NASA/JPL-Caltech

Colliding Clouds

in the

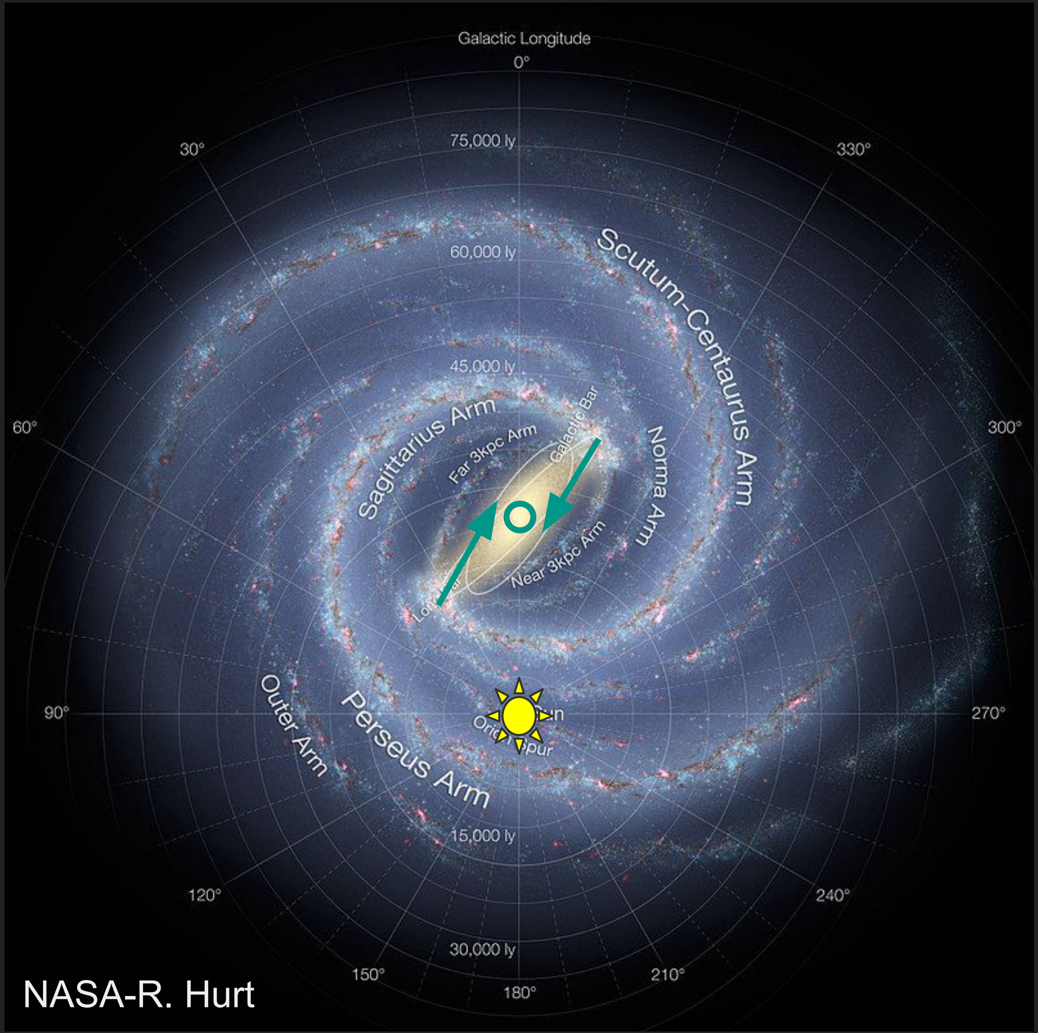
Milky Way's Central Bar

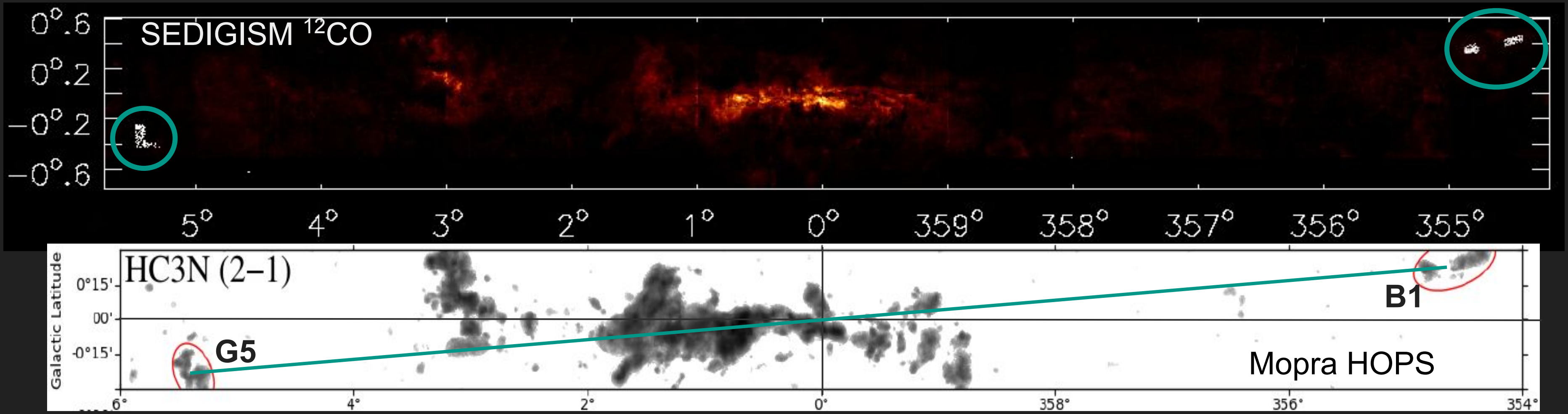
Savannah Gramze

Juergen Ott, David Meier, Brian Svoboda,
Yancy Shirley, Adam Ginsburg

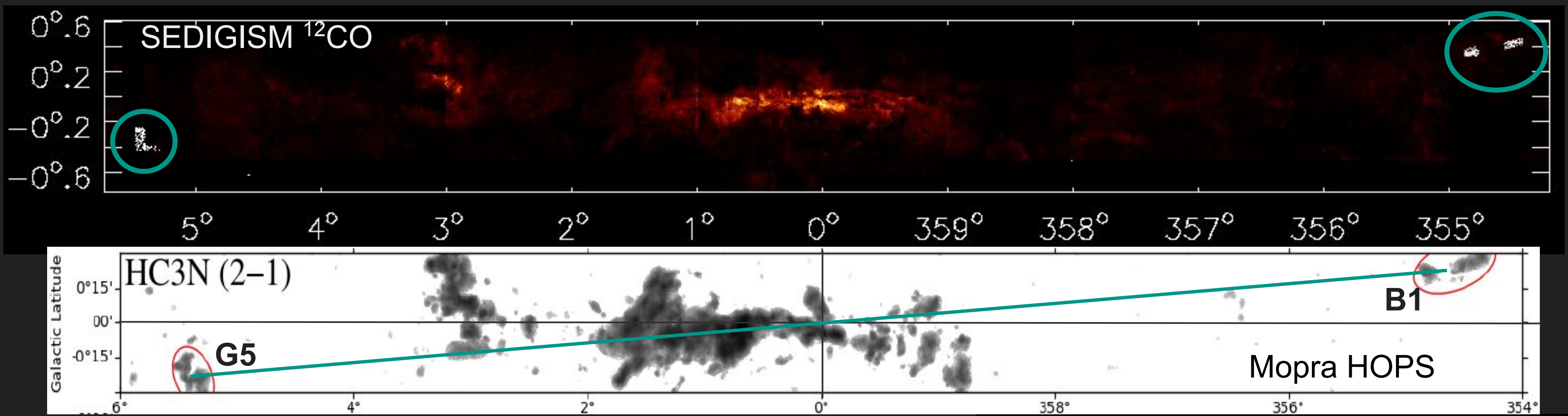
Introduction

- The Milky Way is a barred spiral galaxy.
- Gas flows into the Galactic Center (GC) from the spiral arms along the bar potential.
- The gas and dust streaming in from the spiral arms form molecular clouds.
- These clouds become hotter and more turbulent as they travel from the disk along the arms approaching the Central Molecular Zone (CMZ).





- Continuation of last summer's work on ALMA spectral line data.
- Two clouds near the galactic center at point symmetric coordinates. G5 and B1.
- Both have properties that place them near the Galactic Center.



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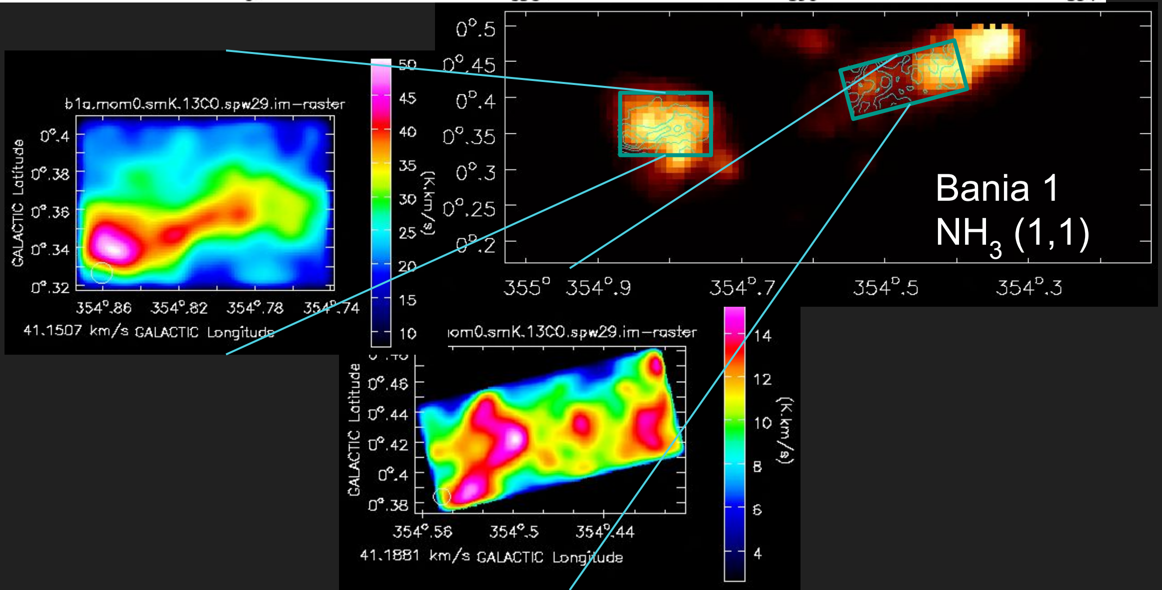
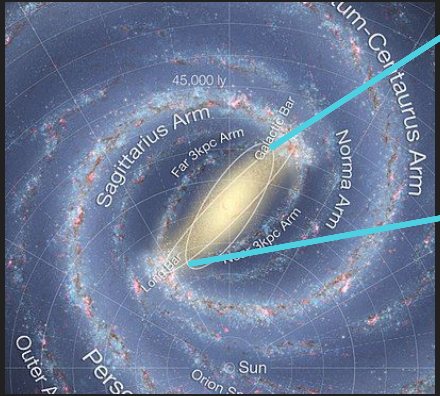
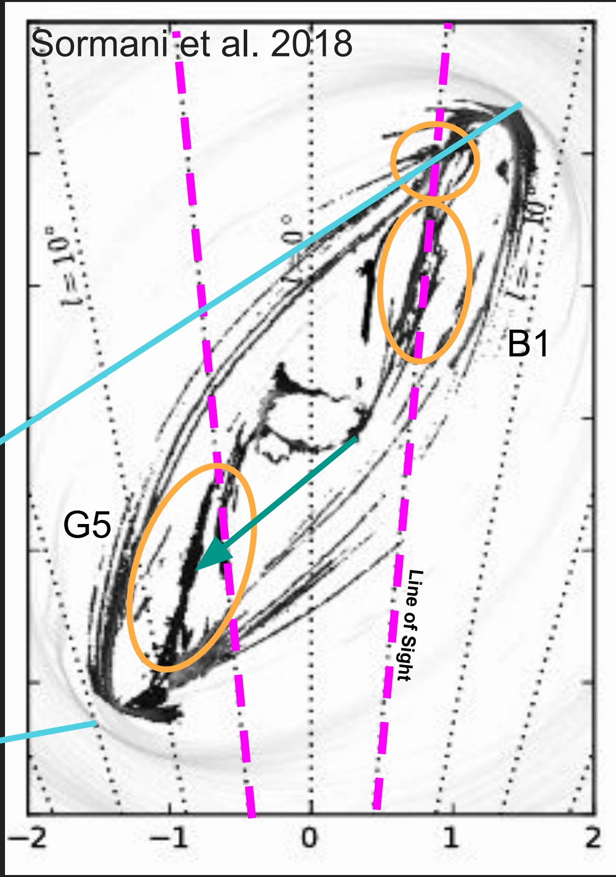
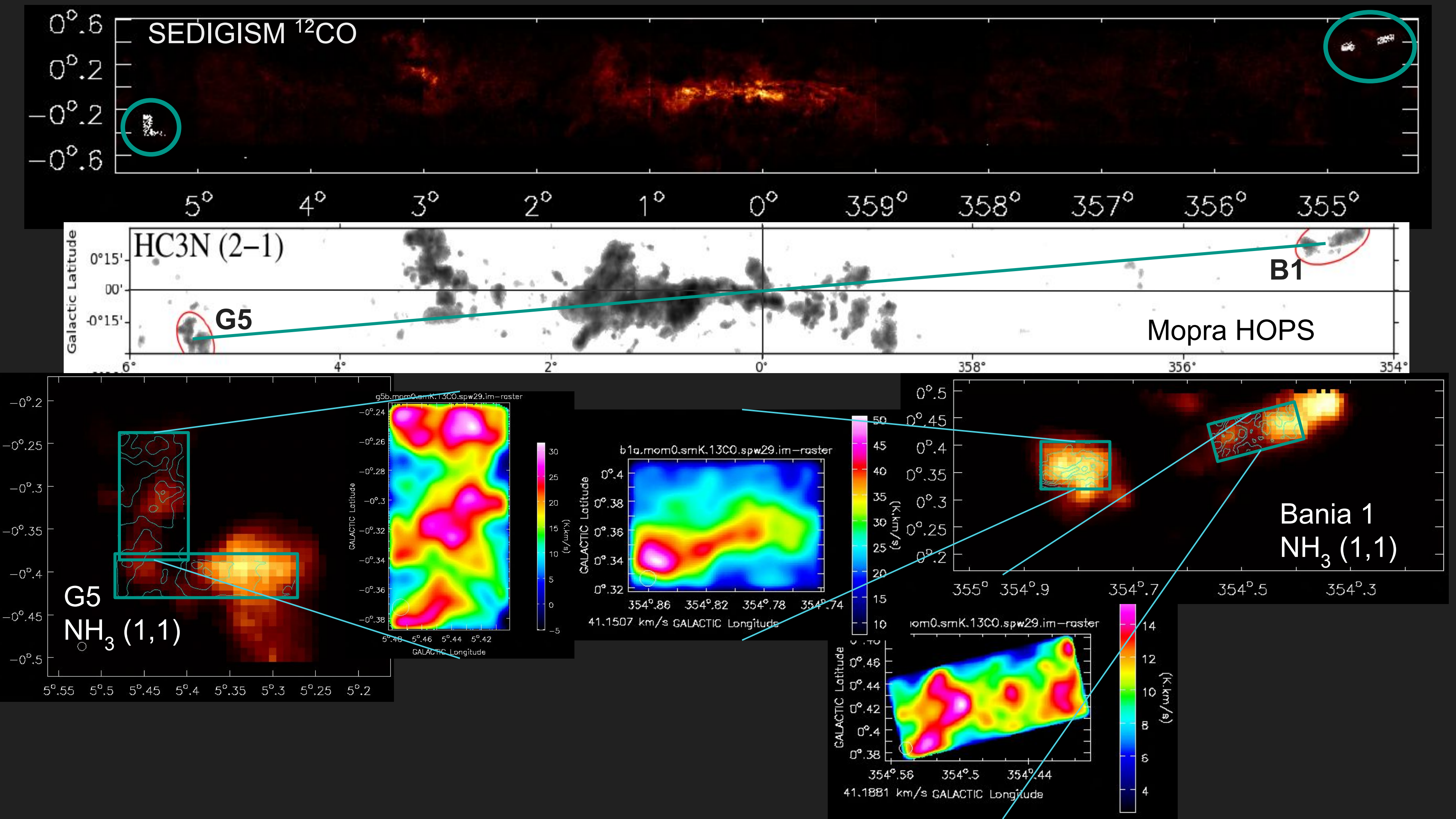


Motivation

- Not symmetric processes on opposite sides of the galaxy's bar.
- Using Sormani et al's model, we interpreted the gas flows as:
    - G5 is a molecular gas cloud that overshot the CMZ and is in the process of colliding with an inbound dust lane.
    - B1 is either a view down a dust lane or the end of the bar.
- This summer's goal was to look at the second part of G5, which was not delivered by last summer.



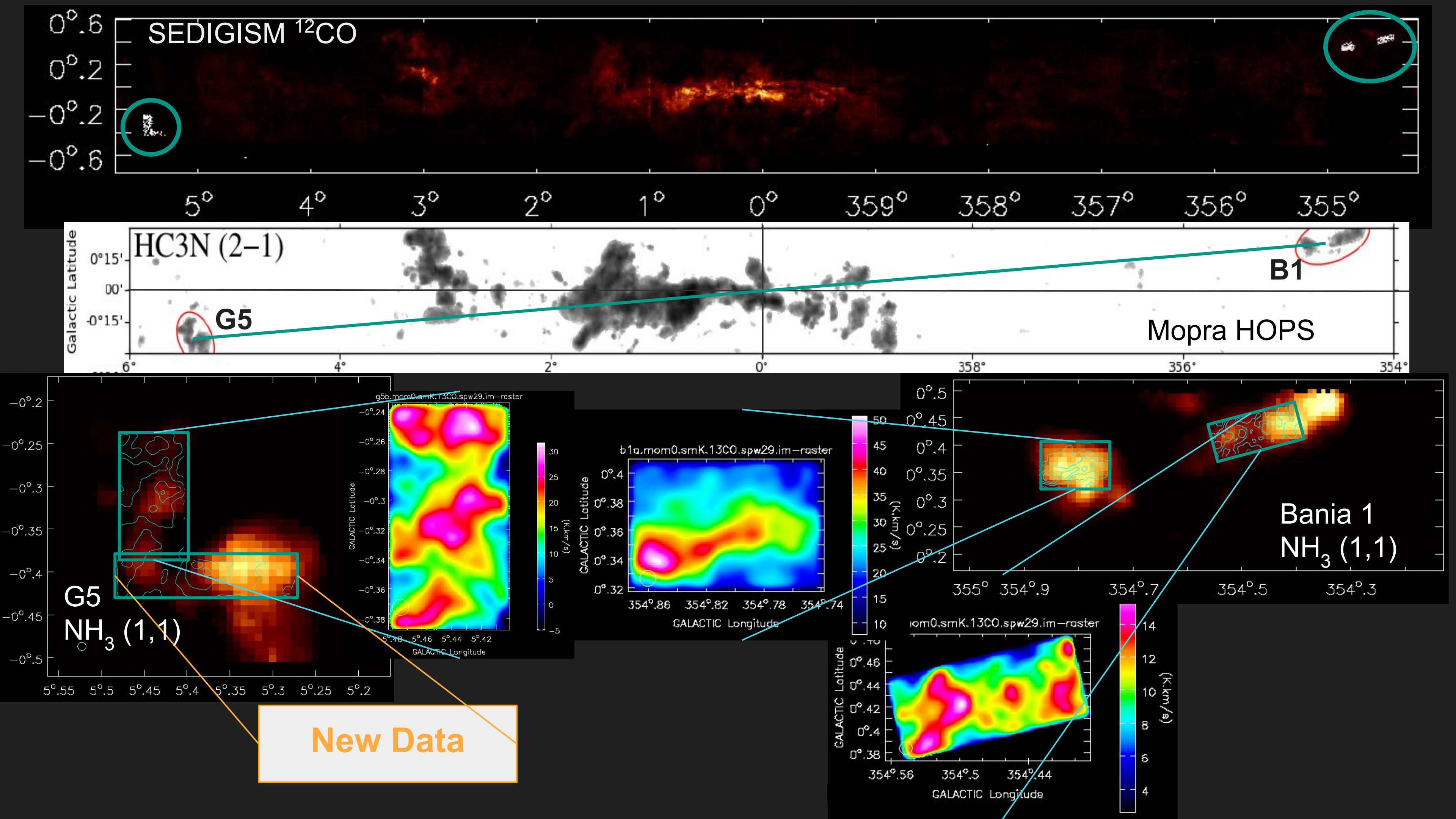




SEDIGISM 12CO
HC3N (2–1)
Galactic Latitude
G5
B1
Mopra HOPS
G5
NH3 (1,1)
g5b.mom0.smK.13CO.spw29.im–raster
GALACTIC Latitude
GALACTIC Longitude
(K.km/s)
b1a.mom0.smK.13CO.spw29.im–raster
41.1507 km/s GALACTIC Longitude
GALACTIC Latitude
Bania 1
NH3 (1,1)
mom0.smK.13CO.spw29.im–raster
41.1881 km/s GALACTIC Longitude

Observations

- ALMA, Atacama Compact Array.
    - Both 7m and TP observations.
- About 60 hours in total used to observe.
- Band 6, around 220 GHz. TP 12m resolution of 30” (1.25pc at 8.2kpc).
    - Resolution ~6” (~0.25pc) with ACA.
- Four regions in total, two at each cloud.
    - This summer focused on new G5 total power data.
- Observed transitions of CO (2-1) isotopologues, H30α, SiO (5-4), CH_3OH ($4_{2,2}$-$3_{1,2}$), OCS (18-17), H_2CO ($3_{2,1}$-$2_{2,0}$), and H_2CO ($3_{0,3}$-$2_{0,2}$).



SEDIGISM ^{12}CO
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NH_3 (1,1)
om0.smK.13CO.spw29.im–raster
GALACTIC Latitude
GALACTIC Longitude
(K.km/s)
New Data

Total Power Data Reduction

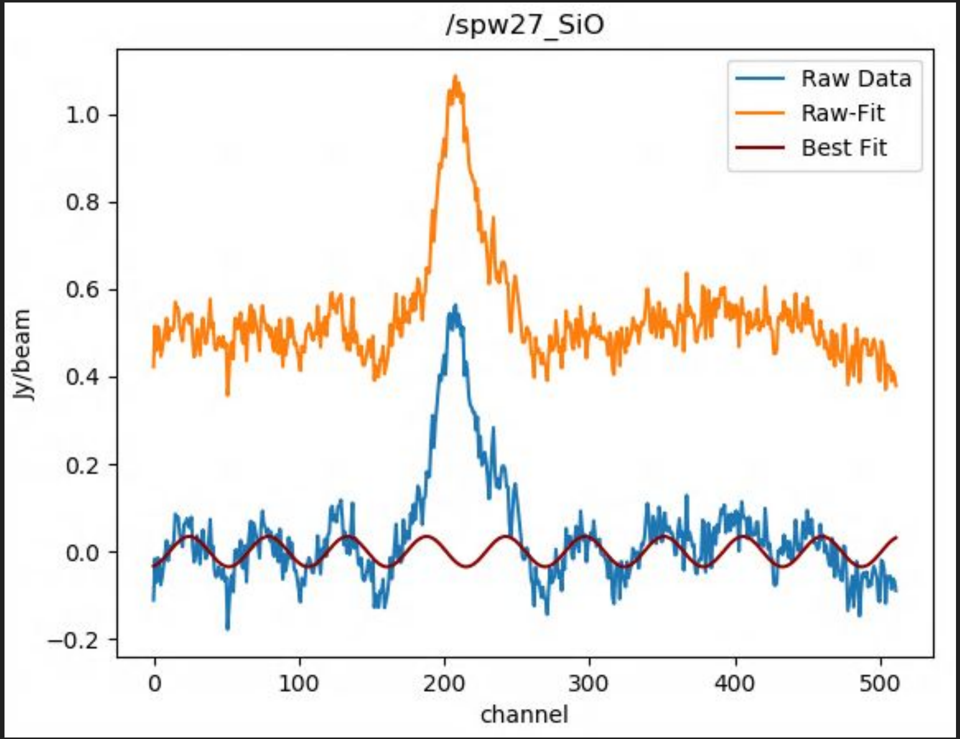
ALMA delivers calibrated image cubes.

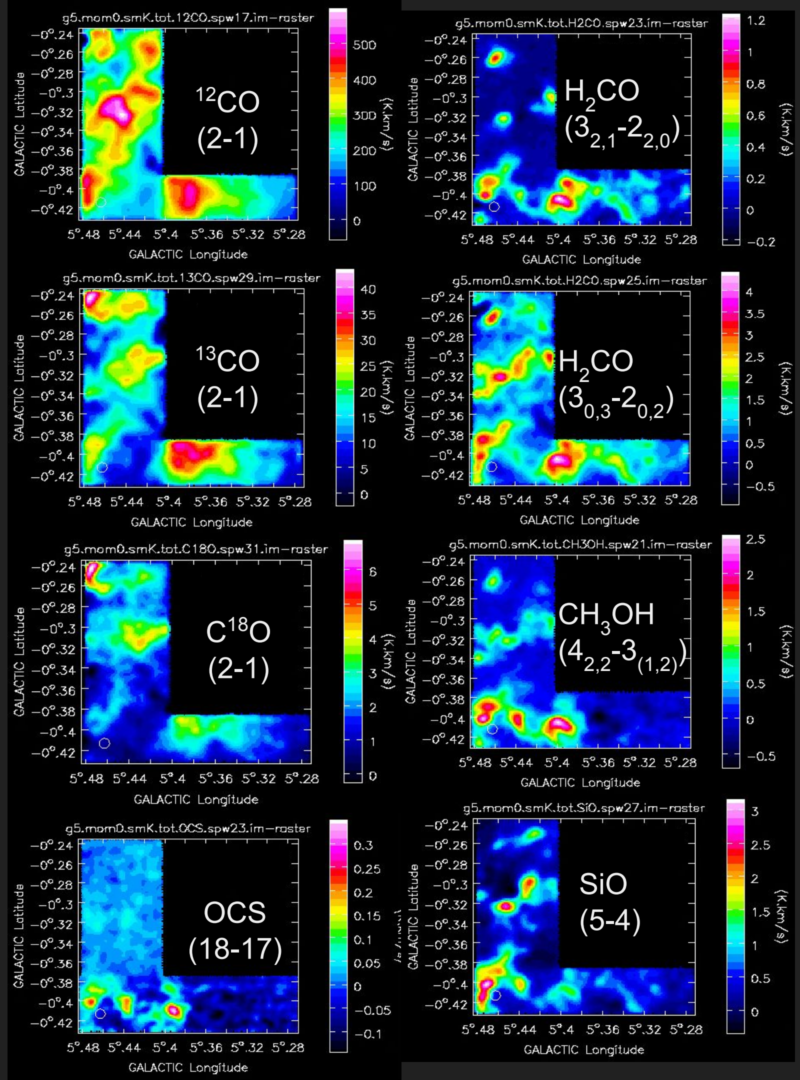
Baseline

- Residual baseline ripple present in most of the data cubes.
- Removed by using Python (LMFIT) to create a sine wave across the cubes using channels without emission.
- Averaged cube spatially, derived a sine curve for the entire cube, subtracted it from each pixel.

Combining Cubes

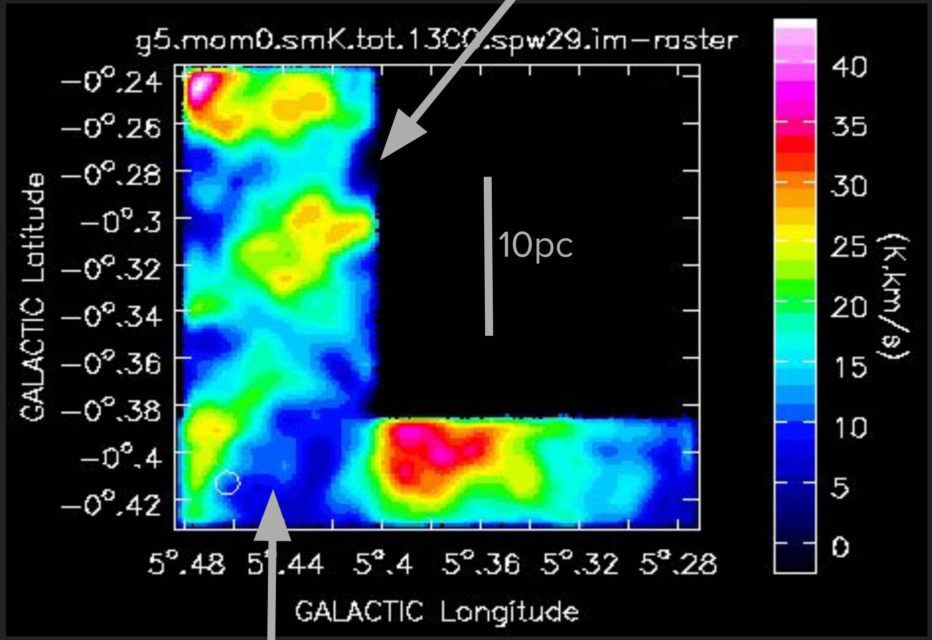
- The two parts of G5 were merged by averaging where they overlapped.





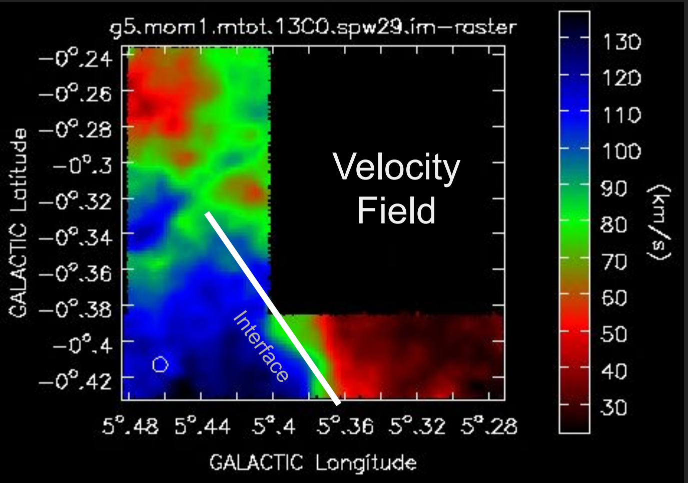
Line Intensity

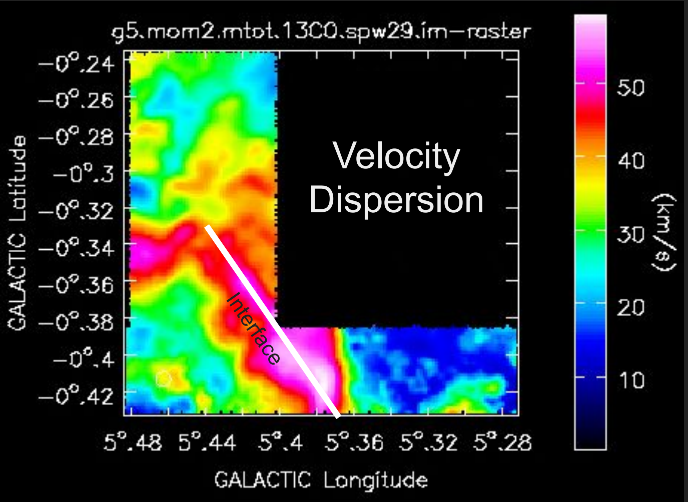
G5b (from last summer)



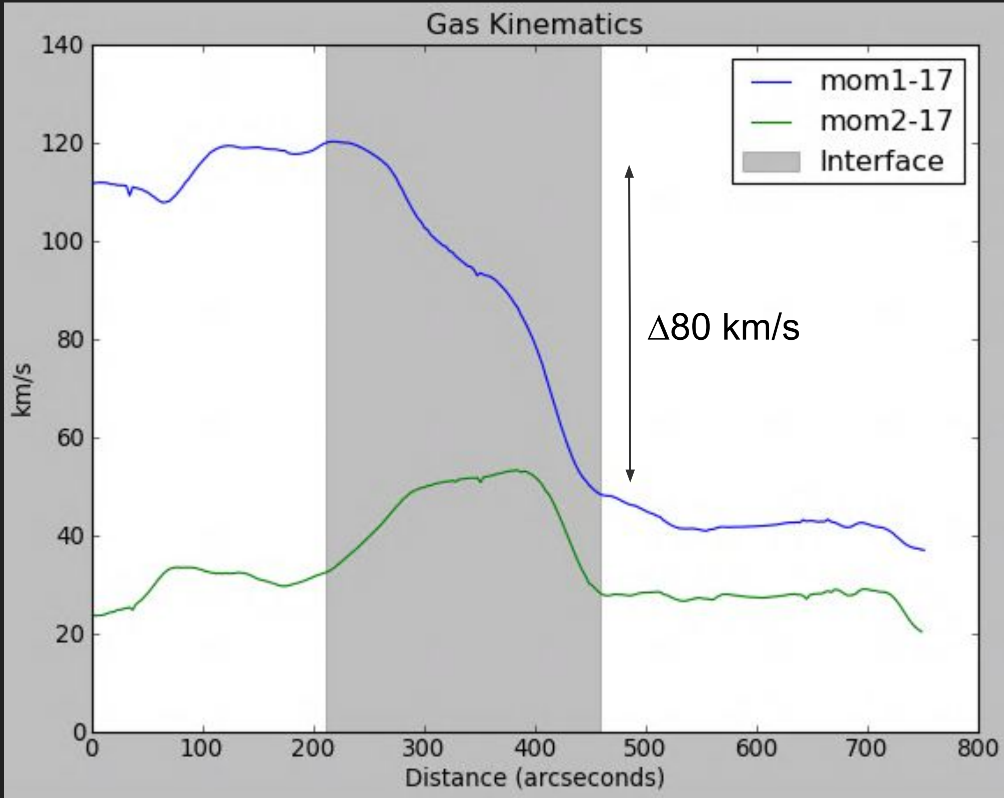
G5a (new data)

Gas Kinematics

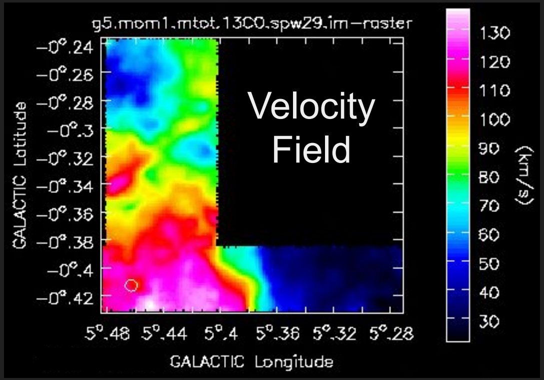


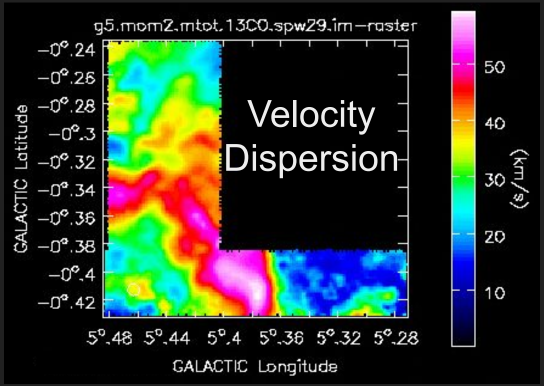


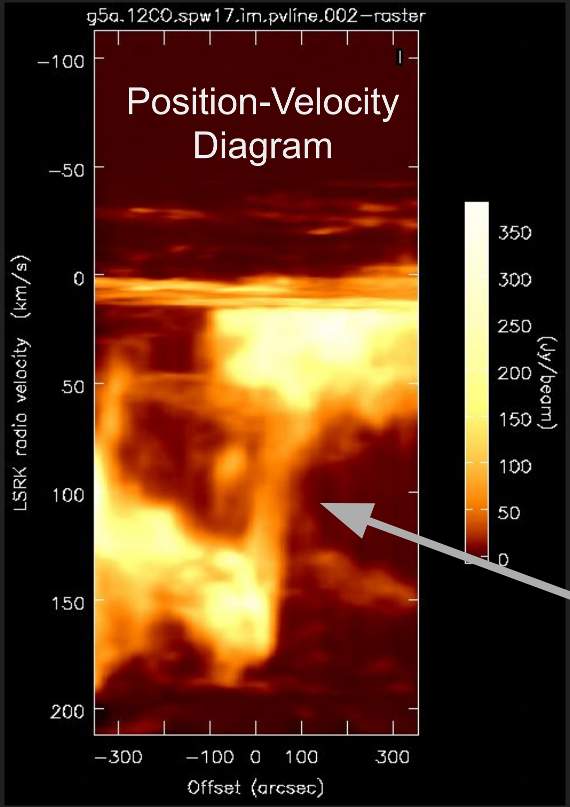
- Velocity gradients
- Large dispersion
- Interface



Gas Kinematics







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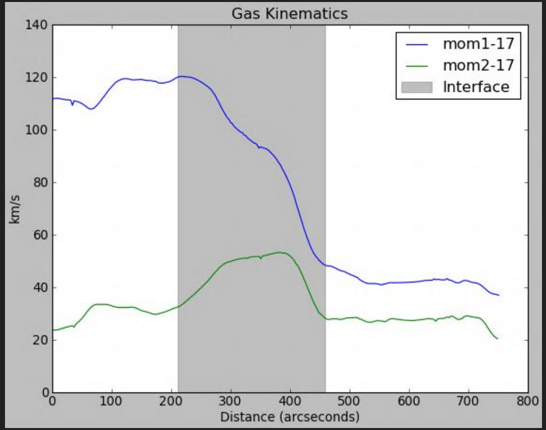
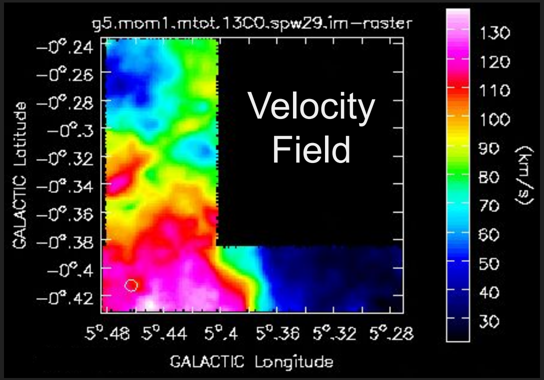
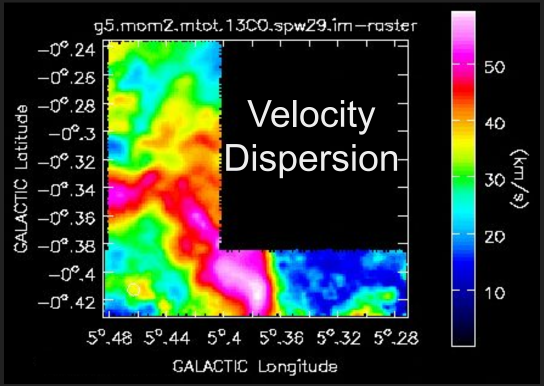
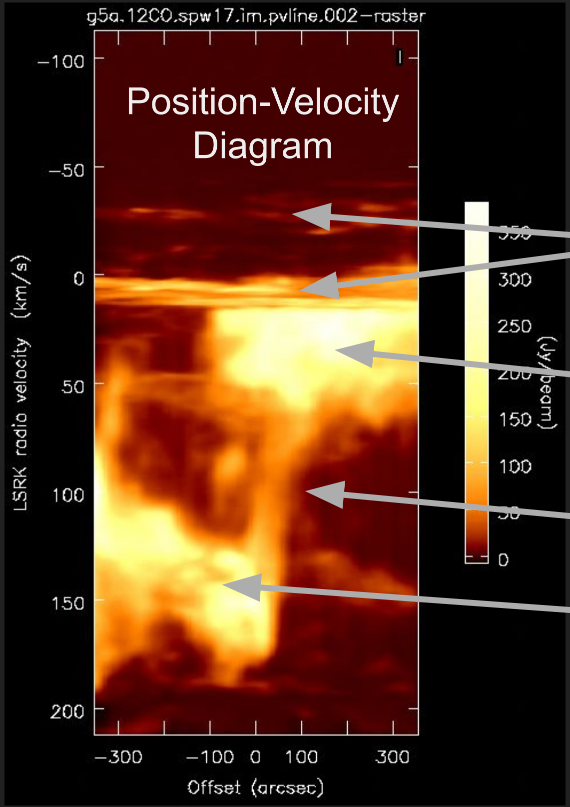


- Vertical extended velocity feature (aka the velocity bridge) connecting the two clouds is evidence of a cloud-cloud collision.

Gas Kinematics







Line of Sight, galactic emission.

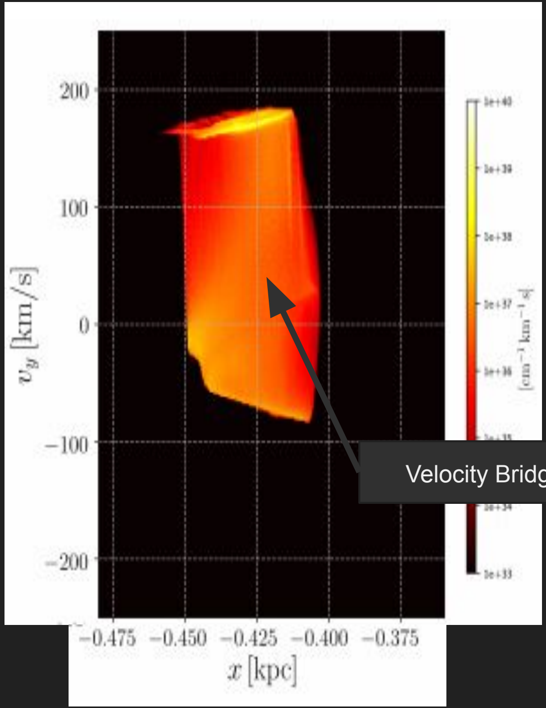
Lower velocity GC cloud. (Over-Shooting)

Velocity Bridge

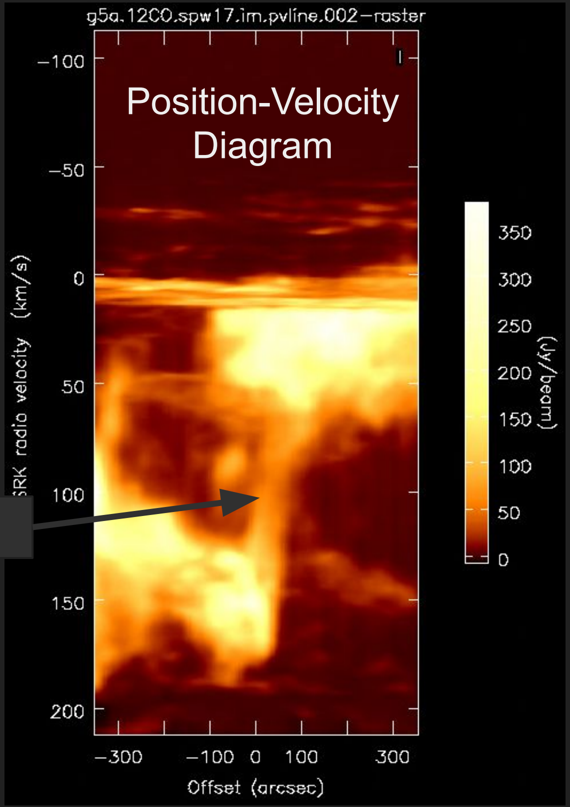
Higher velocity GC cloud. (Dust Lane)

Gas Kinematics

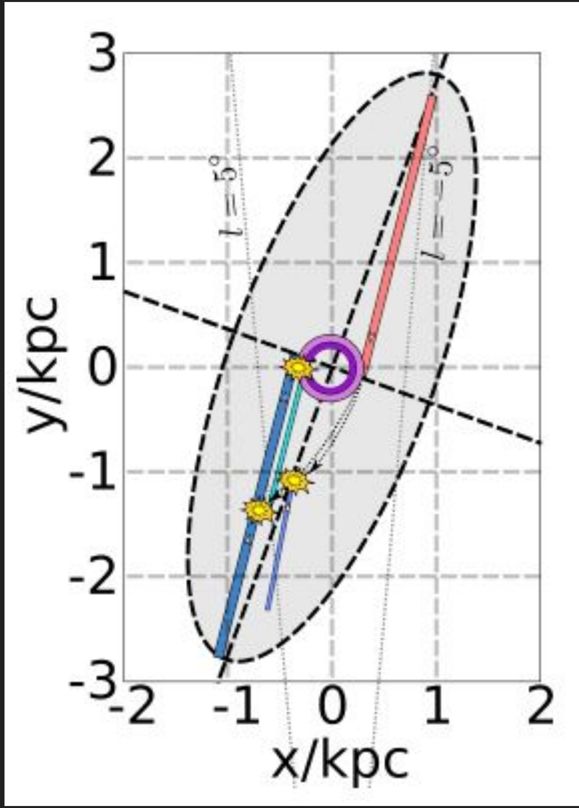
Model of a PV Diagram of Velocity Bridge
in bar cloud-cloud collision.



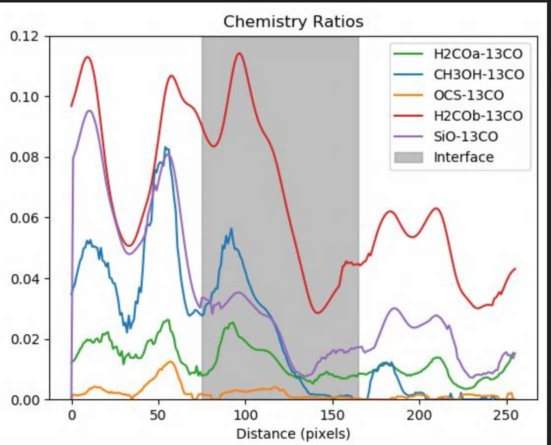
Sormani et al. 2019



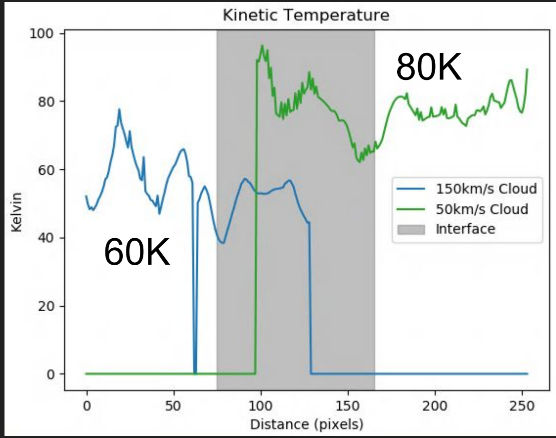
Sormani et al. 2019



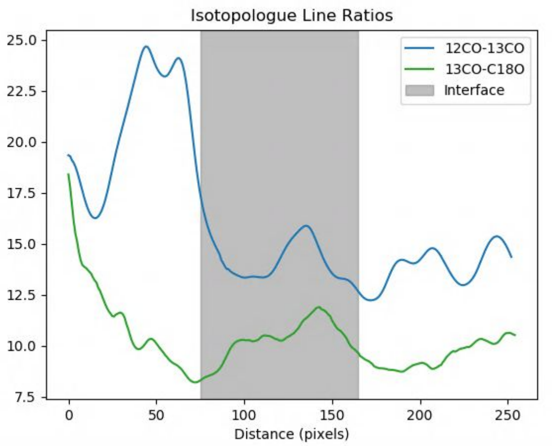
Various Slices



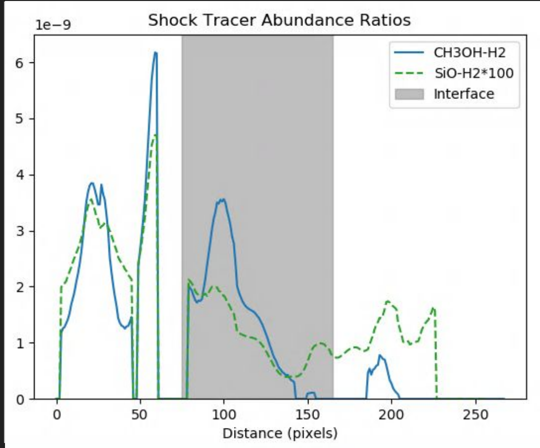
- Chemical Line Abundance Ratios.



- Kinetic Temperature of the right, over -shooting, cloud is higher than the left, dustlane, one.
- Traced with H_2CO.



- Higher Isotopologue ratio (12/13) trace where the cloud is translucent in CO.
- Clear difference between the clouds.

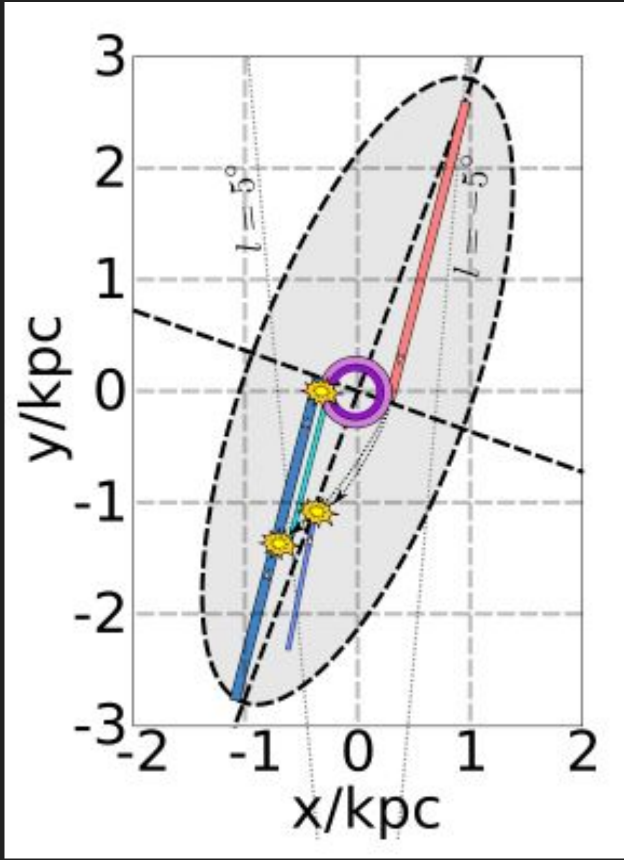


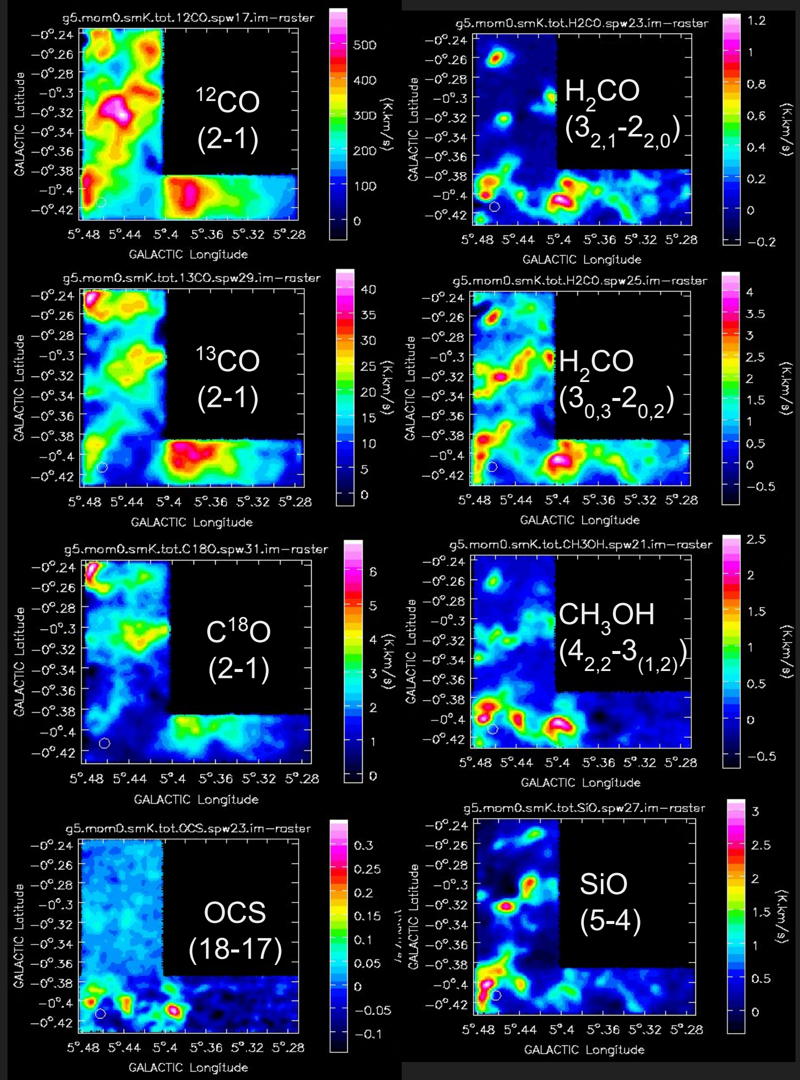
- Shock Tracer Abundance Ratios.
- Enhanced downstream of the interface.

Conclusion

- Observed gas flows within the Milky Way's bar helps to create a better model of the galaxy.
- ALMA used to observe two clouds which seemed relevant to the bar model.
- Found that G5 is composed of two clouds near the Galactic Center which are colliding with each other.
- This collision supports Sormani's model of gas overshooting the CMZ after travelling down a dust lane and hitting the dust lane on the other side of the bar.

Sormani et al. 2019





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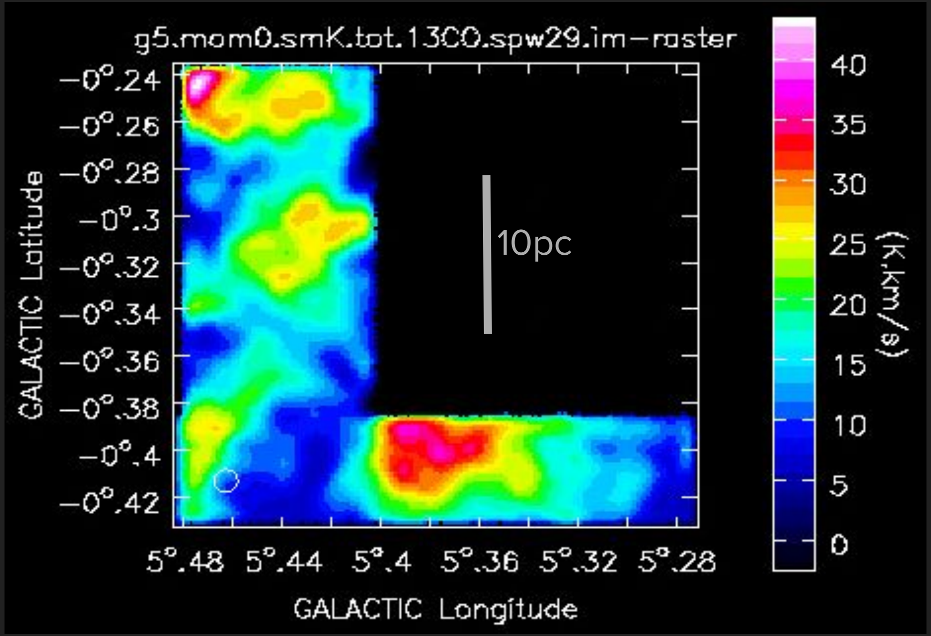

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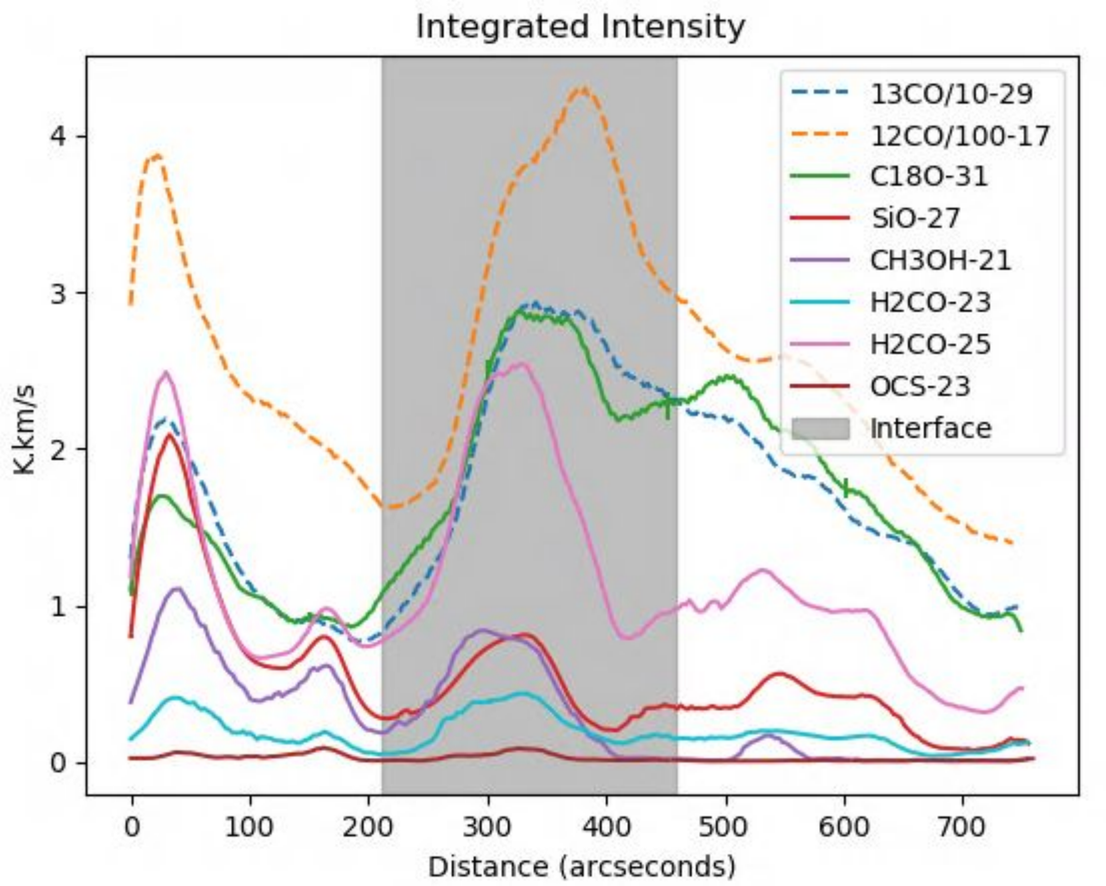
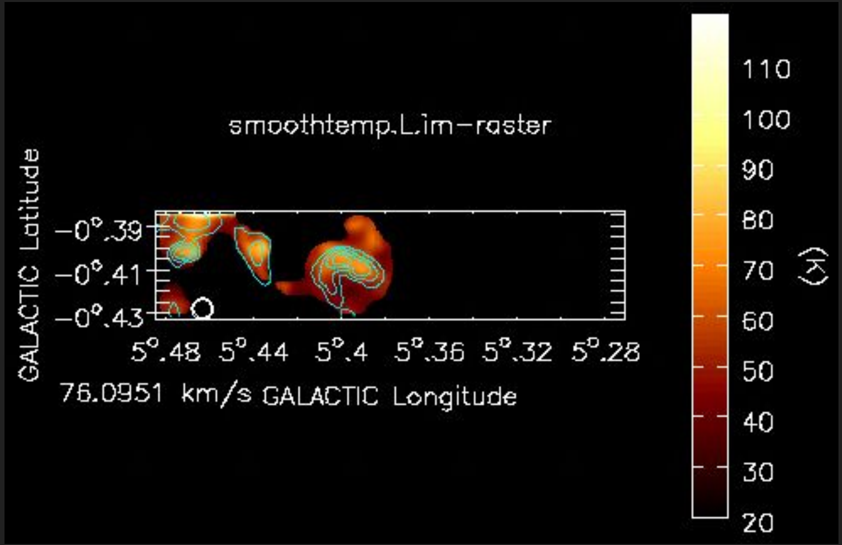
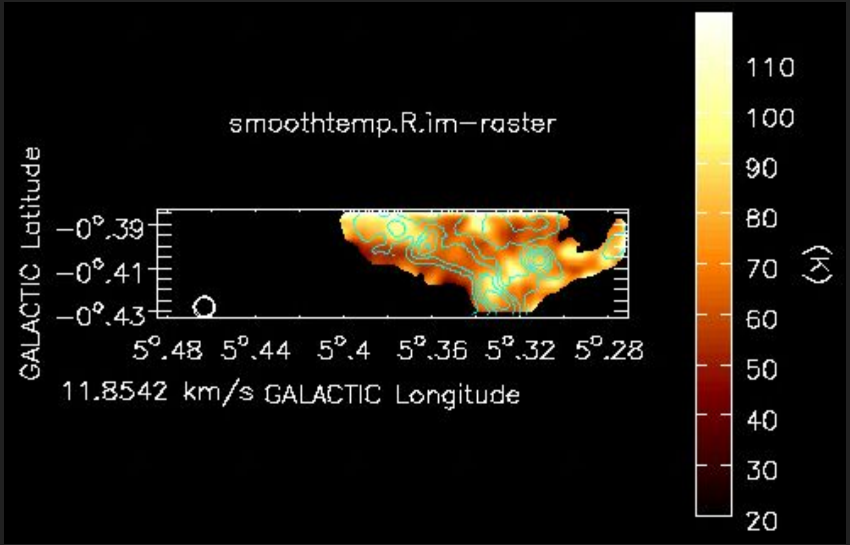
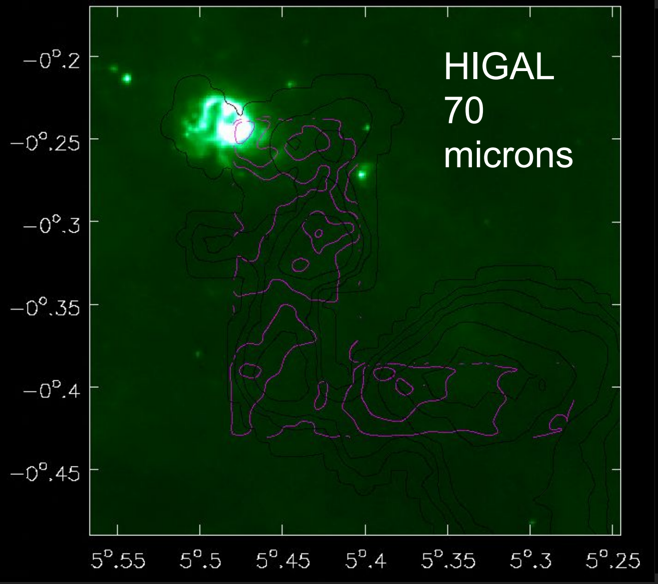

Integrated Intensity
13CO/10-29
12CO/100-17
C18O-31
SiO-27
CH3OH-21
H2CO-23
H2CO-25
OCS-23
Interface
K.km/s
0
1
2
3
4
0
100
200
300
400
500
600
700
Distance (arcseconds)

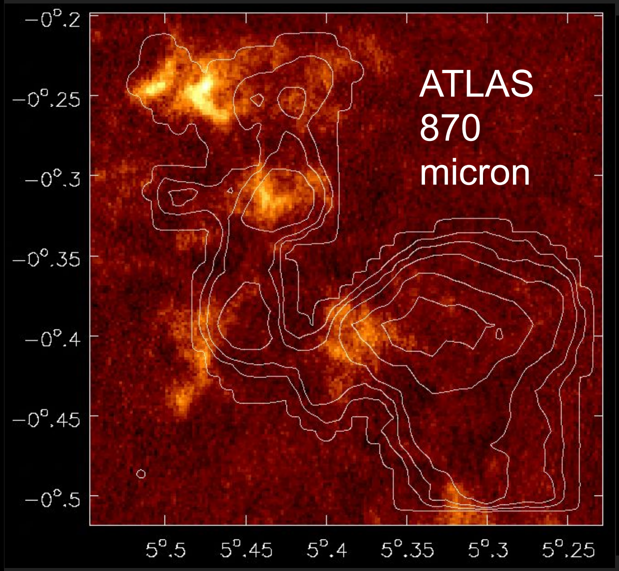


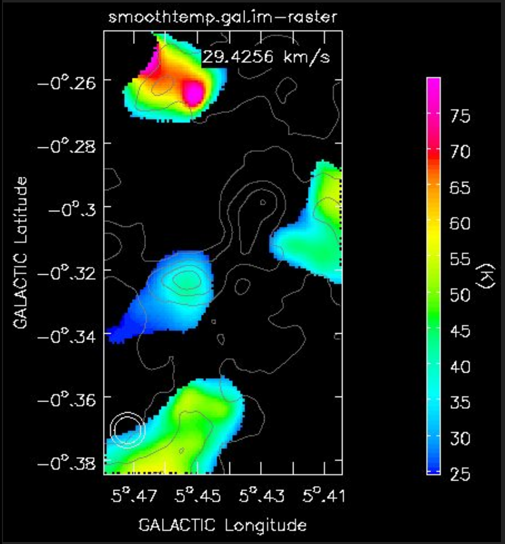
smoothtemp.L.im-raster
GALACTIC Latitude
−0°.39
−0°.41
−0°.43
5°.48 5°.44 5°.4 5°.36 5°.32 5°.28
76.0951 km/s GALACTIC Longitude
110
100
90
80
70
60
50
40
30
20
(K)

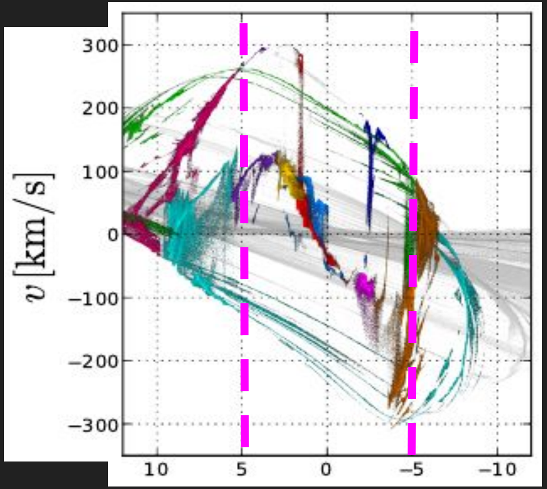


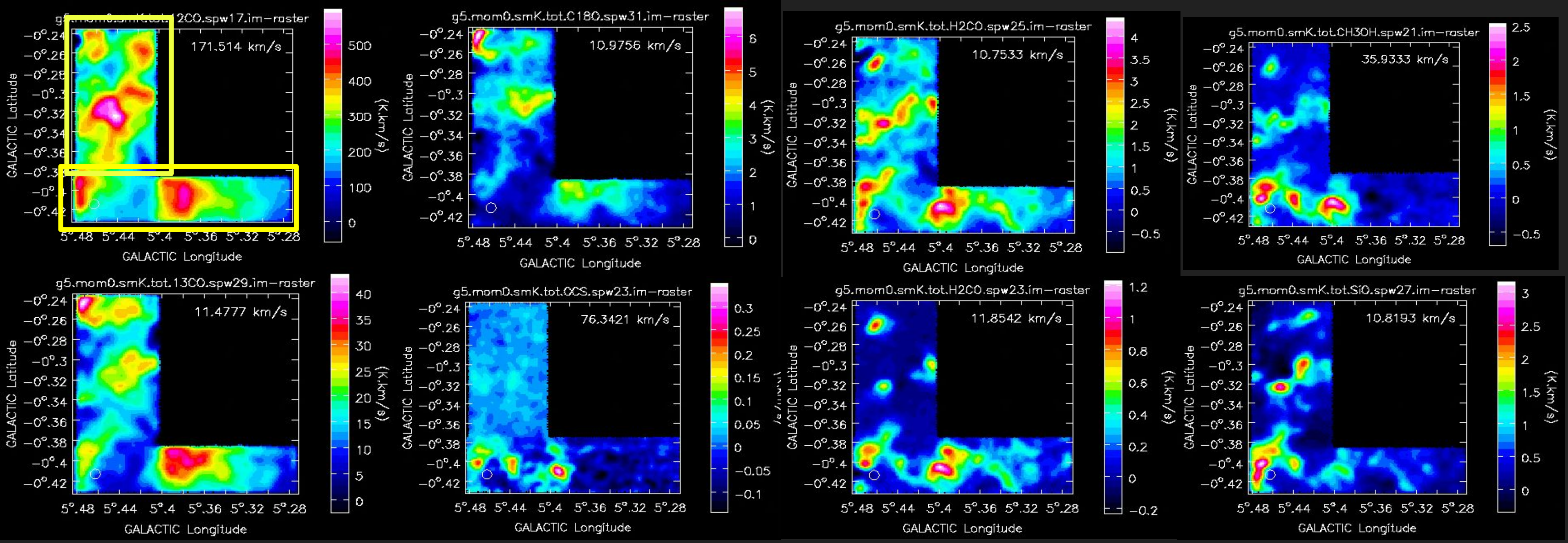
smoothtemp.R.im-raster
GALACTIC Latitude
−0°.39
−0°.41
−0°.43
5°.48 5°.44 5°.4 5°.36 5°.32 5°.28
11.8542 km/s GALACTIC Longitude
110
100
90
80
70
60
50
40
30
20
(K)


HIGAL
70
microns
−0°.2
−0°.25
−0°.3
−0°.35
−0°.4
−0°.45
5°.55 5°.5 5°.45 5°.4 5°.35 5°.3 5°.25

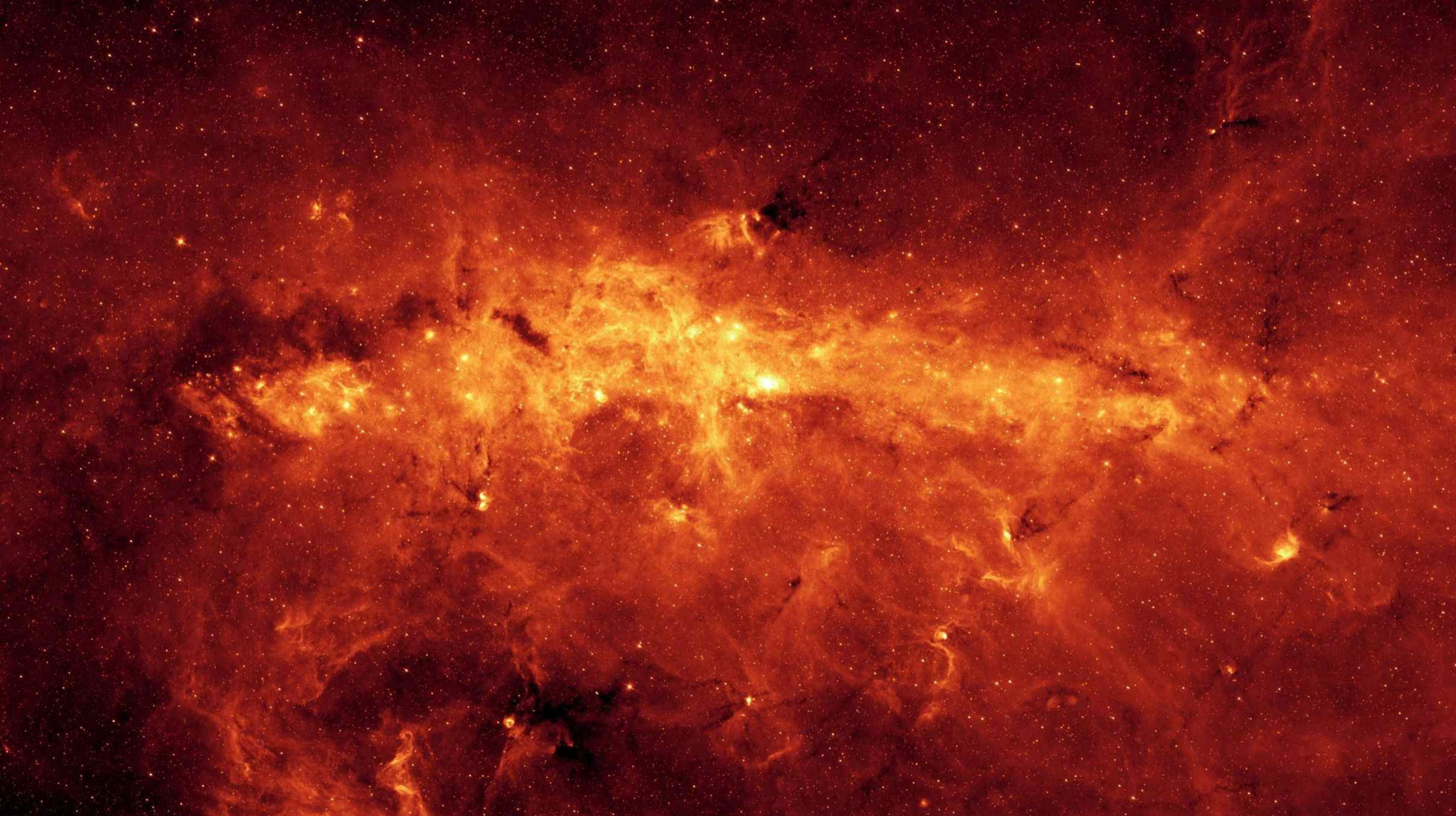

ATLAS
870
micron
−0°.2
−0°.25
−0°.3
−0°.35
−0°.4
−0°.45
−0°.5
5°.5 5°.45 5°.4 5°.35 5°.3 5°.25


smoothtemp.gal.im−raster
29.4256 km/s
GALACTIC Latitude
−0°.26
−0°.28
−0°.3
−0°.32
−0°.34
−0°.36
−0°.38
5°.47 5°.45 5°.43 5°.41
GALACTIC Longitude
75
70
65
60
55
50
45
40
35
30
25
(K)


v [km/s]
300
200
100
0
−100
−200
−300
10 5 0 −5 −10

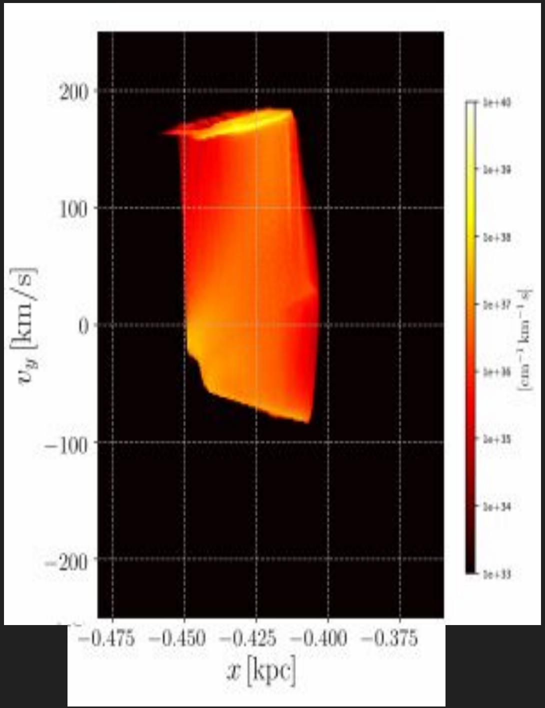


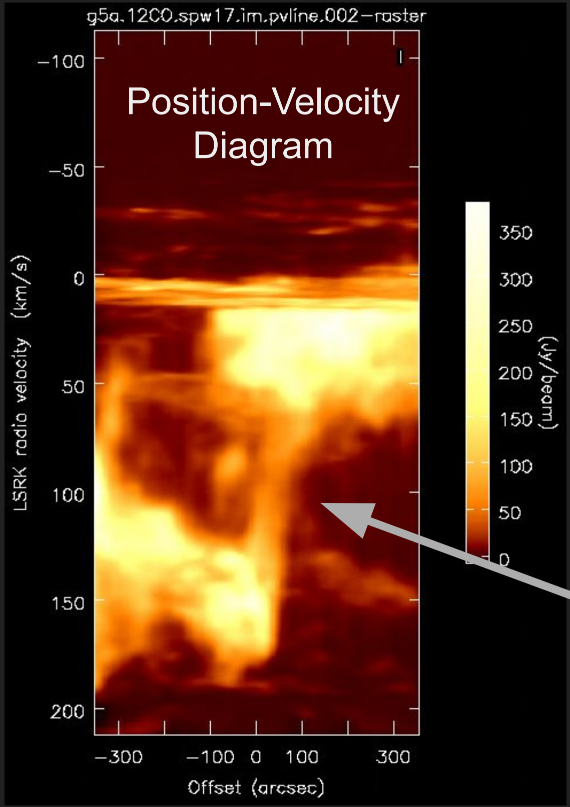
171.514 km/s
g5.mom0.smK.tot.C18O.spw31.im-raster
10.9756 km/s
g5.mom0.smK.tot.H2CO.spw25.im-raster
10.7533 km/s
g5.mom0.smK.tot.CH3OH.spw21.im-raster
35.9333 km/s
g5.mom0.smK.tot.13CO.spw29.im-raster
11.4777 km/s
g5.mom0.smK.tot.OCS.spw23.im-raster
76.3421 km/s
g5.mom0.smK.tot.H2CO.spw23.im-raster
11.8542 km/s
g5.mom0.smK.tot.SiO.spw27.im-raster
10.8193 km/s
GALACTIC Latitude
GALACTIC Longitude
(K.km/s)



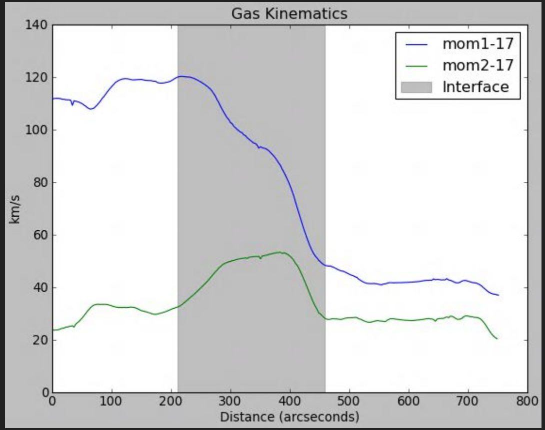
Gas Kinematics

Sormani et al. 2019





- High velocity cloud on left is in the dust lane shock front, low velocity cloud on the right is the overshooting cloud.



- Vertical extended velocity feature (aka the velocity bridge) connecting the two clouds is evidence of a cloud-cloud collision.

Observations

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  - **Both 7m and TP observations.**
- **About 60 hours in total used to observe.**
- **Band 6, around 220 GHz. TP 12m resolution of 30” and structure size of 1.25pc.**
  - **Resolution ~6” with ACA, structure sizes of ~0.25pc at 8.2kpc away in the galactic center.**
- **Four regions in total, two at each cloud.**
  - **B1 (Bania 1) at (l,b) = (-5.4,+0.4), G5 at (+5.4, -0.4)**
  - **This summer focused on G5.**
- **Observed transitions of CO isotopologues, H30α, HC_3N, SiO, and two H_2CO transitions.**

ALMA:(ESO/NAOJ/NRAO): C. Padilla