Solid CO Variation in CMZ Clouds

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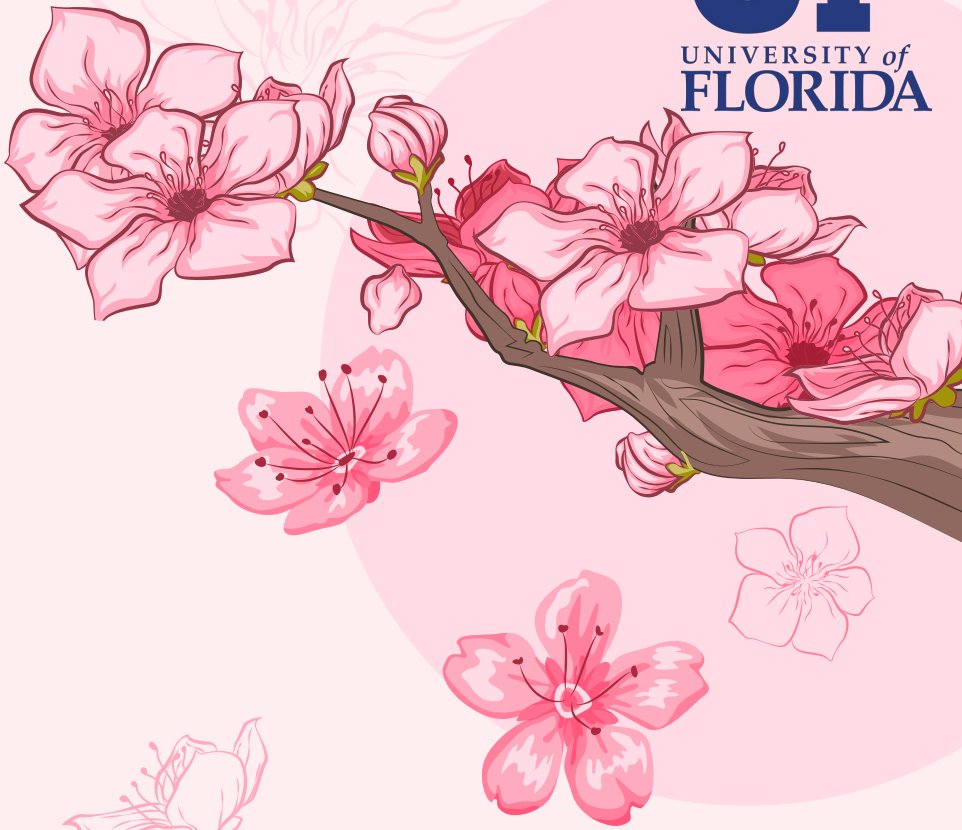

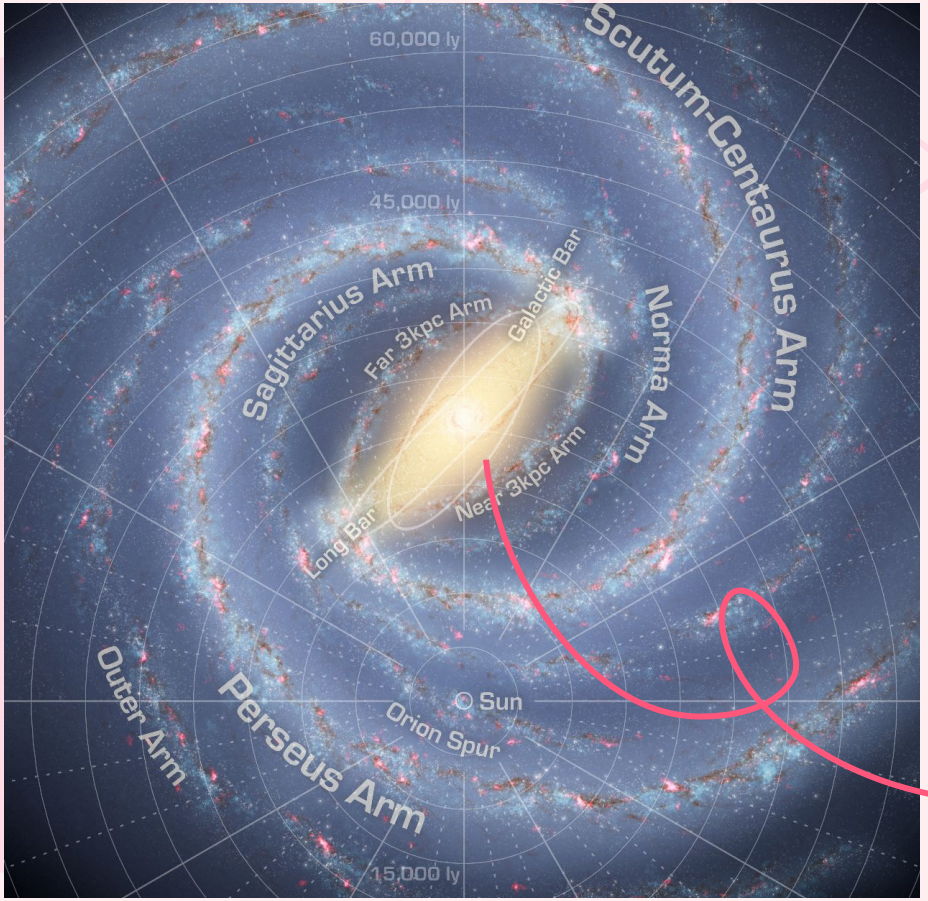

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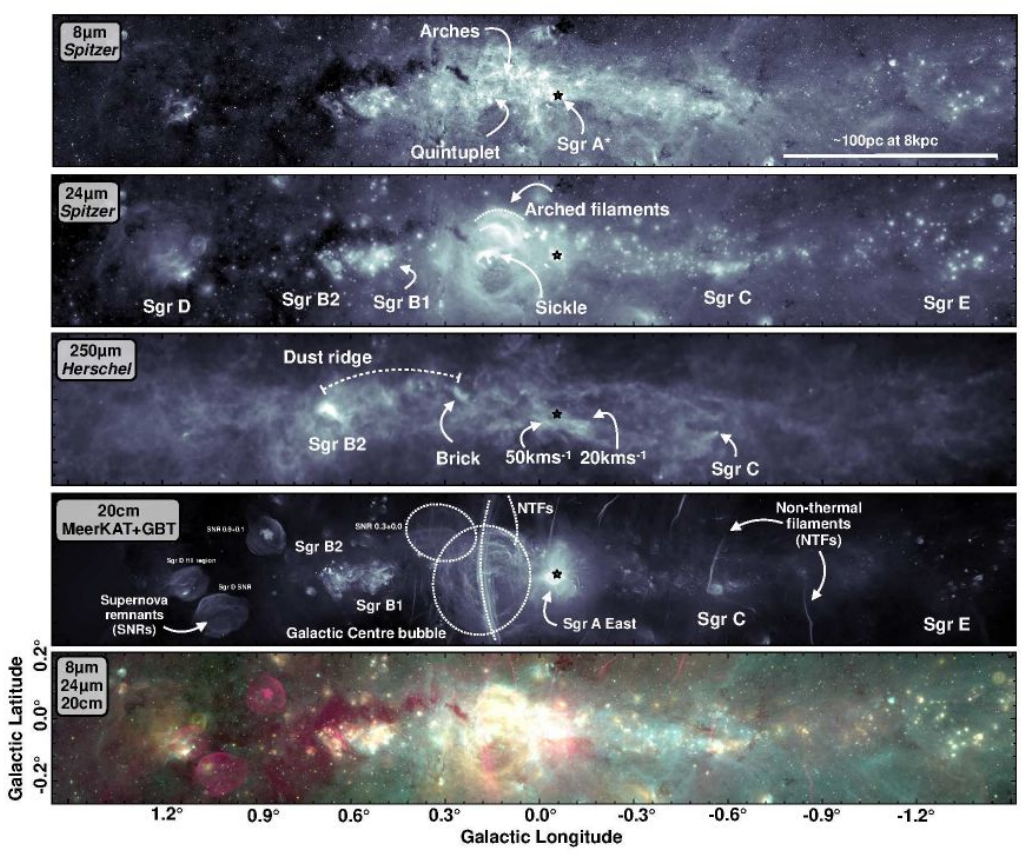
The Milky Way Galaxy

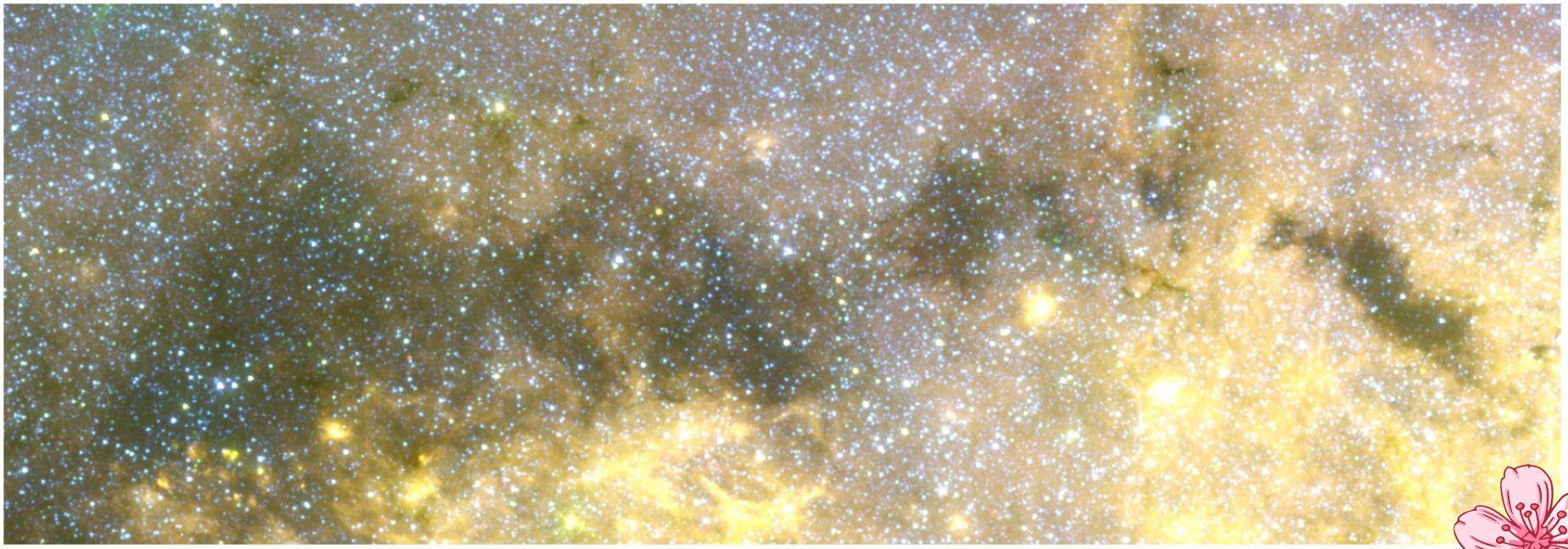
- ★ Barred spiral galaxy
- ★ The Galaxy has several spiral arms
- ★ At its center is the Central Molecular Zone (CMZ)

The Central Molecular Zone



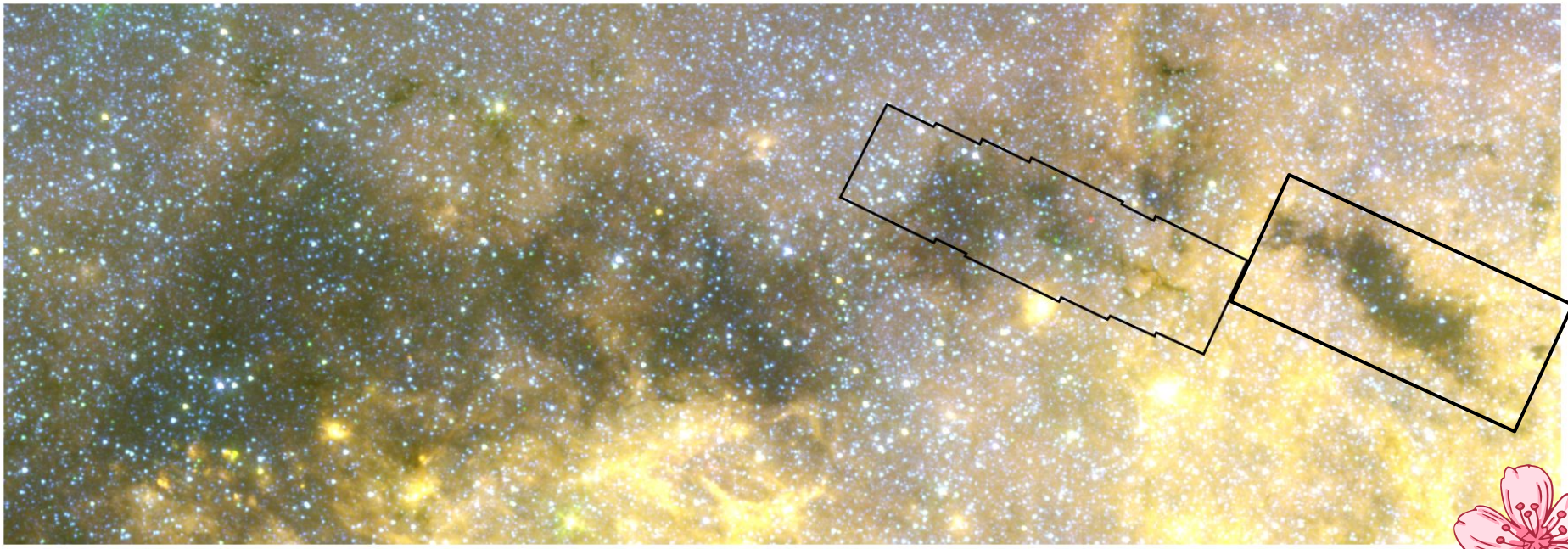
- ★ Gas and dust orbiting the Galactic Center, Sgr A*
- ★ Gas is warm (~50 K) and turbulent
- ★ Extreme environment
- ★ Exact structure unknown

Henshaw et al 2023



Spitzer

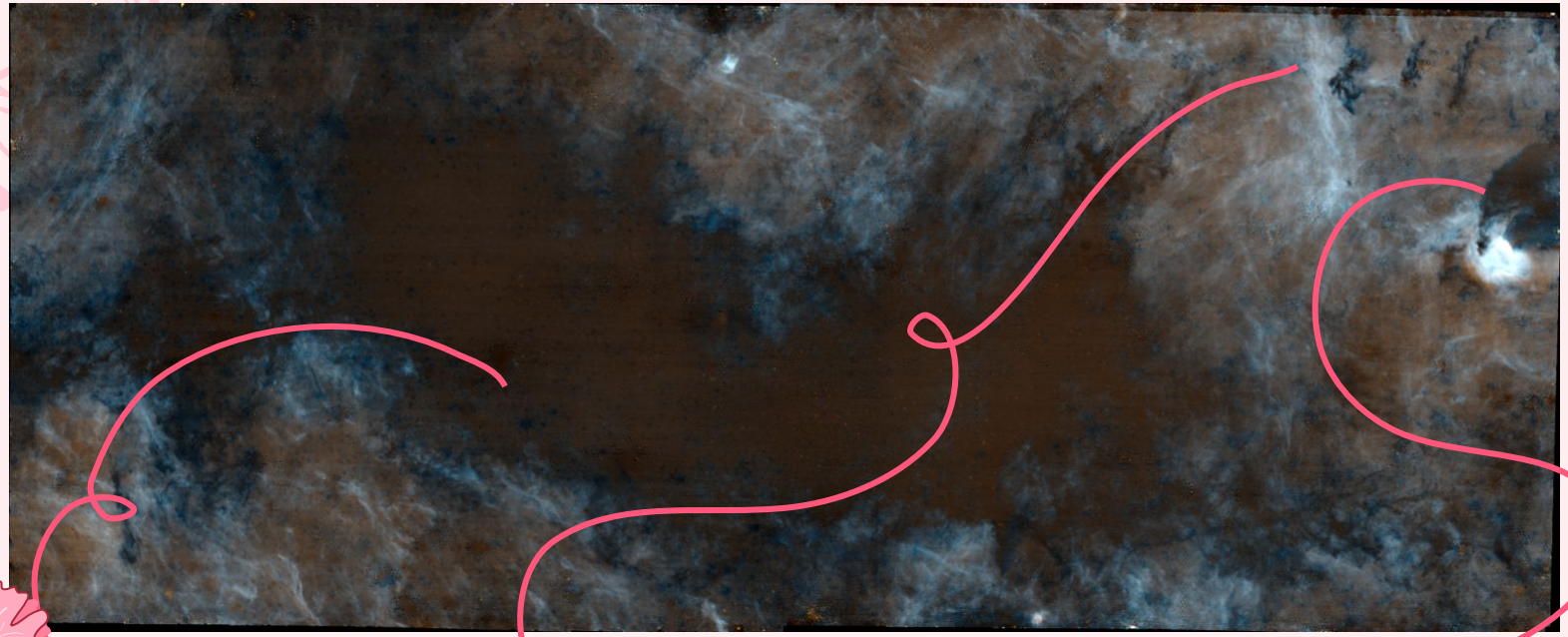
CMZ: Dust Ridge



Spitzer

CMZ: Dust Ridge – JWST Observations

Ginsburg et al 2023



Brick

Claws
+18 km/s

Star
Formation
Region
+40 km/s

Gramze et al submitted

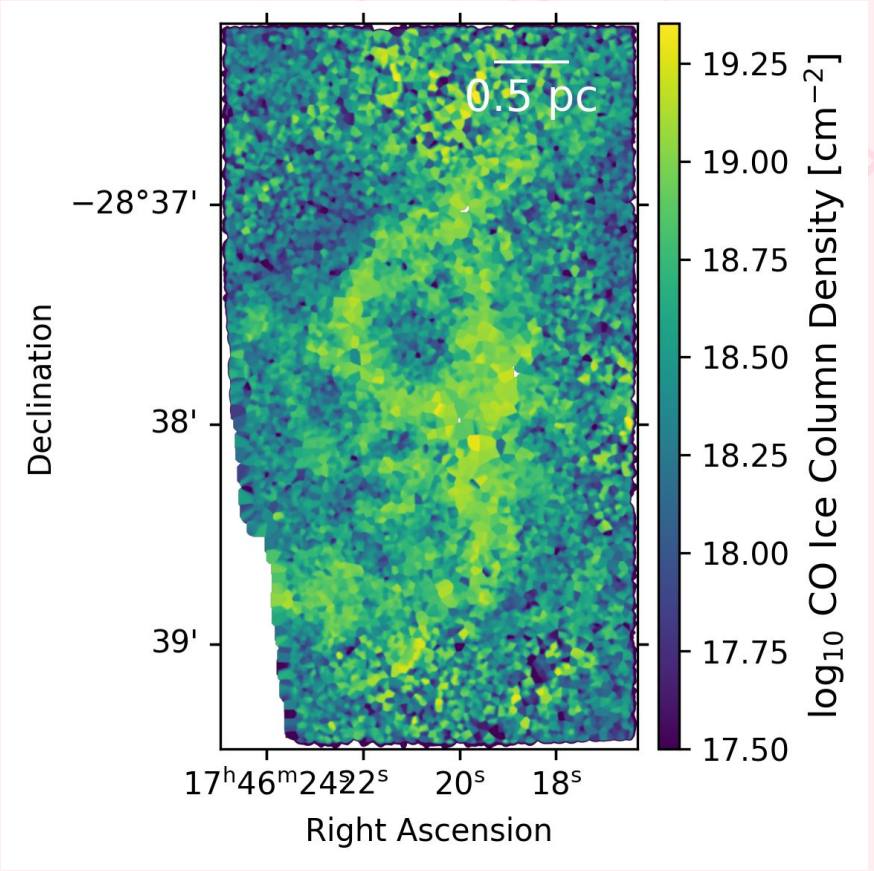
Cloud D

Cloud C

Filament
-55 km/s
3 kpc arm

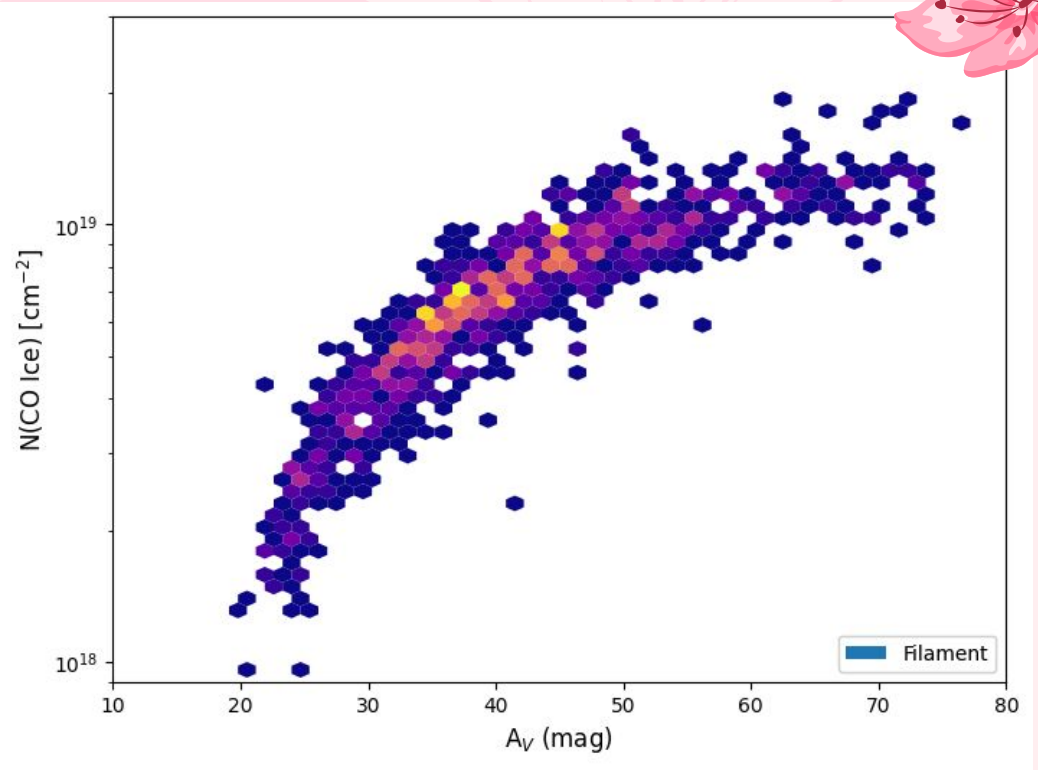
Interstellar Ice

- We can measure the CO ice column density using JWST (F466N)
- In cold, dense parts of the ISM, molecules freeze out of the gas onto dust grains
- Astrochemistry



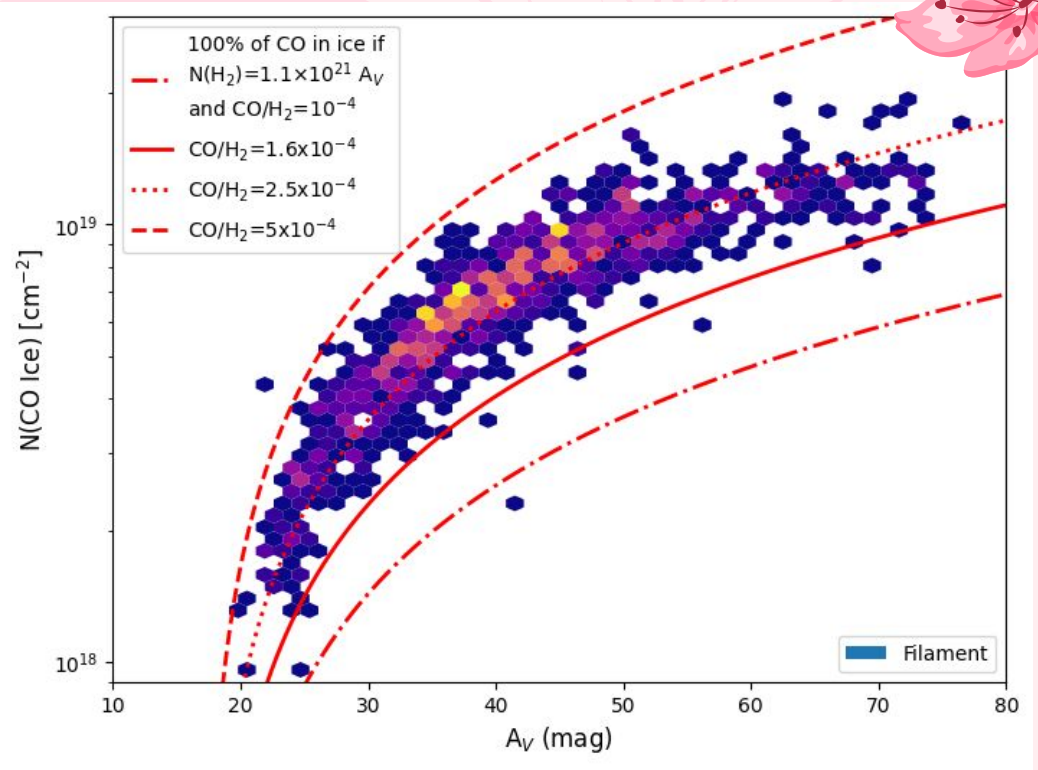
Gramze et al submitted

Galactic Variation in Solid CO to Dust



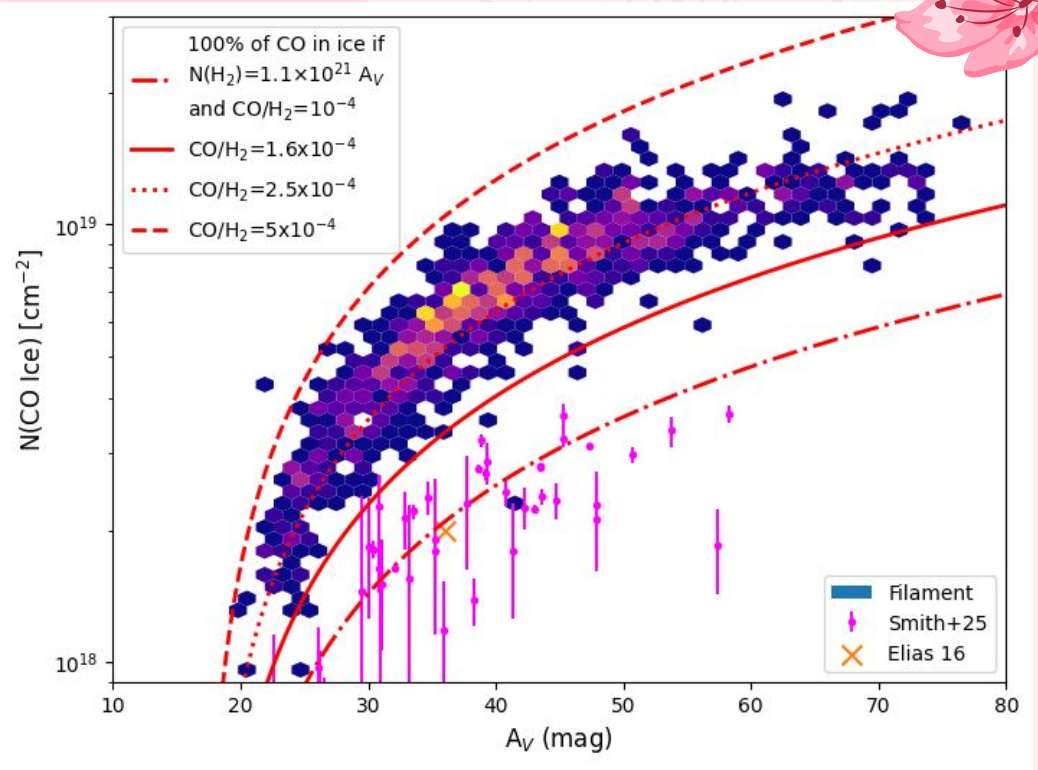
The Filament

- ★ We measure the CO ice column density toward each red clump star
- ★ Assuming H_2O:CO_2:CO = 10:1:1

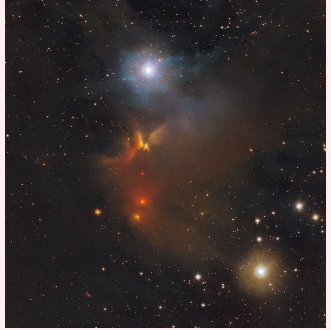


CO Abundance

- ★ Each red line is a different CO abundance
- ★ Higher abundance = more CO in ice

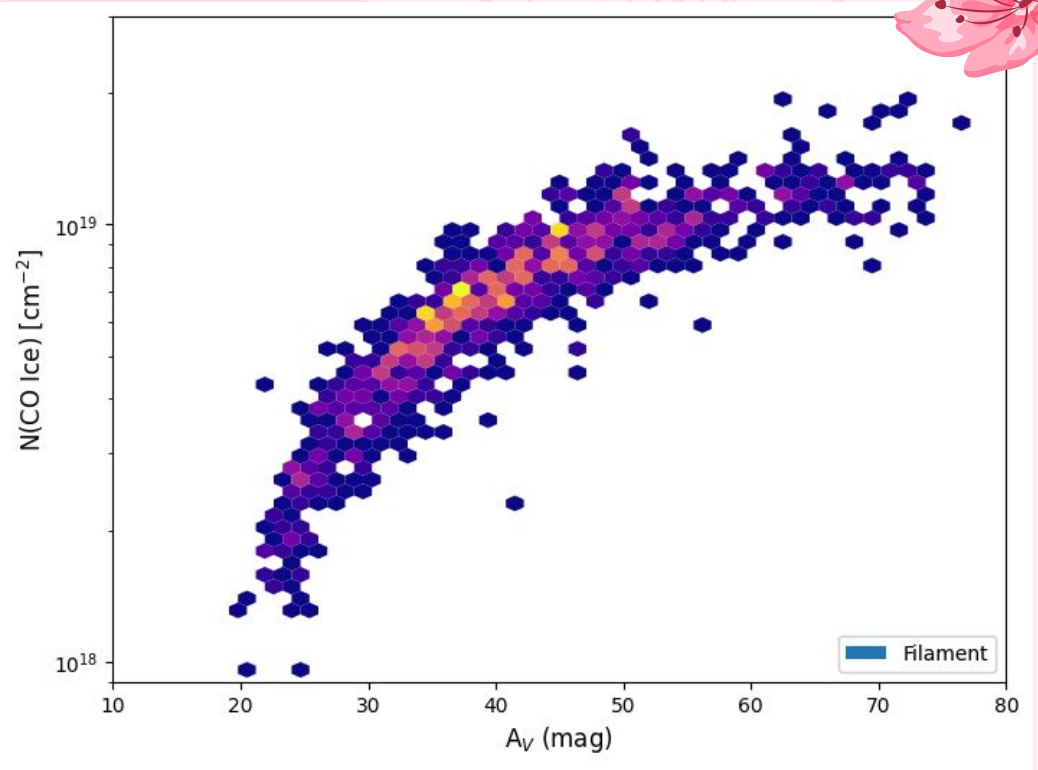


The Filament Chameleon I



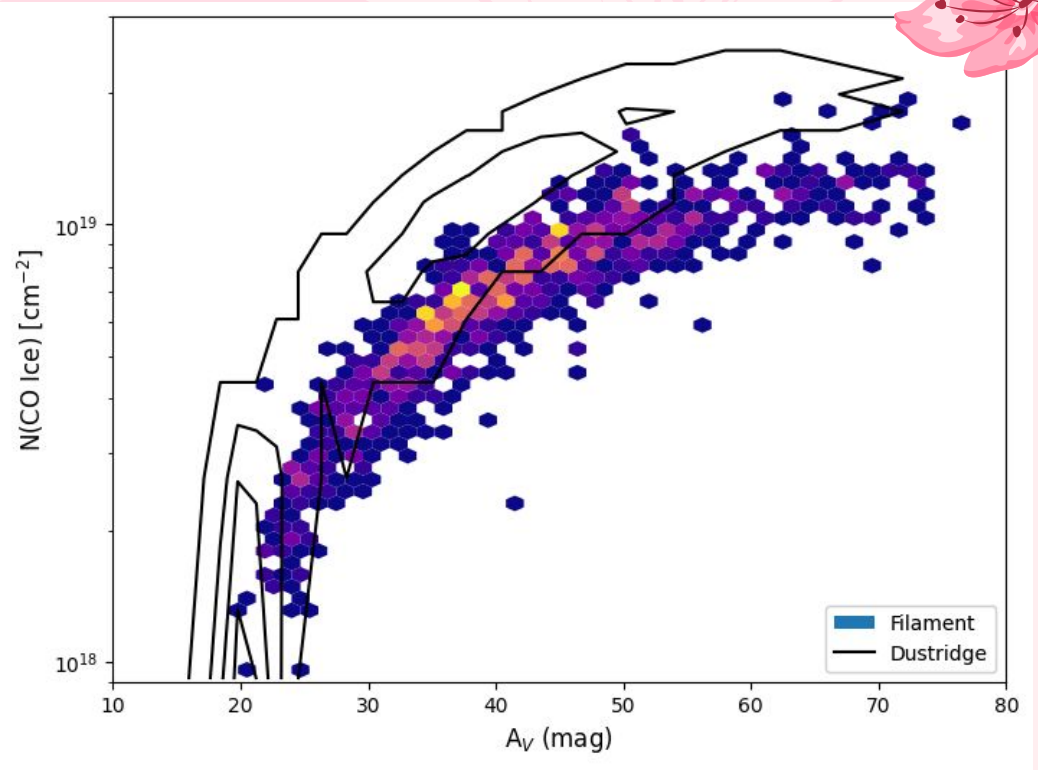
Ed Meingast et al

- ★ Chameleon I = solar neighborhood low mass star forming region
- ★ Lower CO abundance than the filament



The Filament

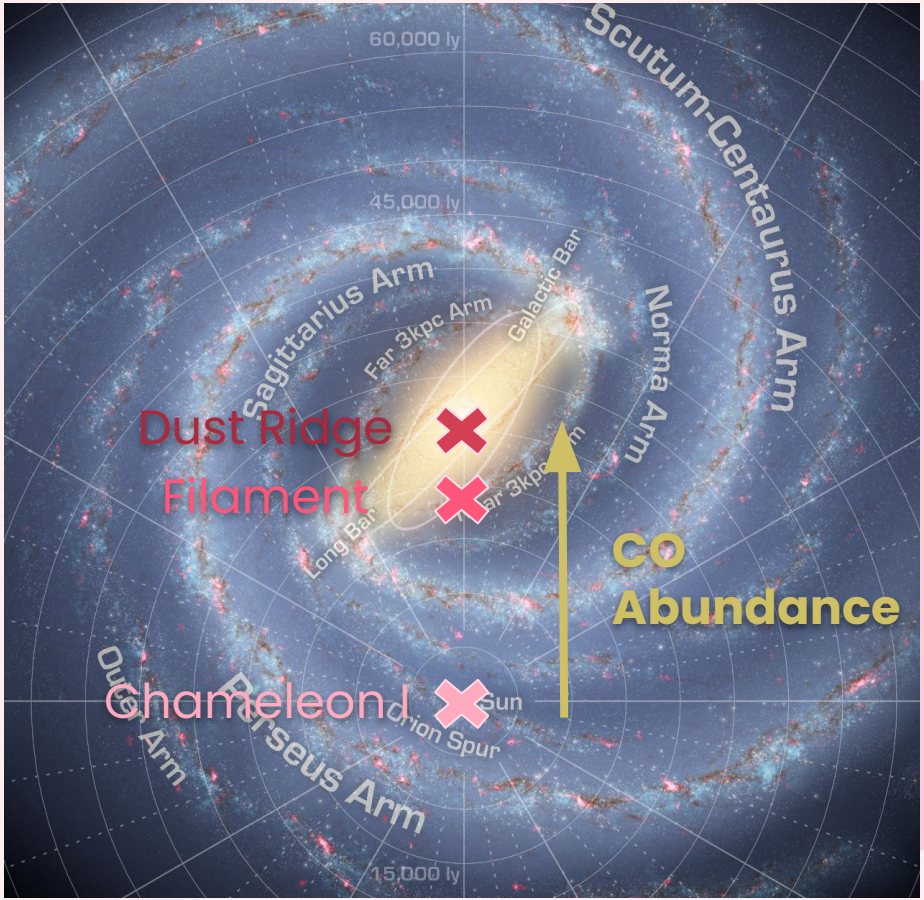
★ Removed extra points for clarity



Filament vs dust ridge

- ★ The dust ridge is in the CMZ
- ★ It has an even higher CO abundance than the filament!

CO Abundance Increases as Galactic Radius Decreases



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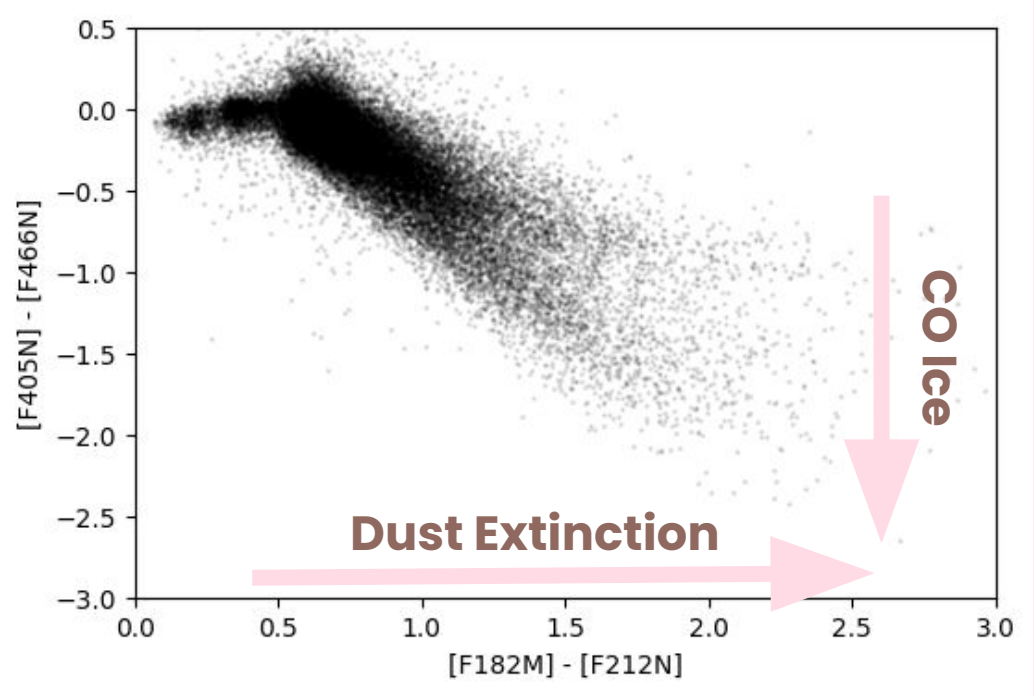
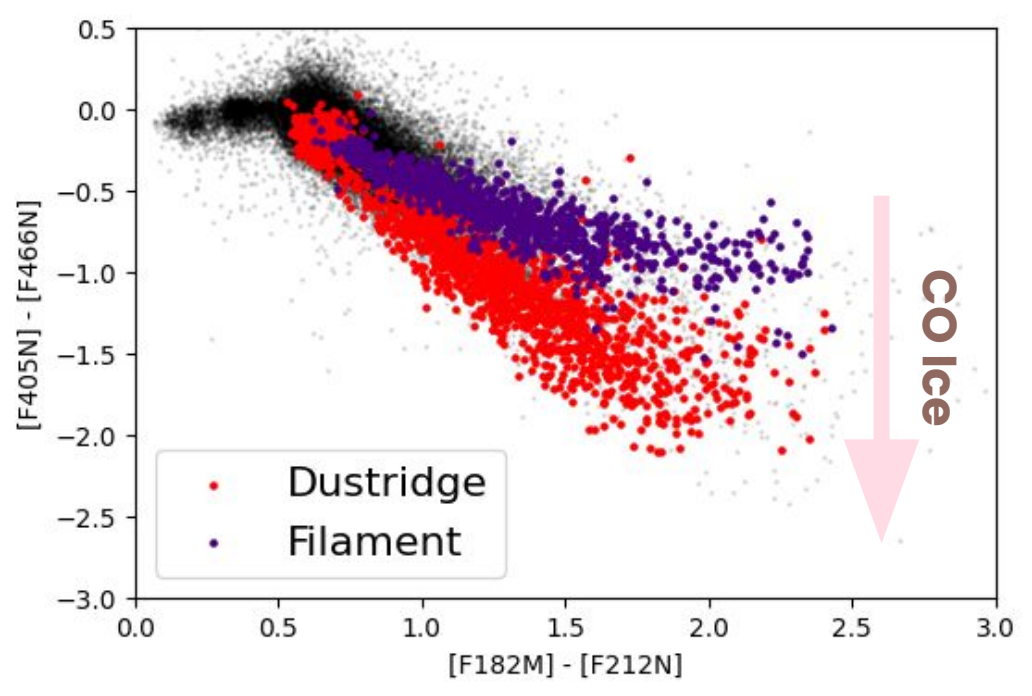
CMZ Cloud Variation

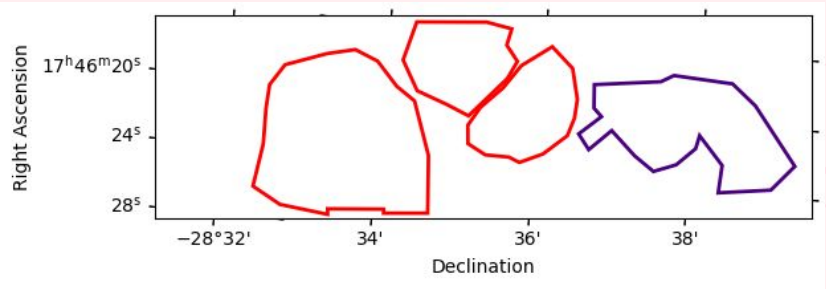


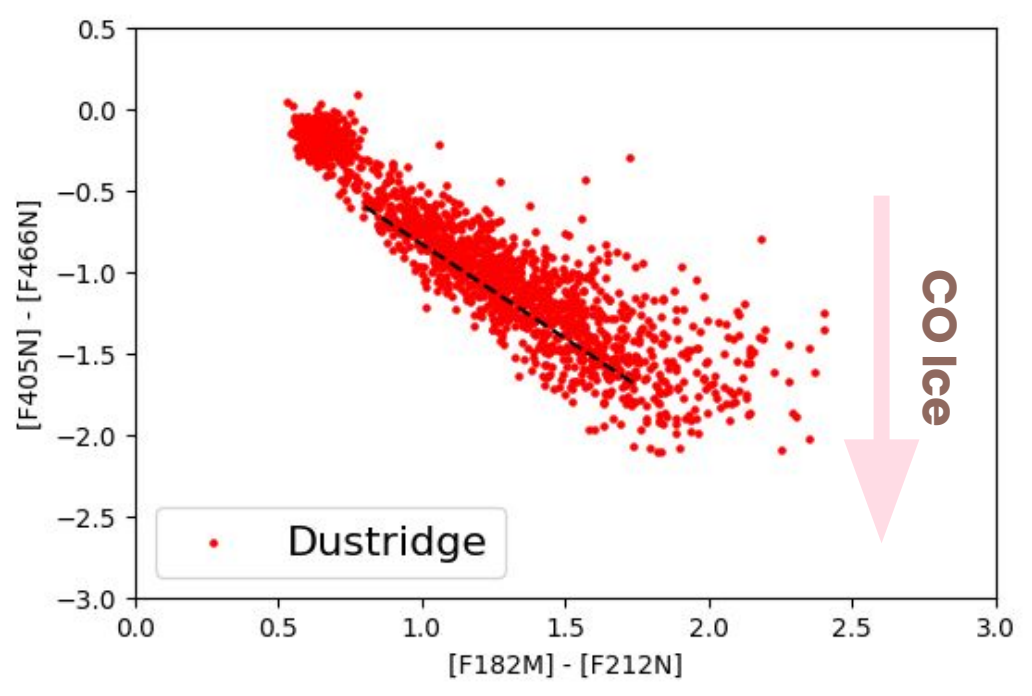
Color-Color Diagram

- ★ Shorthand for dust extinction and CO ice ratio
- ★ [F466N] becomes fainter as N(CO ice) increases

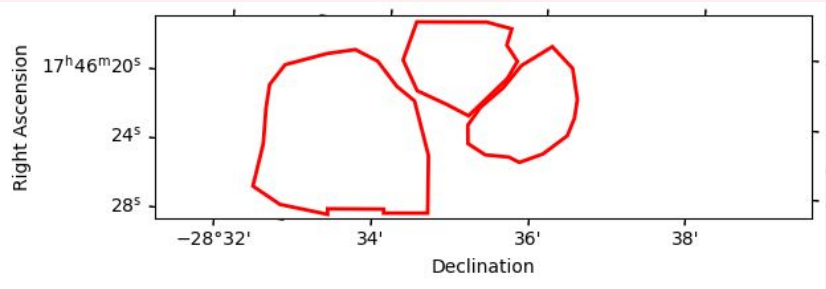


Different Slopes = Differences in Solid CO

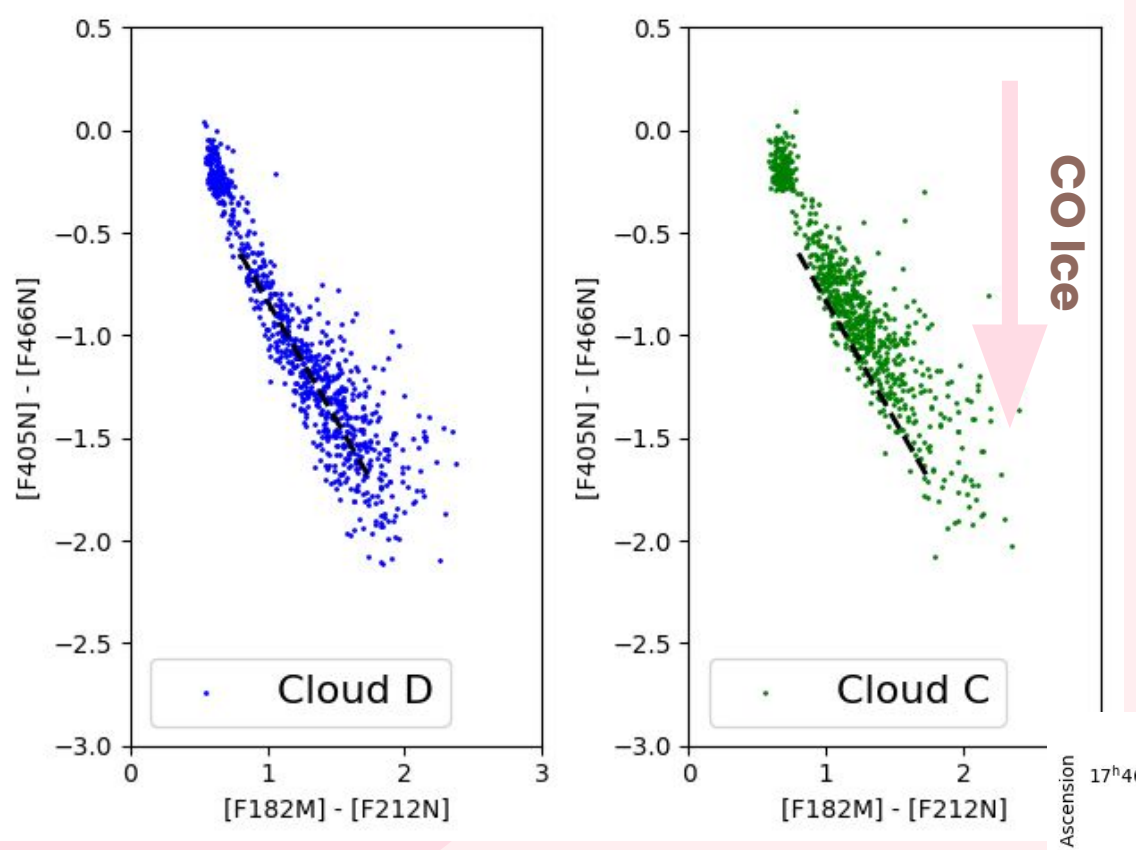


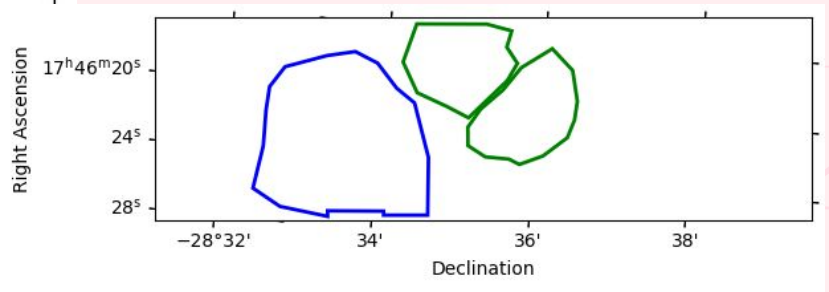

0.5
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
−3.0
[F405N] - [F466N]
0.0
0.5
1.0
1.5
2.0
2.5
3.0
[F182M] - [F212N]
Dustridge
CO Ice

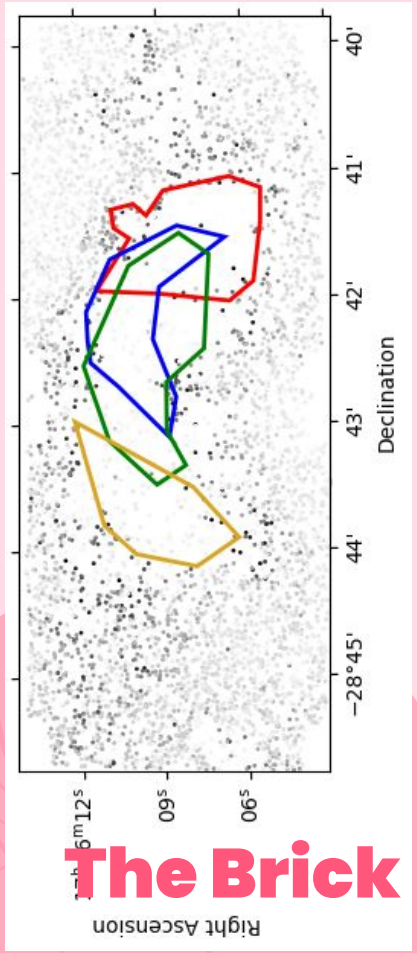
Dust Ridge


Right Ascension
17h46m20s
24s
28s
−28°32'
34'
36'
38'
Declination

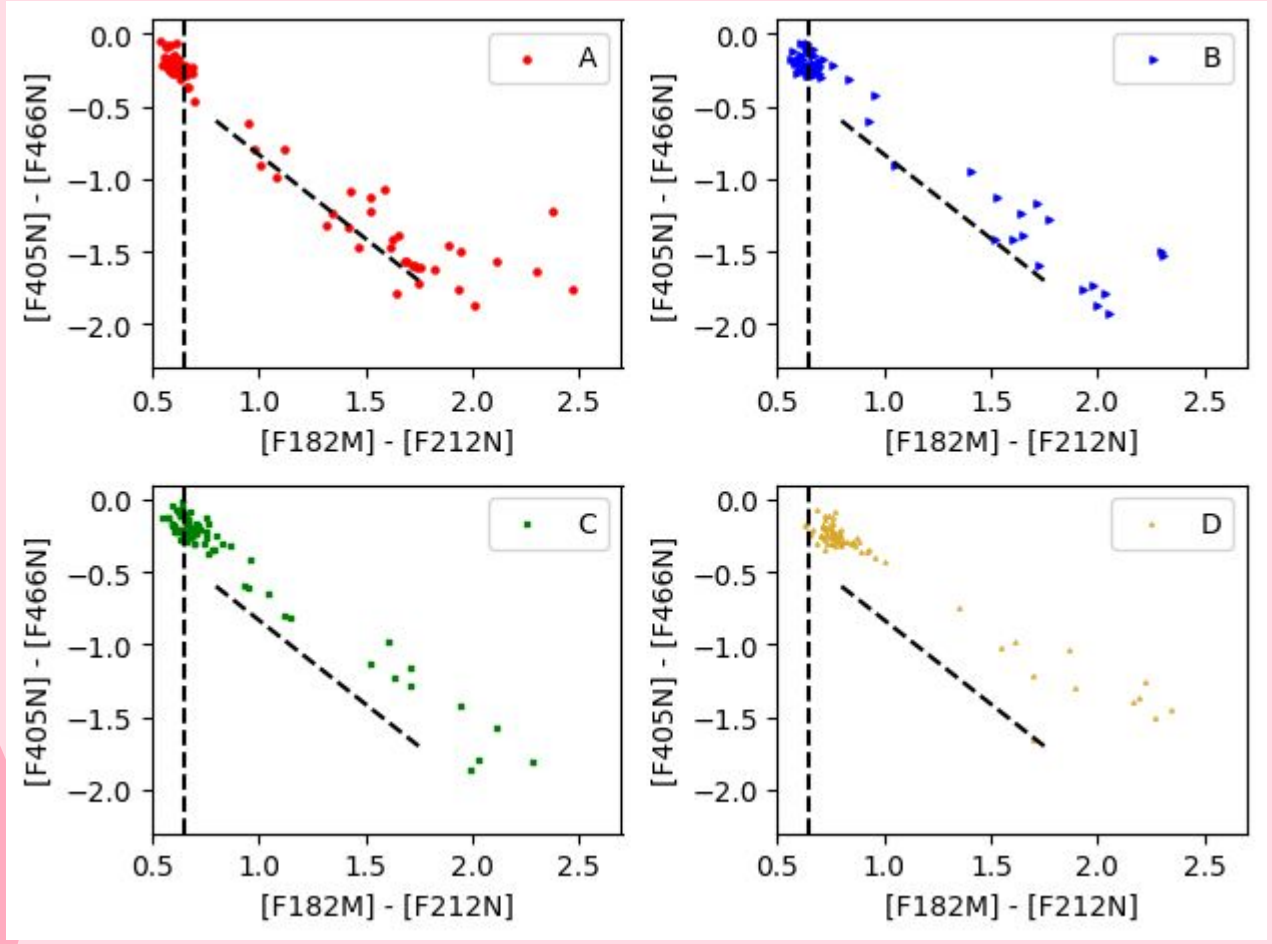
Comparing Dust Ridge Clouds



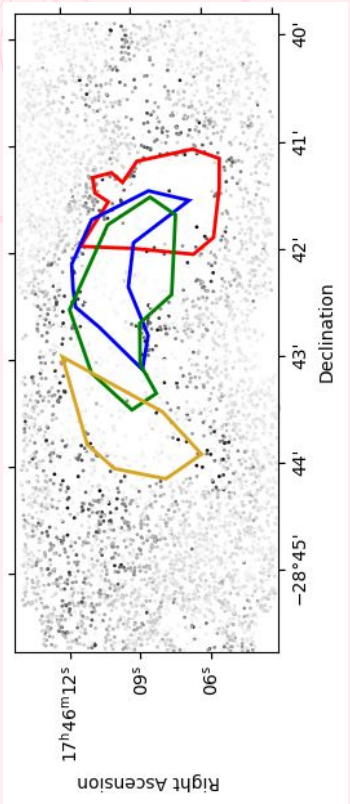


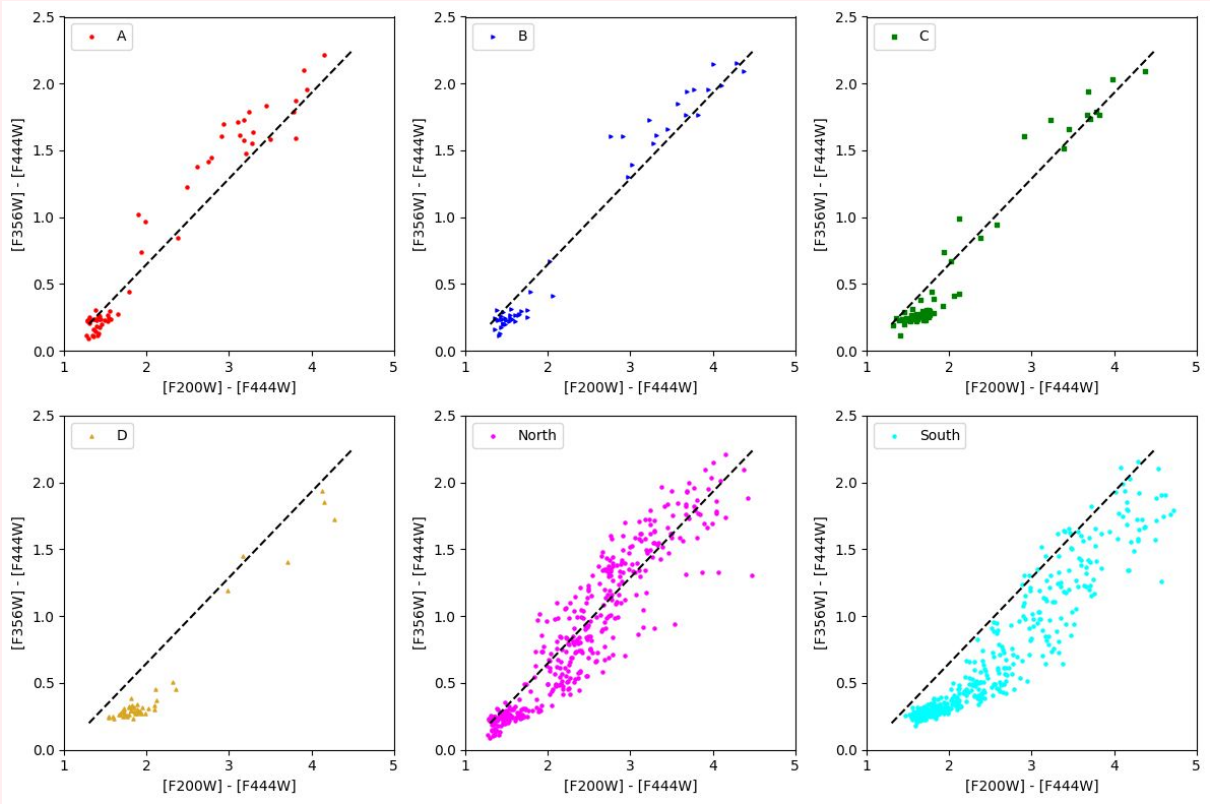

Declination
40'
41'
42'
43'
44'
−28°45'
09ˢ
06ˢ
Right Ascension

The Brick

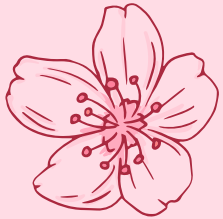

A
B
C
D
[F405N] - [F466N]
[F182M] - [F212N]
0.0
−0.5
−1.0
−1.5
−2.0
0.5
1.0
1.5
2.0
2.5

We also see variation in solid CH_3OH





What Causes These Differences?



Gas Metallicity?

But clouds in the same region of the Galaxy should have the same metallicity, right?

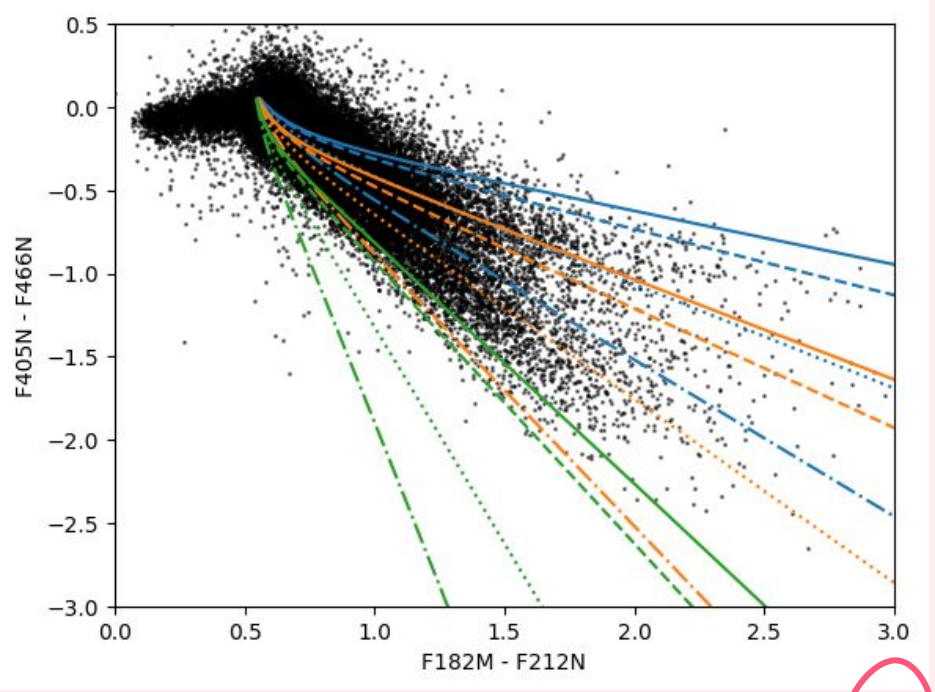
Ice Composition?

But why would the ice composition change from cloud to cloud?

CMZ Structure

For the Brick, the variations are extreme within one cloud, so maybe it isn't just one cloud.

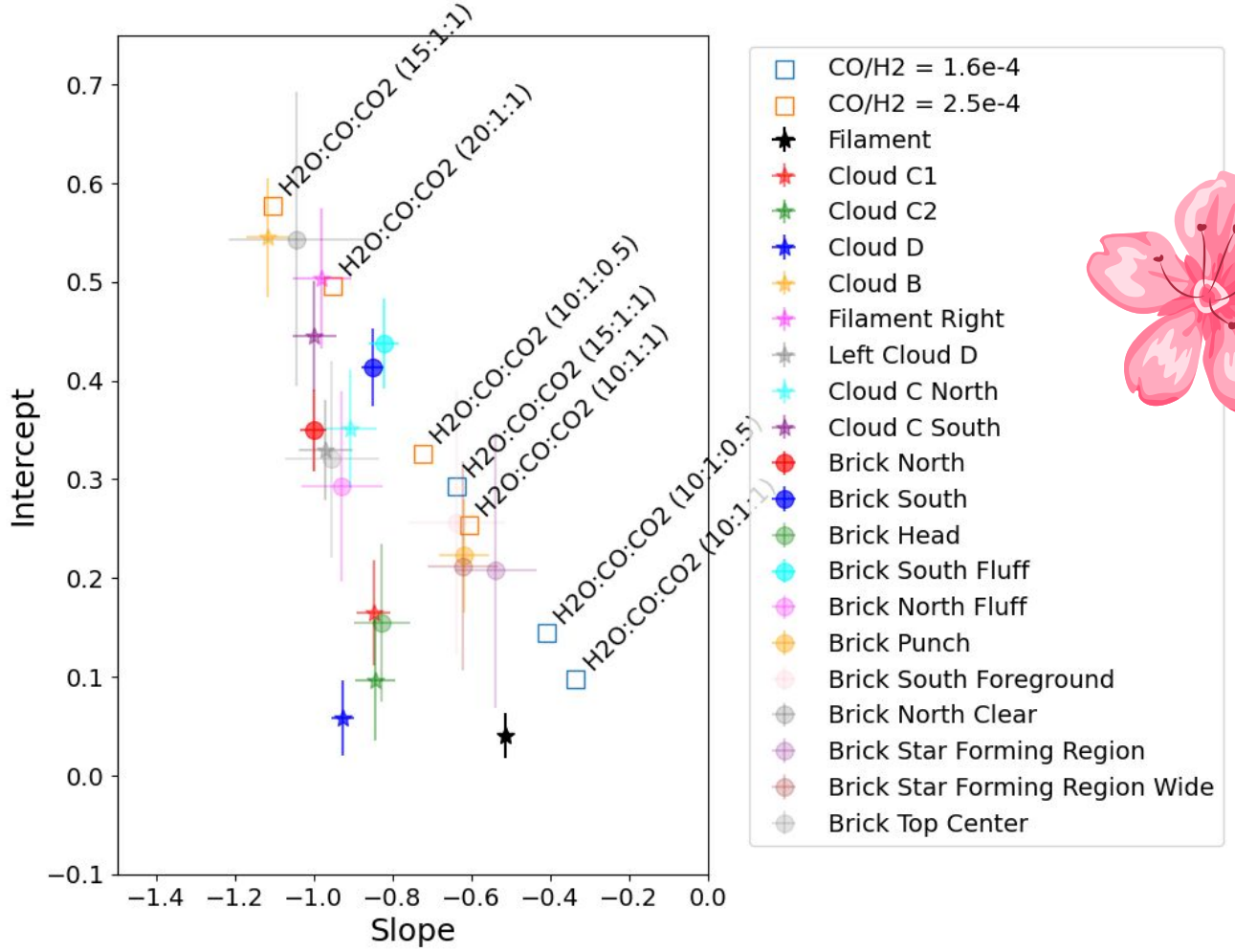
H_2O:CO:CO_2 = 10:1:1 10:1:0.5 15:1:1 20:1:1

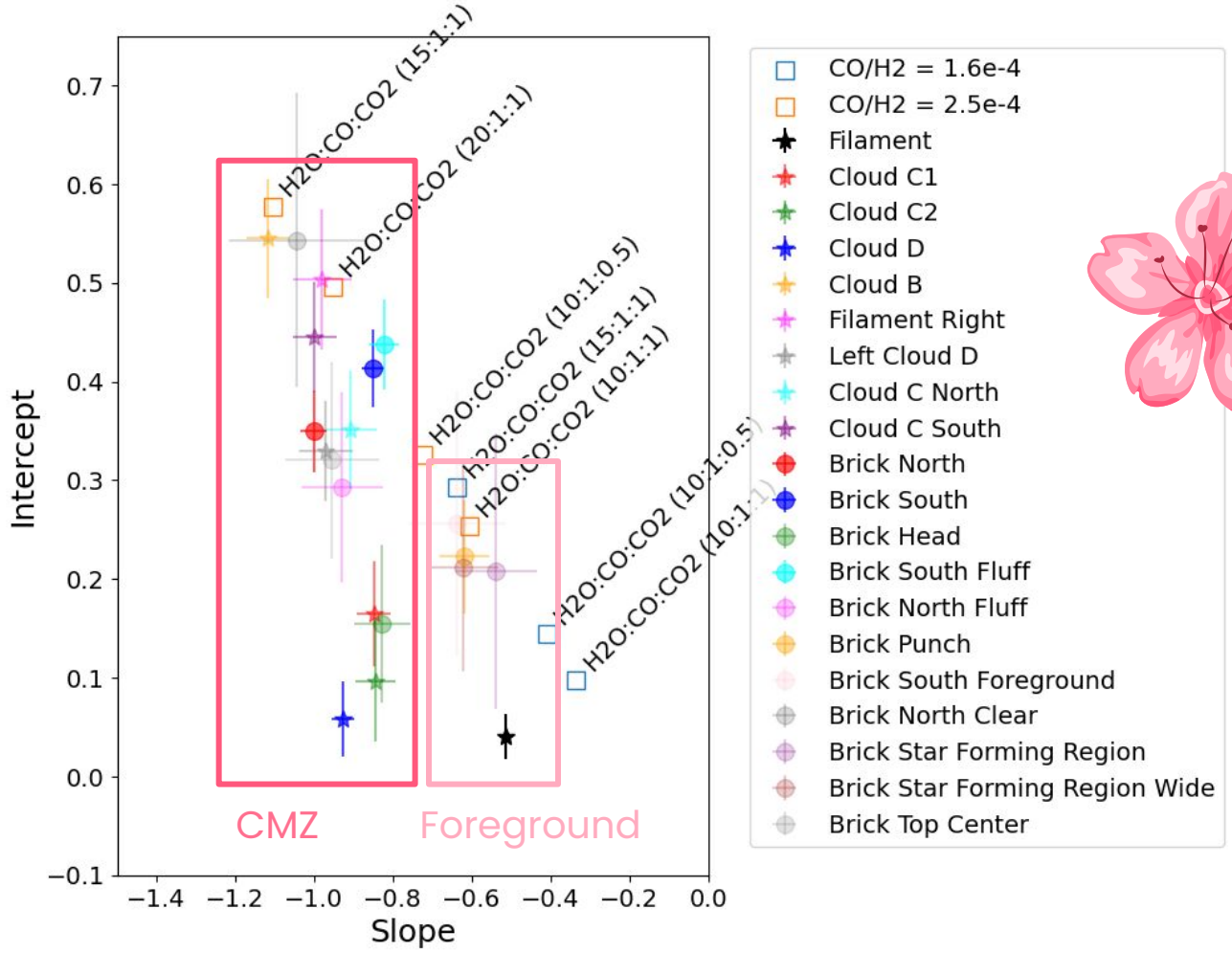


CO/H_2 = 5x10^{-4} 2.5x10^{-4} 1x10^{-4}

Modeling Ice

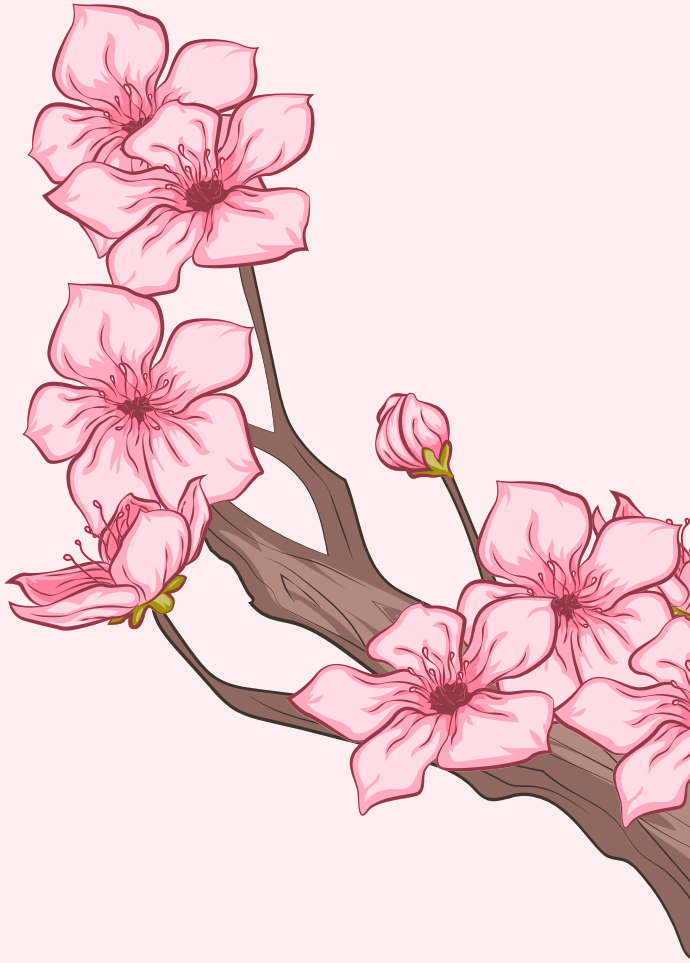
- ★ We can model the influence of ice column on the observed colors.
- ★ Two properties matter:
  - CO abundance
  - Ice composition
- ★ These properties are degenerate in this space, overlapping models
- ★ Spectroscopy is needed


H2O:CO:CO2 (15:1:1)
H2O:CO:CO2 (20:1:1)
H2O:CO:CO2 (10:1:0.5)
H2O:CO:CO2 (15:1:1)
H2O:CO:CO2 (10:1:1)
H2O:CO:CO2 (10:1:0.5)
H2O:CO:CO2 (10:1:1)
Intercept
Slope
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
−0.1
−1.4
−1.2
−1.0
−0.8
−0.6
−0.4
−0.2
0.0
CO/H2 = 1.6e-4
CO/H2 = 2.5e-4
Filament
Cloud C1
Cloud C2
Cloud D
Cloud B
Filament Right
Left Cloud D
Cloud C North
Cloud C South
Brick North
Brick South
Brick Head
Brick South Fluff
Brick North Fluff
Brick Punch
Brick South Foreground
Brick North Clear
Brick Star Forming Region
Brick Star Forming Region Wide
Brick Top Center

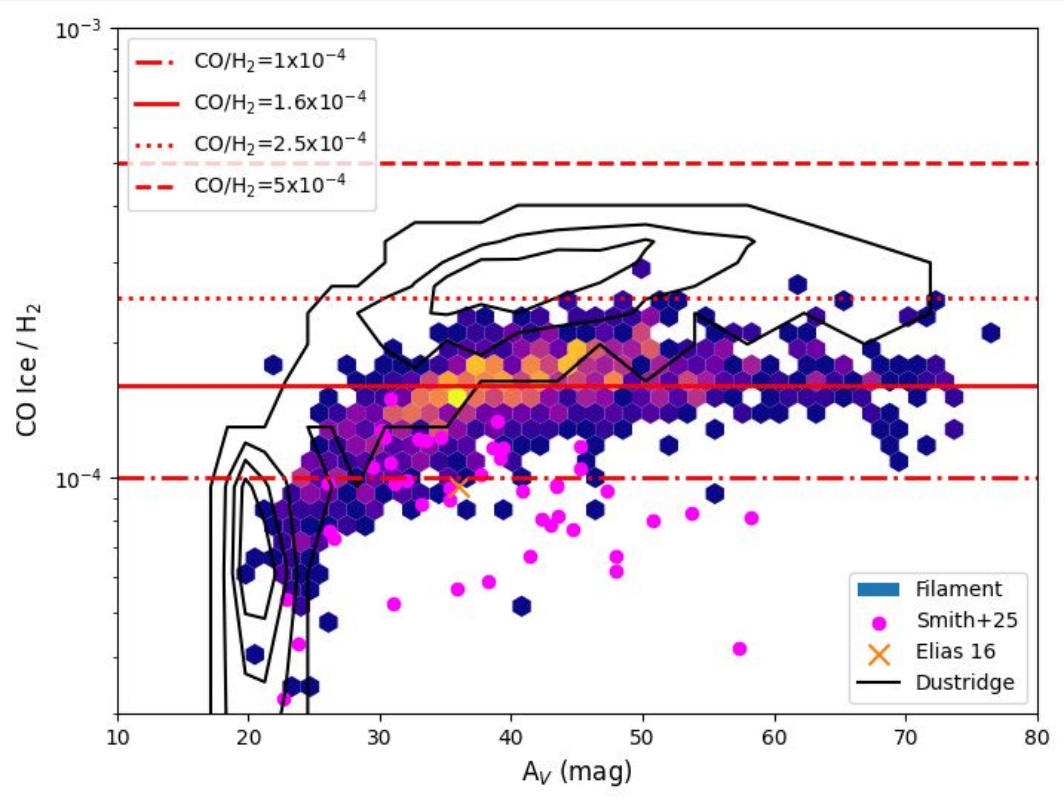

H2O:CO:CO2 (15:1:1)
H2O:CO:CO2 (20:1:1)
H2O:CO:CO2 (10:1:0.5)
H2O:CO:CO2 (15:1:1)
H2O:CO:CO2 (10:1:1)
H2O:CO:CO2 (10:1:0.5)
H2O:CO:CO2 (10:1:1)
CMZ
Foreground
Intercept
Slope
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
−0.1
−1.4
−1.2
−1.0
−0.8
−0.6
−0.4
−0.2
0.0
CO/H2 = 1.6e-4
CO/H2 = 2.5e-4
Filament
Cloud C1
Cloud C2
Cloud D
Cloud B
Filament Right
Left Cloud D
Cloud C North
Cloud C South
Brick North
Brick South
Brick Head
Brick South Fluff
Brick North Fluff
Brick Punch
Brick South Foreground
Brick North Clear
Brick Star Forming Region
Brick Star Forming Region Wide
Brick Top Center

What dominates variation in the ice to dust ratio?

- ★ Either CO abundance or ice composition
- ★ Future spectroscopic surveys are needed to determine which dominates



In Abundance Space



Dust Extinction VS Solid CO Column