.
 - Understanding the interaction of cosmic rays with the ISM is a major requirement to understand Galaxies.
- Major focus: Map the ISM around SNRs

Dark molecular gas

- Molecular gas (H₂) without CO
 - Too little CO for self-shielding
 - So the carbon should be atomic (C I)
- Compare CO/C I/H I maps
- Preliminary work with Mopra/HEAT/SGPS suggests that ~1/3 of molecular gas is CO-dark (Burton et al 2015)

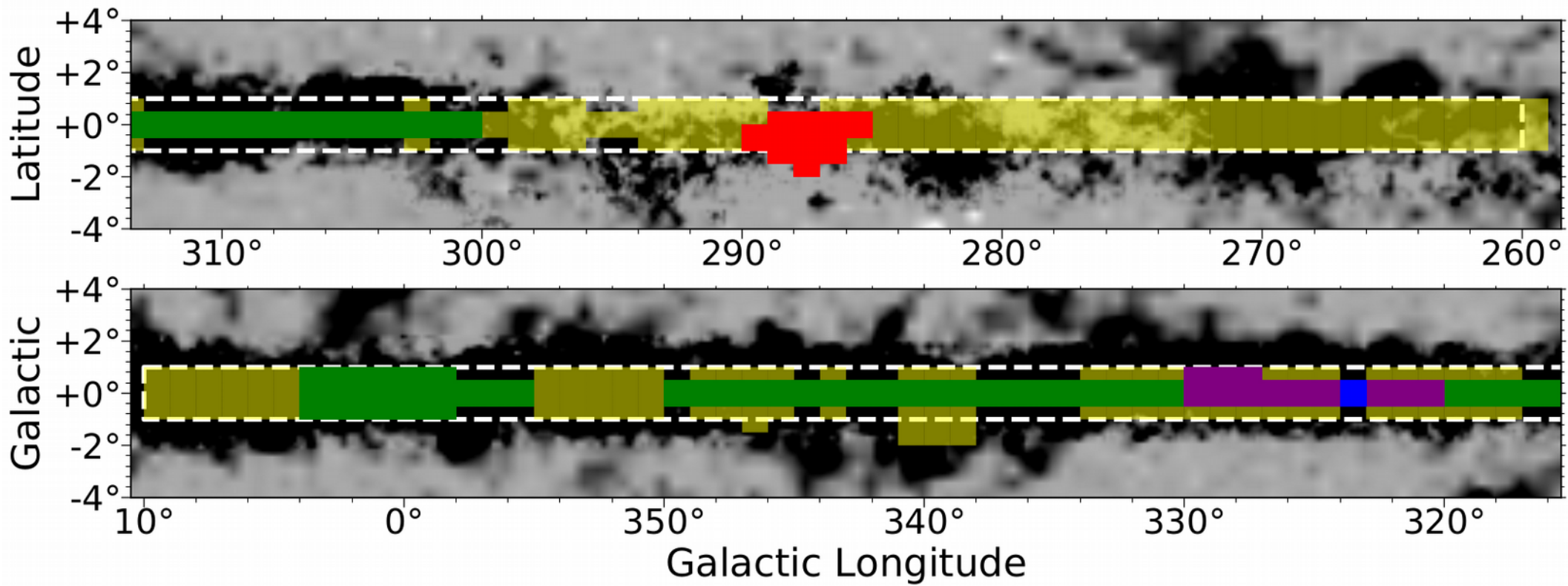
Galactic Objects

- Distance estimates
 - Circinus X-1 at 9kpc (Heinz et al 2015)
- Molecular Clouds and Star Formation
 - Carina (Rebolledo et al 2016)
 - Chamaeleon (G Wong PhD thesis, Wong et al in prep)
- The Galactic Centre
 - Ground state CO
 - dynamics

Data products

- Raw data available on ATOA under normal rules
- Processed data public (on ATOA et al)
 - DR 1 pilot survey 11.5 sq deg (Braiding et al 2015)
 - DR 2 Carina (Rebolledo et al 2016)
 - DR 3 in prep (Braiding et al)

Progress and Prospects



Progress and Prospects

- We have applied for further funding for next winter
 - Completion of survey
 - Expansion of coverage
 - 7mm mapping (eg CS, SiO)
 - Mass tracers for CTA
 - 3mm transitions (eg ions)
 - Tracing eg cosmic ray ionisation
 - Cosmic ray physics
 - ISM physics

The Mopra Survey in Context

- Major Galactic Plane CO Surveys
 - PMO (N)
 - Nobeyama 45m (N)
 - FCRAO (old!)
 - CfA, NANTEN (low res, N/S)
 - Only S surveys can be combined with THz
- Very small-scale SKA Pathfinder*
- Very low energy gamma-ray telescope
- Low latitude, low elevation, low frequency Antarctic terahertz telescope

*Not an official SKA pathfinder!