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, C18O, C17O
  - Simultaneous observations
- Resolution: 0.5 arcmin, ~0.1 km/s
- > 3Mpix, 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 (>~1000 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 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 (CI)

• Compare CO/CI/HI 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
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- 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!