New Flavours in Galactic Surveys: HOPS and beyond

Andrew Walsh, Centre for Astronomy, James Cook University
HOPS – The H$_2$O southern Galactic Plane Survey

Andrew (Is it beer time yet?) Walsh, JCU
Cormac (MopraBoy) Purcell, Leeds/USyd
Steven (Hoots Man!) Longmore, ESO
Michael (The Bloodnut) Burton, UNSW
Nadia (Lo-Lo) Lo, U Chile
Kate (El Presidente) Brooks, ATNF
Chris (VLBIBoy) Phillips, ATNF
Shari (Shazaaahh) Breen, ATNF
Lyshia (The Teacher) Quinn, Manchester
Maxim (PlaneBoy) Voronkov, ATNF
Maria (QuietGirl) Cunningham, UNSW

Paul (NoisyBoy) Jones, UNSW
James (Hames) Urquhart, ATNF
Melvin (Pommie Bastard) Hoare, U. Leeds
Mark (Pommie Bastard) Thompson, U. Hertfordshire
Lisa (Pommie Bastard) Harvey-Smith, ATNF
Tui (Kiwi Bastard) Britton, Macquarie/ATNF
Luke (Pommie Bastard) Hindson, Hertfordshire/ATNF
Jimi (WorldBeer) Green, ATNF
Vicki (GeeThreeThreeThree) Lowe, UNSW/ATNF
Balt (Baltipoos) Indemuehle, ATNF
AIMS

• Survey the southern Galaxy with Mopra at 12mm

• Use MOPS zoom mode to survey multiple lines

• 100 square degrees at 2’ resolution

• $|l|=290^\circ - 30^\circ; \ |b| < 0.5^\circ$
Main lines surveyed

- $\text{H}_2\text{O}$ maser
- $\text{NH}_3$ (1,1), (2,2), (3,3), (6,6), (9,9)
- $\text{HC}_3\text{N}$ (3-2)
- $\text{H}69\alpha$ radio recombination line
- Many $\text{CH}_3\text{OH}$ lines
- Many others including $\text{H}62\alpha$, $\text{H}64\alpha$, $\text{H}65\alpha$, $\text{NH}_3$ (non-metastable), CCS, $\text{HC}_5\text{N}$
$\text{NH}_3\ (1,1)$ Emission Peak Temperature Maps
$\text{NH}_3 \ (1,1)$
NH$_3$ (2,2)
$l = 359-010^\circ$

Sgr B2

- $\text{H}_2\text{O}$ masers
- $\text{NH}_3$ (1,1)
- $\text{NH}_3$ (2,2)
- $\text{NH}_3$ (3,3)
- $\text{HC}_3\text{N}$ (3-2)
- $\text{H}_6\text{H}\alpha$ RRL
- $\text{CH}_3\text{OH}$
- $\text{HC}_6\text{N}$

H$_2$O Masers
NH$_3$ (1,1)
NH$_3$ (2,2)
NH$_3$ (3,3)
HC$_3$N(3-2)
H$_6$H$\alpha$
Hot gas emission in the CMZ

$\text{NH}_3 (6,6)$

$\text{NH}_3 (9,9)$

50pc
Kinematics of the Inner Galaxy with NH$_3$

Colours = NH$_3$ (1,1)
Contours = CO (1-0) (Dame et al. 2001)
Kinematics of the Inner Galaxy with $\text{NH}_3$

Colours = $\text{NH}_3 (1,1)$
Contours = CO (1-0) (Dame et al. 2001)
Water masers

$\text{NH}_3(1,1)$ integrated intensity [dense molecular gas]
$\text{NH}_3$ cores = blue

$\text{H}_2\text{O}$ masers = red

Lada et al. (2010)

$\text{SF} > 10^4 \text{ cm}^{-3}$

$\text{NH}_3 > 10^4 \text{ cm}^{-3}$

Galactic longitude [deg]
Large number of surveys in recent years searching for high mass protoclusters

Based on measured gas density these seem destined to predominantly form Open clusters
G0.253+0.016 – the initial conditions of a young high mass cluster?  
(aka “The Brick”, “The Lima Bean”, “M0.25”, “Mr Hankey”)
G0.25
• $1.4 \times 10^5 \, M_{\text{sun}}$
• Radius 2.8pc
• Almost no signs of current star formation
• Gravitationally-bound so likely to form stars

• Potentially unique in Galaxy?

Initial conditions of a precursor to a YMC

Detailed study can reveal important information about YMC formation and help test theoretical models
ALMA Follow UP

- Awarded 6 hours of ALMA Early Science time to map G0.25 at 90GHz
Accurate positions of water masers using ATCA

Processed data from $l=10$ to $l=25$, including 90 water masers
Mosaic of GLIMPSE infrared around water maser positions
Mosaic of GLIMPSE infrared around water maser positions

Star formation associations
Mosaic of GLIMPSE infrared around water maser positions
Evolved star associations
Mosaic of GLIMPSE infrared around water maser positions

Unknown associations
Mosaic of GLIMPSE infrared around water maser positions

- 63 (70%) associated with star formation
- 20 (22%) associated with evolved stars
- 7 (8%) unclear associations
HOPS Summary

- Mopra observations of 100 square degrees finished
- 540 water masers (64% new)
- 568 NH$_3$ (1,1) detections
- ~30% of NH$_3$ (1,1) sources also show NH$_3$ (2,2) and NH$_3$ (3,3)
- Occasional detections: HC$_3$N (3-2), RRLs, multiple Class I methanol masers, HC$_5$N, NH$_3$ (6,6) and (9,9)
- Lack of star formation in the CMZ?
- ATCA followup complete; 90 masers processed (70% SF, 22% ES, 8% ?)
HOPS2
(or YSO Extended Area Single-dish Telescope survey)
Increase sensitivity by ~20x over HOPS

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• **Trace $\text{H}_2\text{O}$ masers right across the Galaxy**
  -> Compare $\text{H}_2\text{O}$, $\text{CH}_3\text{OH}$ and OH masers
  -> Galactic population of masers associated with evolved stars
  -> Galactic population of masers associated with star formation

• **Trace star formation right across the Galaxy**
  -> Use $\text{NH}_3$ as tracer of star forming gas
  -> Expected to follow spiral structure much more closely than $\text{H}\text{I}$ or CO
HOPS2 on Parkes
(or YSO Extended Area Single-dish Telescope survey)

Increase sensitivity by 20x -> 10 minutes per beam
Beam is ~50 arcsec at 24GHz
100 square degrees = 518 400 beams
Requires 5 184 000 minutes = 86 000 hours

Solution is a multibeam/PAF with (for example) 8x8 elements
Survey requires ~1350 hours
Conclusion

Single dish astronomy still extremely powerful

Parkes can potentially map out star formation across our Galaxy

Thank you!