



August 24th, Canberra

HI clouds near the Galactic Center: Possible tracers for a Milky-Way nuclear wind?

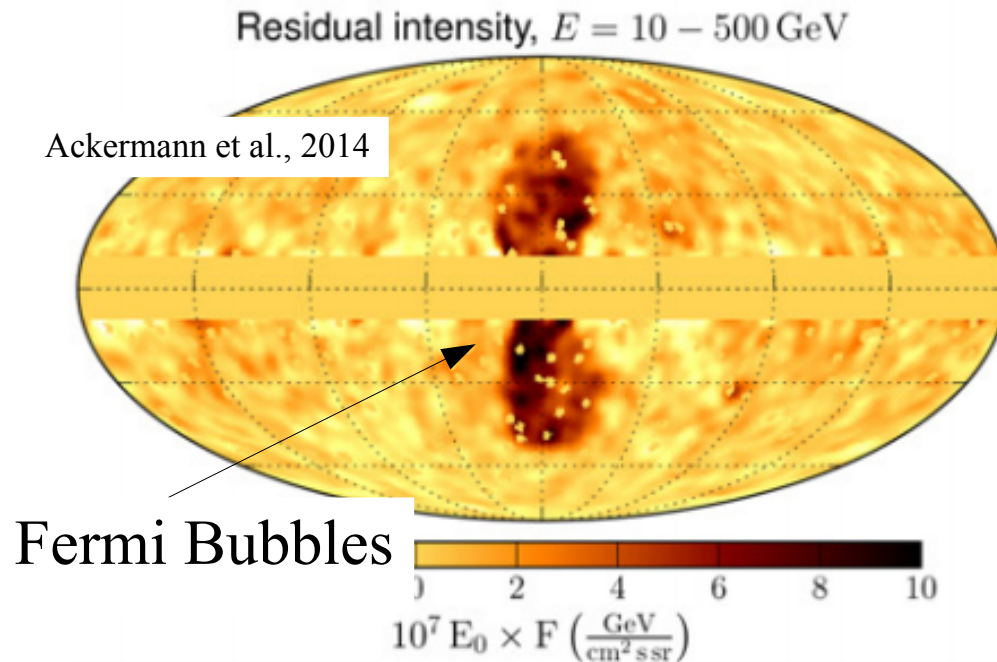
Enrico Di Teodoro

Research School of Astronomy and Astrophysics

Australian National University

Collaborators: Naomi McClure-Griffiths (RSAA), Felix J. Lockman (NRAO-GBT)



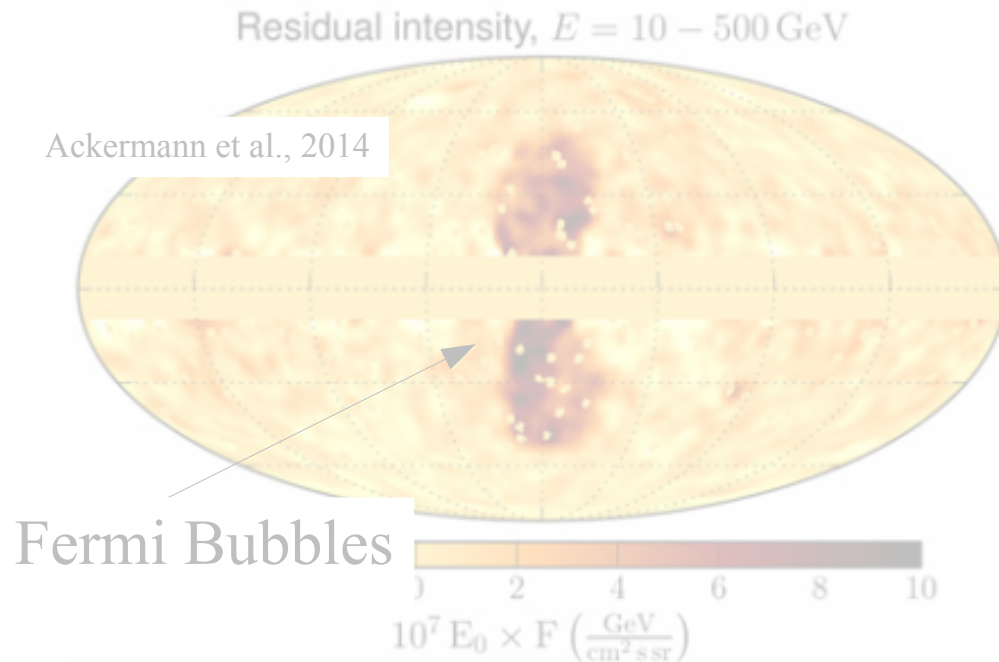


Our Galaxy has its own wind!

Giant lobes extending to 8-10 kpc



Bi-conical outflow generated a few 10^6 years ago by either SF (Crocker+11) or SMBH (Yang+12)

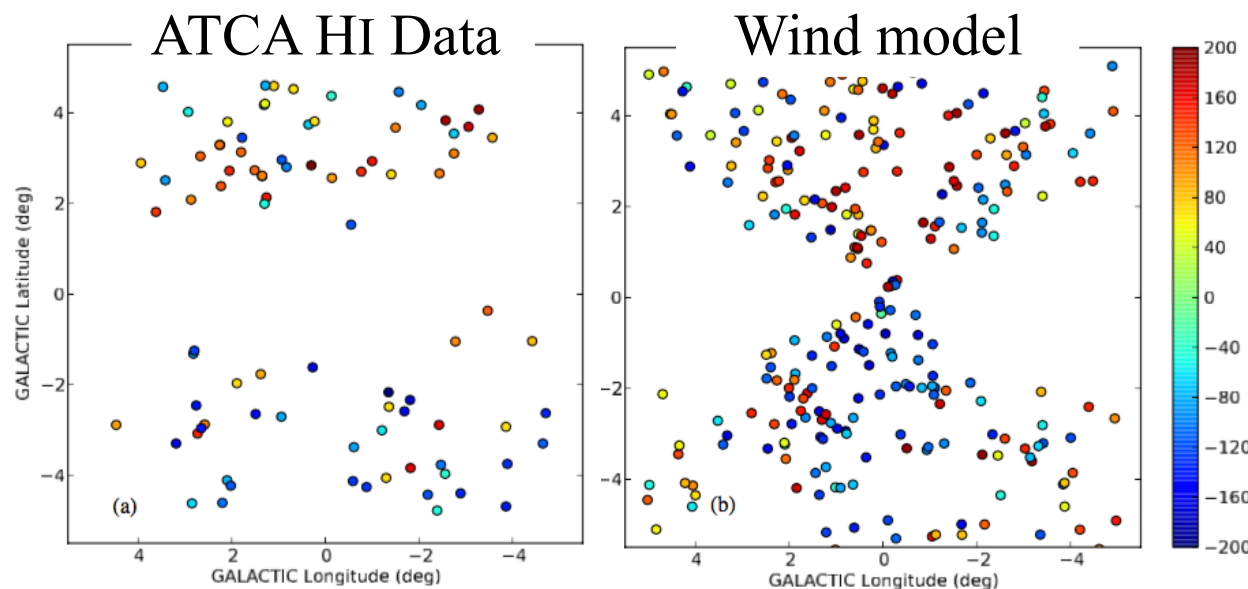


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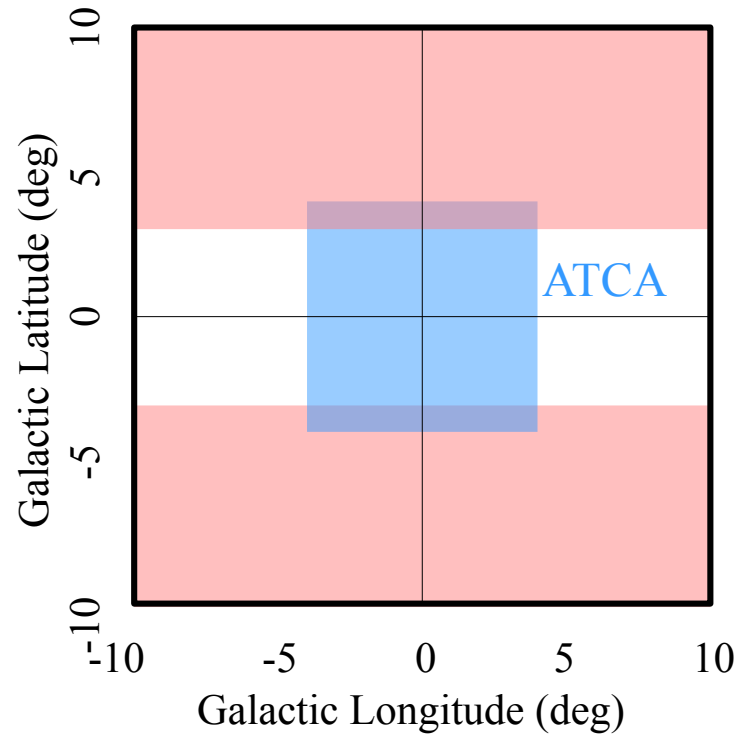


McClure-Griffiths+13 found 86 clouds at the GC not following rotation



Entrained in a wind at ~ 200 km/s

A new Green Bank Telescope survey

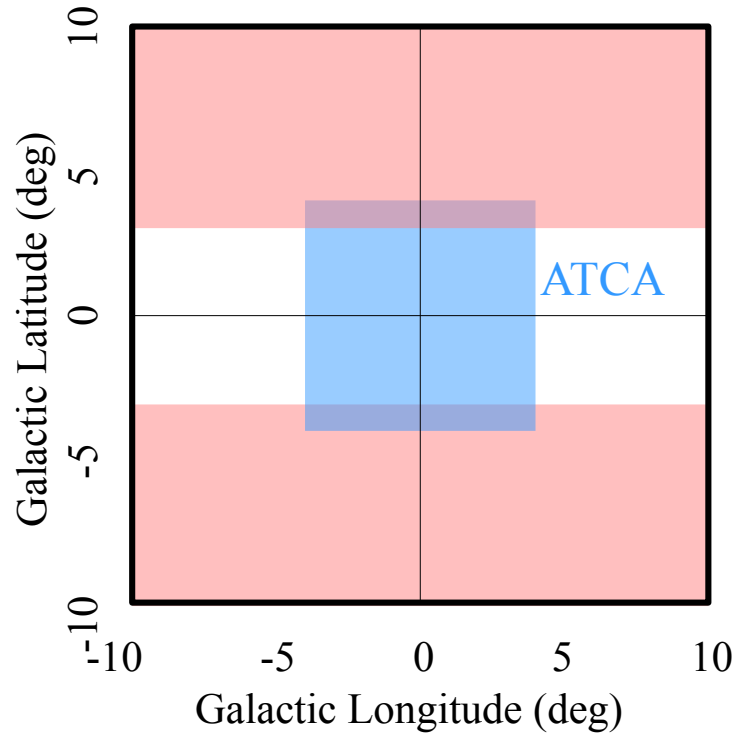


A new survey with 100 m GBT
single-dish telescope to widen
McClure-Griffiths+13 work



High sensitivity





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High sensitivity



	ATCA-GC (McClureGriffiths+13)	GASS (HI4PI) (McClureGriffiths+09)	GBT (Di Teodoro+, in prep)
(l,b) region	$\pm 4^\circ$	All sky	$\pm 10^\circ$
Velocity range (km/s)	± 250	± 450	± 650
Spatial resolution (arcmin)	2.4	15.9	9.1
Channel width (km/s)	1.00	0.82	0.90
Sensitivity (Kelvin)	0.700	0.057	0.025

GOAL: detecting and studying anomalous clouds above and below the GC

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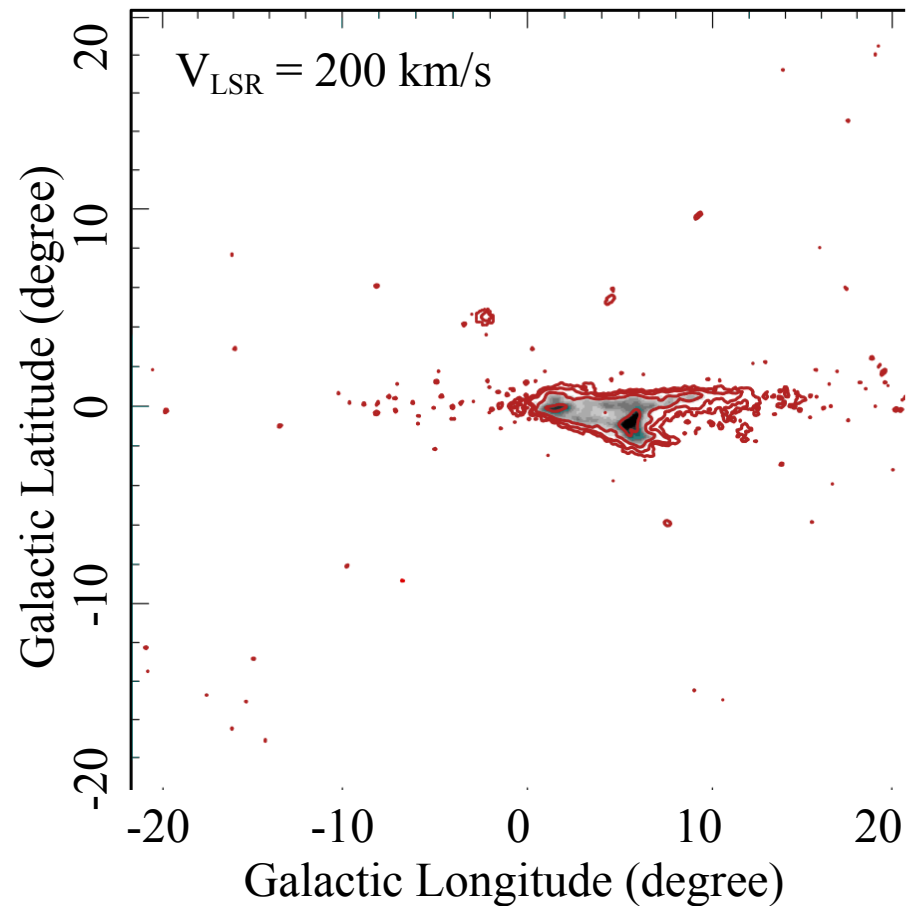
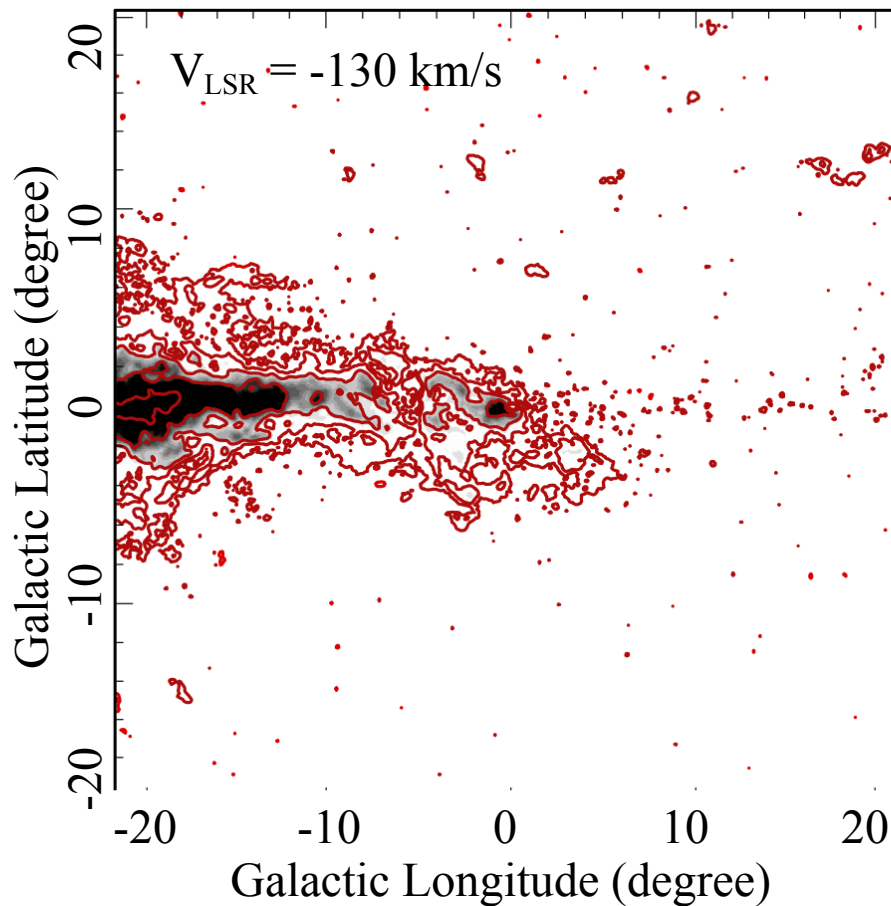
Clouds not in the disk  Masking the MW disk by modelling it!

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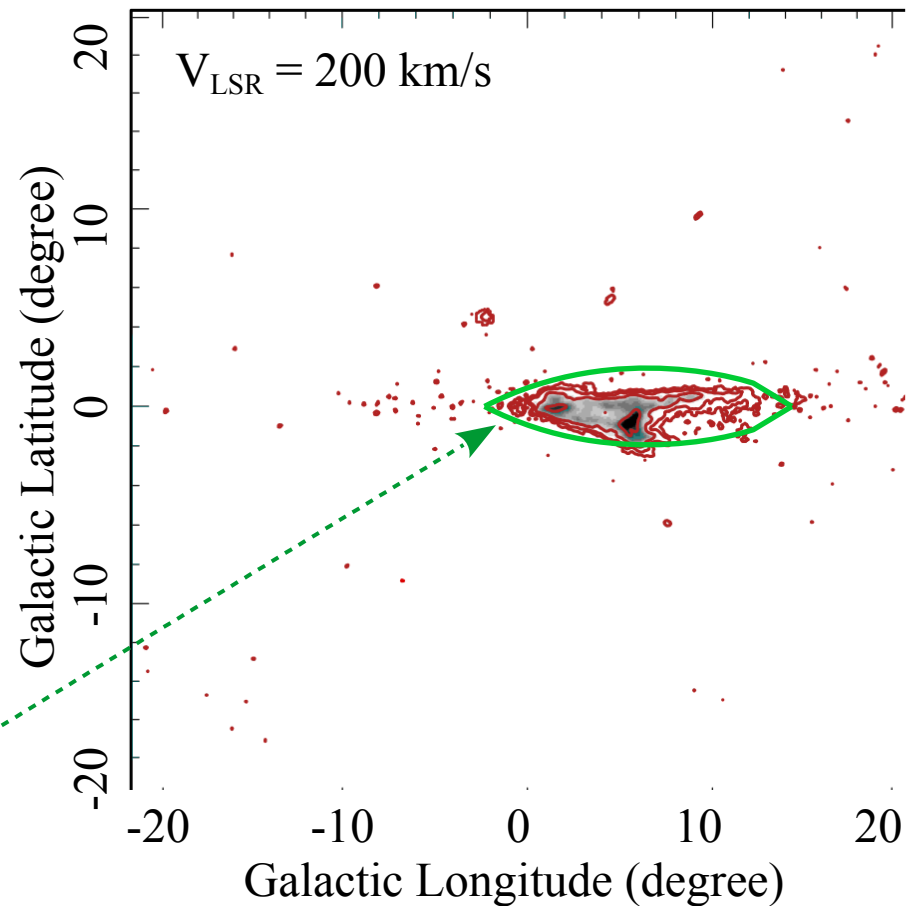
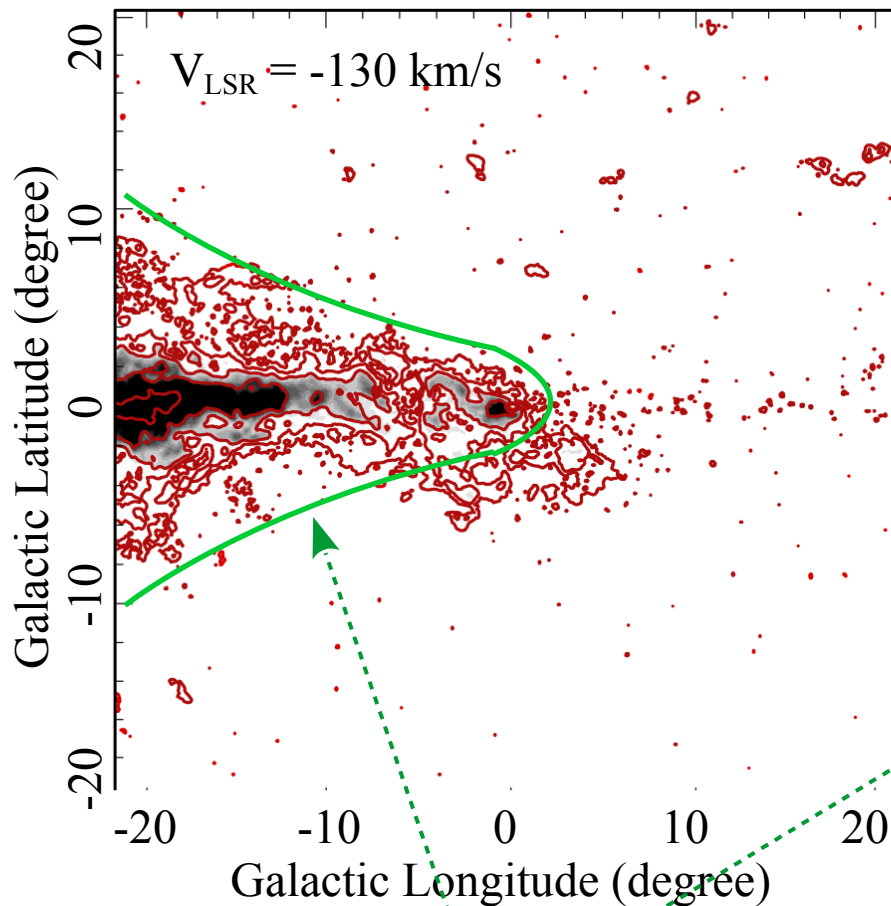


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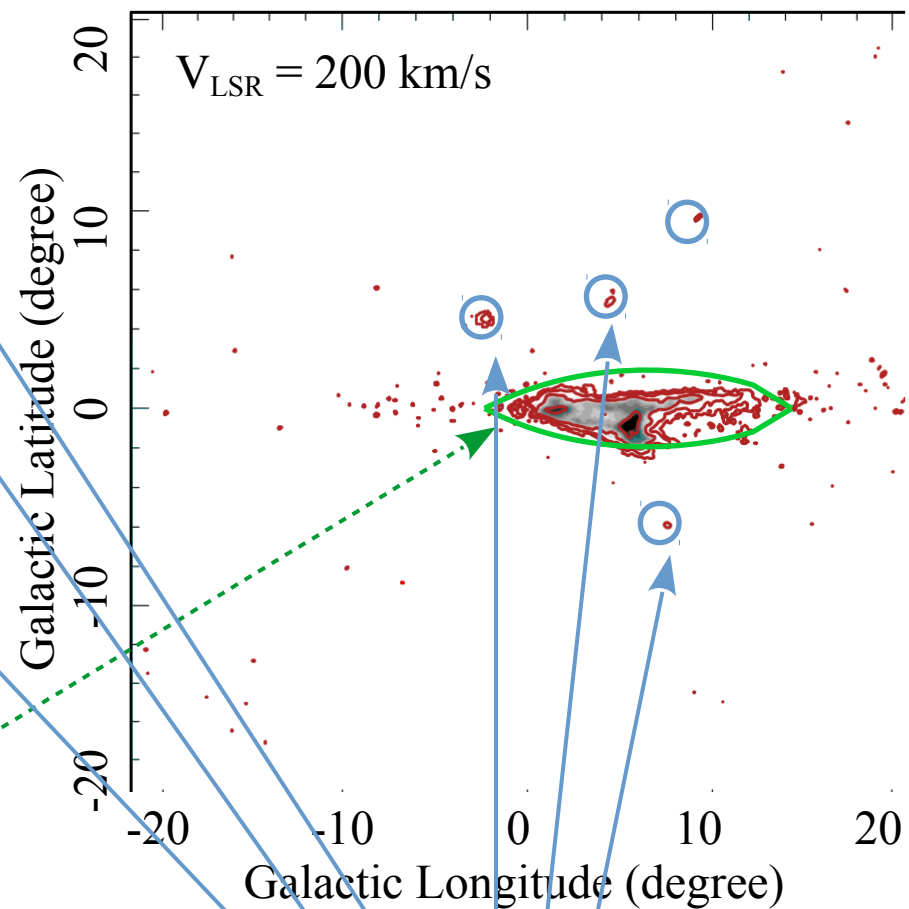
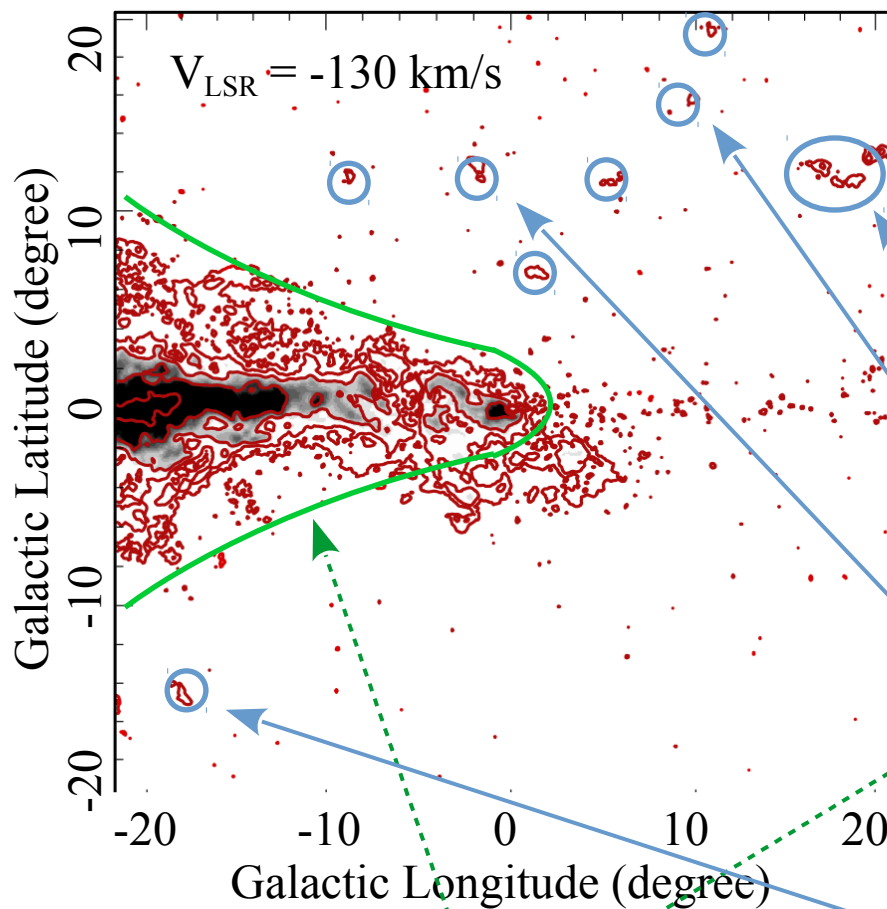
GALACTIC DISK ROTATION

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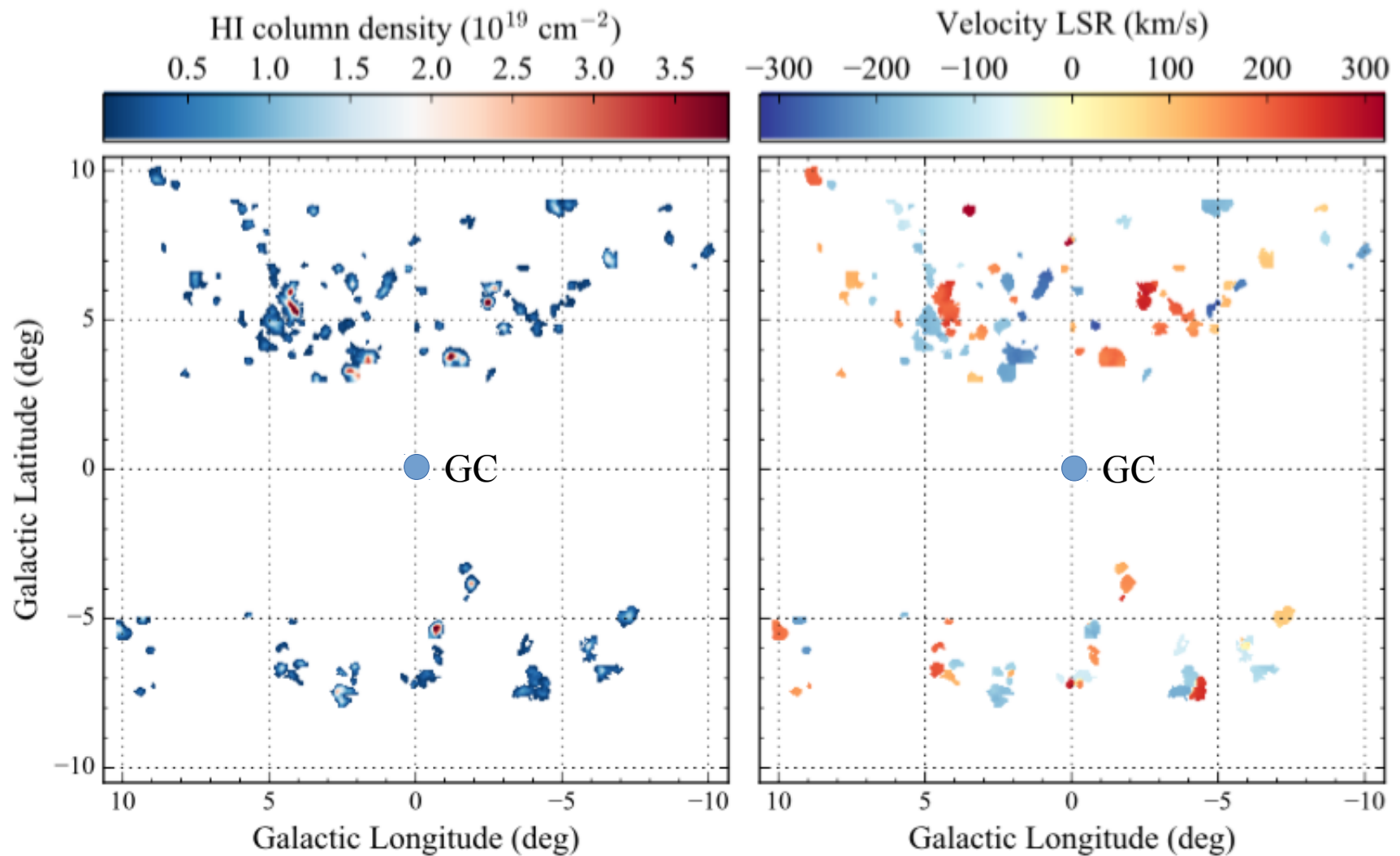


Masking the MW disk by modelling it!



GALACTIC DISK ROTATION

ANOMALOUS CLOUDS



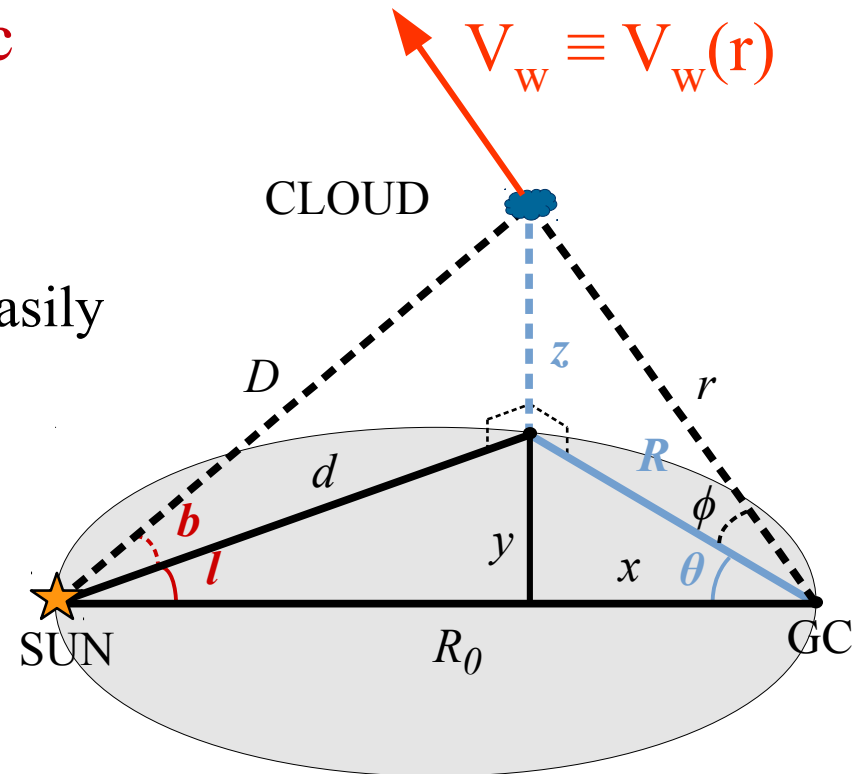
106 anomalous clouds covering $\sim 130 \text{ deg}^2$

Describing observed cloud kinematic with a simple a galactic wind model

A cloud in (R, z, θ) with $V = V(r)$ can be easily mapped into the (l, b, V_{LSR}) system:

$$\ell = \arcsin \left(\frac{R}{d} \cos \theta \right)$$

$$b = \arctan \left(\frac{z}{d} \right)$$



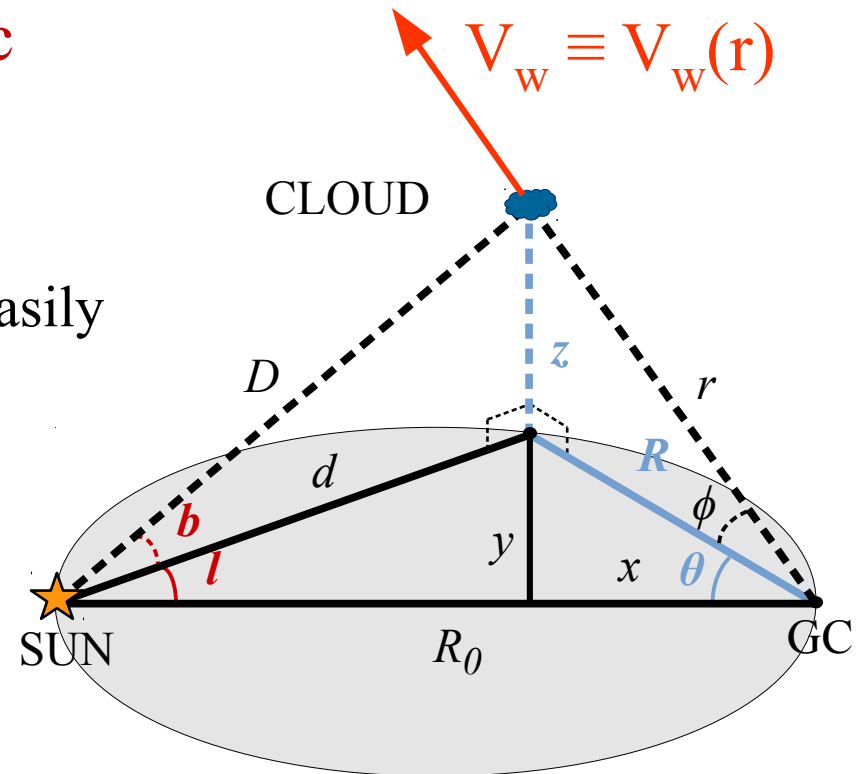
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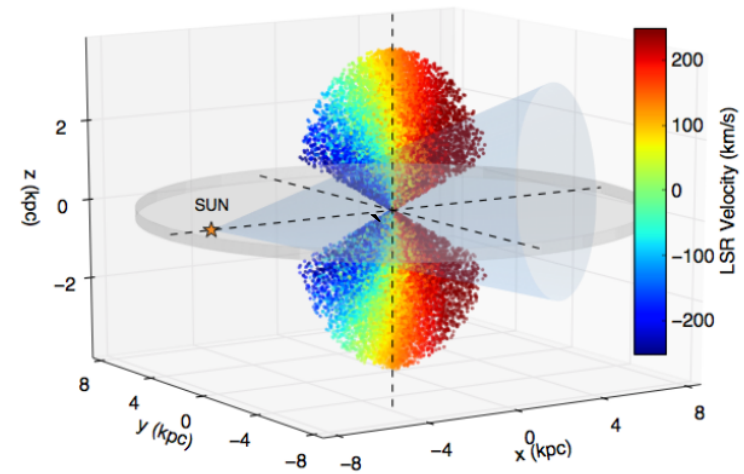
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Simplest model defined by 2 parameters: - wind velocity $V_w = \text{const}$
 - opening angle $\alpha = \pi - 2\phi$

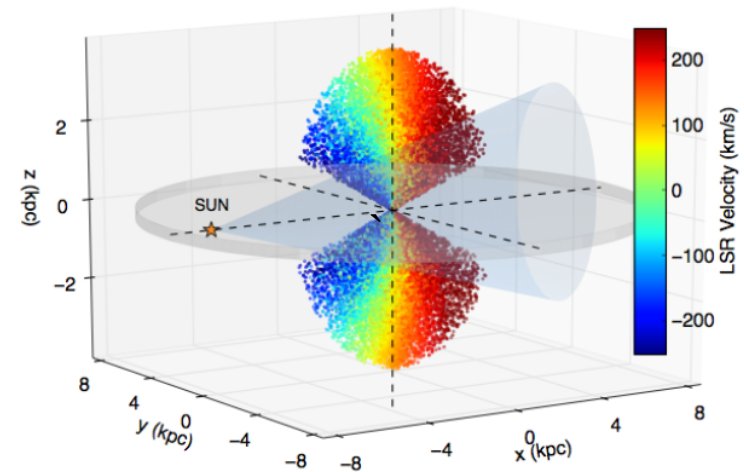
Simulating winds with different velocities and opening angles



Simulating winds with different velocities and opening angles

$$300 \text{ km/s} < V_w < 400 \text{ km/s}$$

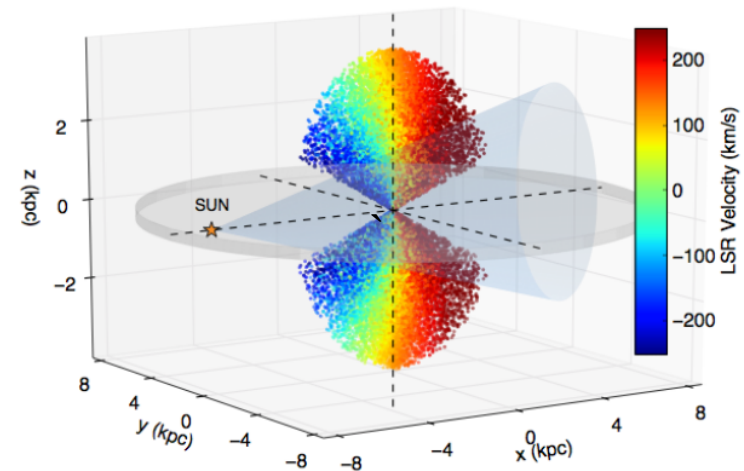
$$\alpha > 140^\circ$$



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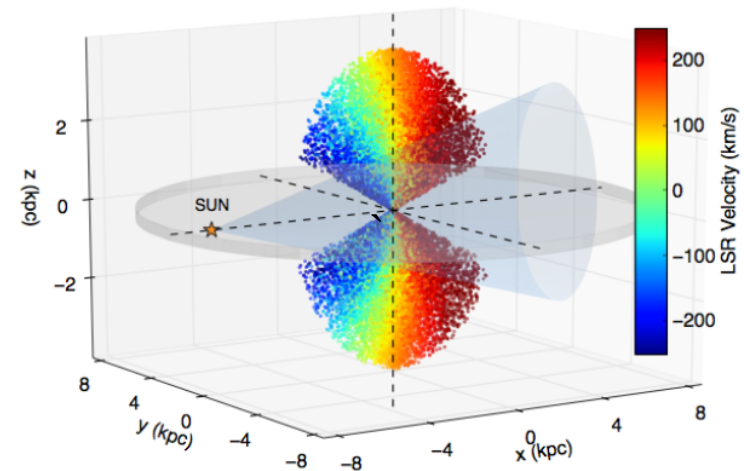
Wind derived properties

- Total HI mass in clouds: $1 \times 10^6 \text{ Msun}$

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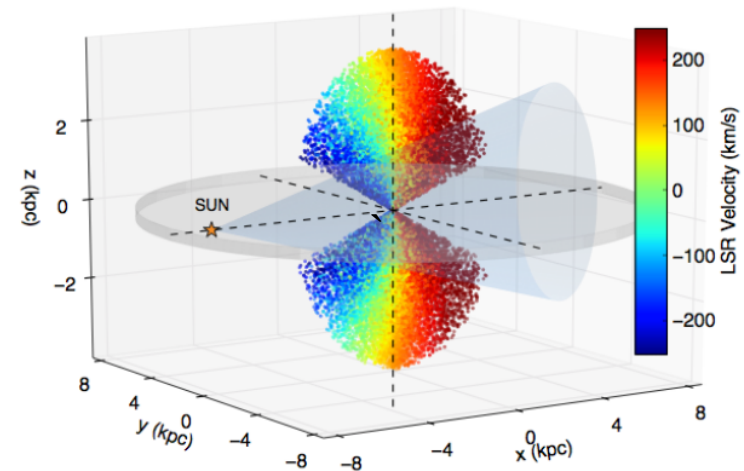
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Challenge for theory. Destruction timescales are generally lower

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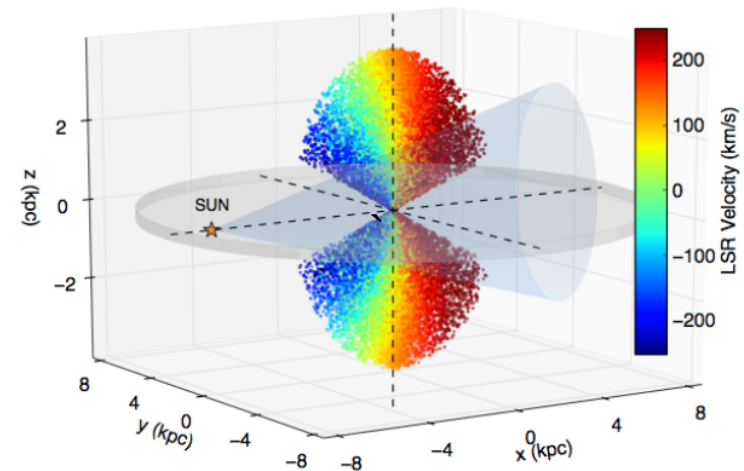
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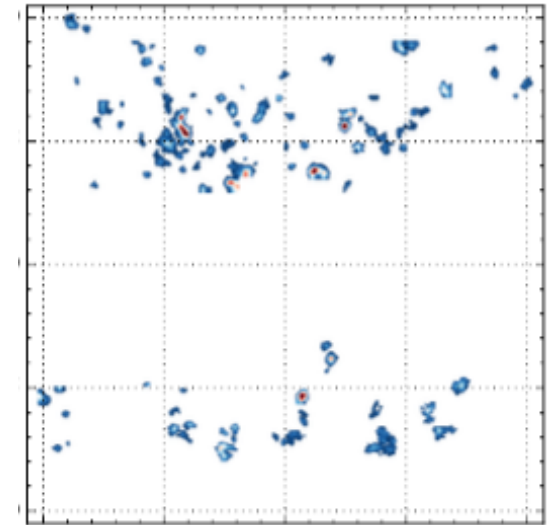
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- Wind luminosity: $1 - 2 \times 10^{40} \text{ erg/s}$ ← Can be supplied by GC with $\text{SFR} \sim 0.1\text{-}0.2 \text{ Ms/yr}$ (Crocker12)

- A population of anomalous clouds definitely exists at the GC



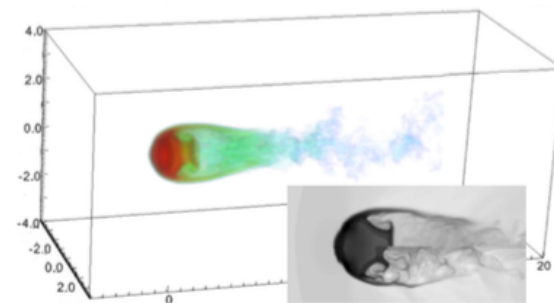
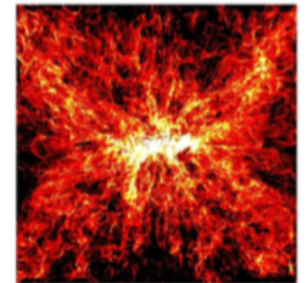
They can be used to trace the properties of MW wind

- Our new GBT survey revealed 106 clouds with kinematics compatible with being entrained in a wind with $300 \text{ km/s} < V_w < 400 \text{ km/s}$ and $\alpha > 140^\circ$



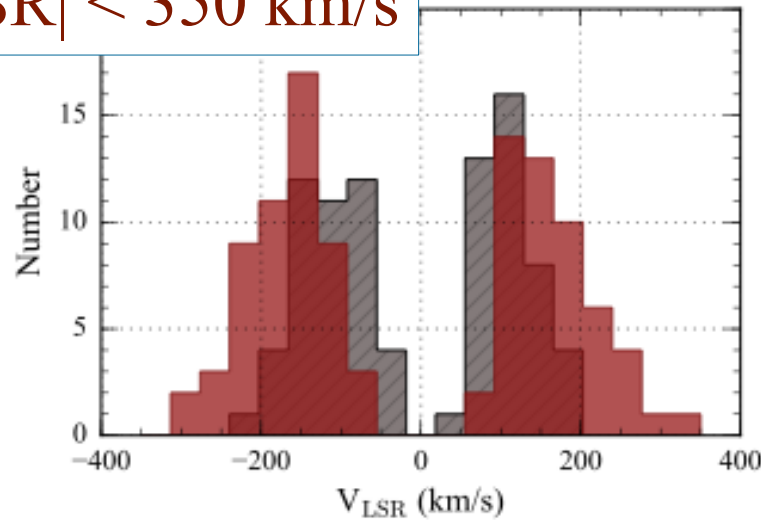
Future developments

- Refine kinematic model with more reliable $V_w(r)$ (e.g., Zhang+17)
- Run HD simulations of MW wind and compare to cloud observed property distributions (e.g., N_{HI} , Δv).
- Follow-up interferometric observations of a few clouds to resolve their morpho-kinematics and compare to simulations

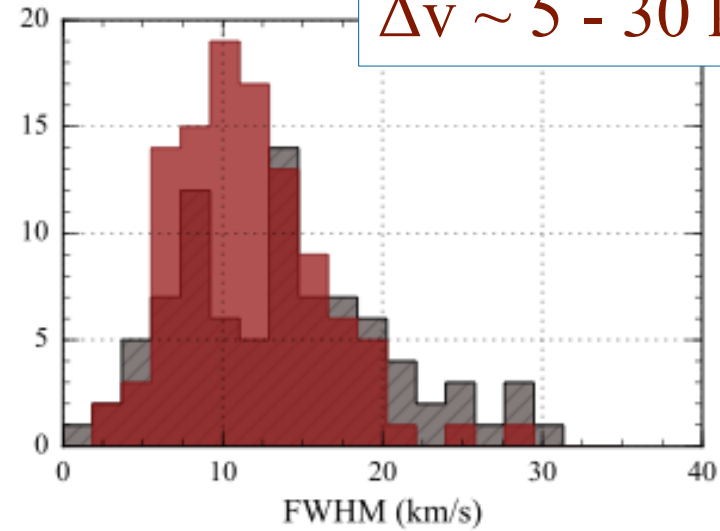


Thank you for your kind attention

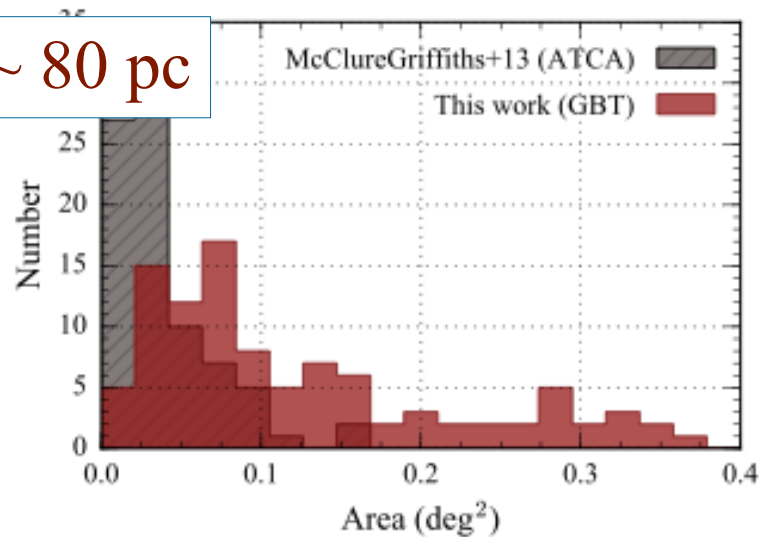
$|V_{\text{LSR}}| < 350 \text{ km/s}$



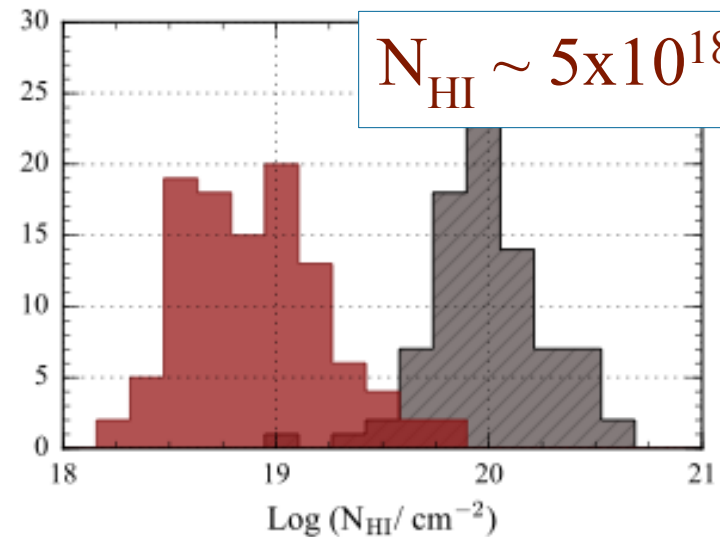
$\Delta v \sim 5 - 30 \text{ km/s}$



$R < \sim 80 \text{ pc}$



$N_{\text{HI}} \sim 5 \times 10^{18} - 10^{20}$



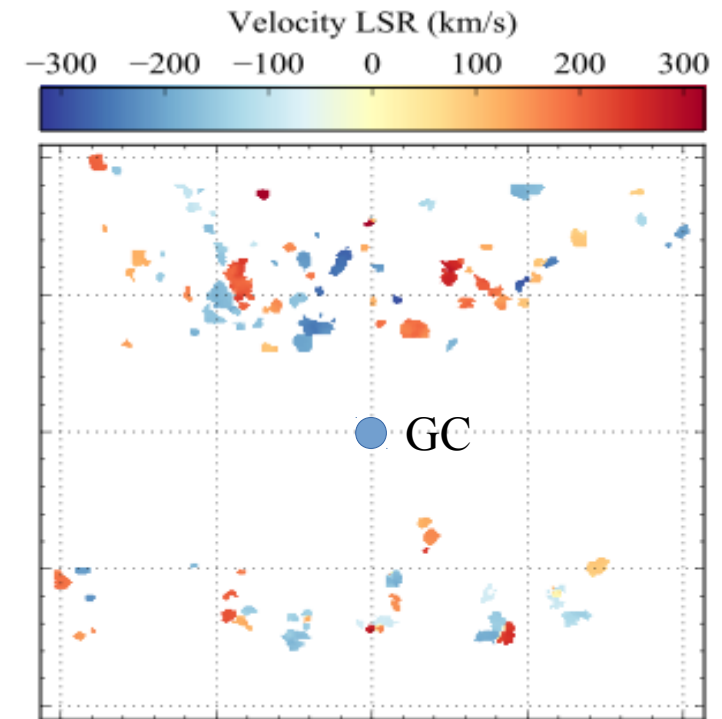
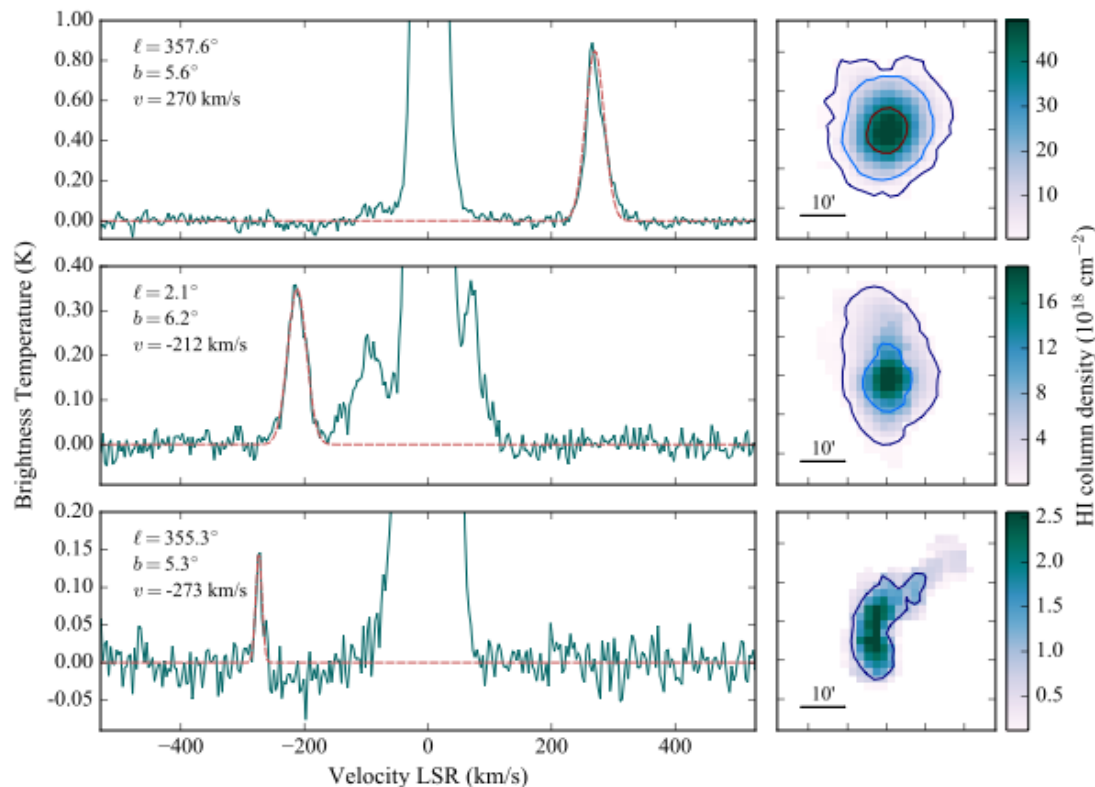
No correlation between FWHM, R or N_{HI} with latitude (height)

Are these local ISM clouds?

- Not rotating with the MW
- Only observed in the inner degrees
- Very high velocities for local ISM



Likely at the GC!



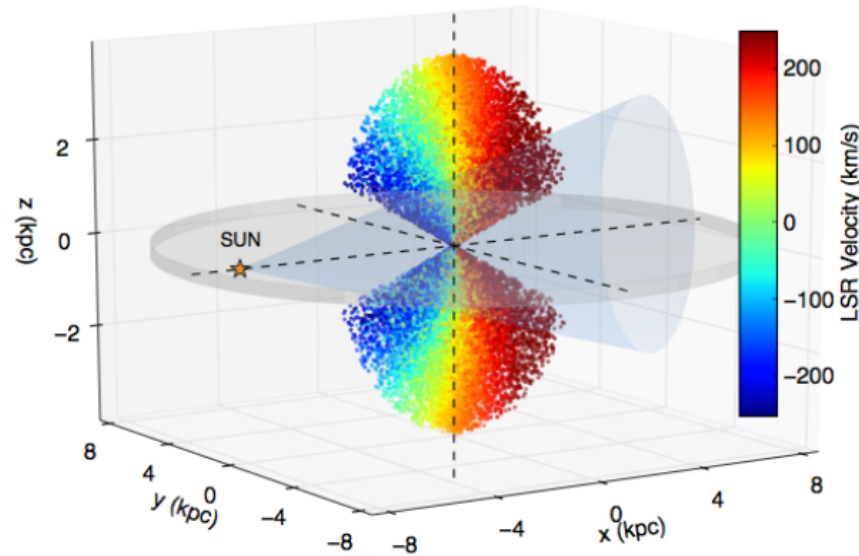
Three cloud examples

- Clear spectral detection
- Head – tail morphology
- Well-fitted by a single Gaussian

Wind kinematic model

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Simulation of a wind with 10^4 particles



$$V_w = 300 \text{ km/s}$$

$$\alpha = 120^\circ$$

