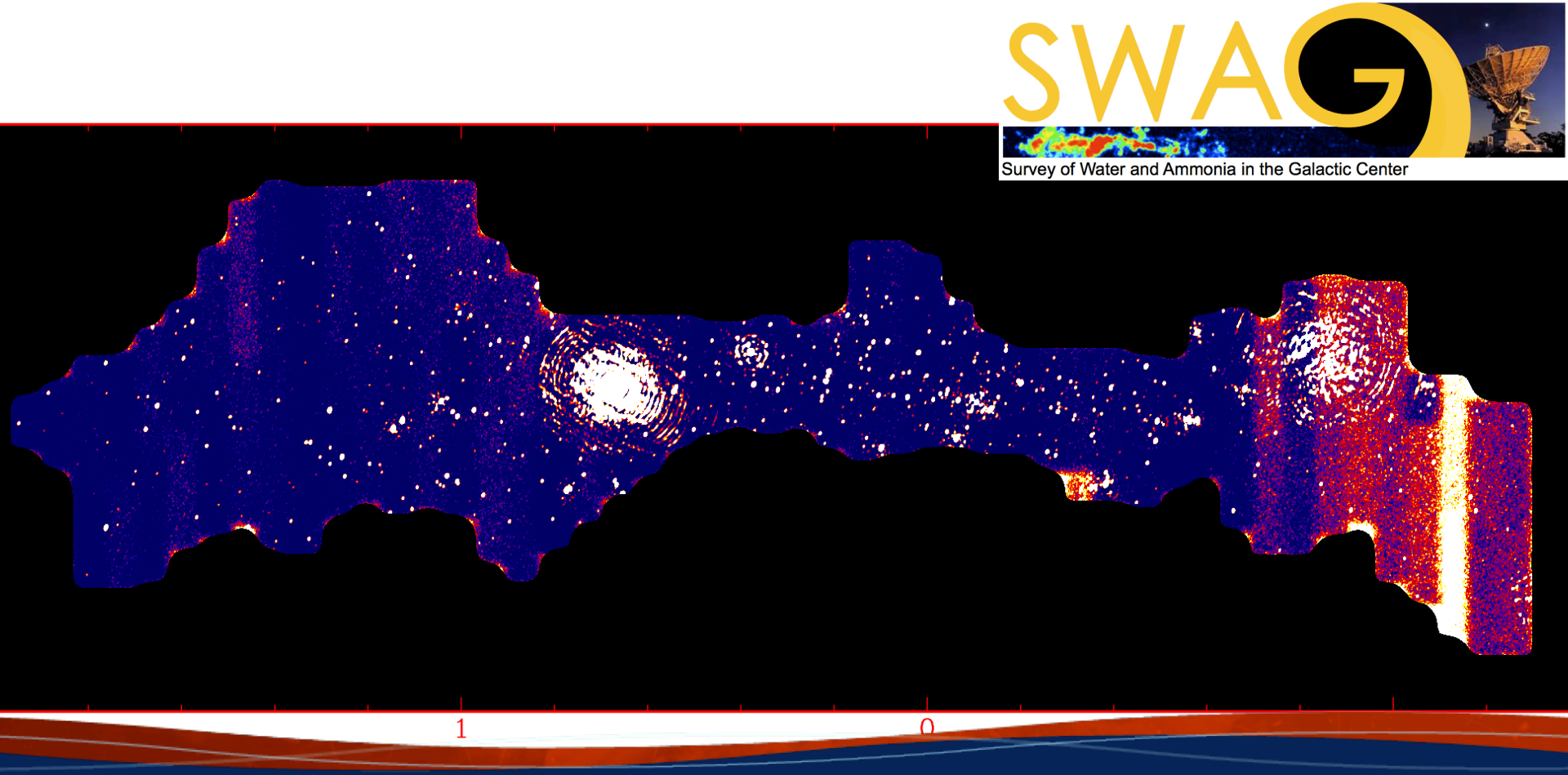

SWAG Water Masers in the Galactic Center

Jürgen Ott (NRAO)

The Galactic Center

Inner 500 pc: Central Molecular Zone

- Contains about 10% of all molecular gas (10^{7-8} M_o in 0.1% of the volume)
- gas density is 100 times that of the disk
- Star formation rate ~0.1 M_o yr^{-1}
- Some of the strongest large scale magnetic fields (filaments)
- Stellar clusters with 10^4 M_o, one in the making
- supernova rate 1/2500 yr^{-1}
- high cosmic ray flux (mainly from SNe)
- high UV and X-ray flux: PDR, XDR (and X-ray echoes)
- large influence of shocks
- origin of outflows vertical to disk (Fermi Bubbles)
- Contains SMBH (Sgr A*) with $4x10^6$ M_o
- Shows 511 keV p-e annihilation radiation
- Good target for DM studies (annihilation signatures)
- extreme, complex, and rich region to study

The Galactic Center

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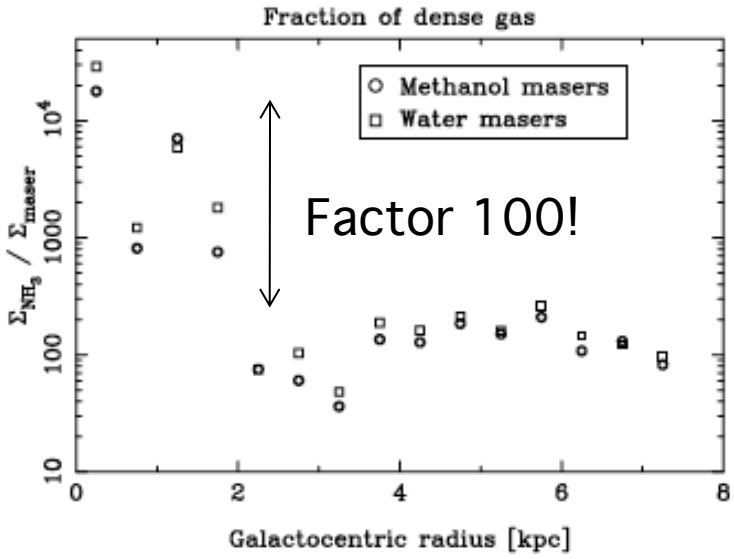
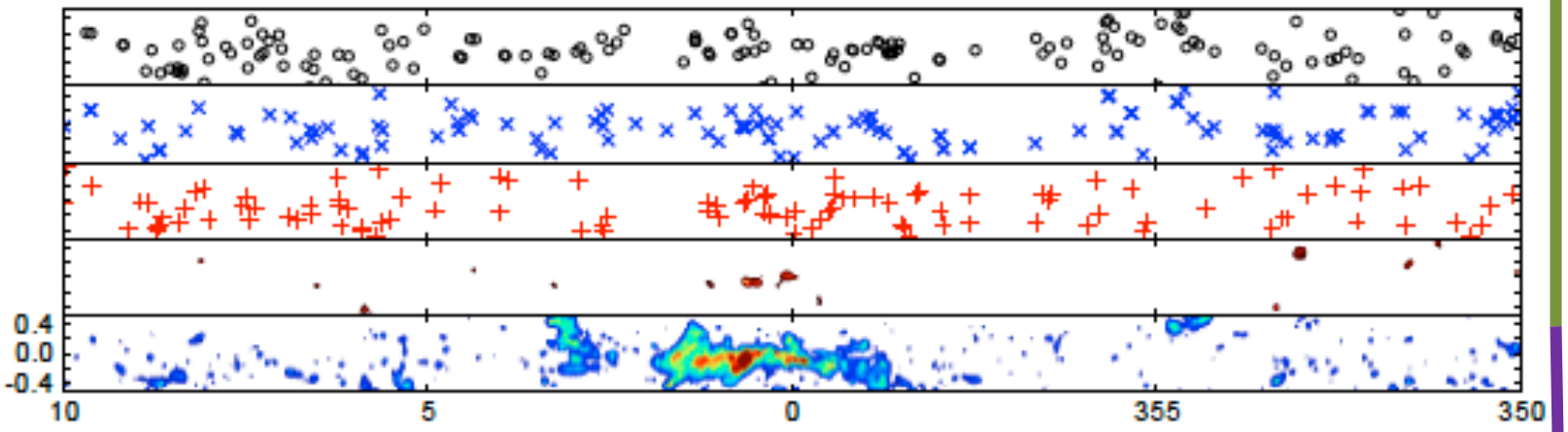
The Galactic Center

Gas in the GC

- Globally: SF suppressed in the GC (Longmore+ 2013; Kruijssen+2014)
- High turbulence most likely reason. Could have implications for KS laws.
- Gas dynamics may raise pressure eq portions (Meidt), t_{ff} correction may explain deviation





SF tracers

HII

Methanol

H_2O

H68α

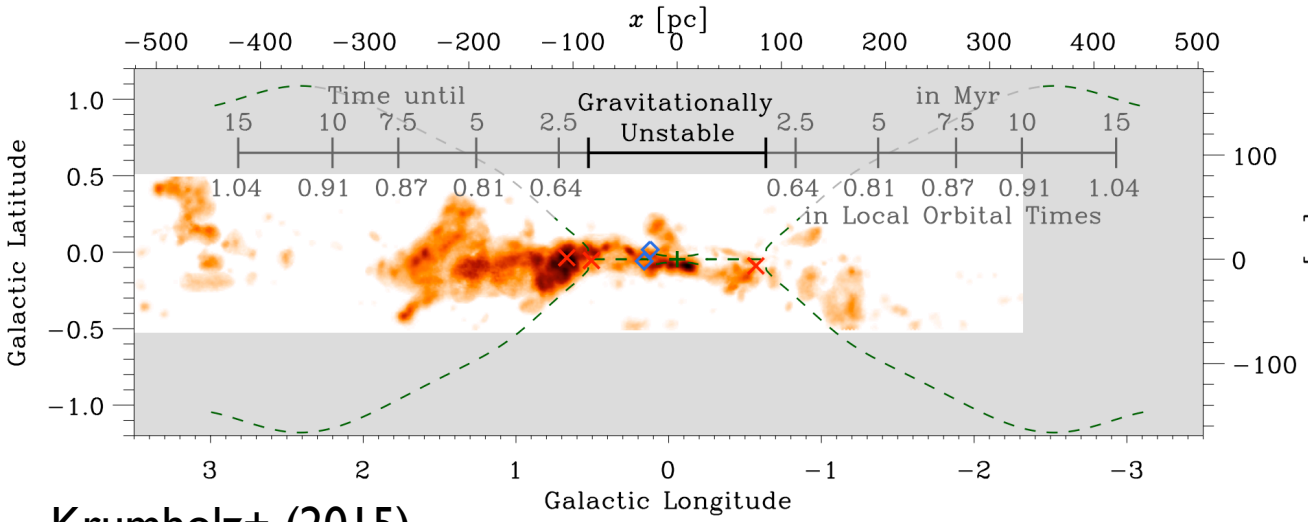
NH_3

Dense gas tracer

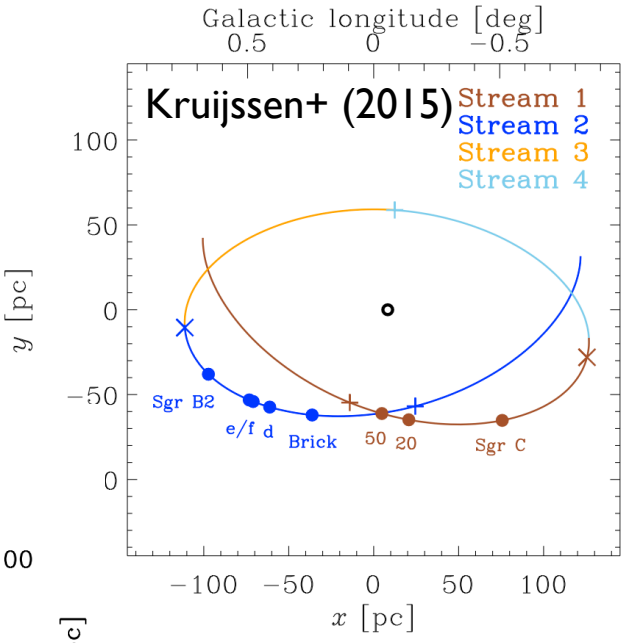
The Galactic Center

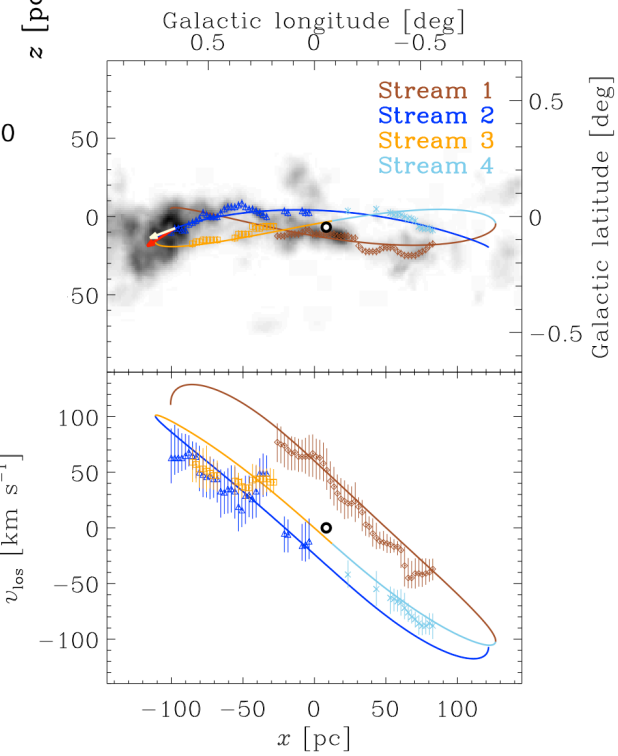
Gas in the GC

- 10% of all molecular gas in about 0.1% of the volume
- Gas funneled through bar into the GC, streamers

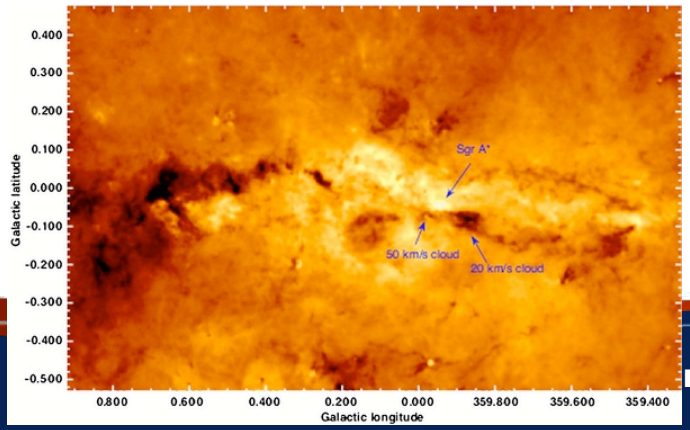


Krumholz+ (2015)





HERSCHEL
T_{dust}

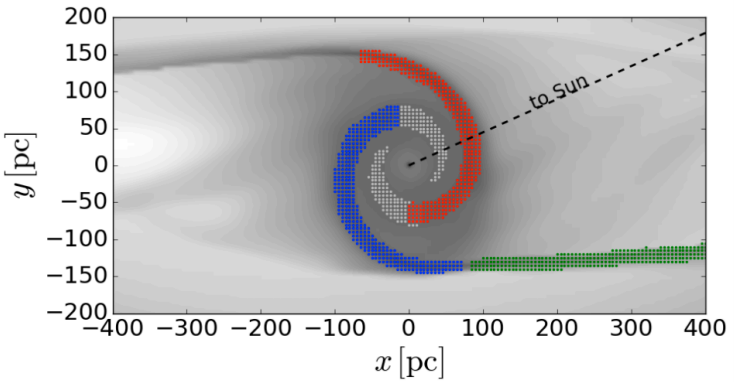


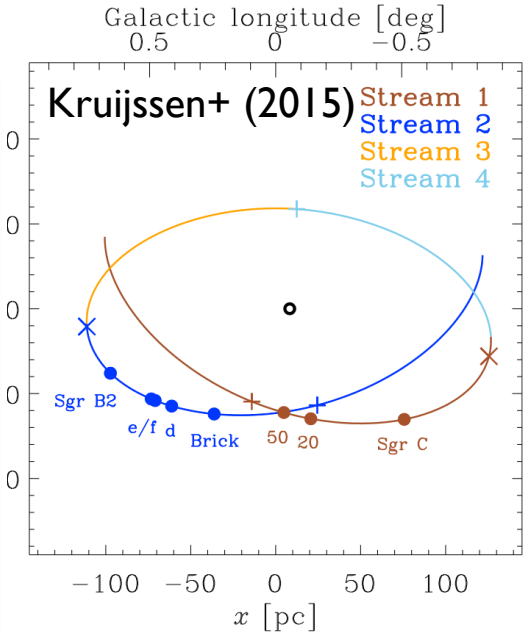
Molinari+ (2011)

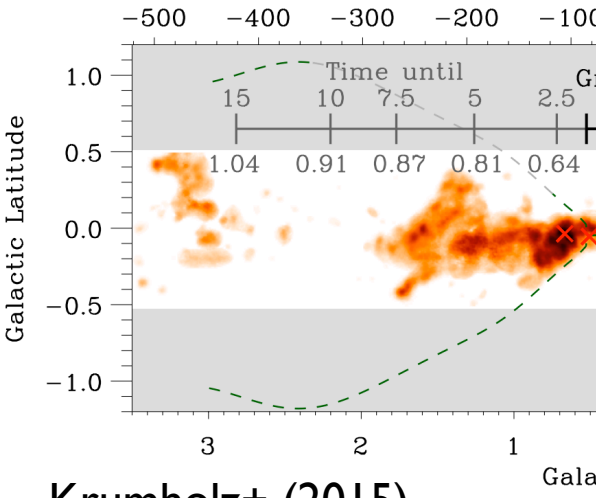
The Galactic Ce

Gas in the GC

- 10% of all molecular ga
- Gas funneled through

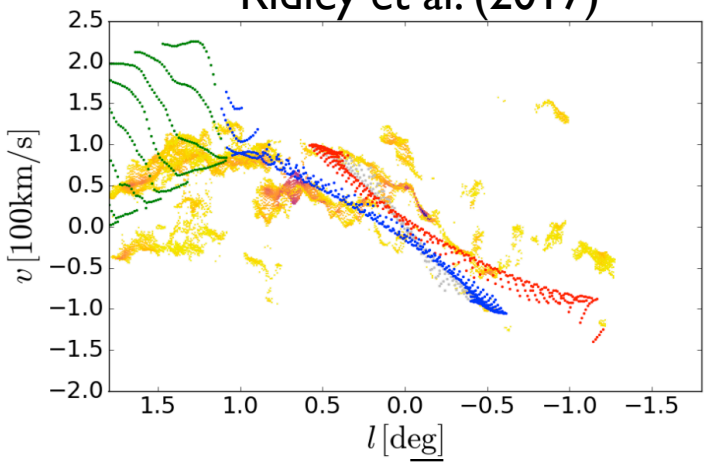


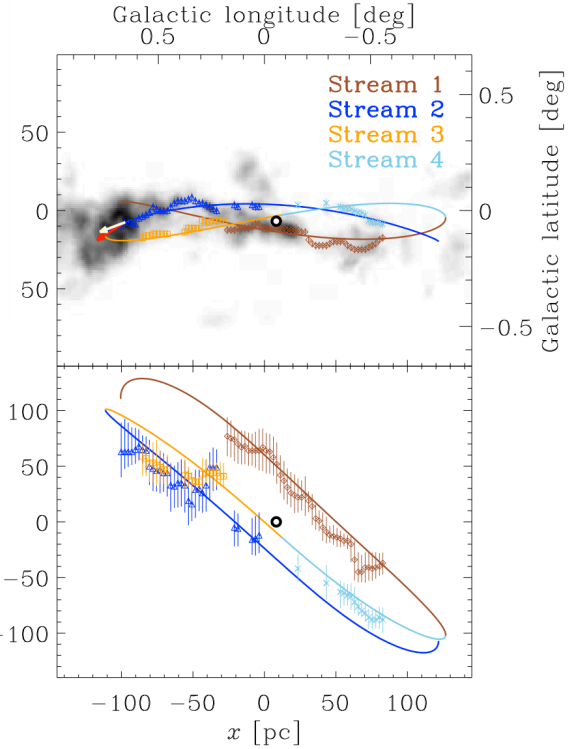




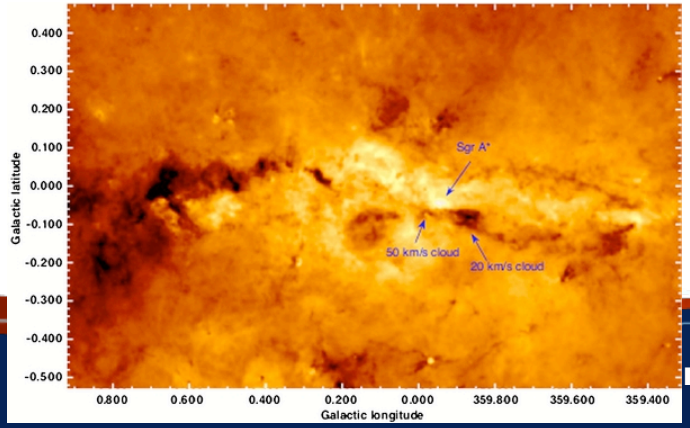
Krumholz+ (2015)

Ridley et al. (2017)





HERSCHEL
T_{dust}



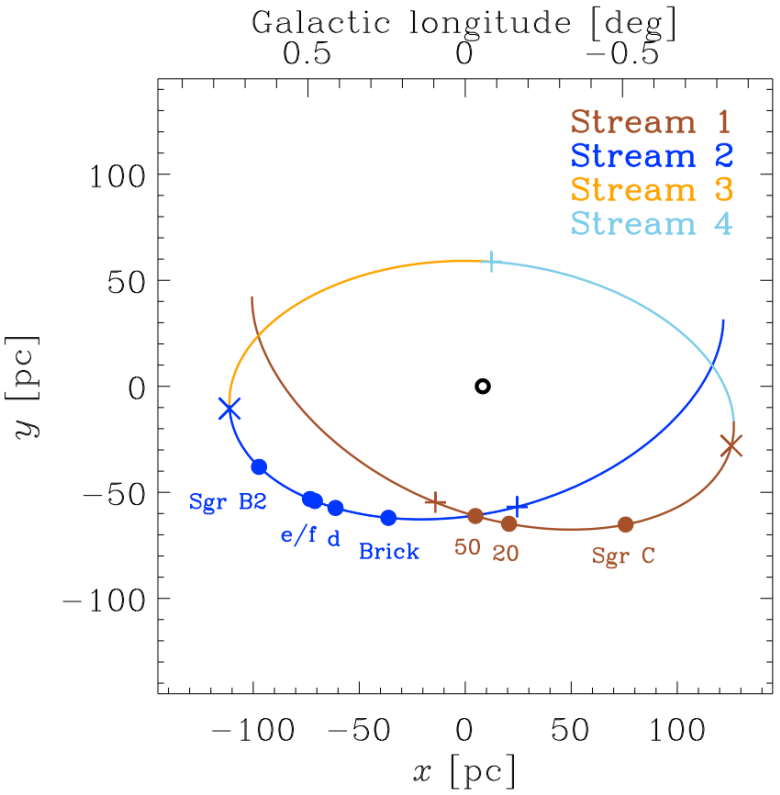
Molinari+ (201

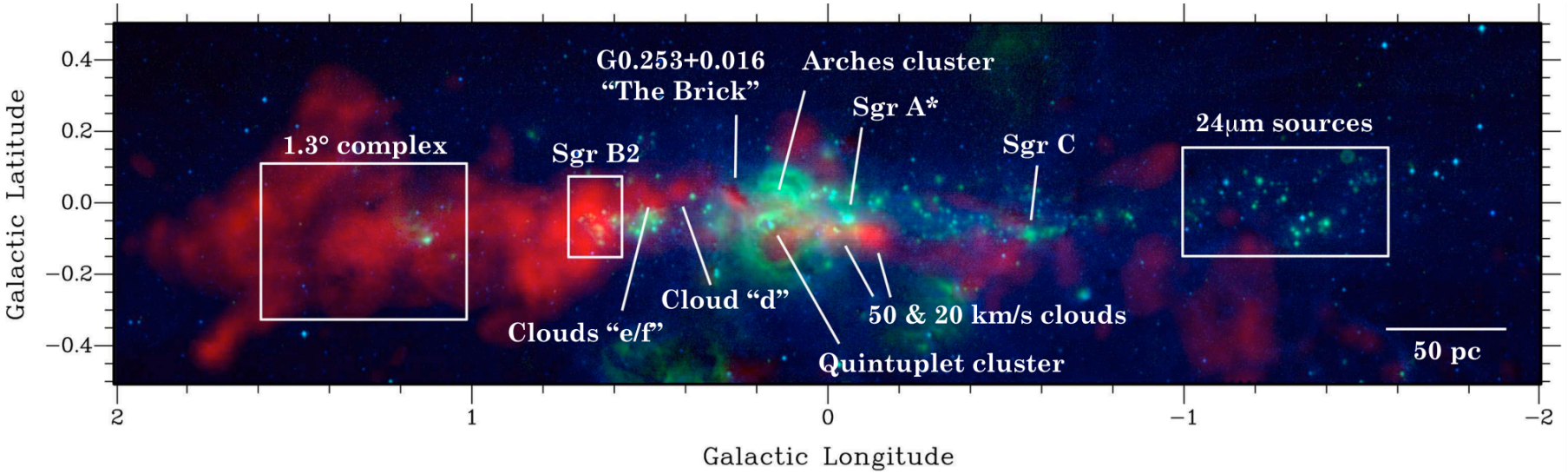
m 2017

The Galactic Center

Gas in the GC

- Possibility of a SF sequence (Longmore+ 2013; Kruijssen+ 2015)
- Brick: very dense, massive, compact (10^5 Mo), but hardly any SF, many substructure and internal shocks (Rathborne+ 2015)
- Some SF, masers, evolved stars in clumplets
- Extreme SF in Sgr B2
- Fading toward B1?
- 24μm sources (YSOs?) excess toward negative Glon

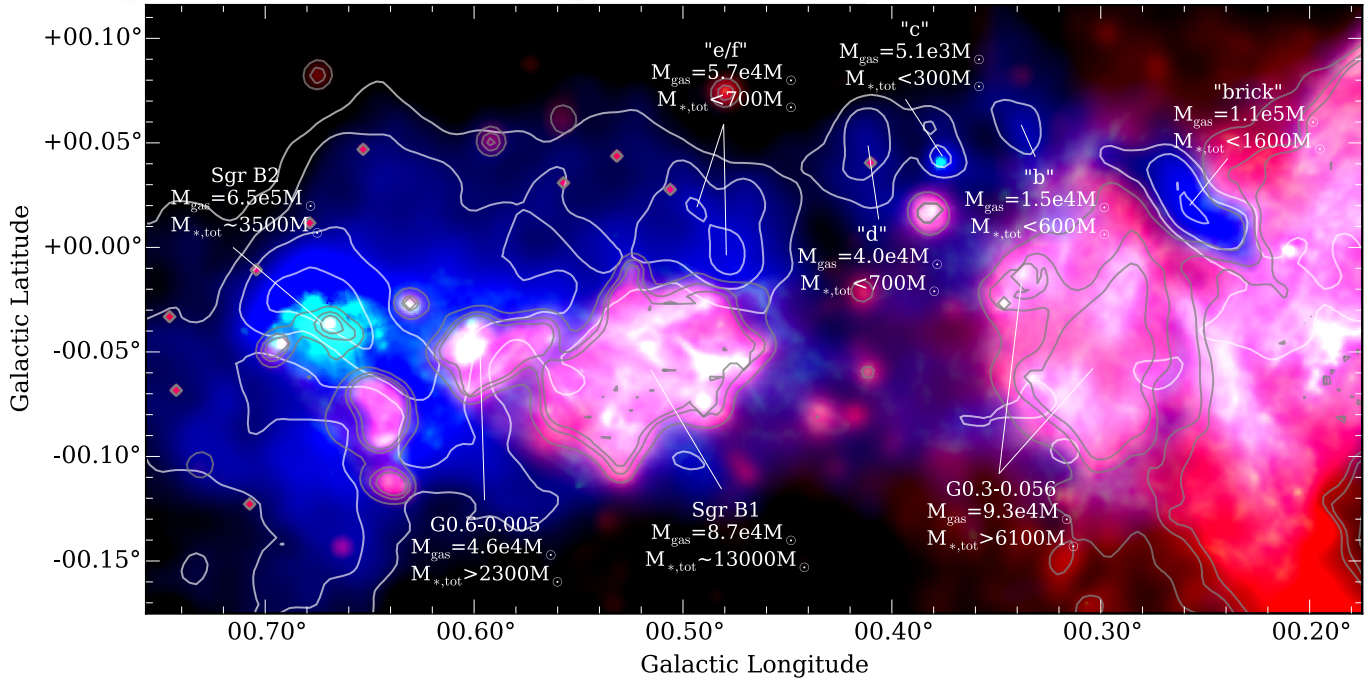




Kruijssen+ (2014b)

Longmore et al. (2012, 2013a,b, 2014)
Kruijssen, Dale & Longmore (2015)
Henshaw, SNL, et al (2015)
Rathborne, SNL, et al (2014, 2015a,b)

Barnes, Longmore et al (in prep.)



= cold (molecular) gas

= warm (ionised) gas

= young/forming stars

200 pc

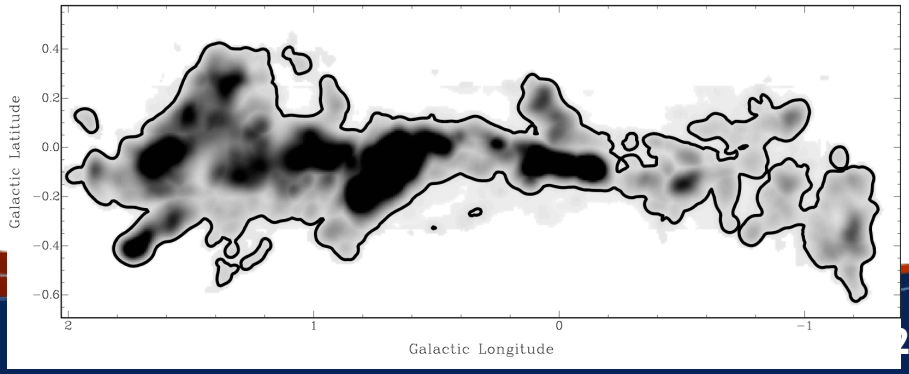
SWAG: Survey of Water and Ammonia in the Galactic Center

- ATCA (H75 config, 64M-32k mode)
- 525 hours
- $-1^\circ \lesssim l \lesssim +2^\circ$, $|b| \lesssim 0.4^\circ$, central 400 pc (CMZ)
- > 6500 pointings
- 21.2 - 25.4 GHz
- 42 lines + 4 GHz continuum

  NH_3 (1,1) – (6,6), H_2O, radio recombination lines, …

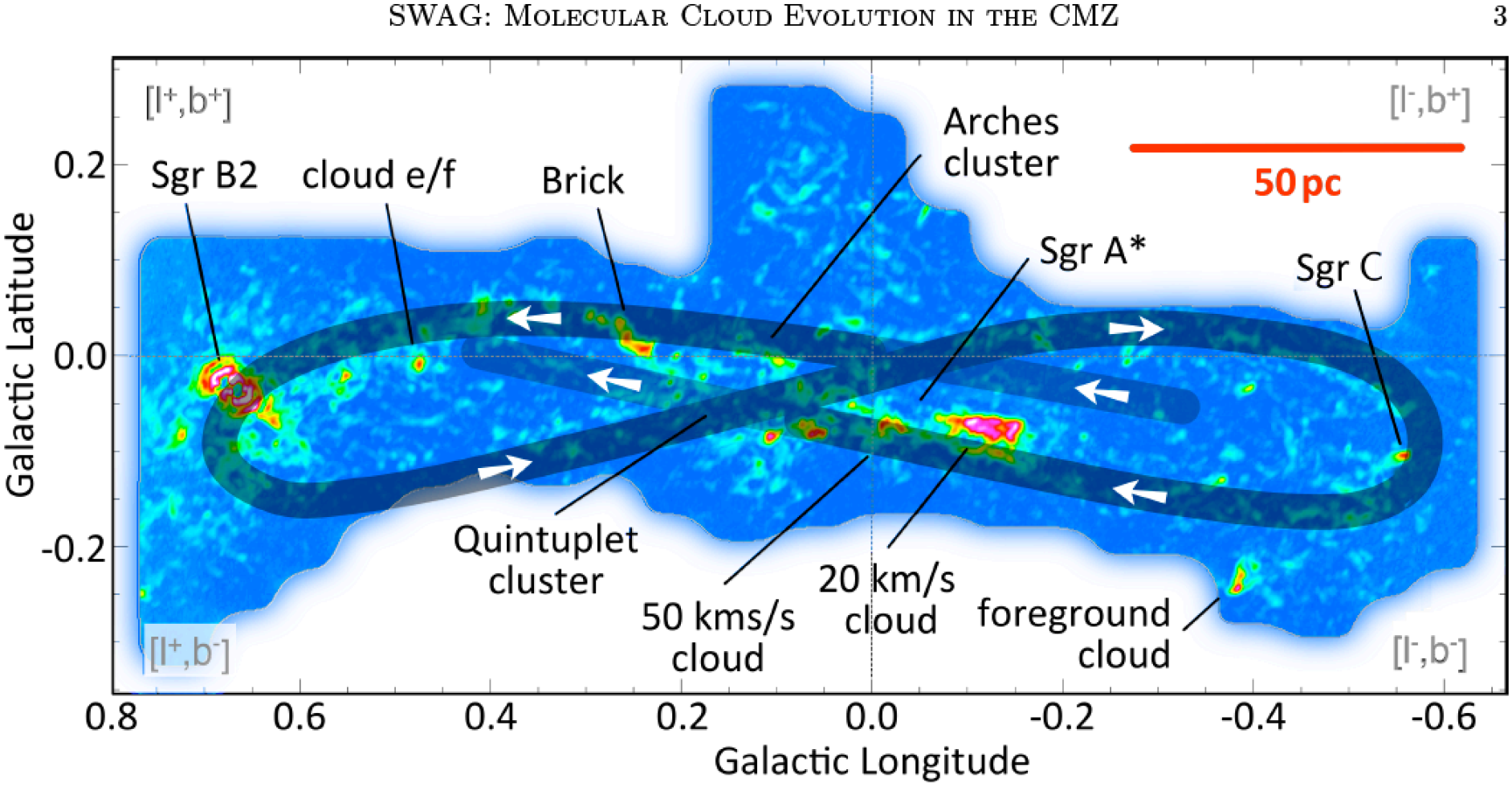
  temperature, maser, shock, photon-dominated region, …
- resolution: ~20” or ~0.8 pc, 0.4 km/s
- rms: ~8mJy/beam in a 2km/s channel (~18mJy/beam Glon<Sgr C)

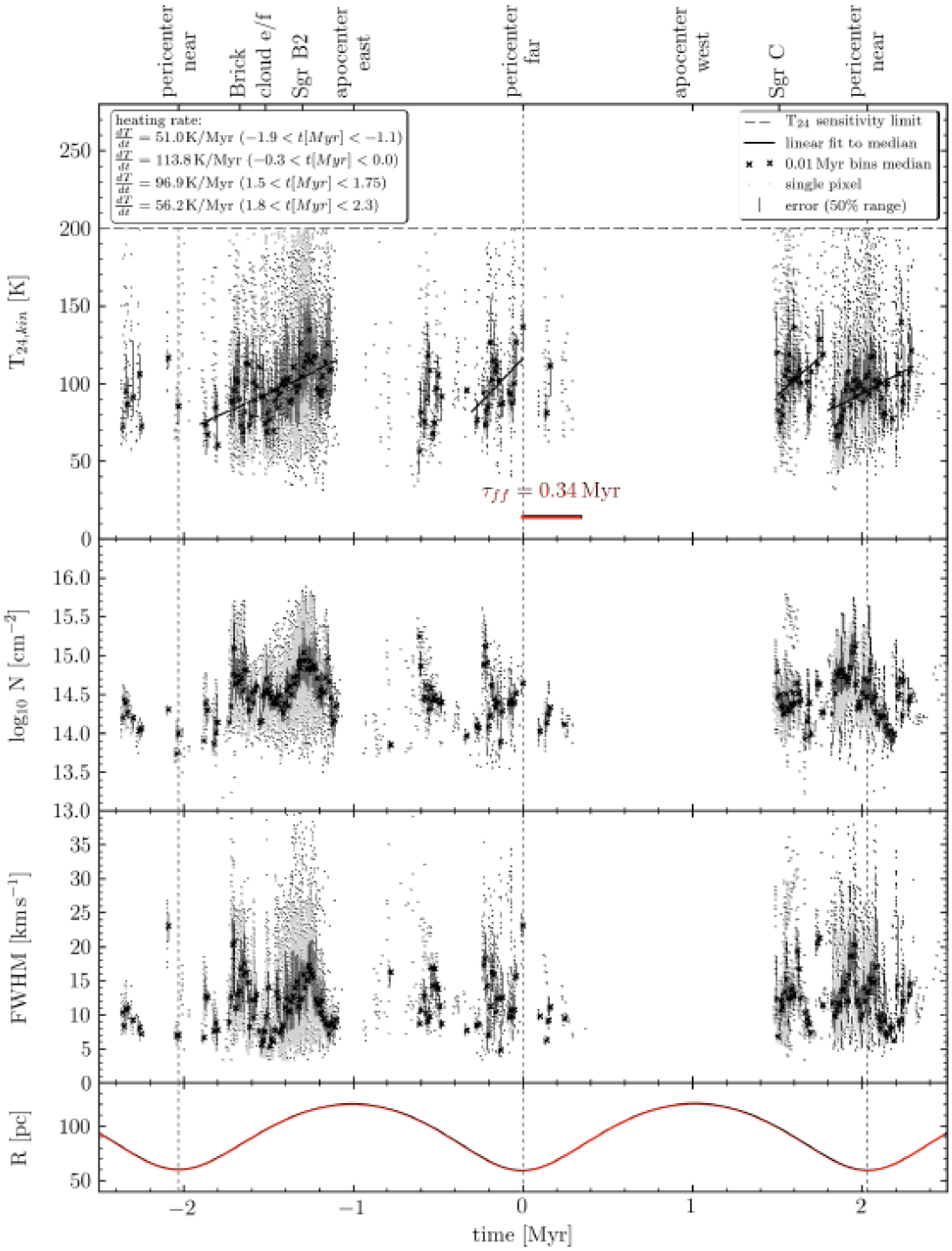
https://sites.google.com/site/atcaswag/

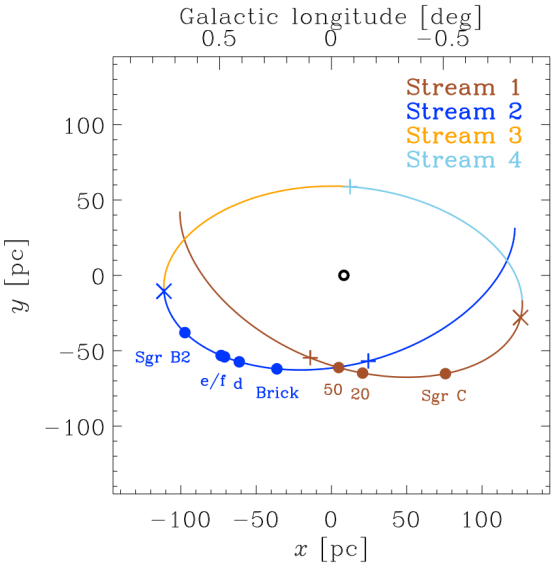


Mopra NH_3 map (Ott +14)

Krieger et al. (2017)

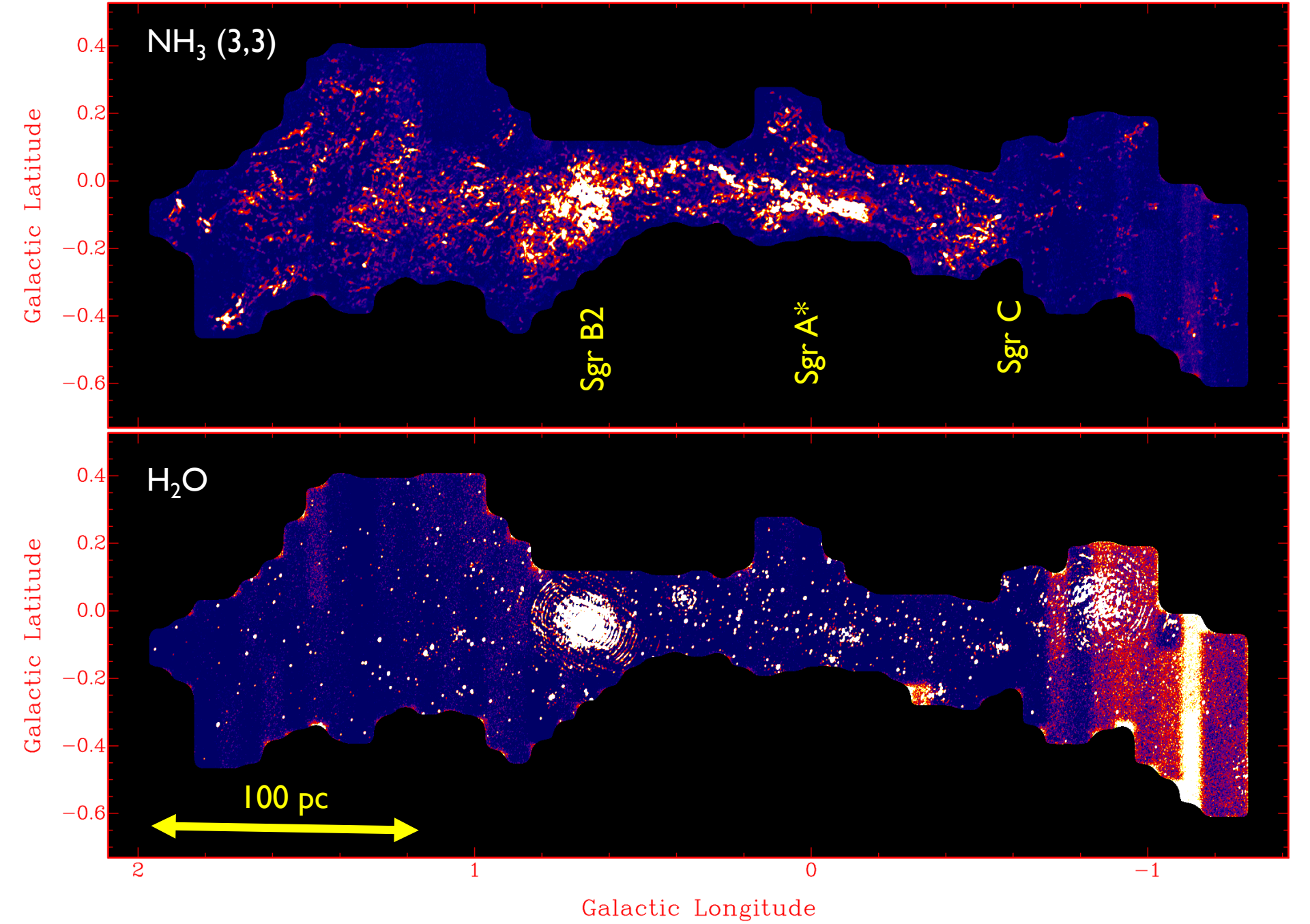


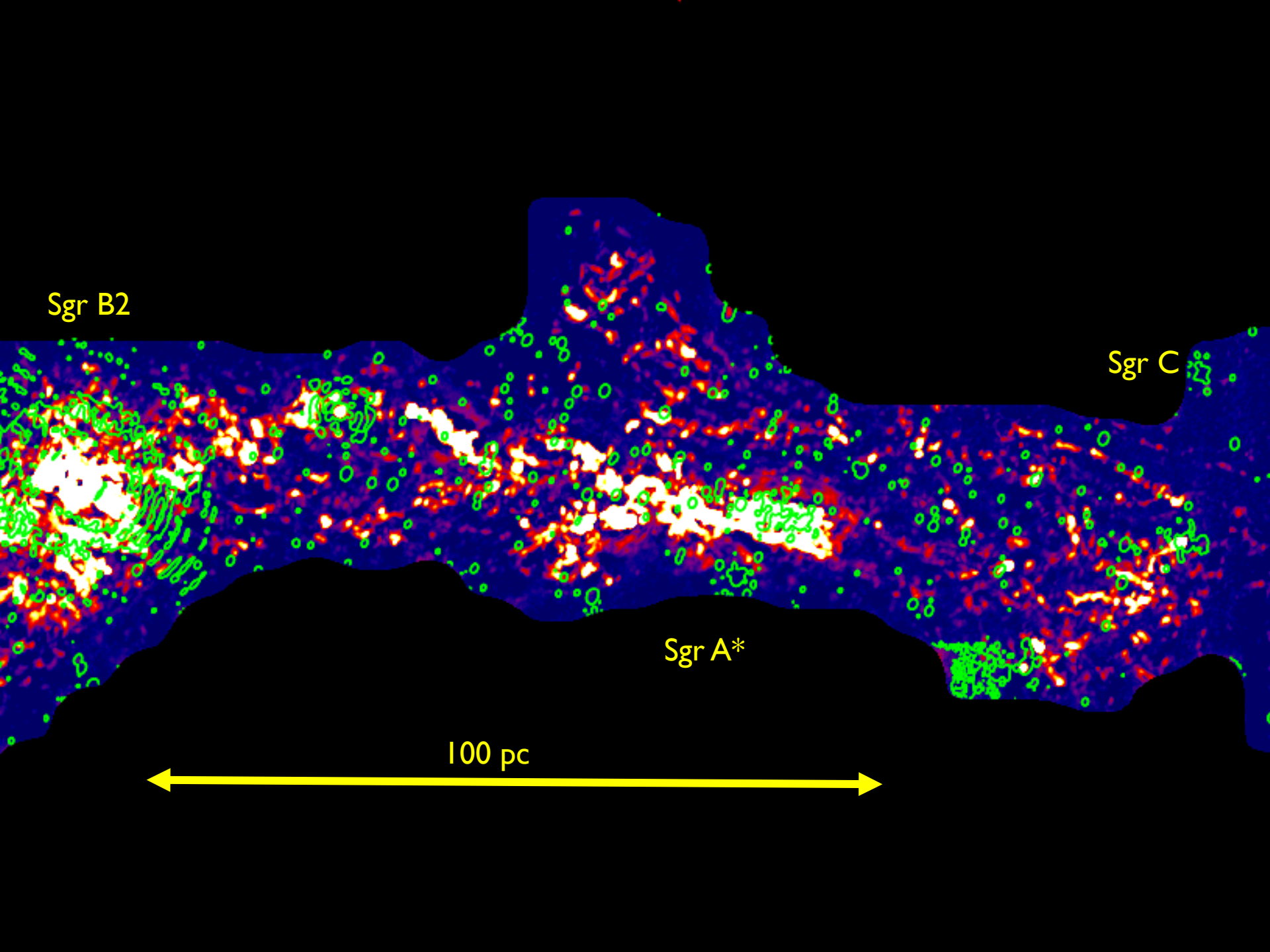


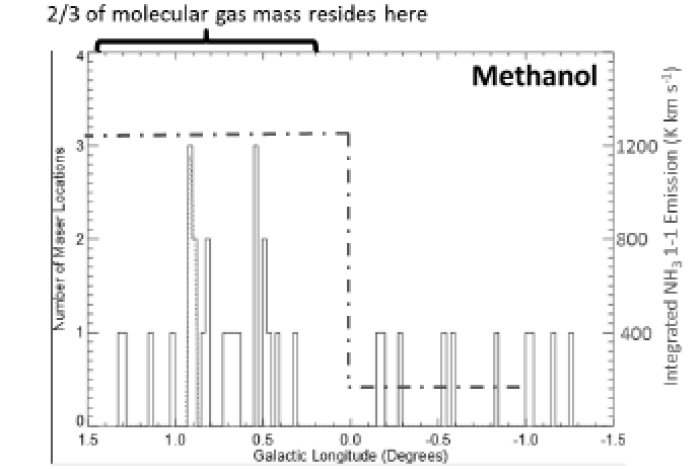


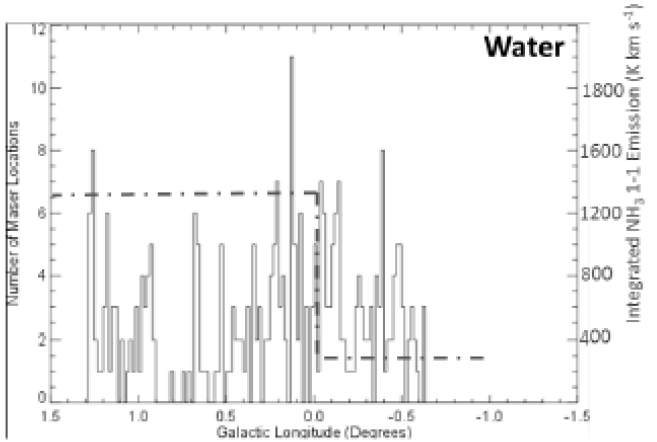
Close to each pericenter passage, the gas temperature appears to rise, possibly due to compression of gas clouds

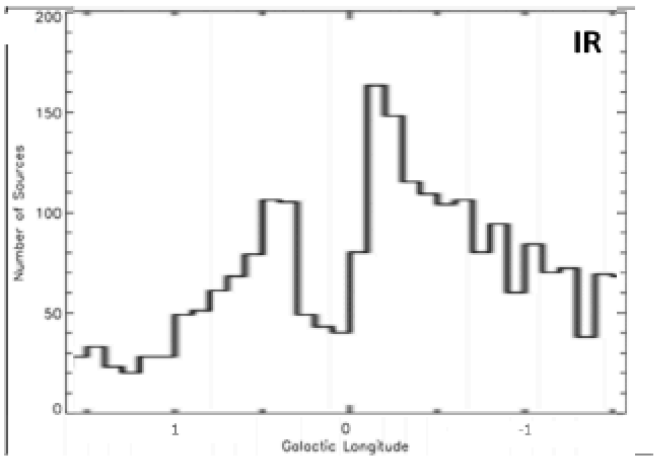
Krieger et al. (2017)


NH3 (3,3)
H2O
Sgr B2
Sgr A*
Sgr C
100 pc
Galactic Latitude
Galactic Longitude
0.4
0.2
0.0
−0.2
−0.4
−0.6
2
1
0
−1


Sgr B2
Sgr C
Sgr A*
100 pc







Rickert et al. (2017) PhD thesis

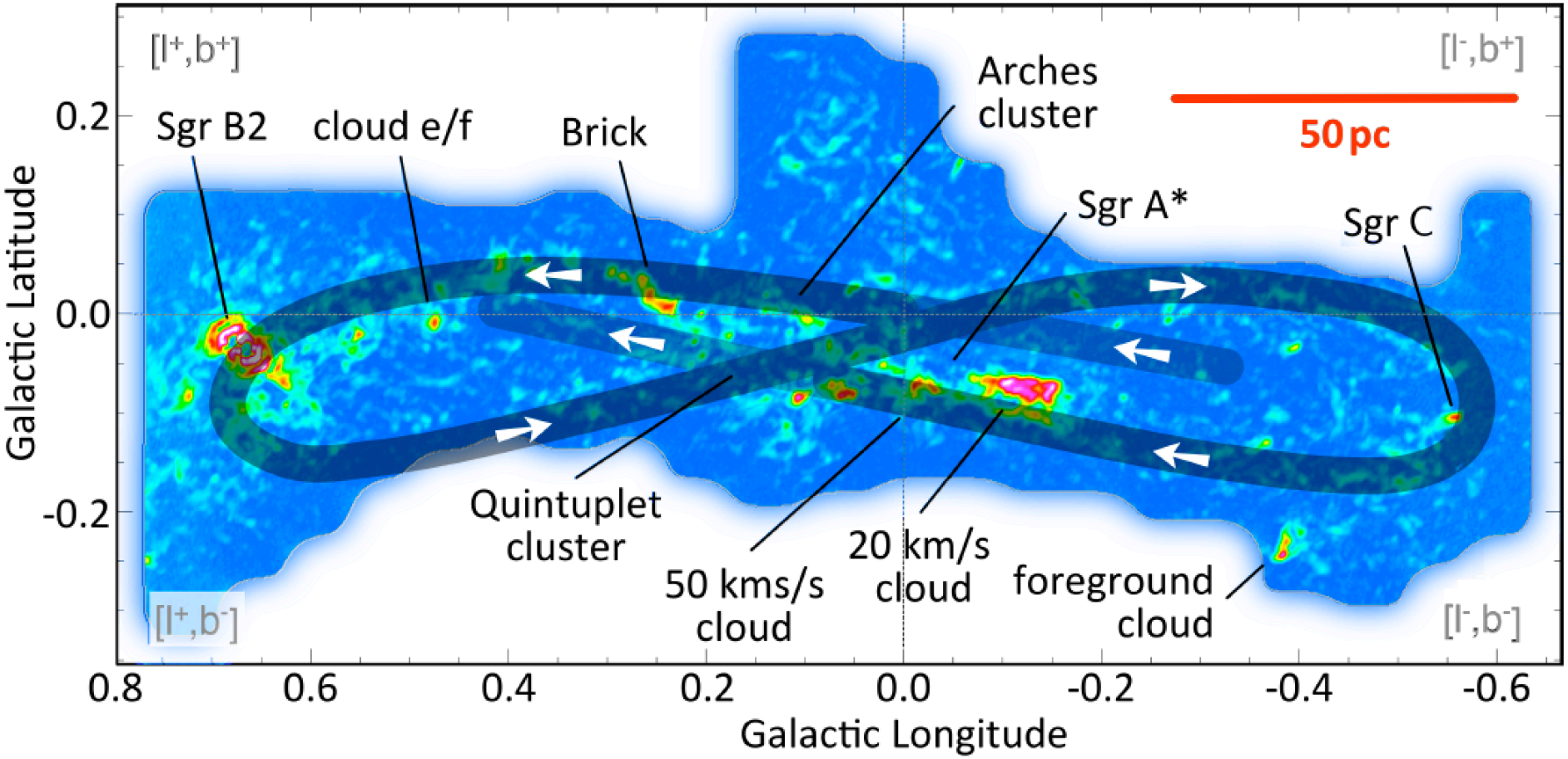
Asymmetry in YSO sources, based on FIR emission. Excess at negative Glon. (Yusef-Zadeh et al. 2009)

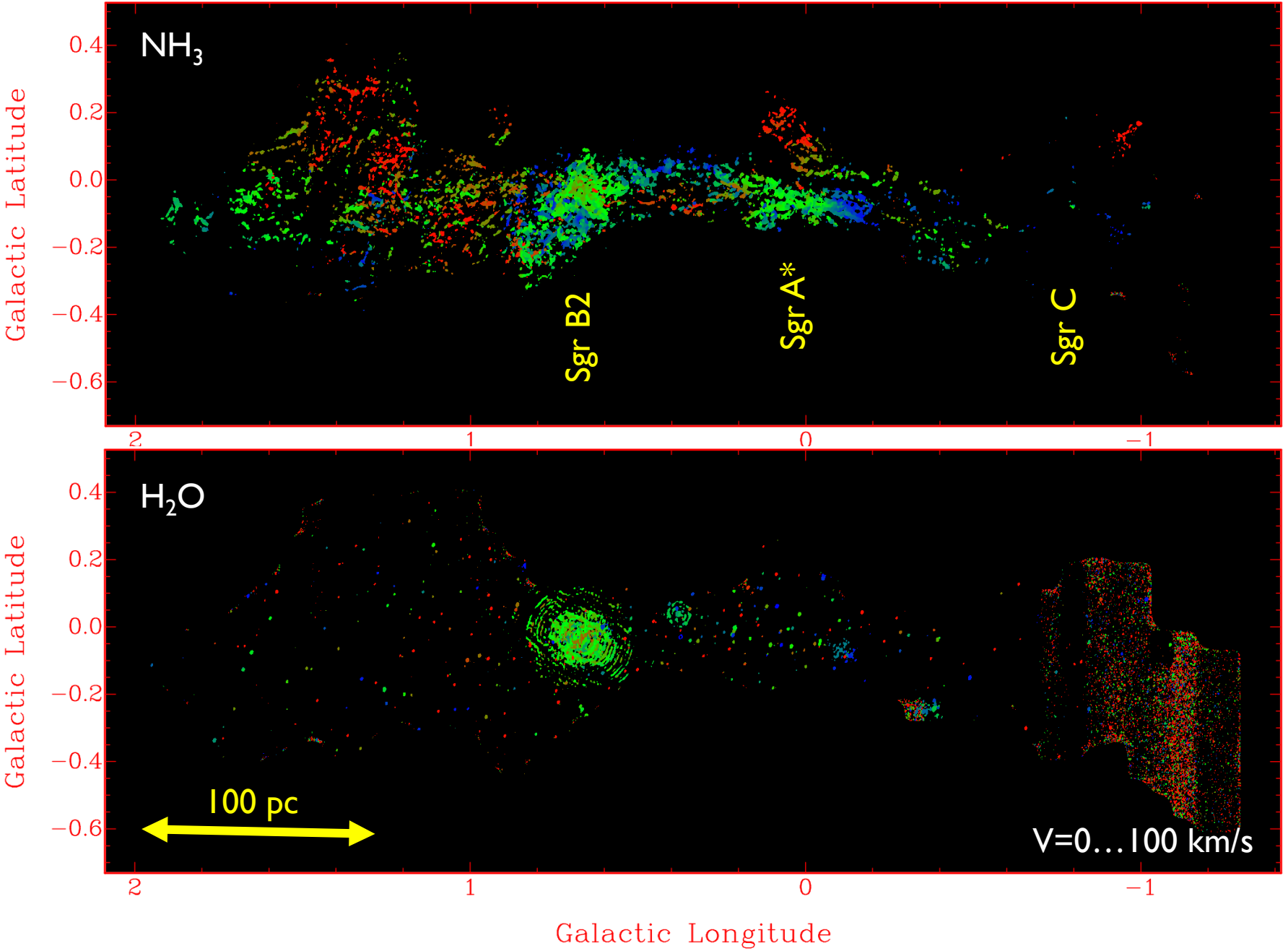
Gas has asymmetry with bulk at positive Glon.

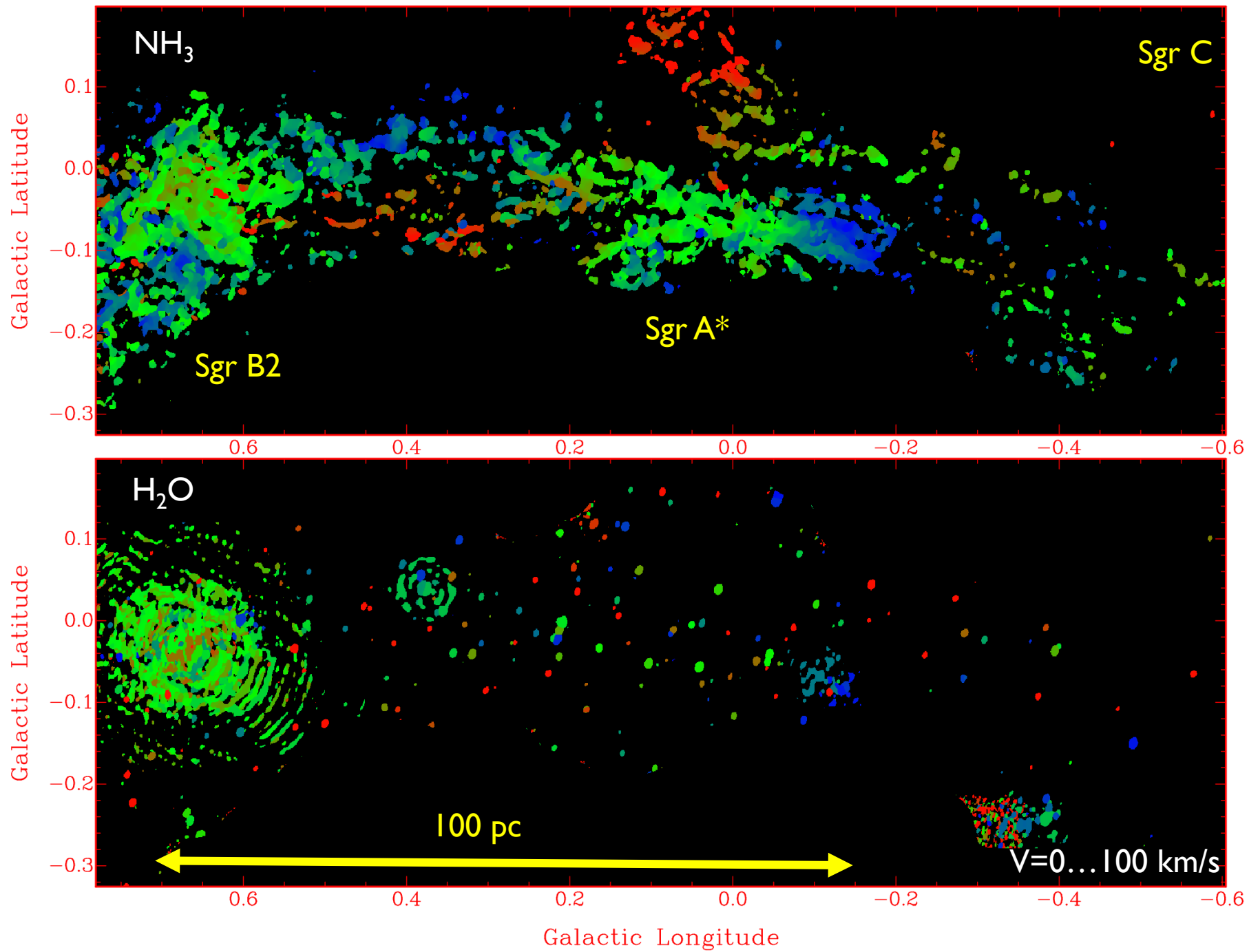
H_2O maser distribution peaks at Glon=0

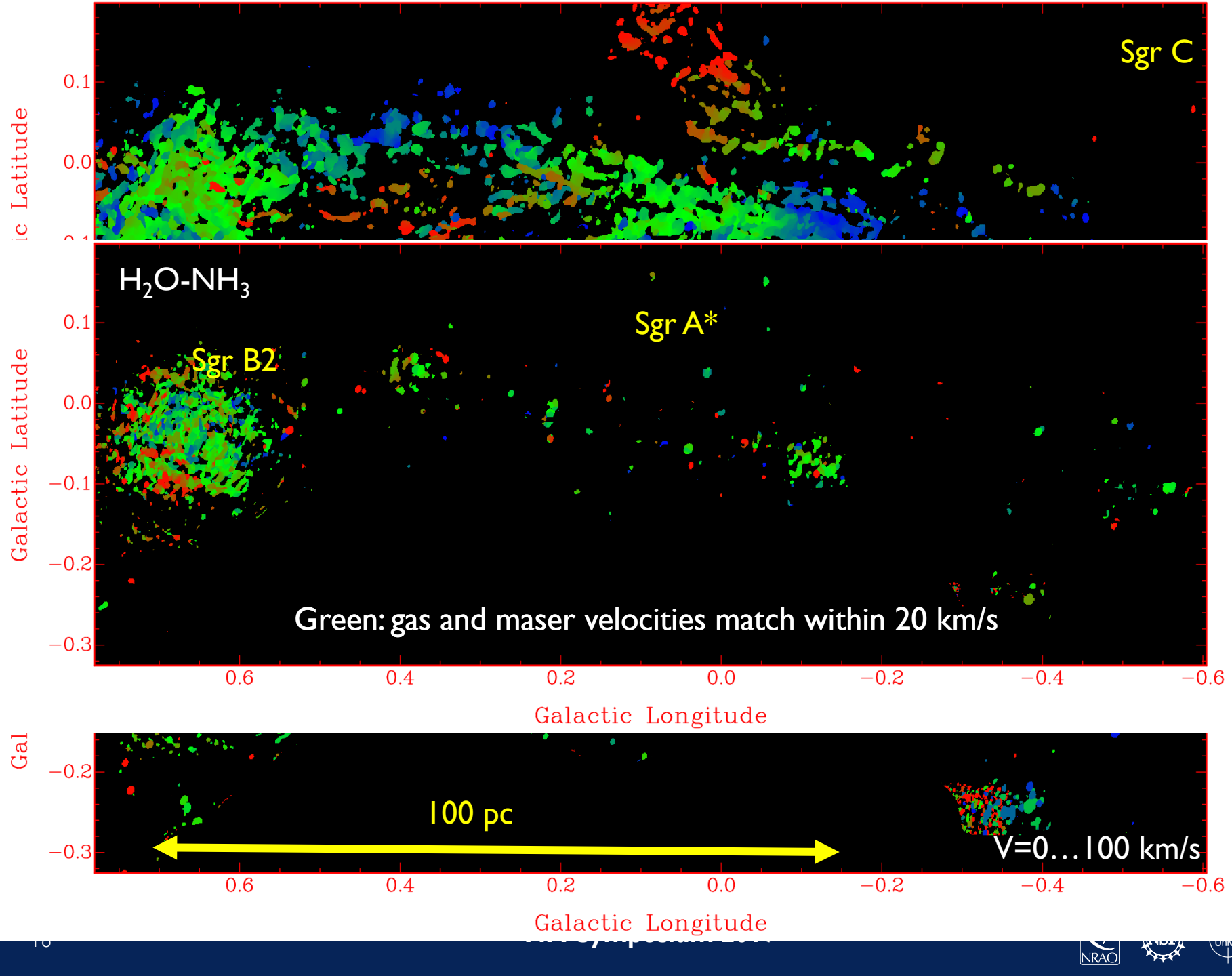
Methanol masers appear to follow the gas (VLA survey)

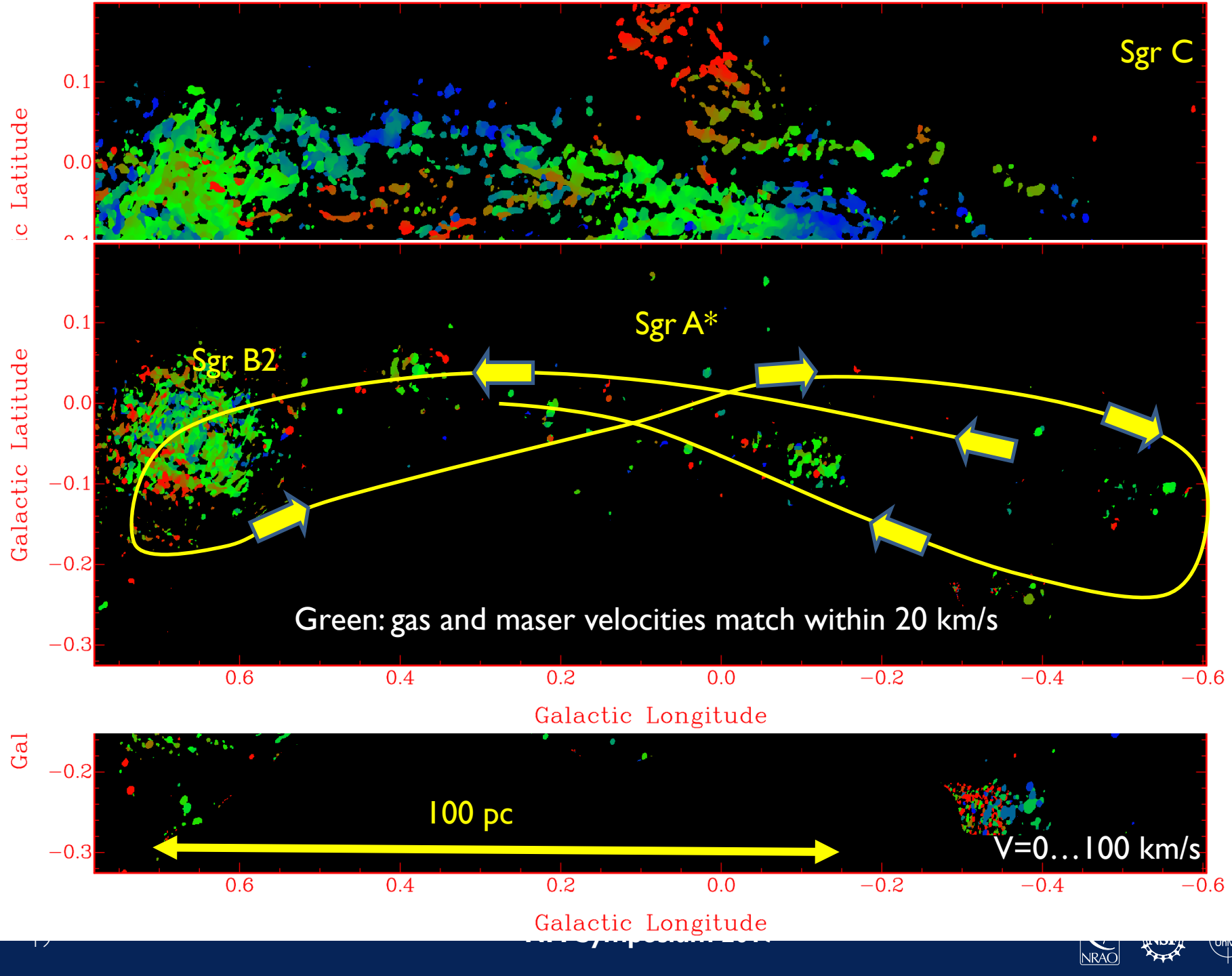
YSO candidates (Yusef-Zadeh et al. 2009)


[l+,b+]
[l-,b+]
[l+,b-]
[l-,b-]
Sgr B2
cloud e/f
Brick
Arches cluster
50 pc
Sgr A*
Sgr C
Quintuplet cluster
50 kms/s cloud
20 km/s cloud
foreground cloud
Galactic Latitude
0.2
0.0
-0.2
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
Galactic Longitude


NH3
H2O
Sgr B2
Sgr A*
Sgr C
100 pc
V=0…100 km/s
Galactic Latitude
Galactic Latitude
Galactic Longitude
0.4
0.2
0.0
−0.2
−0.4
−0.6
2
1
0
−1


NH3
Sgr C
Sgr A*
Sgr B2
H2O
100 pc
V=0…100 km/s
Galactic Latitude
Galactic Longitude
0.1
0.0
−0.1
−0.2
−0.3
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6

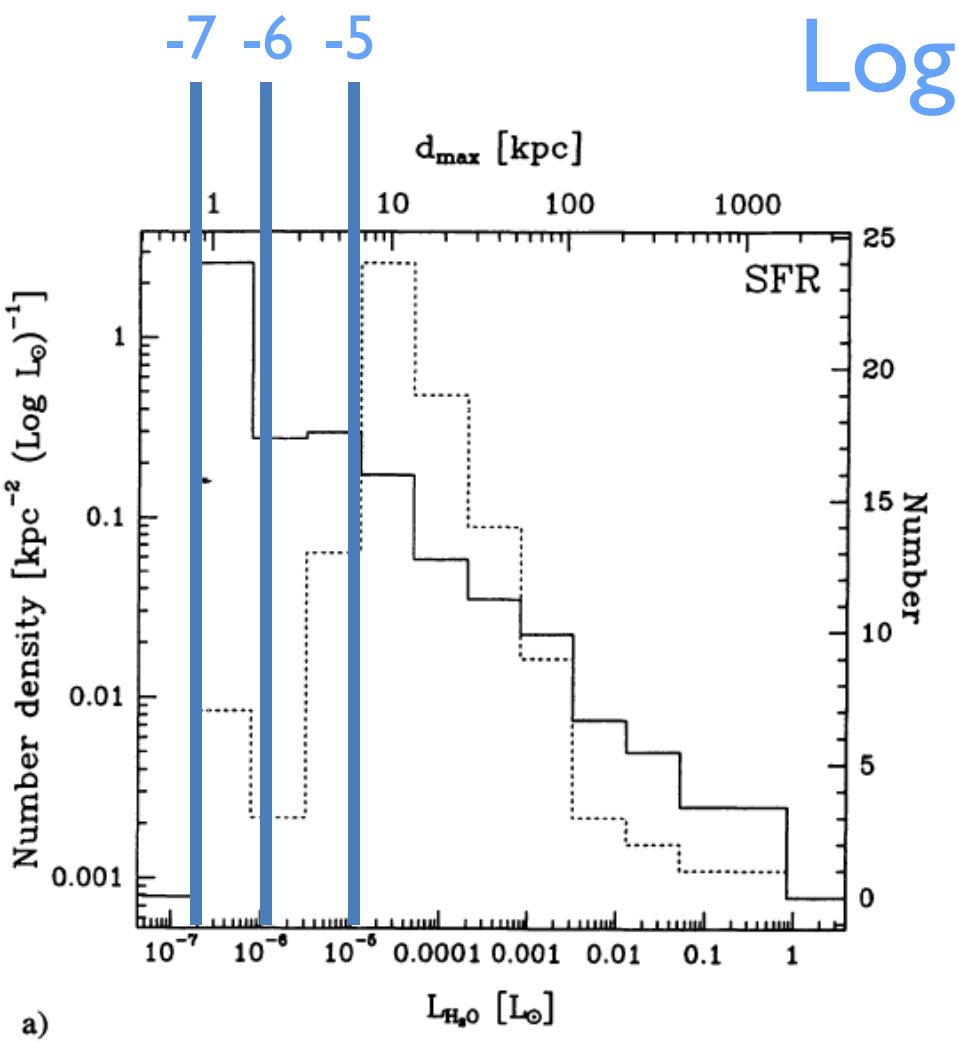

Sgr C
H_2O-NH_3
Sgr A*
Sgr B2
Green: gas and maser velocities match within 20 km/s
Galactic Latitude
Galactic Longitude
100 pc
V=0…100 km/s
0.1
0.0
−0.1
−0.2
−0.3
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6

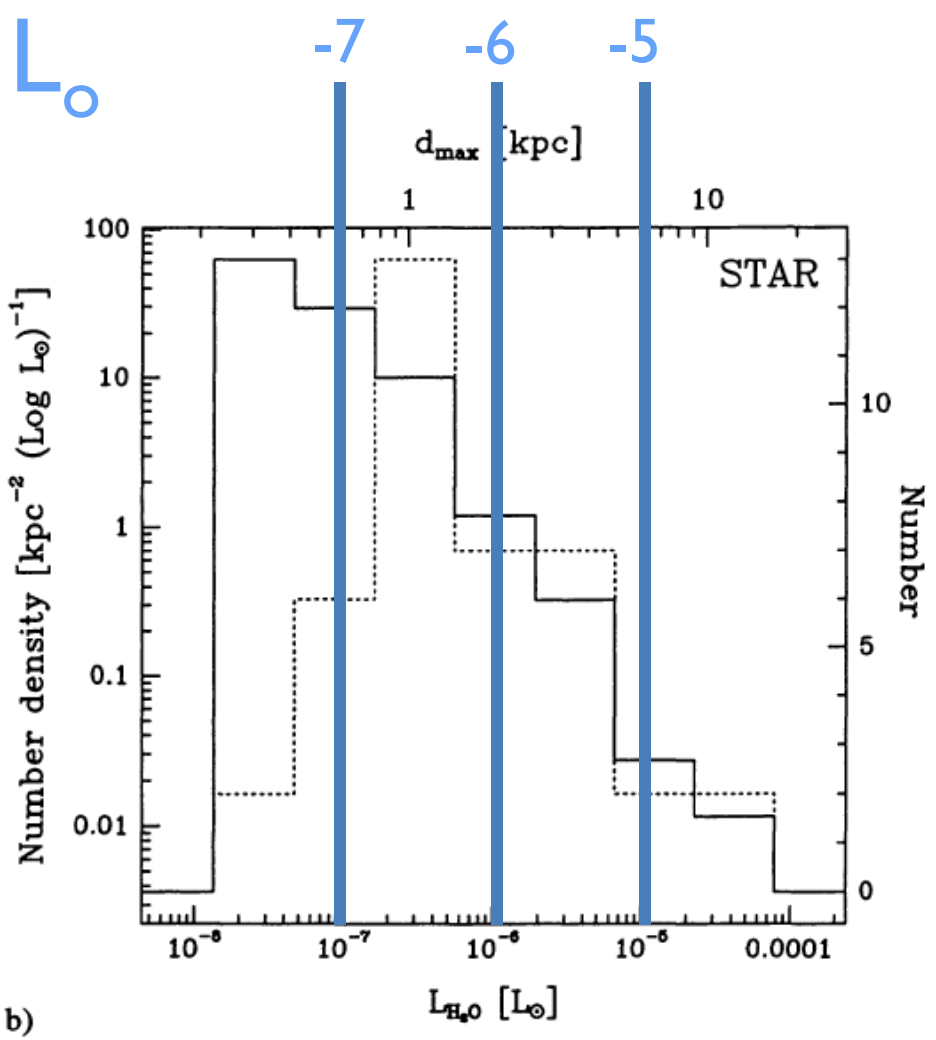

Sgr C
Sgr A*
Sgr B2
Green: gas and maser velocities match within 20 km/s
100 pc
V=0…100 km/s
Galactic Latitude
Galactic Longitude
0.1
0.0
−0.1
−0.2
−0.3
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6

YSO

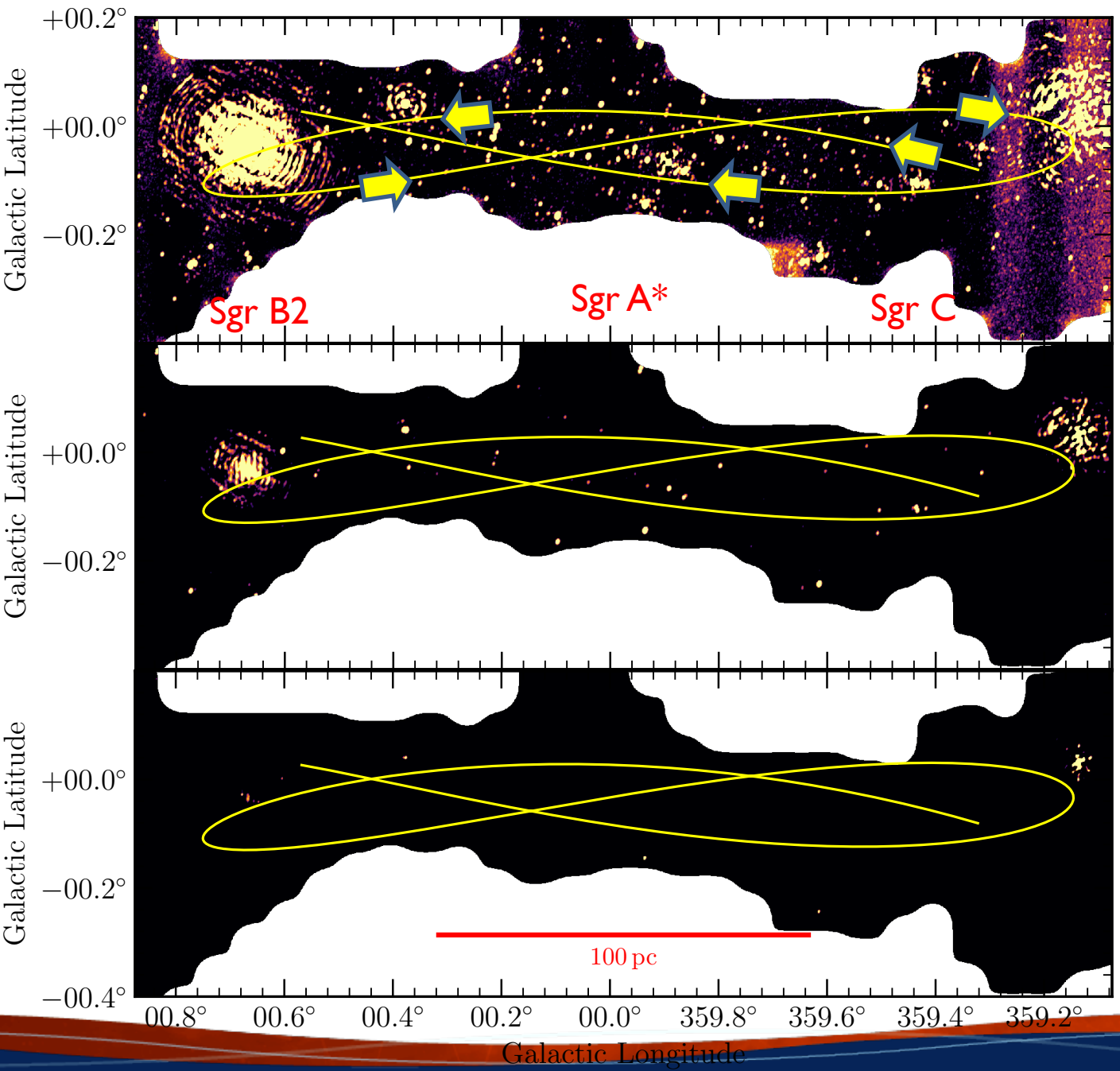
AGB

Log L_o





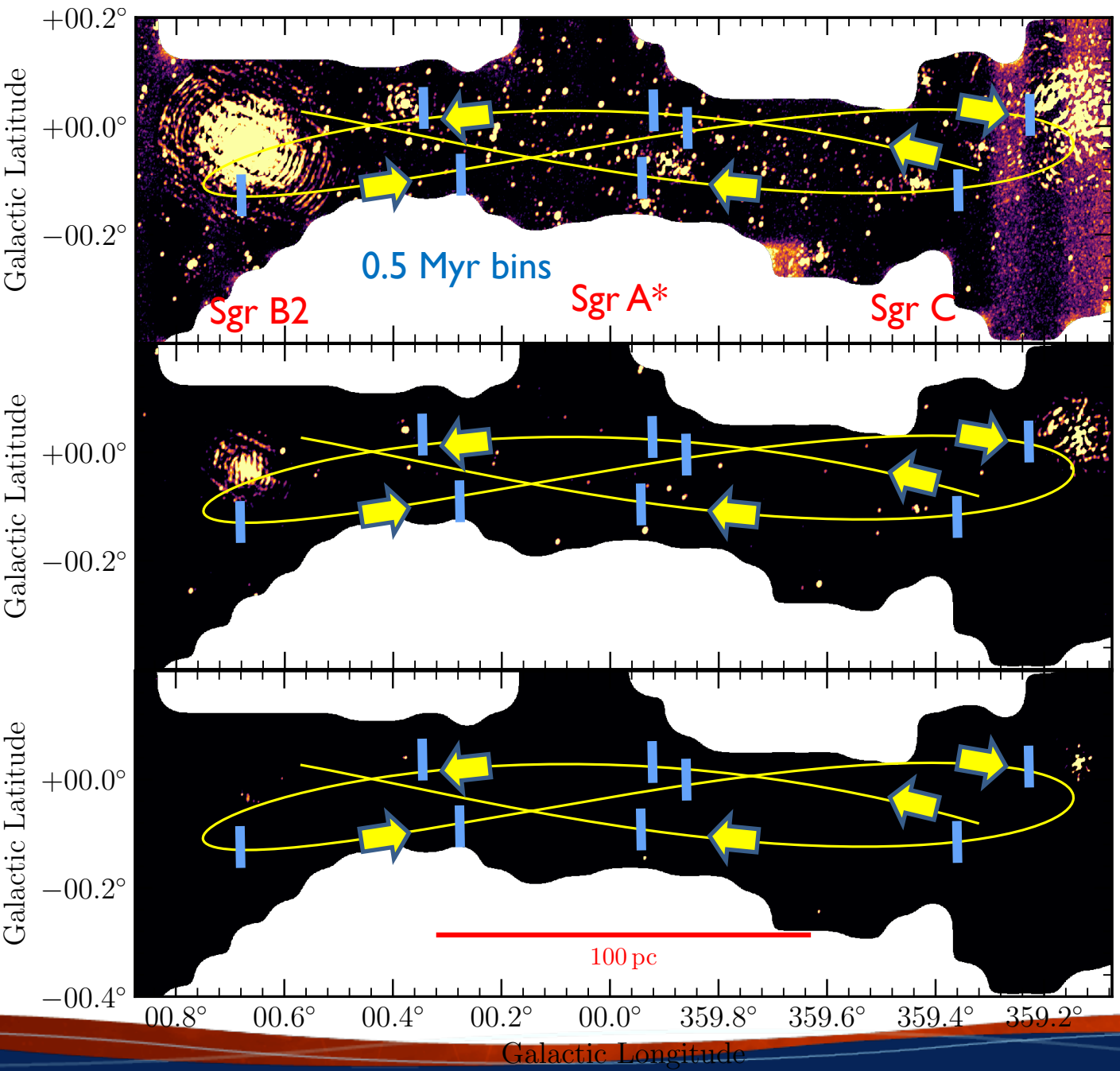
Palagi et al. (1993)



L (8.5kpc) $>10^{-7}$ L_o

L (8.5kpc) $>10^{-6}$ L_o

L (8.5kpc) $>10^{-5}$ L_o



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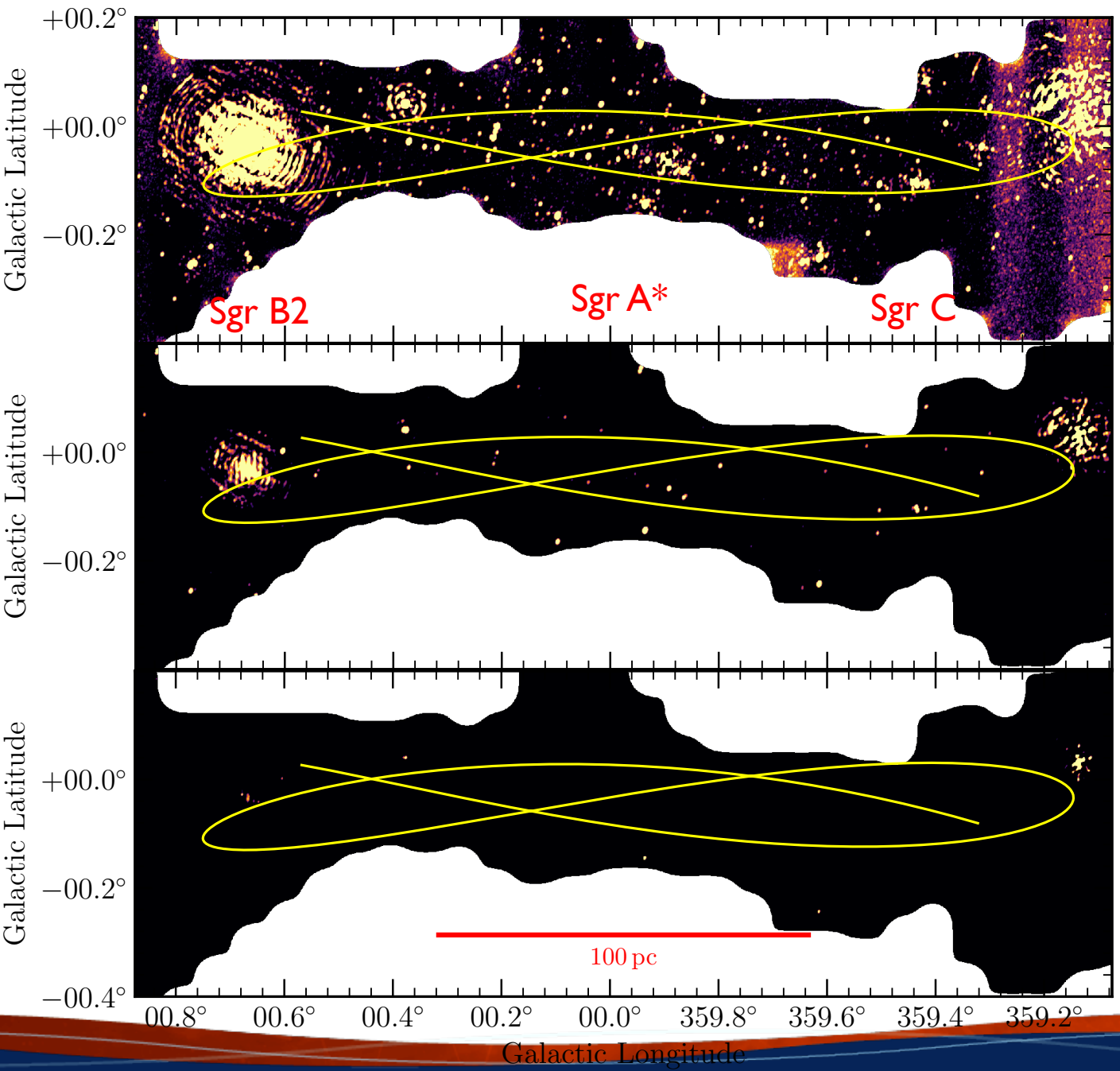
L (8.5kpc) $>10^{-6}$ L_o

L (8.5kpc) $>10^{-5}$ L_o



Concentration ↔ Uniformity

Single/multiple ν comp ↔ two ν comp Δv~30km/s

YSO ↔ AGB

Summary

- We detect o(600) water masers in the CMZ (5σ=50mJy) > 1 order of magnitude more masers than previously known
- The low luminosity population is likely dominated by AGB stars
- Unlike the IR 24μm sources, water and methanol masers do not show an excess for negative Glon (CH_3OH follows gas, H_2O centered on Glon=0)
- Some YSO/SF masers (H_2O and methanol) can be identified along the streamers (higher luminosities)
- The SF sequence is not contradicted with weak masers near the brick, strong masers near cloud c, very strong masers in Sgr B2, other ~10^{-6} L_o H_2O masers along the gas streamers
- The number of SF related tracers is low enough to be in agreement with other SF tracers which show a low SFR/gas mass ratio

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