NANTEN
Submillimeter Observatory

Large scale and high sensitivity multi line CO surveys toward the Galactic Center

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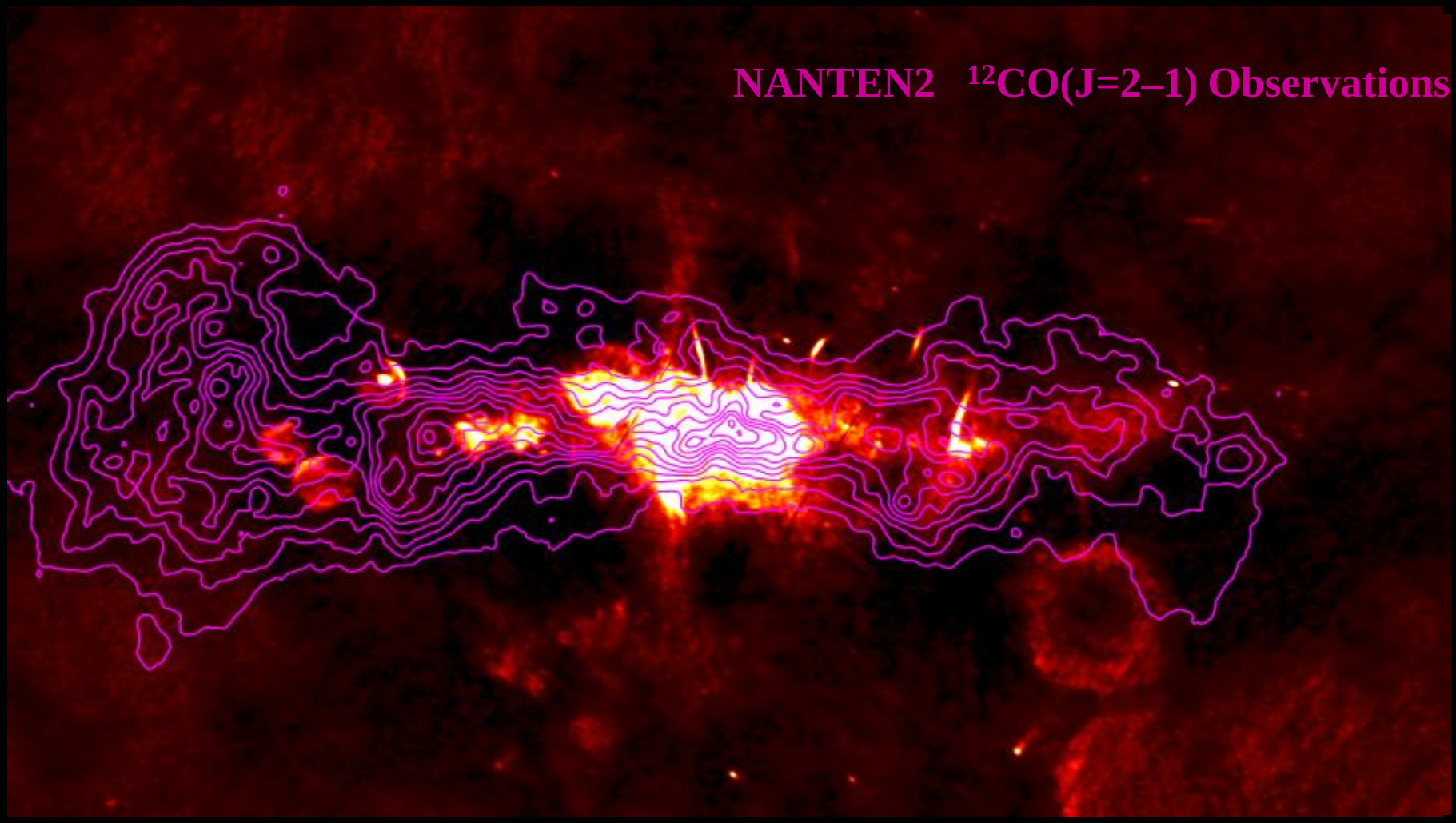
IAU303 (1.Oct. 2013 @Santa Fe)



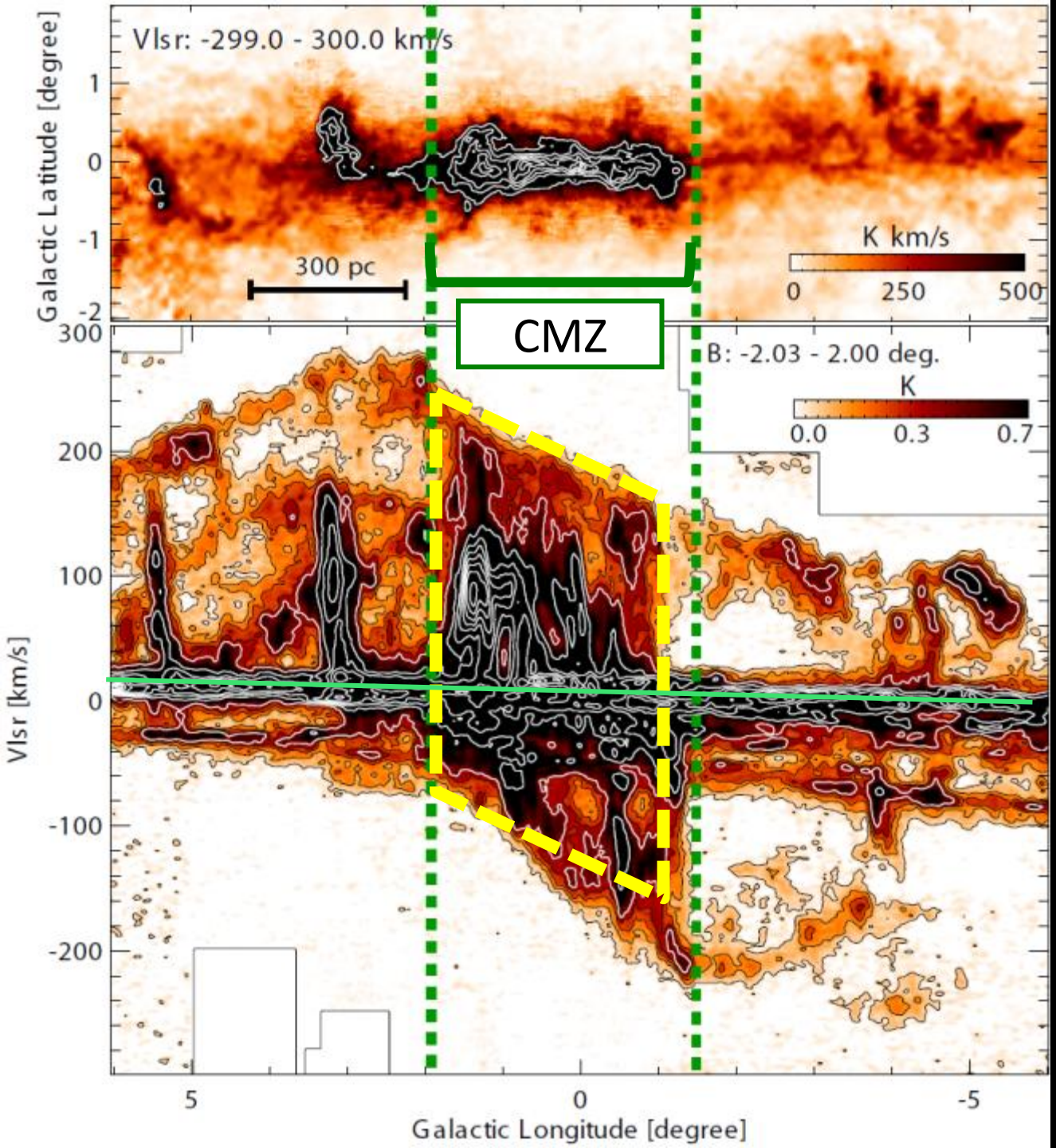
VLA 90 cm Radio continuum
(LaRosa et al. 1999)

CMZ (Central Molecular Zone)
Morris & Serabyn 1996

NANTEN

^{12}CO(J=1 – 0)

Observations

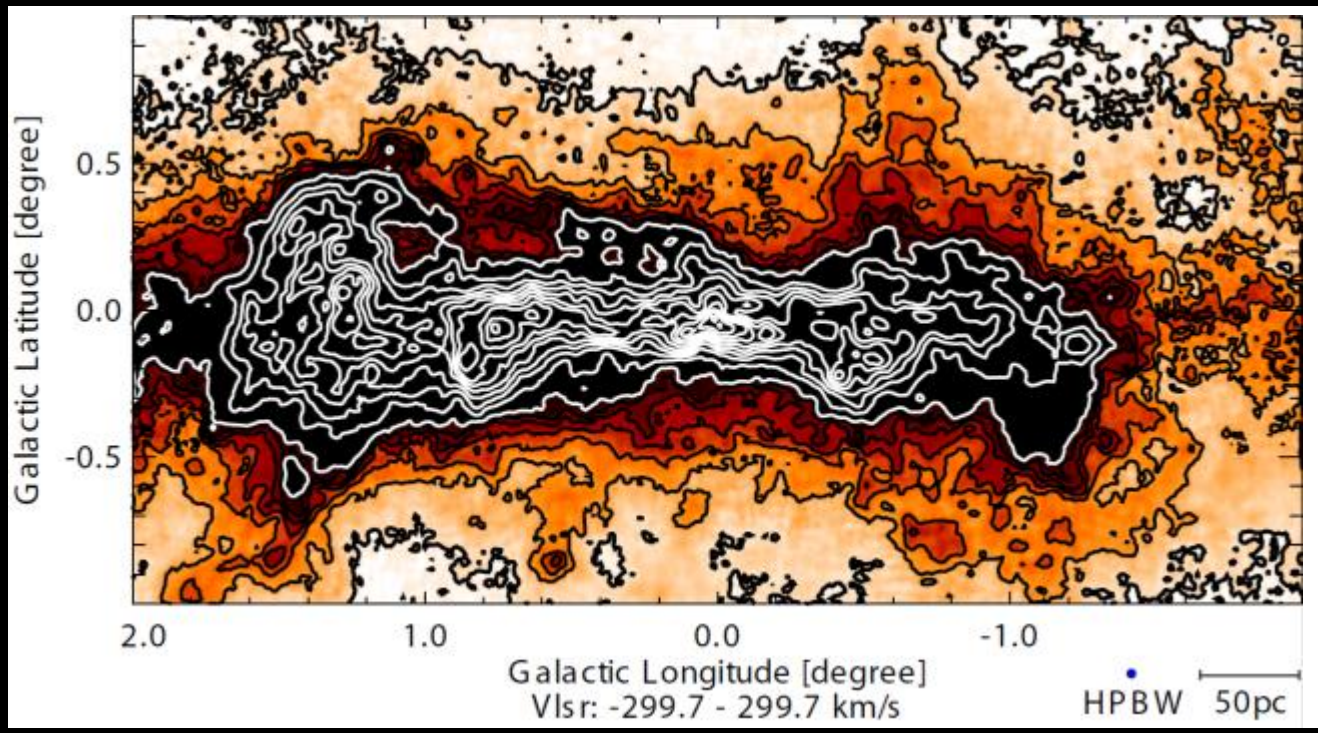


Foreground

Observation (NANTEN2)

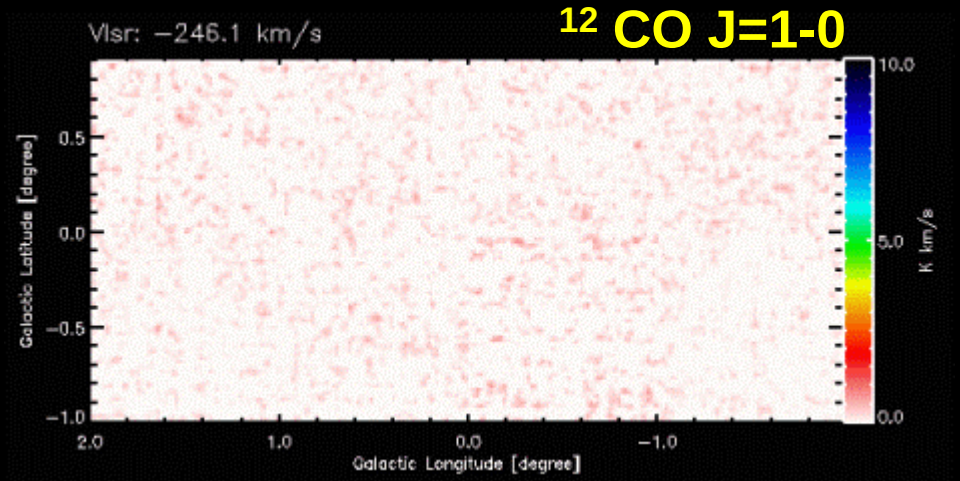
mm / sub-mm telescope

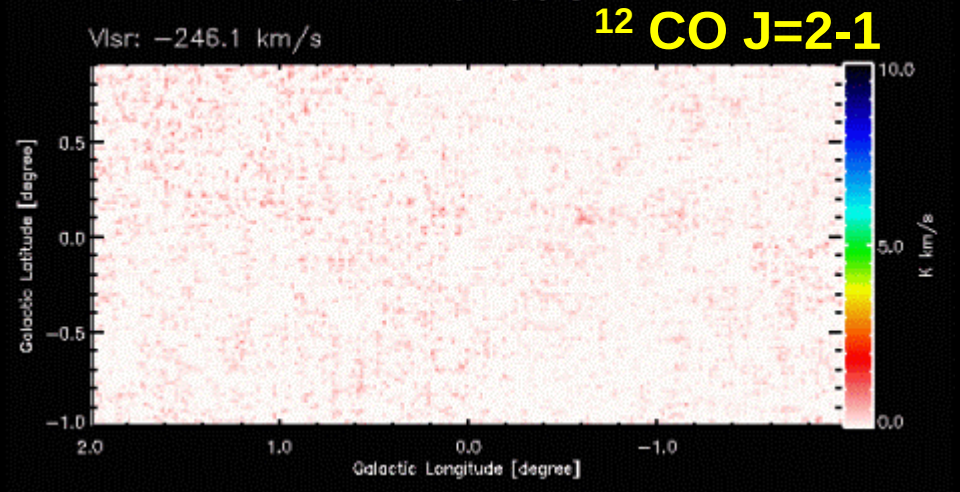
- Atacama, Chile (Alt. 4865m)

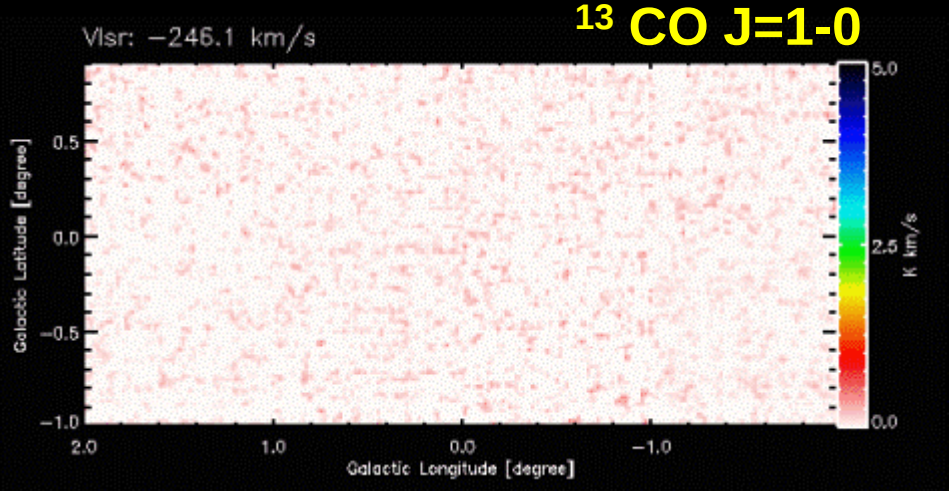


Line	^{12}CO, ^{13}CO (1-0)	^{12}CO (2-1)
Beam size (HPBW)	180”	90”
Spatial resolution (@8kpc)	**7.0 pc**	**3.5 pc**
Vel. resolution (km/s)	0.16	0.08
Sensitivity (K/ch)	**0.58, 0.43**	**0.25**
Covered are (deg)	L =± 10, B=± 1	L=± 2, B=± 1

CO distribution toward the CMZ

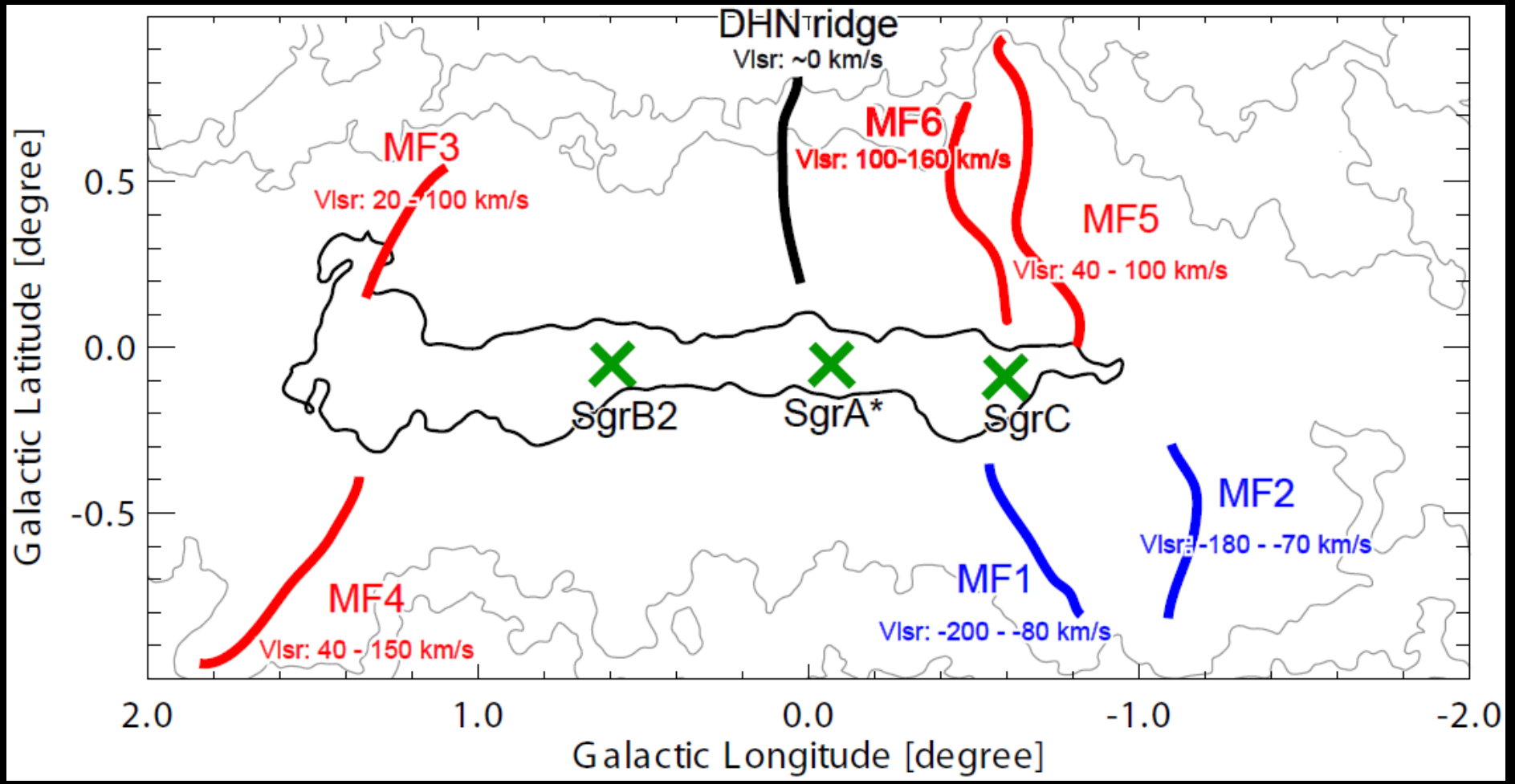






Several molecular filaments are vertically distributed to the plane

Molecular filaments & halo



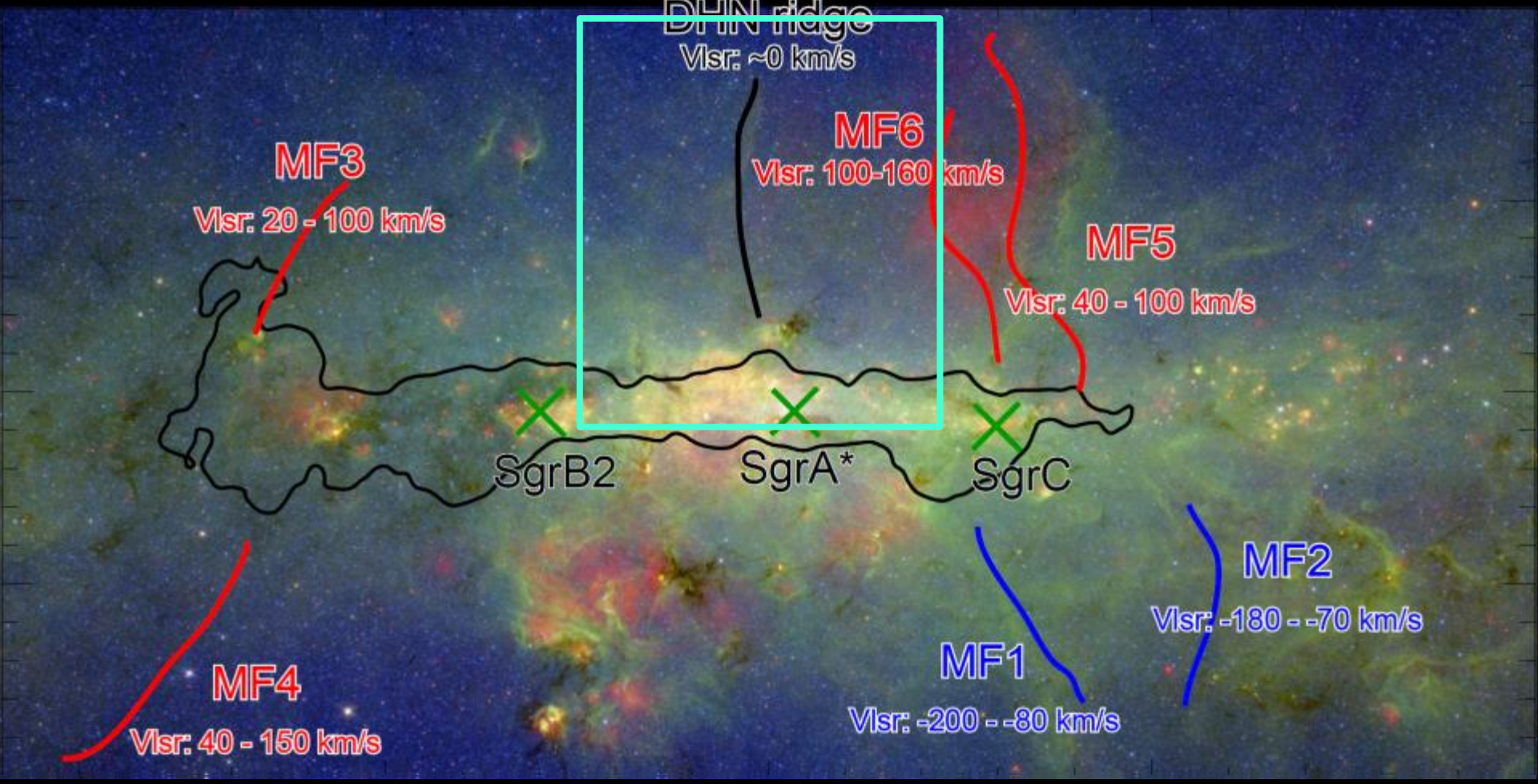
Molecular mass

halo : ~10^6 $M_\odot$ (typically $N(H_2)$~10^{21})

halo + MFs : ~4×10^6 $M_\odot$ (**10% of the M_{CMZ}**)

Xfactor = 7.0×10^{19}
(Torii et al. 2010b)

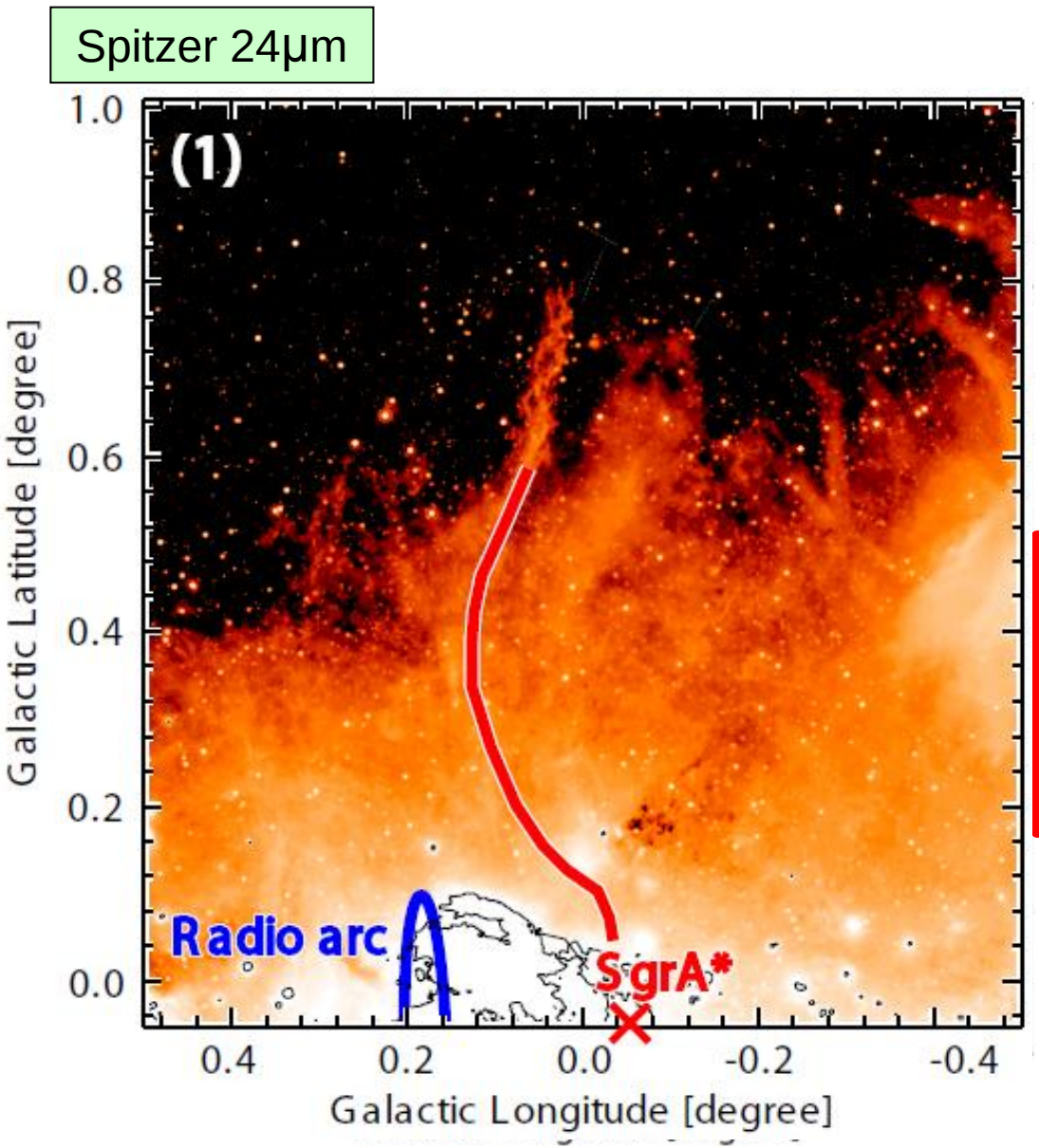
Infrared counterparts to the MFs



Spitzer IRAC+MIPS combine

Red: 24um, Green: 8um

Double Helix Nebula (DHN)



DHN

- ~ 0.7 deg from the GC
- seems to be a magnetic event

(Morris, Uchida & Do. 2006)

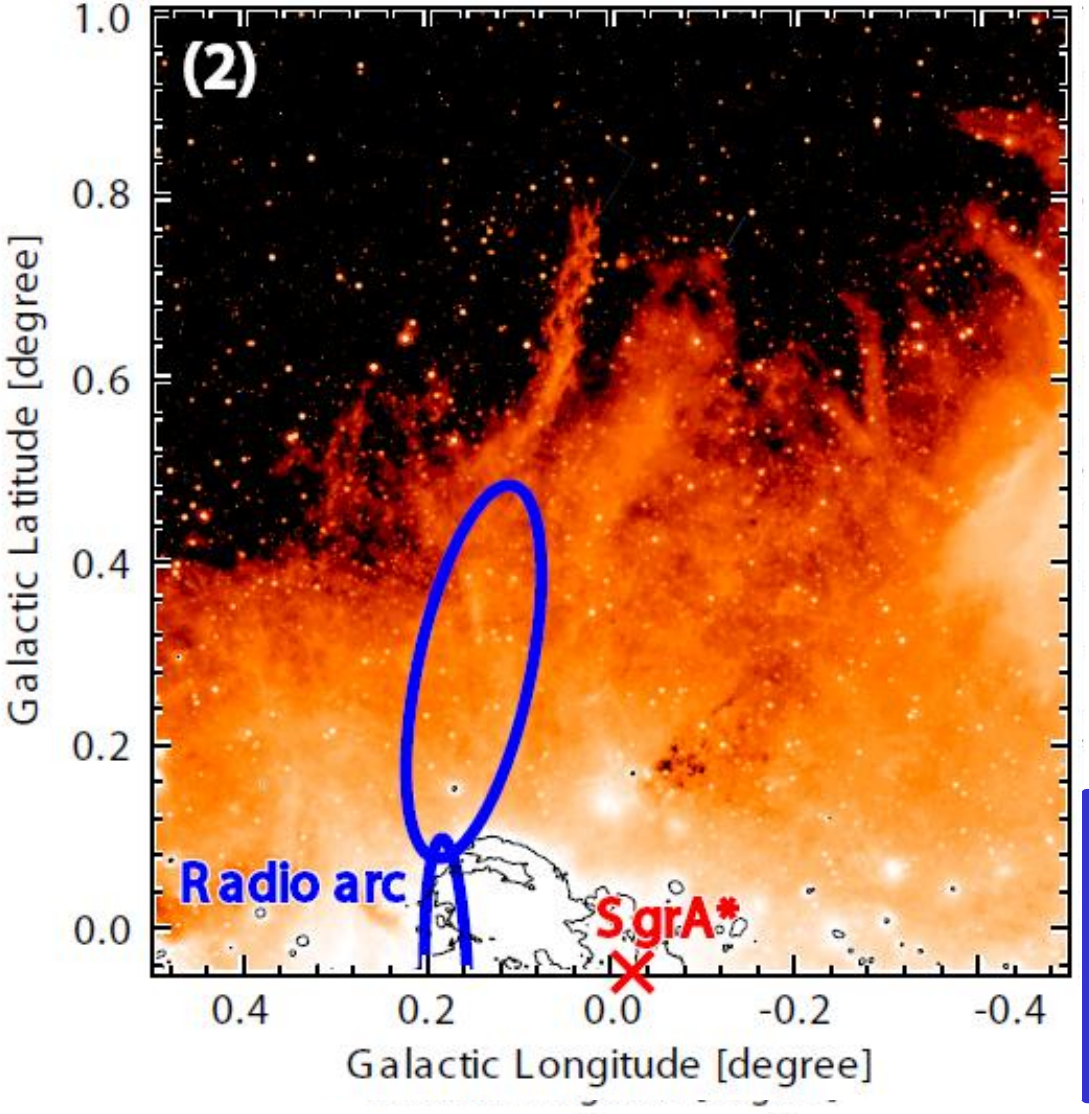
Possible origins..

1. A torsional Alfvén wave launched by rotation of the magnetized CND
(Morris,Uchida & Do.2006)

2. Polarized lobe extending to the radio arc
(Law et al.2008; Tsuboi & Handa 2010)

Double Helix Nebula (DHN)

Spitzer 24μm



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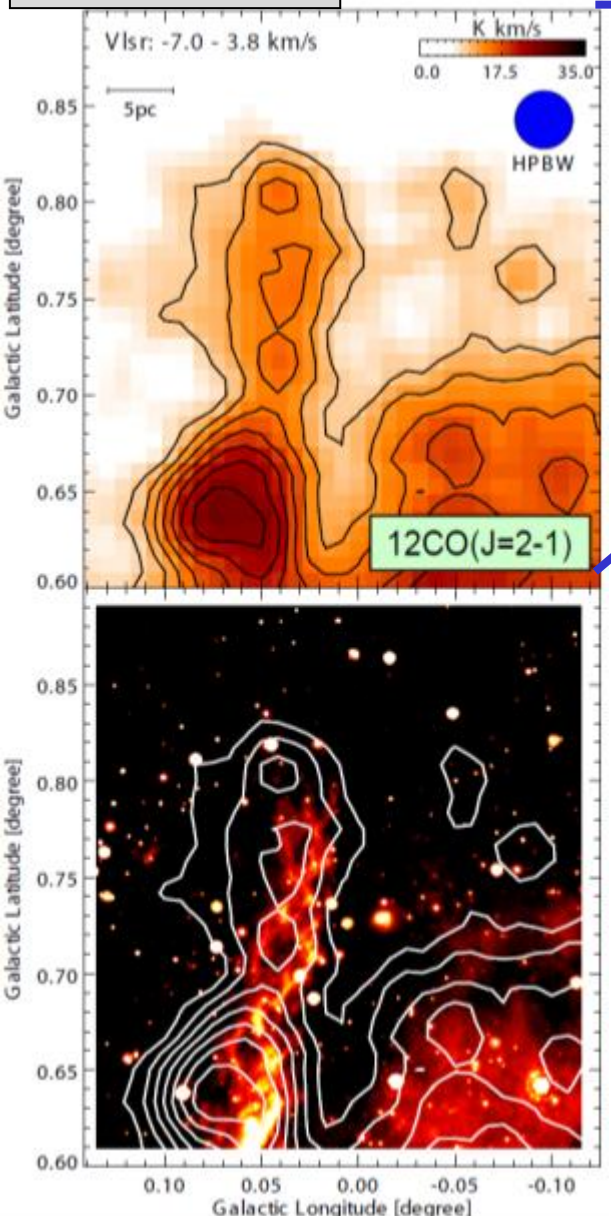
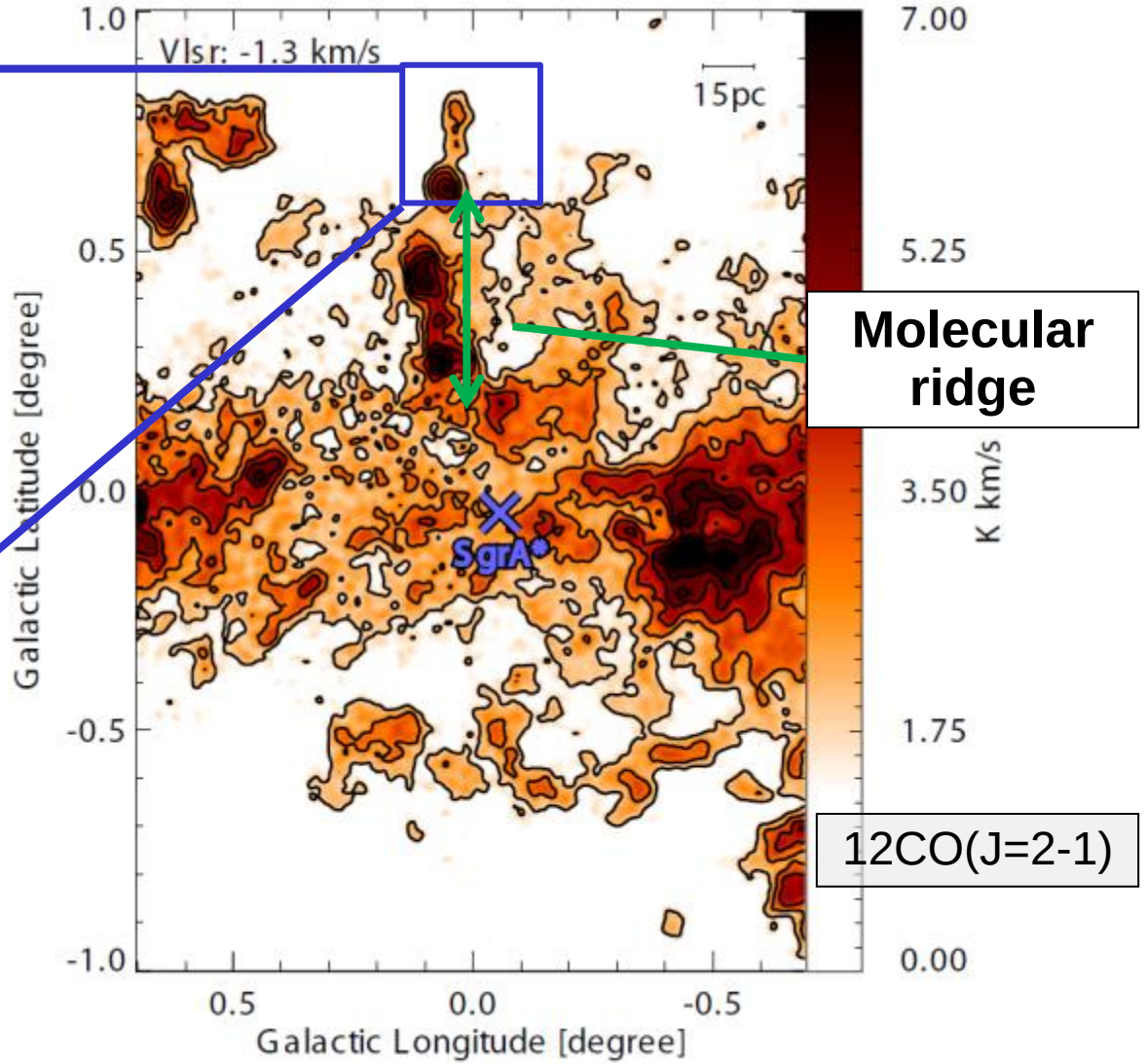
Discovery of CO counterparts

0 component



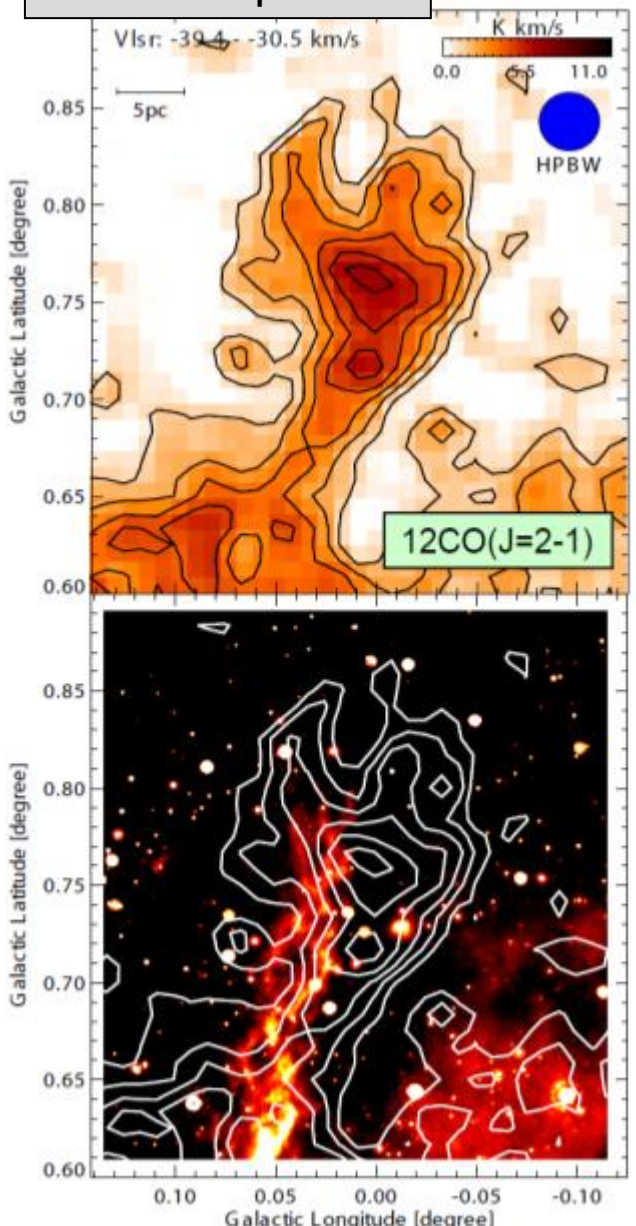


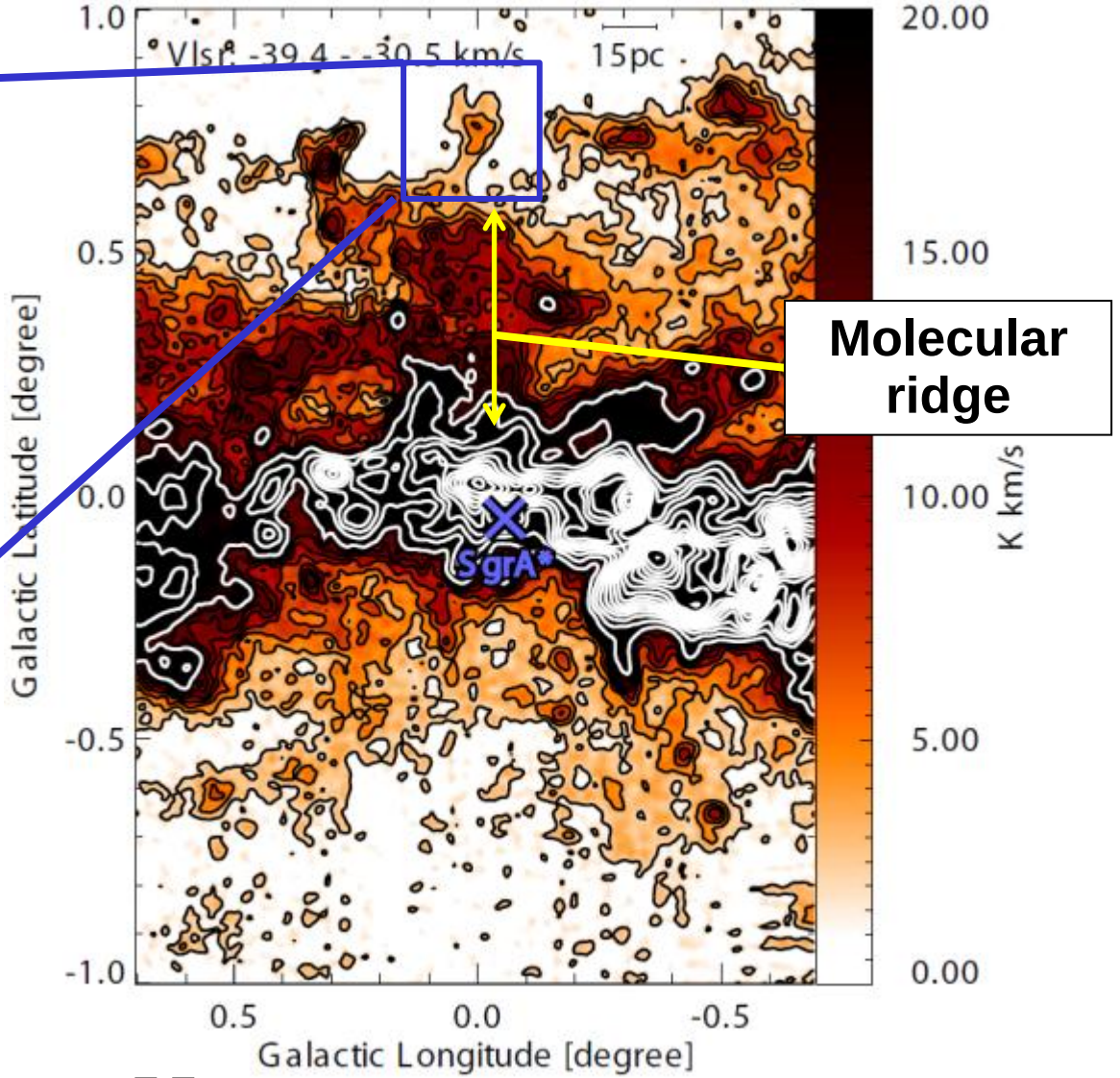
Molecular mass : ~3x10^4 $M_\odot$

Enokiya et al. (2013) accepted by ApJ

Discovery of CO counterparts

Blue component

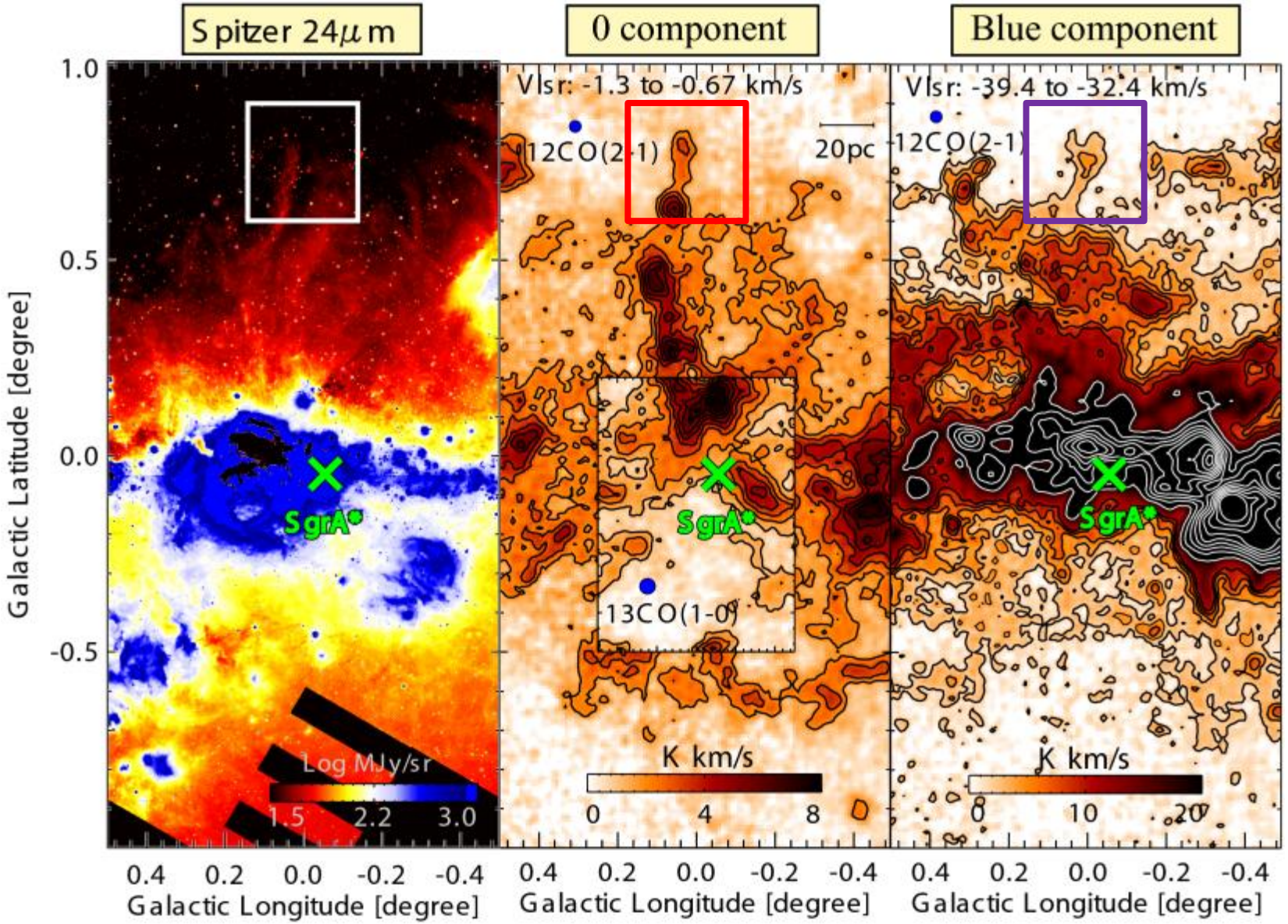




Molecular mass : ~10^5 $M_\odot$

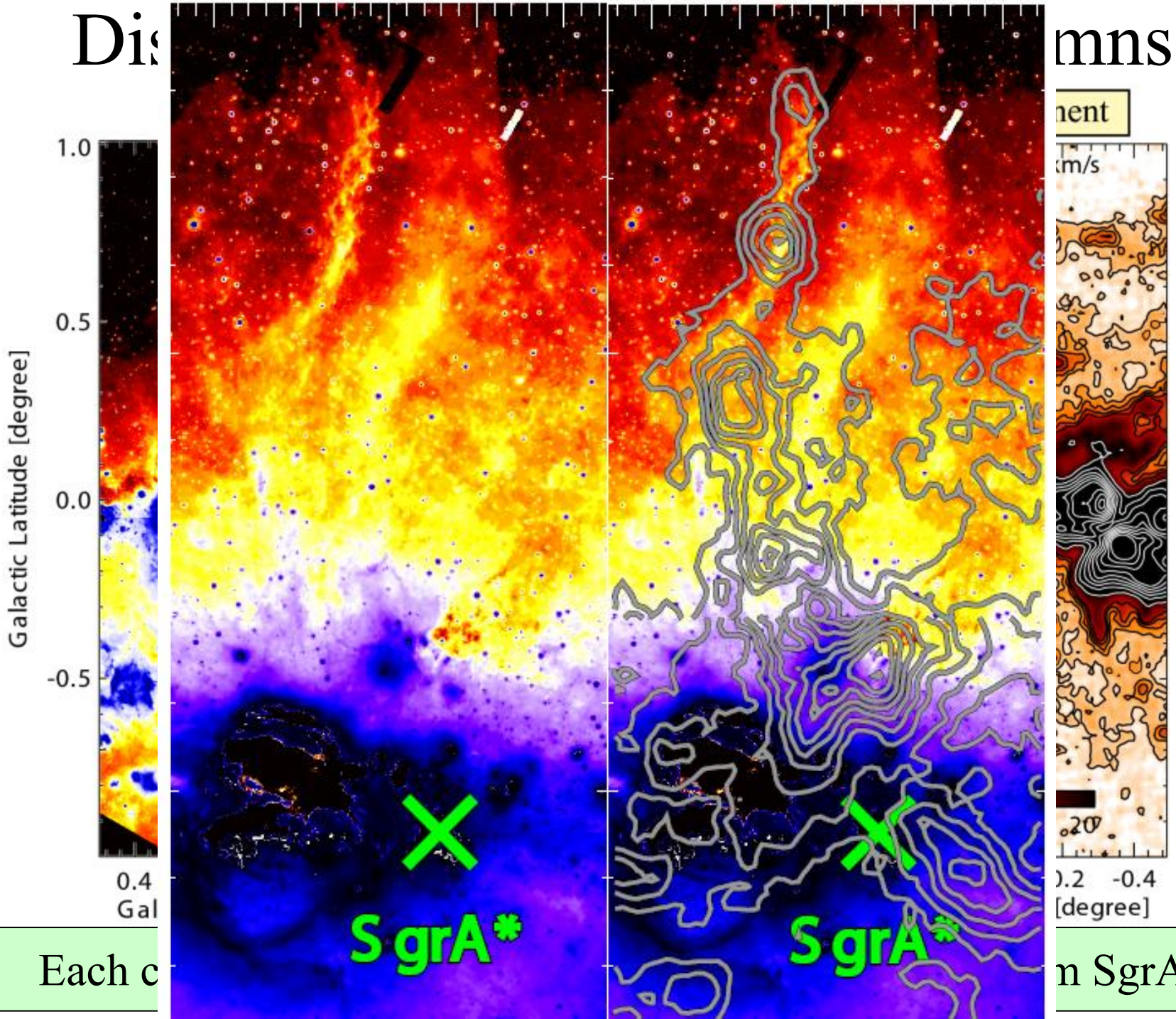
Enokiya et al. (2013) accepted by ApJ

Discovery of the molecular columns



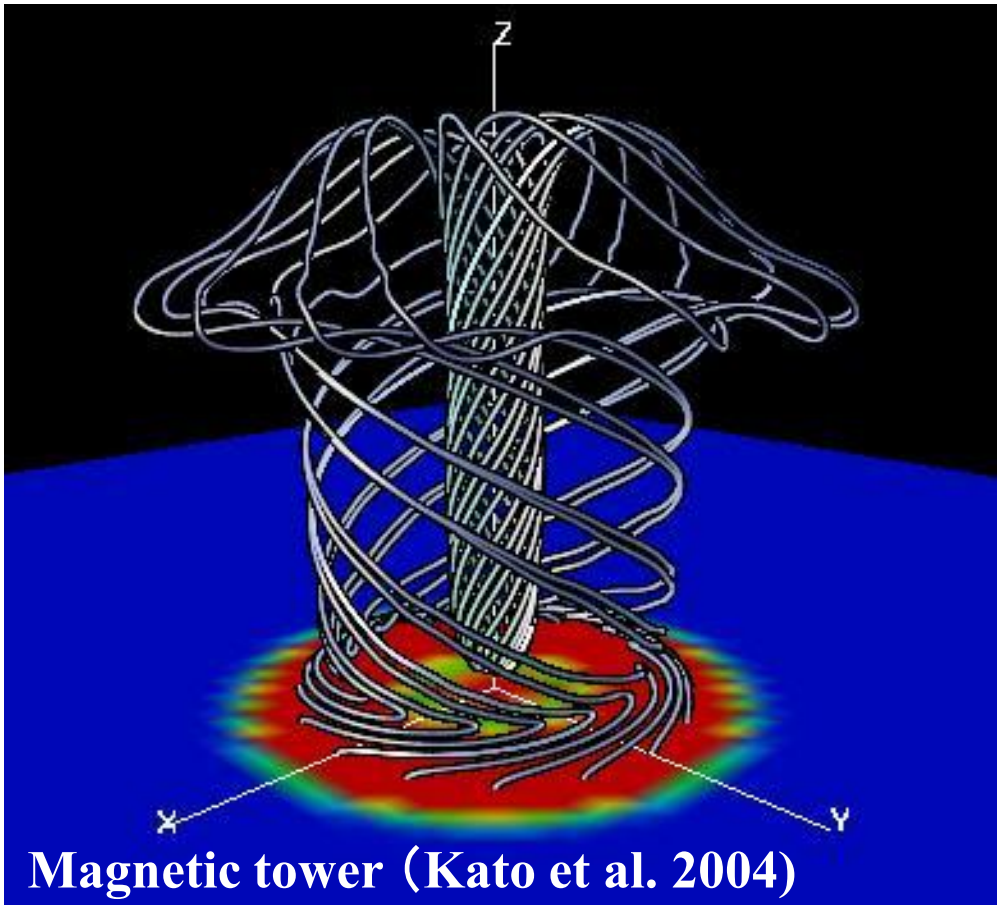
Each counterpart has a molecular column extending from SgrA*

Dis mns

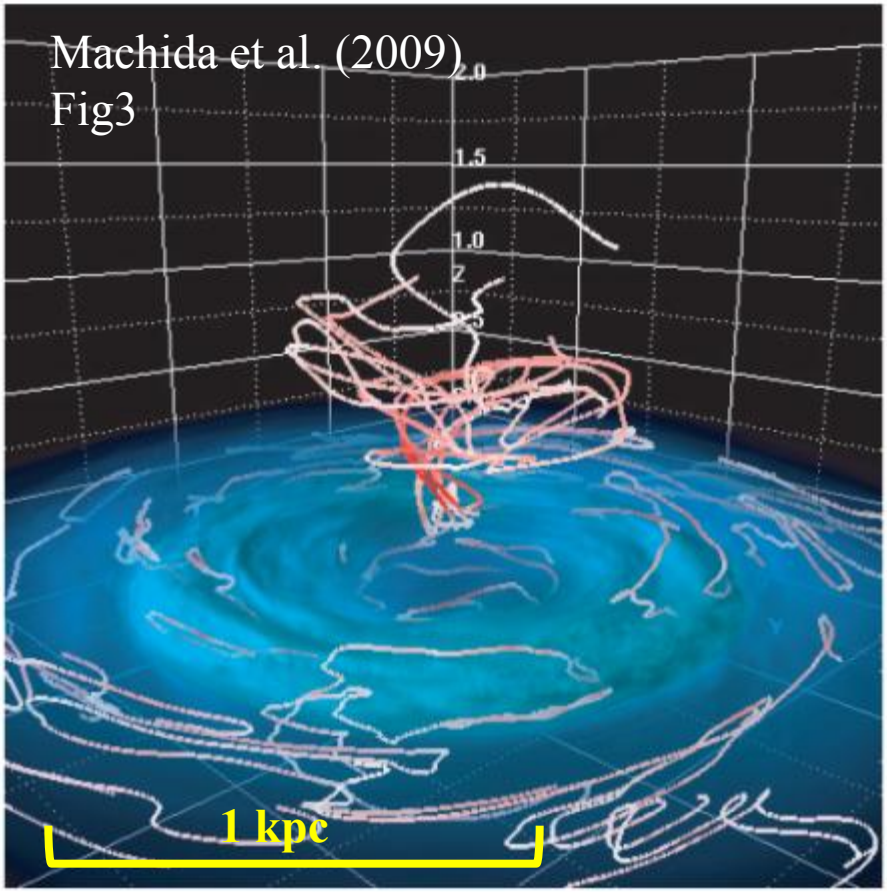


Each c n SgrA*

Discussion : Magnetic tower model

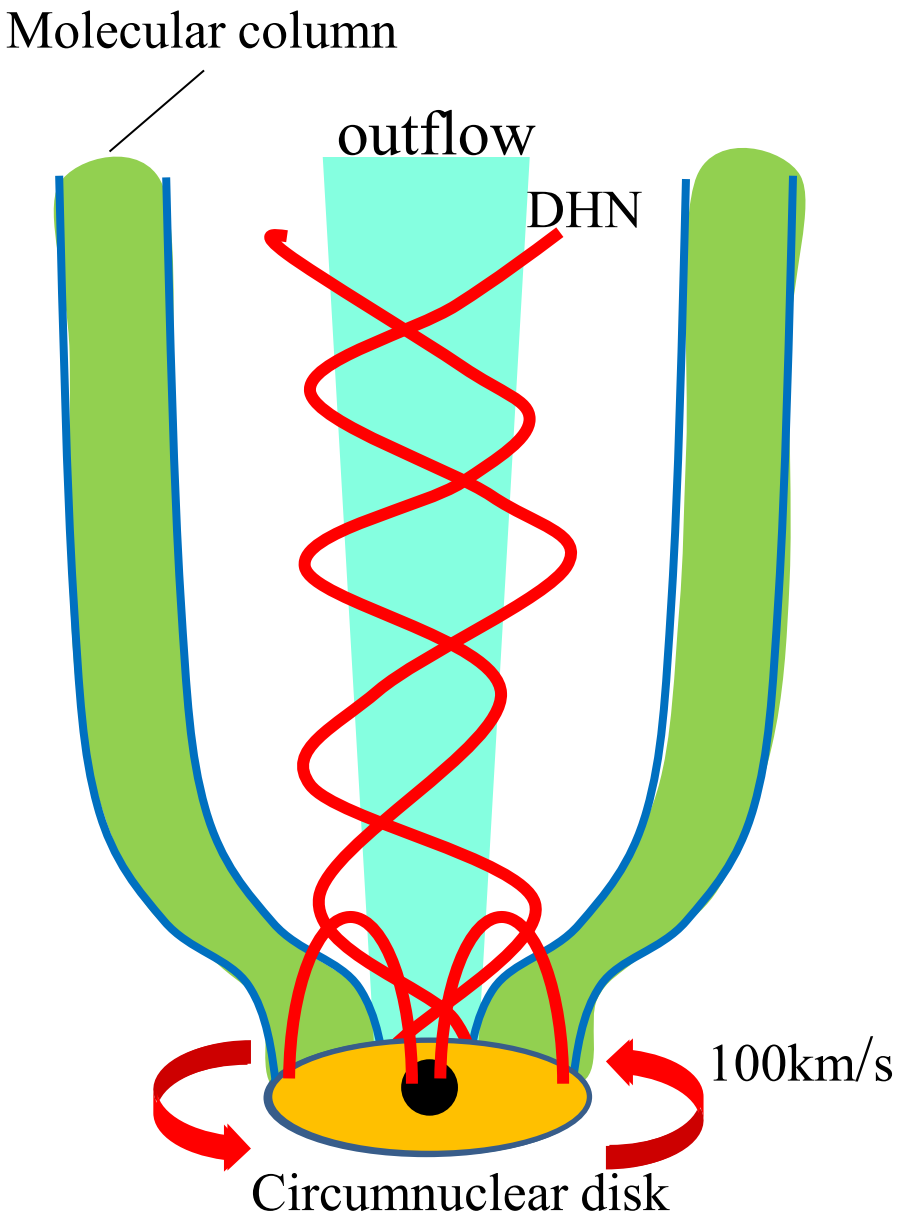


Magnetic tower（Kato et al. 2004)



Magnetic tower model. Rotation of the CND twists and ejects upward loops anchored to the CND

Formation mechanism of the DHN



Magnetic tower model

- The rotating CND twists the loop like magnetic fields and blows up the ISM upward from the Galactic plane

- Dense HI gasses grew up to molecular clouds by the compression of an outflow

There is a possibility that the DHN is a remnant of an outflow from the CND

Order estimation

Given timescale of formation of the DHN is ~5 Myr (10 times rotation of the CND), velocity of the ISM floated from the CND is estimated to be ~25 km s^{-1}

	Mass (M⊙)	Radius (pc)	V_{rot} (km/s)
CND	$\sim 4 \times 10^5$ [2]	~ 6 [2]	~ 80 [3]
DHN	$\sim 10^5$ [1]	~ 2 [1]	~ 2 [1]

[1] Observational results

[2] Oka et al. (2011)

[3] Bradford et al.(2004)

Order estimation

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	Mass (M⊙)	Momentum flux (M⊙ km/s pc /yr)	Energy flux (erg/s)
CND	$\sim 4 \times 10^5$ [	$\sim 5 \times 10^2$	$\sim 3 \times 10^{34}$
DHN	$\sim 10^5$ [	~ 1	$\sim 3 \times 10^{31}$

➡ The CND origin can be explained by this scenario

Summary

• Newly detected CO features are extending up to B=1deg from the CMZ and sorted to two types (Molecular filaments & halo)
• The total mass of them is ~ 4×10^6 $M_\odot$ (~10% of the M_{CMZ})
• Some MFs have their IR counterpart

• The DHN has two CO counterparts and both are located at the top of molecular ridges and at least 0 component is extending from the direction of SgrA*
• We propose a magnetic tower model from the CND as the origin of the DHN and CO counterparts. The estimated parameters are consistent with the model