



International  
Centre for  
Radio  
Astronomy  
Research

# Surveys of water and OH masers

Dr Andrew Walsh

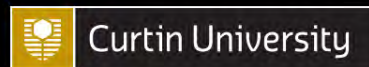
With thanks to the HOPS and SPLASH teams.

In particular:

Jo Dawson (Macquarie/CASS)

Cormac Purcell (Sydney)

Steve Longmore (LJMU)



THE UNIVERSITY OF  
WESTERN AUSTRALIA



# Surveys of water and OH masers

---

HOPS – The H<sub>2</sub>O southern Galactic Plane Survey

SPLASH – The Southern Parkes Large-Area Survey in Hydroxyl

THOR – The HI/OH/Recombination line survey

MMB – The Methanol Multibeam Project

MALT-45 – The Millimetre Astronomers Legacy Team 45GHz Survey



# Surveys of water and OH masers

---

H<sub>2</sub>O masers

SPLASH – The Southern Parkes Large-Area Survey in Hydroxyl

THOR – The HI/OH/Recombination line survey

MMB – The Methanol Multibeam Project

MALT-45 – The Millimetre Astronomers Legacy Team 45GHz Survey



# Surveys of water and OH masers

---

H<sub>2</sub>O masers

OH masers (South)

THOR – The HI/OH/Recombination line survey

MMB – The Methanol Multibeam Project

MALT-45 – The Millimetre Astronomers Legacy  
Team 45GHz Survey



# Surveys of water and OH masers

---

H<sub>2</sub>O masers

OH masers (South)

OH masers (North)

MMB – The Methanol Multibeam Project

MALT-45 – The Millimetre Astronomers Legacy  
Team 45GHz Survey



# Surveys of water and OH masers

---

H<sub>2</sub>O masers

OH masers (South)

OH masers (North)

Class II CH<sub>3</sub>OH masers

MALT-45 – The Millimetre Astronomers Legacy  
Team 45GHz Survey



# Surveys of water and OH masers

---

H<sub>2</sub>O masers

OH masers (South)

OH masers (North)

Class II CH<sub>3</sub>OH masers

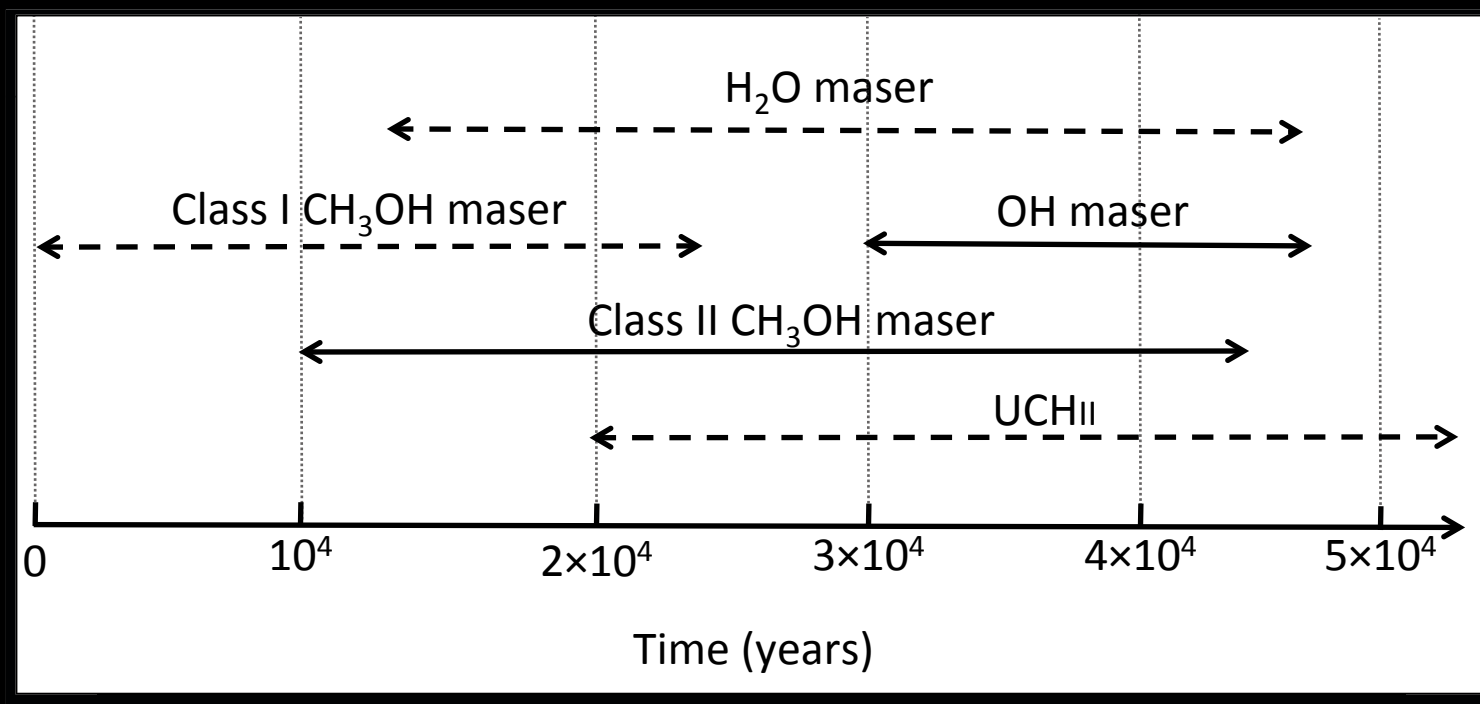
Class I CH<sub>3</sub>OH masers

SiO masers



# Surveys of water and OH masers

Breen et al. (2010) maser timeline:







# HOPS – The H<sub>2</sub>O southern Galactic Plane Survey

---

- Survey the southern Galaxy with Mopra at 12mm
- Use MOPS zoom mode to survey multiple lines
- 100 square degrees at 2' resolution
- $l=290^\circ - 30^\circ$   
 $|b| < 0.5^\circ$





# HOPS

H<sub>2</sub>O Masers

NH<sub>3</sub> (1,1)

310

300

290

330

320

310

350

340

330

010

0

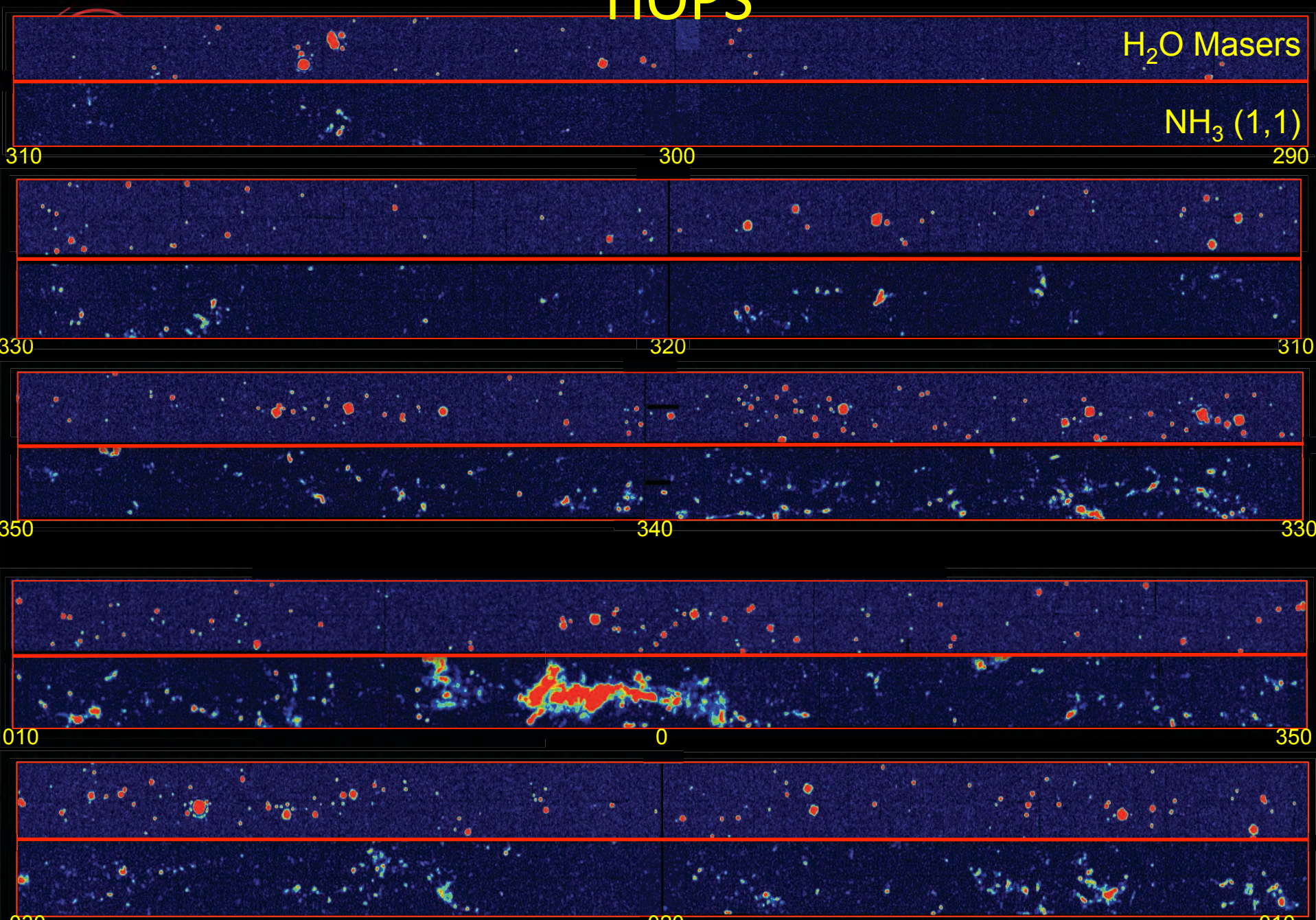
350

030

020

010

Surveys of water and OH masers







# Accurate positions of water masers using the ATCA

## Results

2790 maser spots

631 maser sites

(Walsh et al. 2014)





Accurate

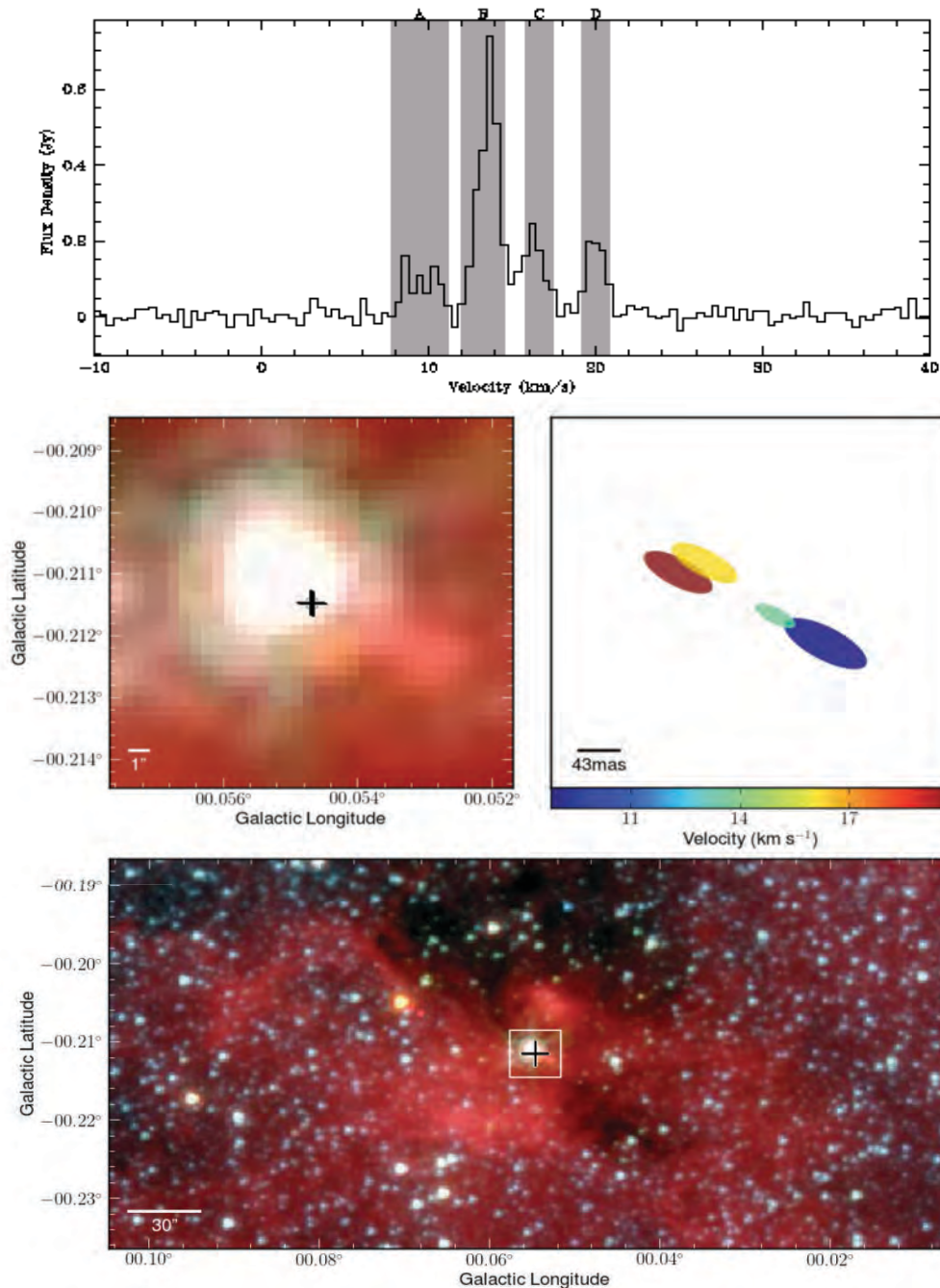
ATCA

# Results

2790 maser spots

631 maser sites

(Walsh et al. 2014)

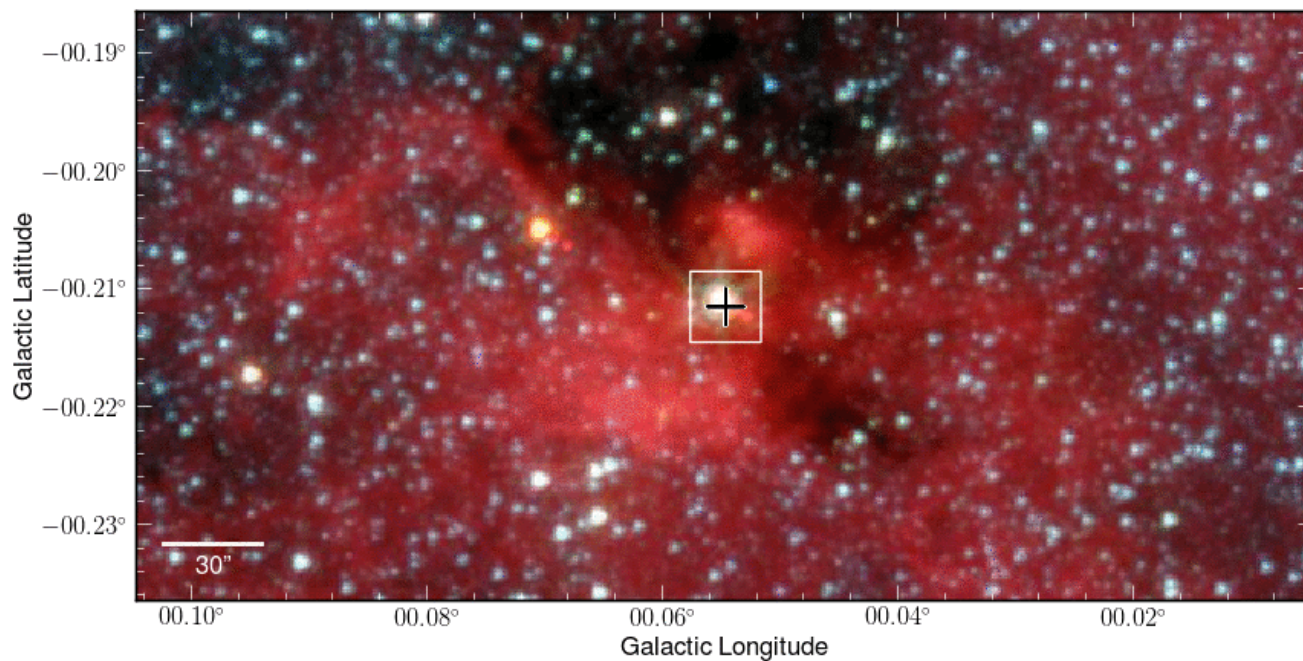
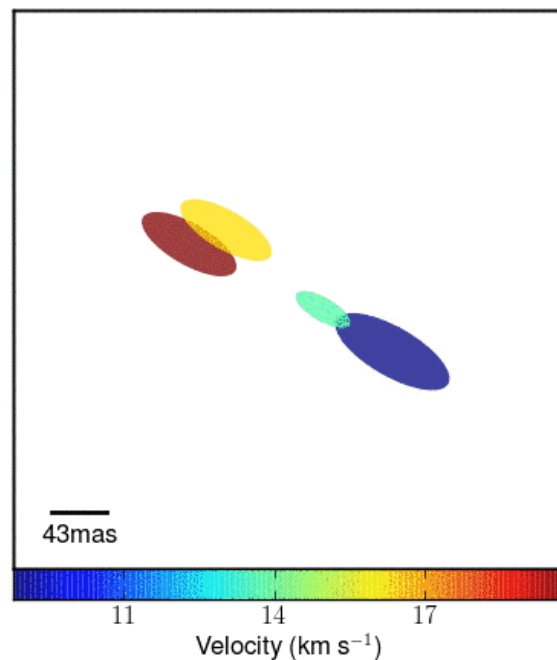
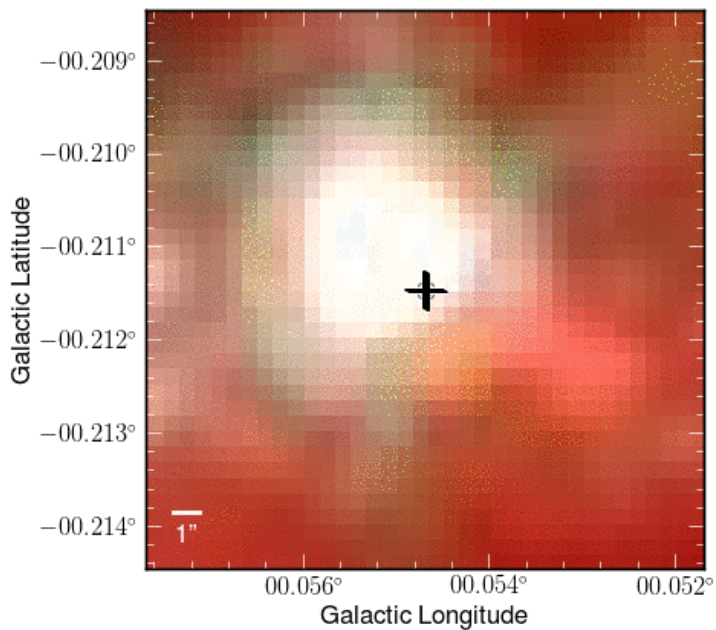




A

Result  
2790 maser  
631 maser

(Walsh et al.)



A





# Accurate positions of water masers using the ATCA

---

## Association of maser sites

- 433 (69%) identified with star formation
- 121 (19%) identified with evolved stars
- 77 (12%) identified as unknown



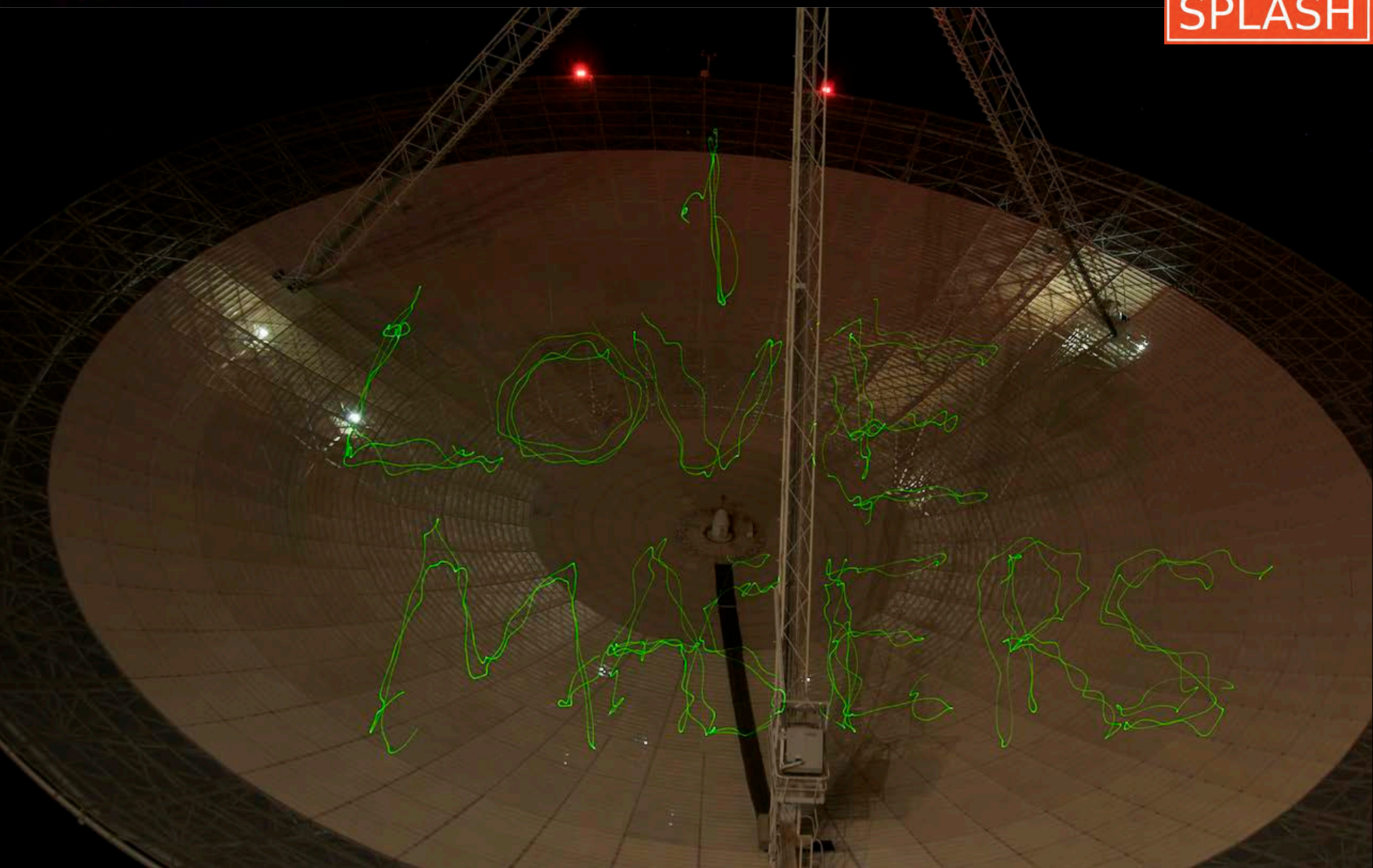
## Extremely high velocity water masers (Harvey-Smith et al. *in preparation*)

Table 1. Measured parameters of the eleven water masers from (Walsh et al.(2014)) that have a velocity spread greater than  $200 \text{ km s}^{-1}$ . Sgr B2 N and Sgr B2 Main are sub-regions of G000.677-0.028.  $v_{sys}$  is an estimate of the systemic velocity based on published velocities of CO, methanol or formaldehyde masers. See the text for references. All velocities are quoted in  $\text{km s}^{-1}$ .

Name	RA	Dec	$S_{peak}$	$v_{low}$	$v_{high}$	$\Delta v$	$v_{sys}$
Sgr B2 North	17:47:19.926	-28:22:19.662	163.7	+11.4	+226.7	215.3	+65
Sgr B2 Main	17:47:20.120	-28:23:03.842	146.9	-66.1	+155.2	221.3	+58
G009.097-0.392	18:07:20.856	-21:16:12.206	16.3	-91.9	+300.5	392.4	+87
G015.974+0.241	18:18:53.857	-14:55:52.013	33.5	-93.1	+278.2	371.3	Unknown
G021.797-0.127	18:31:22.940	-09:57:21.135	35.2	-58.8	+171.6	230.4	+40
G025.825-0.178	18:39:03.604	-06:24:11.174	412.3	-128.8	+137.5	266.3	+90
G305.799-0.245	13:16:43.019	-62:58:32.068	342.9	-183.2	+28.7	211.9	-39
G330.294-0.394	16:07:38.053	-52:31:01.602	6.97	-155.4	+48.9	204.3	-80
G330.954-0.182	16:09:52.705	-51:54:55.581	90.2	-238.5	+61.1	299.6	-91
G345.698-0.090	17:06:50.610	-40:50:59.353	172.3	-154.5	+100.7	255.2	-20
G355.130-0.302	17:34:43.833	-33:13:22.843	23.5	-0.5	+218.6	219.1	+14



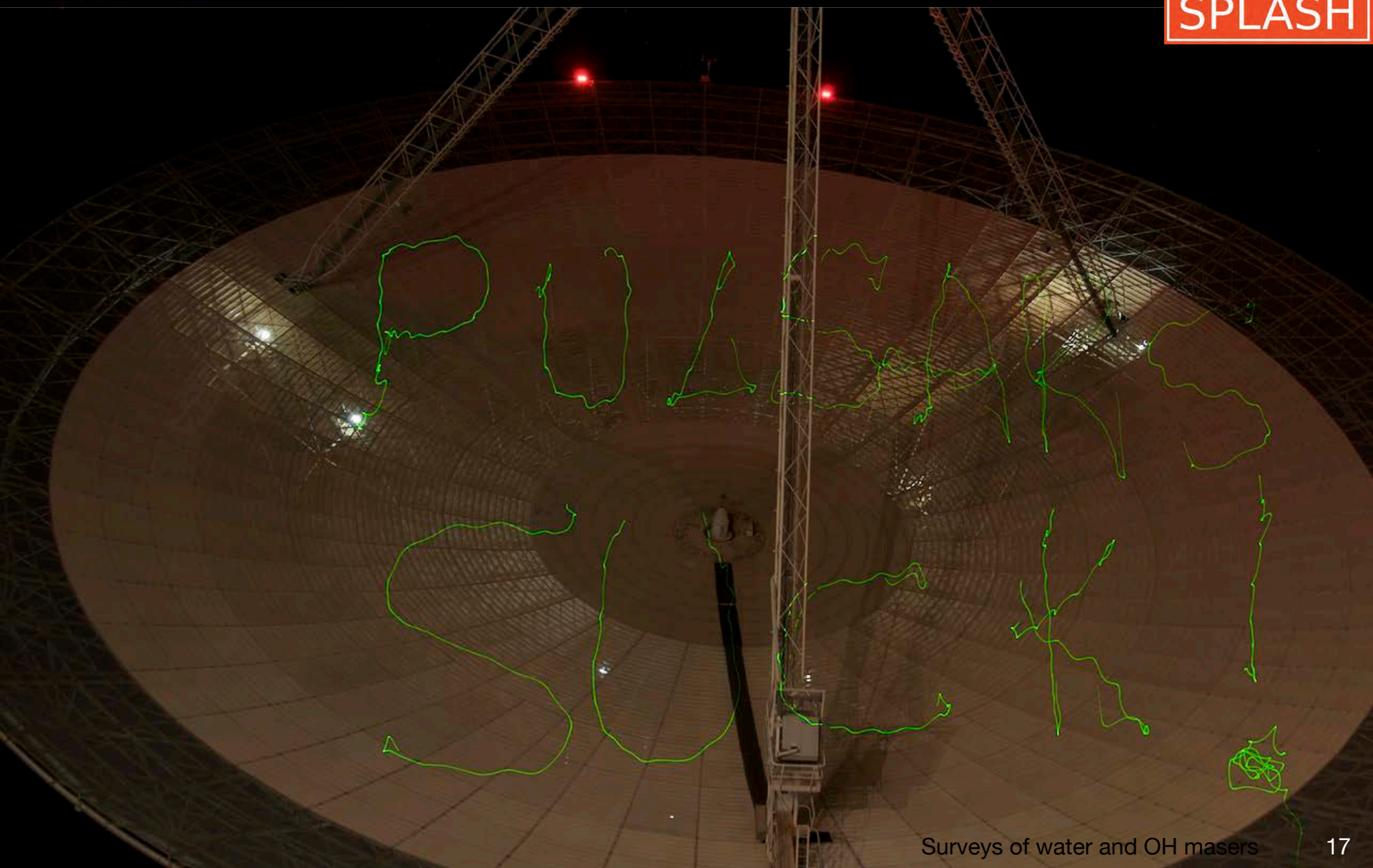
# SPLASH: The Southern Parkes Large-Area Survey in Hydroxyl





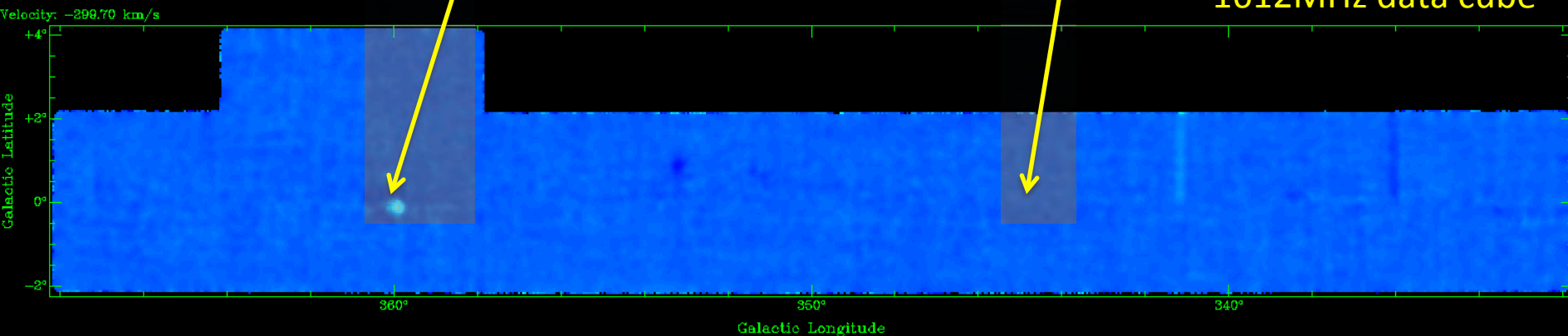
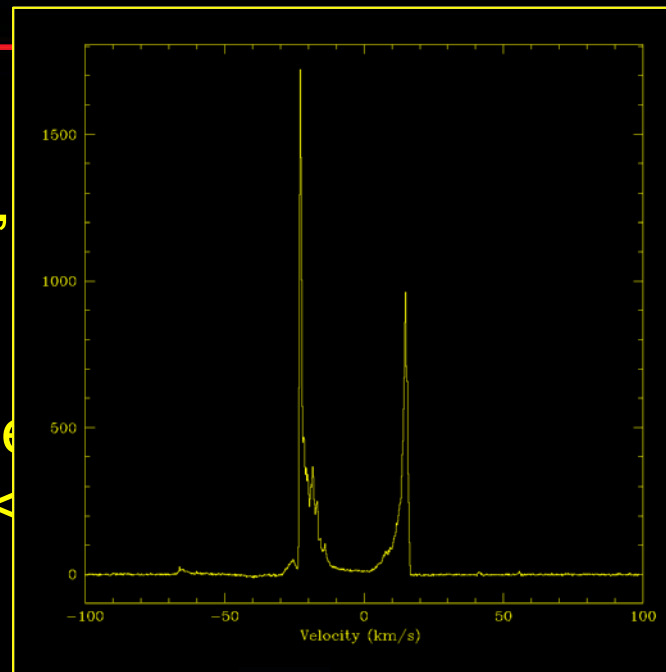
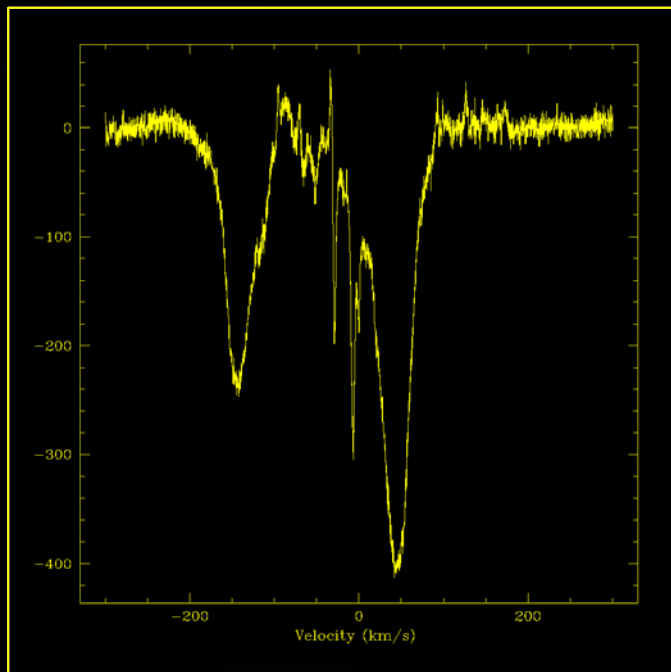


# SPLASH: The Southern Parkes Large-Area Survey in Hydroxyl



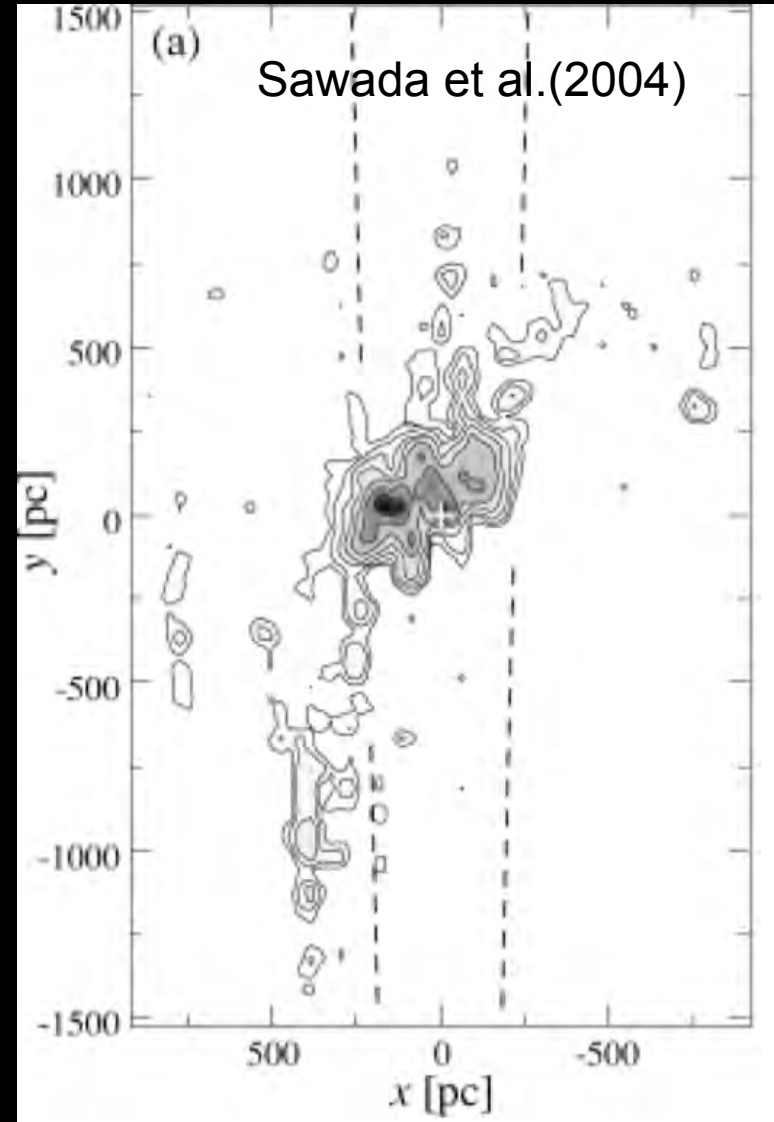
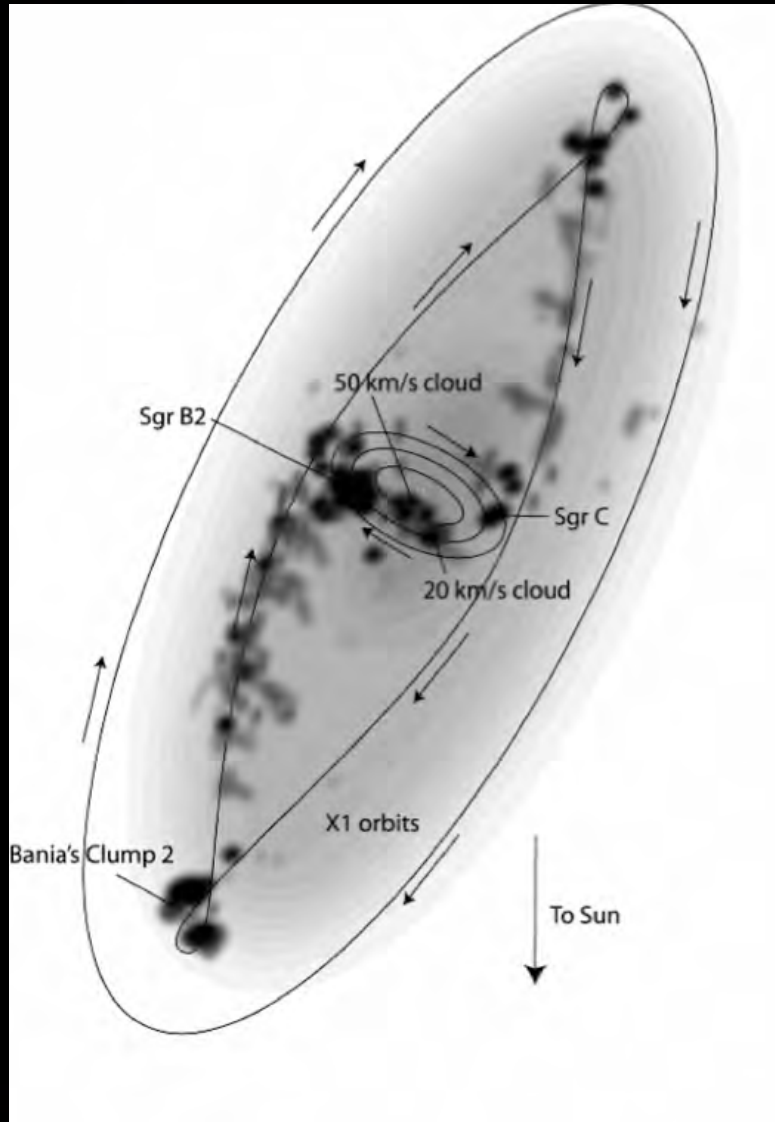


# SPLASH: The Southern Parkes Large-Area Survey in Hydroxyl

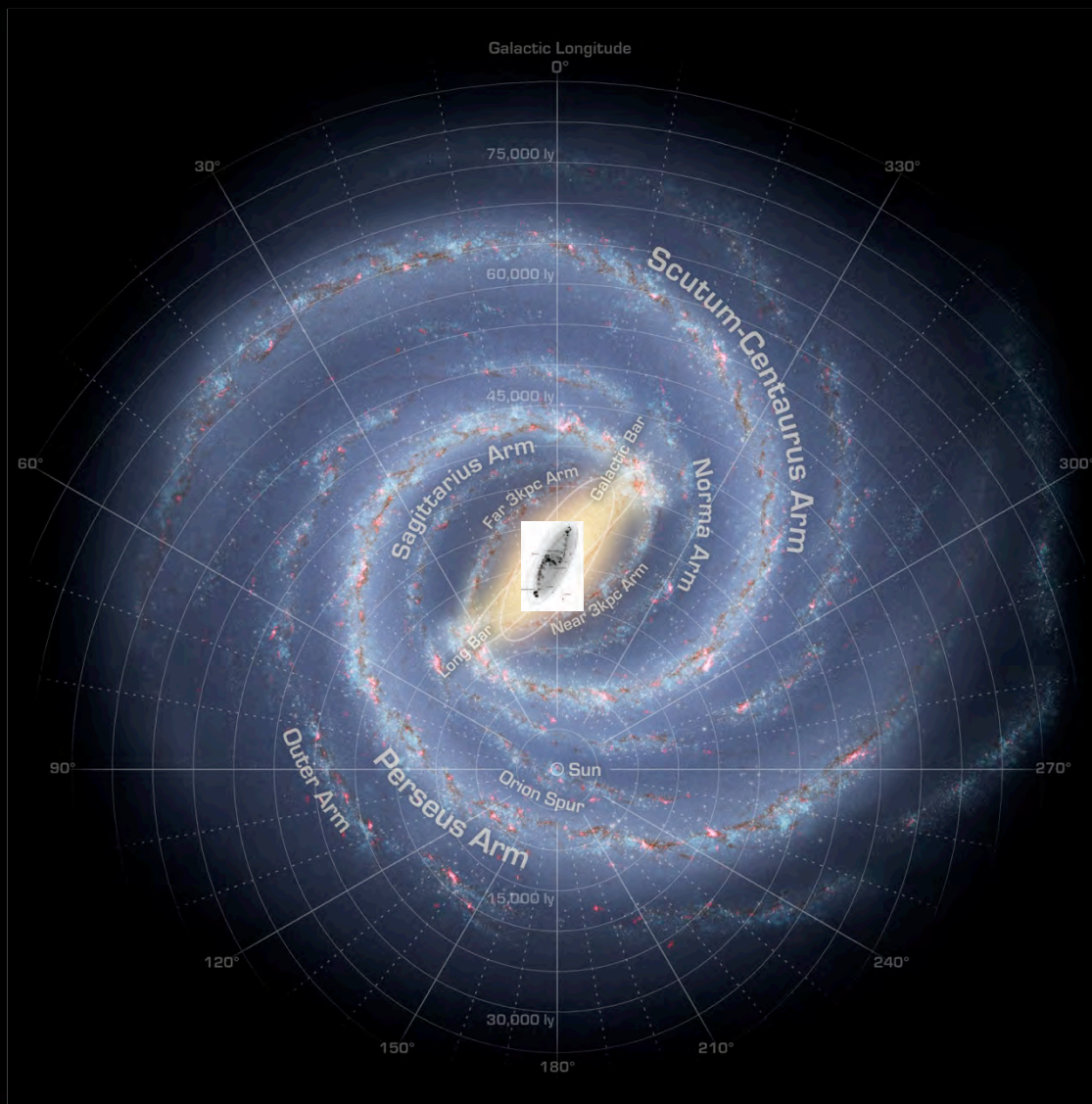


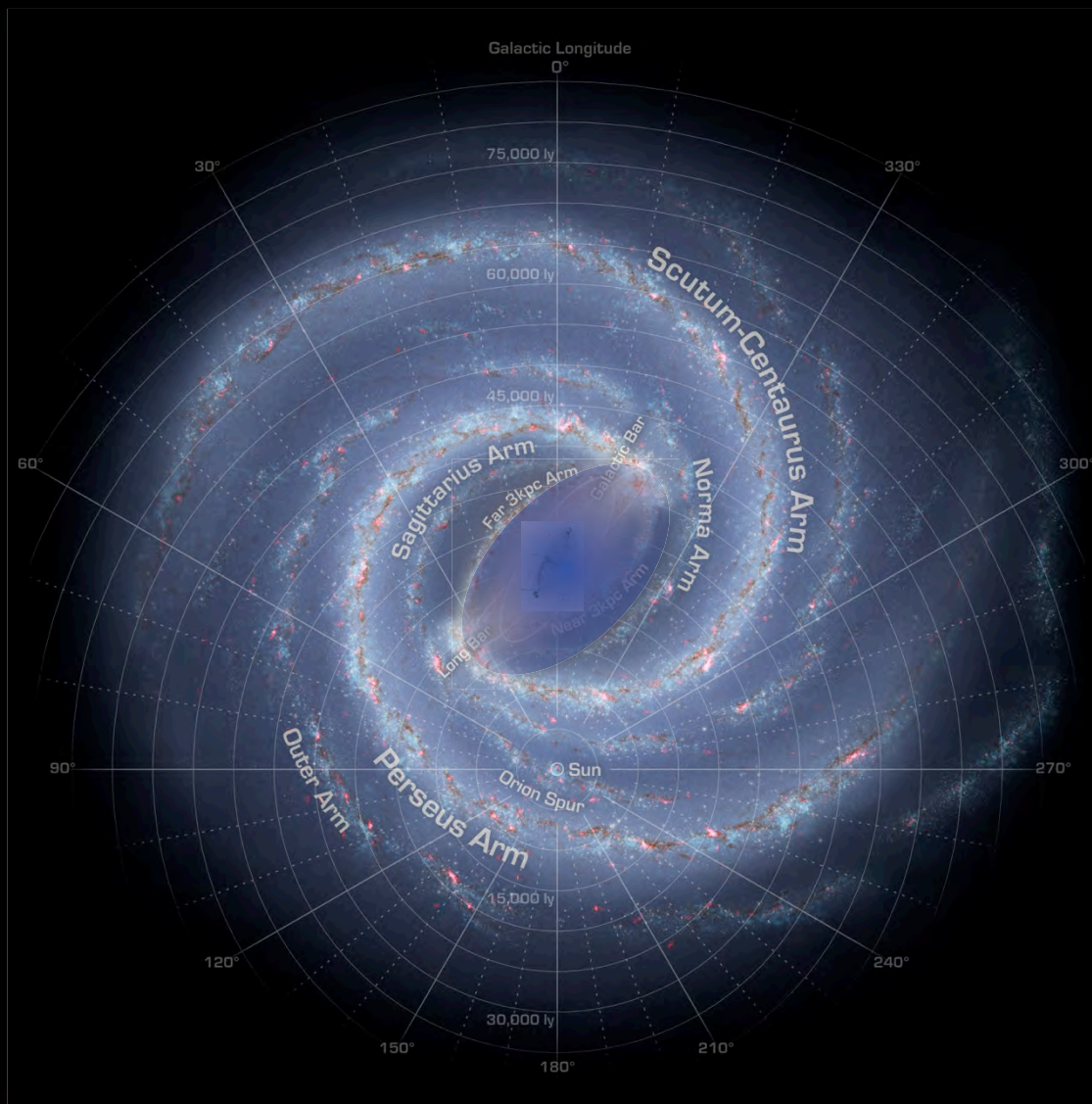
# The Central Molecular Zone

## Artist's impression (c/o John Bally)





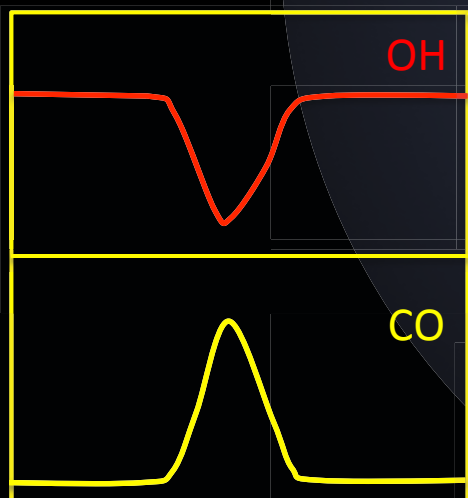
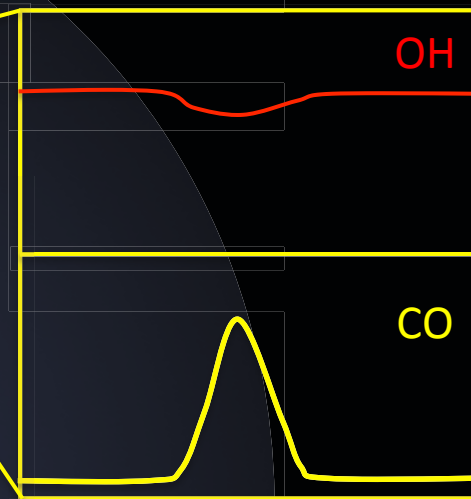
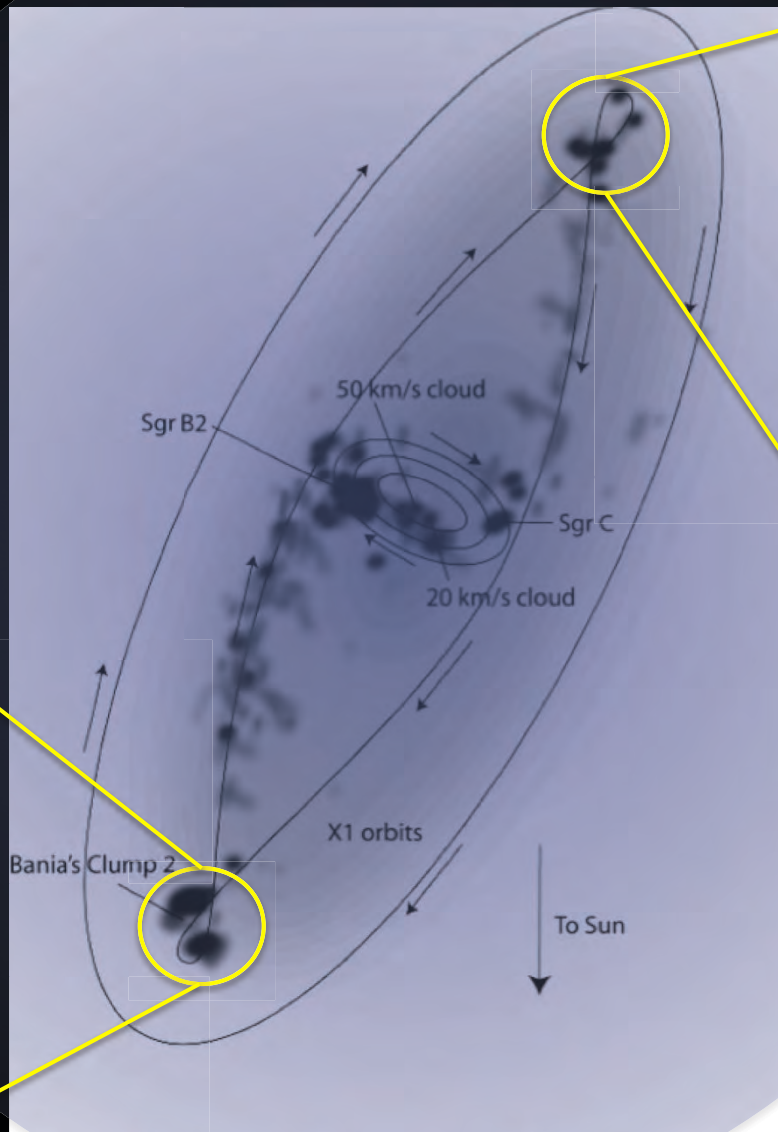






# SPLASH: The Southern Parkes Large-Area Survey in Hydroxyl

CO in emission  
OH in absorption  
Diffuse continuum

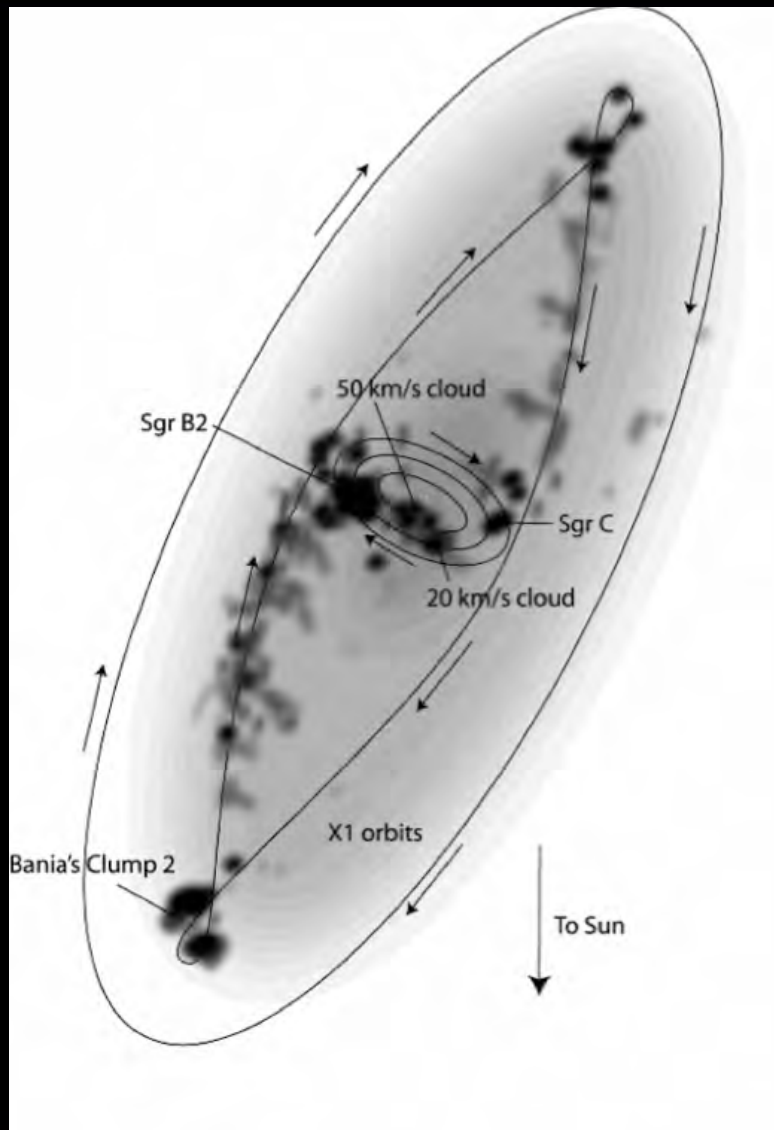


OH: SPLASH + VLA

CO: NANTEN2  
(both  $^{12}\text{CO}$  and  $^{13}\text{CO}$ )

Very good sensitivity

Very good spatial  
resolution – 30''







# Summary

---

- Many Galactic Plane maser surveys delivering data
- 631 HOPS water maser sites
- SPLASH and THOR: OH masers
- Model the structure of the Central Molecular Zone

Note: The only thing that is NOT massive is a photon!

Both high-mass and low-mass stars are massive by the definition of “massive” – the quality of having mass.

Solution: Don't talk about massive star formation, which is technically correct, but not useful. Talk about high-mass star formation 😊