Which lines trace what physical processes in the Galactic Center?

Building a toolkit, brick by Brick

Galactic Center (Spitzer IRAC)
Image credit: NASA, JPL-Caltech, Susan Stolovy (SSC/Caltech) et al.

Alyssa Bulatek (she/her)
Advisor: Adam Ginsburg
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October 1, 2021
Graduate Symposium

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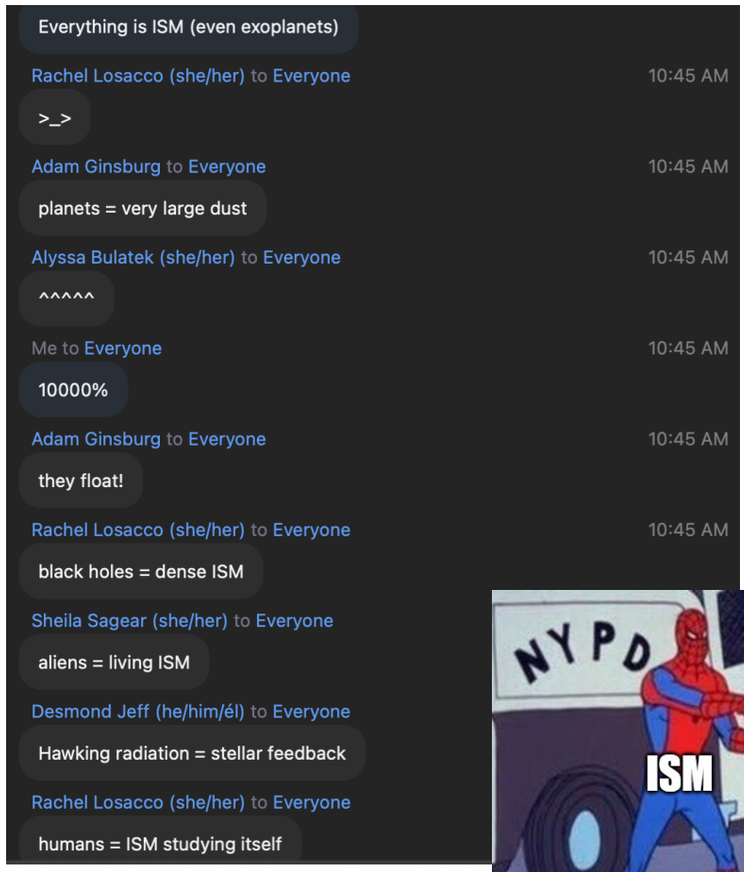
The Interstellar Medium

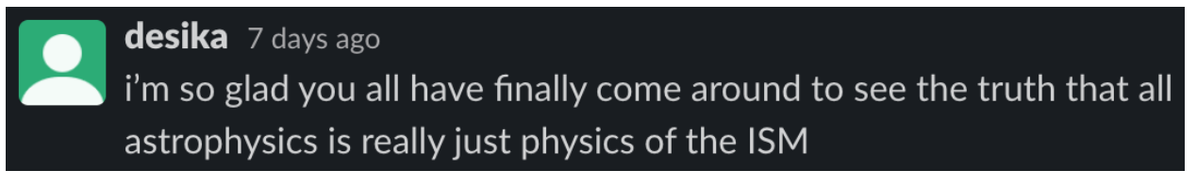
Why do we care about the ISM?

- The most important and beautiful component of a galaxy (imo, and: Draine 2011)
- **The ISM is where star formation happens**
- Submillimeter emission from gas and dust in the ISM is an important tool for studying star formation
  - Physical properties (e.g. temperature, density)
  - Physical processes (e.g. shocks, jets, cores)



Lower et al. 2021*

Losacco 2021*



Narayanan 2021*

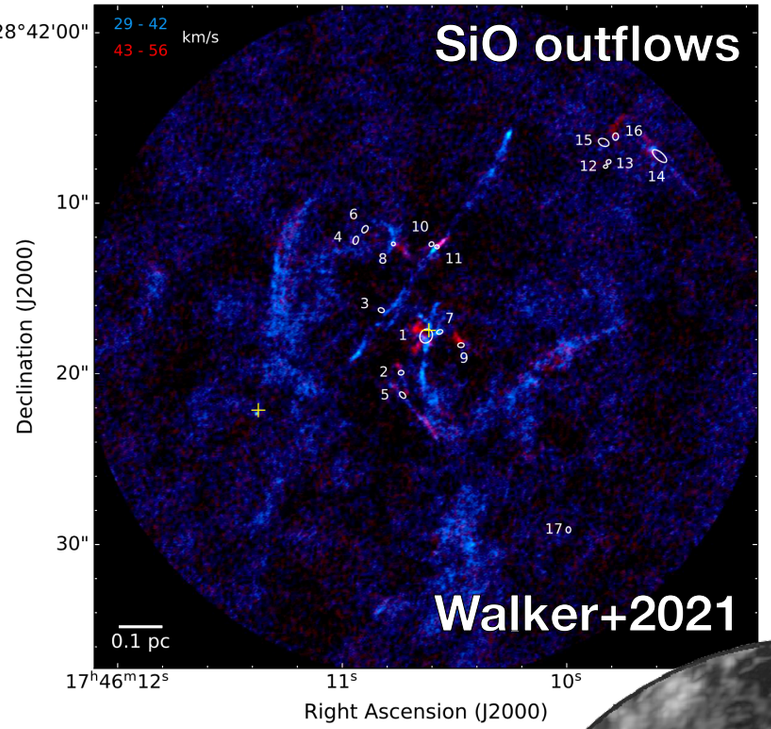
*These are not real citations.

Molecular Fingerprints

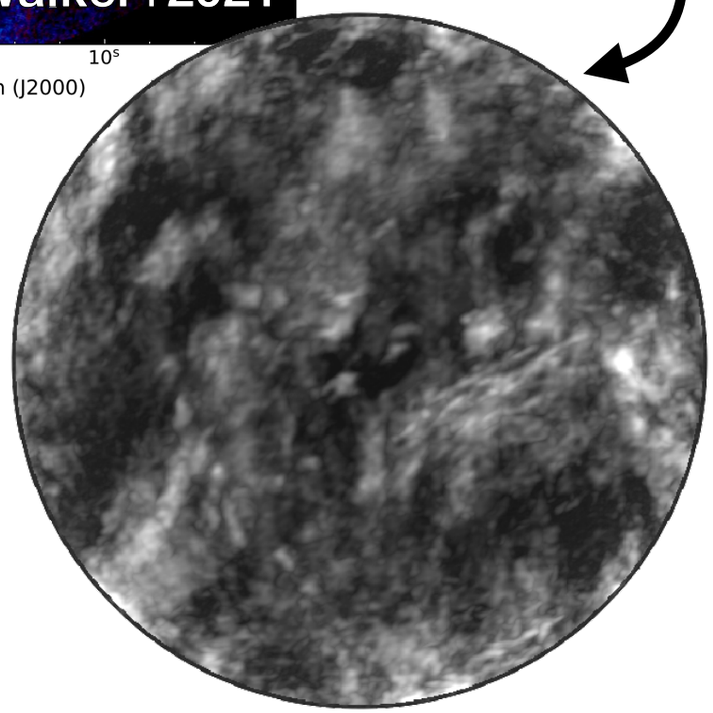
Where do our "rules of thumb" fail?

- Several molecules are widely used as heuristic tracers for different ISM processes
  - Outflows: CO, SiO
  - Hot cores: CH_3OH, CH_3CN
  - Shocks: SiO, HNCO
  - Dense gas: HCN, HCO+

- **Problem:** all of these molecules are *widespread* in the Central Molecular Zone
  - These molecules don't uniquely trace processes... they trace everything!



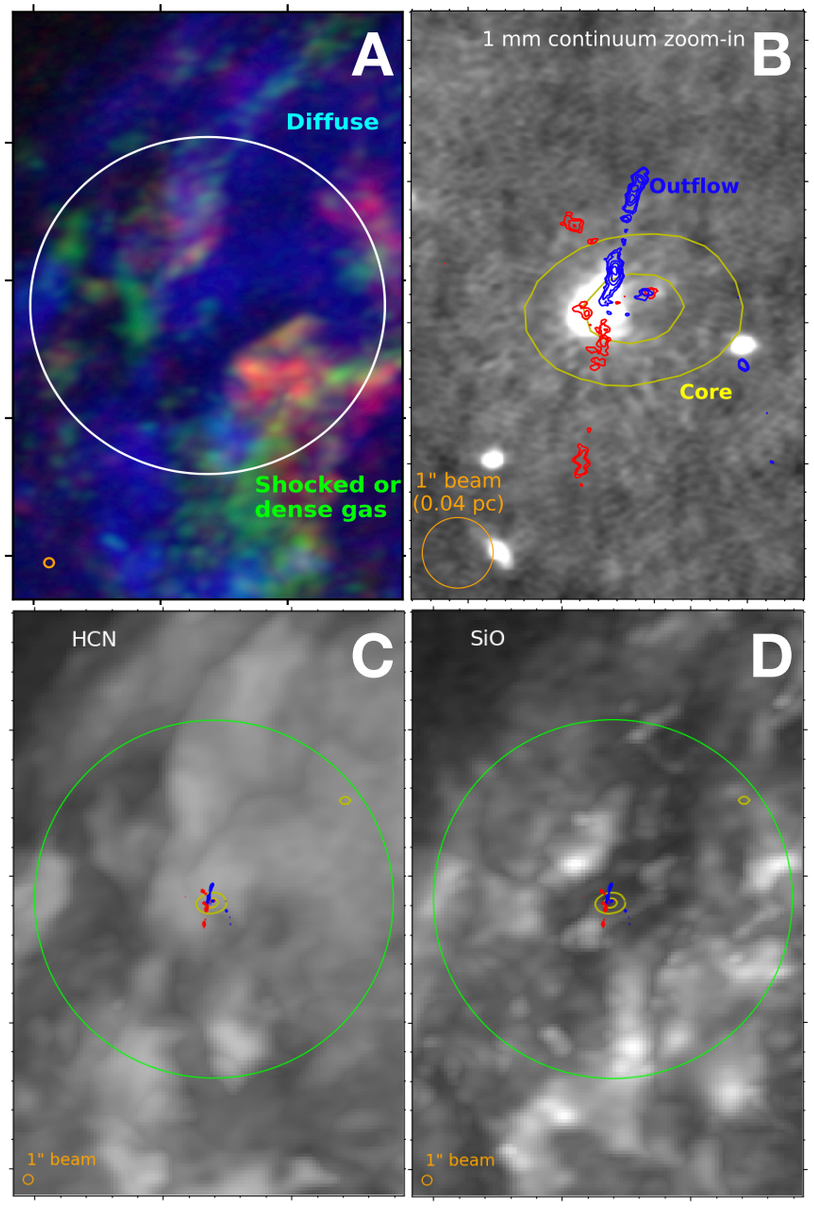
multiple turbulent layers of material



The CMZ and The Brick

The Brick is the prototypical dense but low-SF cloud

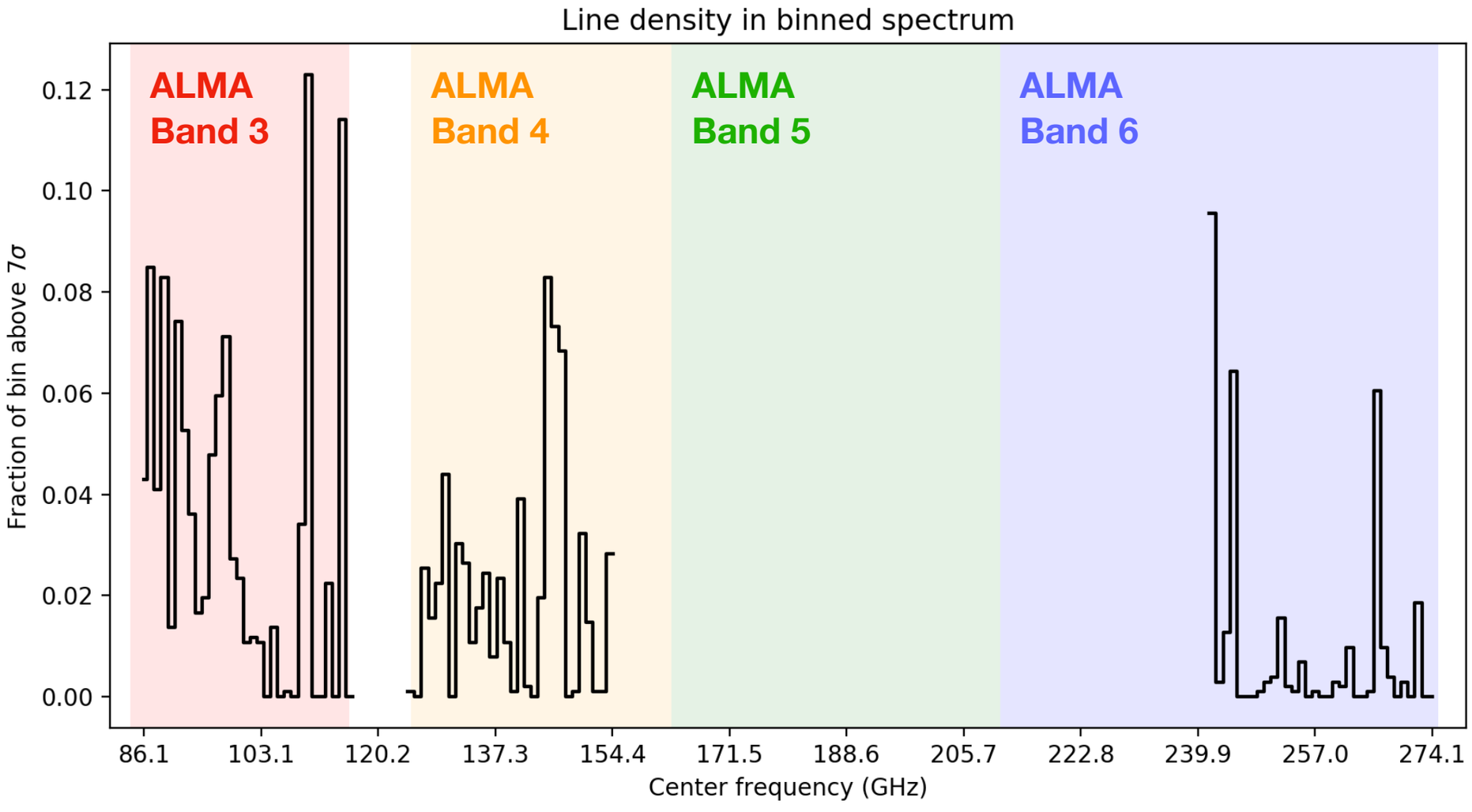
- Need unique tracers
- **G0.253+0.015** ("The Brick") contains examples of four ISM processes:
  - Protostellar outflows
  - Pre- and protostellar cores
  - Turbulent shocks
  - Diffuse, quiescent molecular gas
- ALMA proposal: wideband (4:1) spectral line survey
  - **Goal:** build a toolkit of tracers that *uniquely* identify these processes, for use in the CMZ and intensely star-forming galaxies



Rathborne+2015 and Walker+2021

Spectral Line Density

How many lines are in the delivered data?



Target resolution: 1 arcsec

Sensitivity: 0.25 K in 1 km/s channels

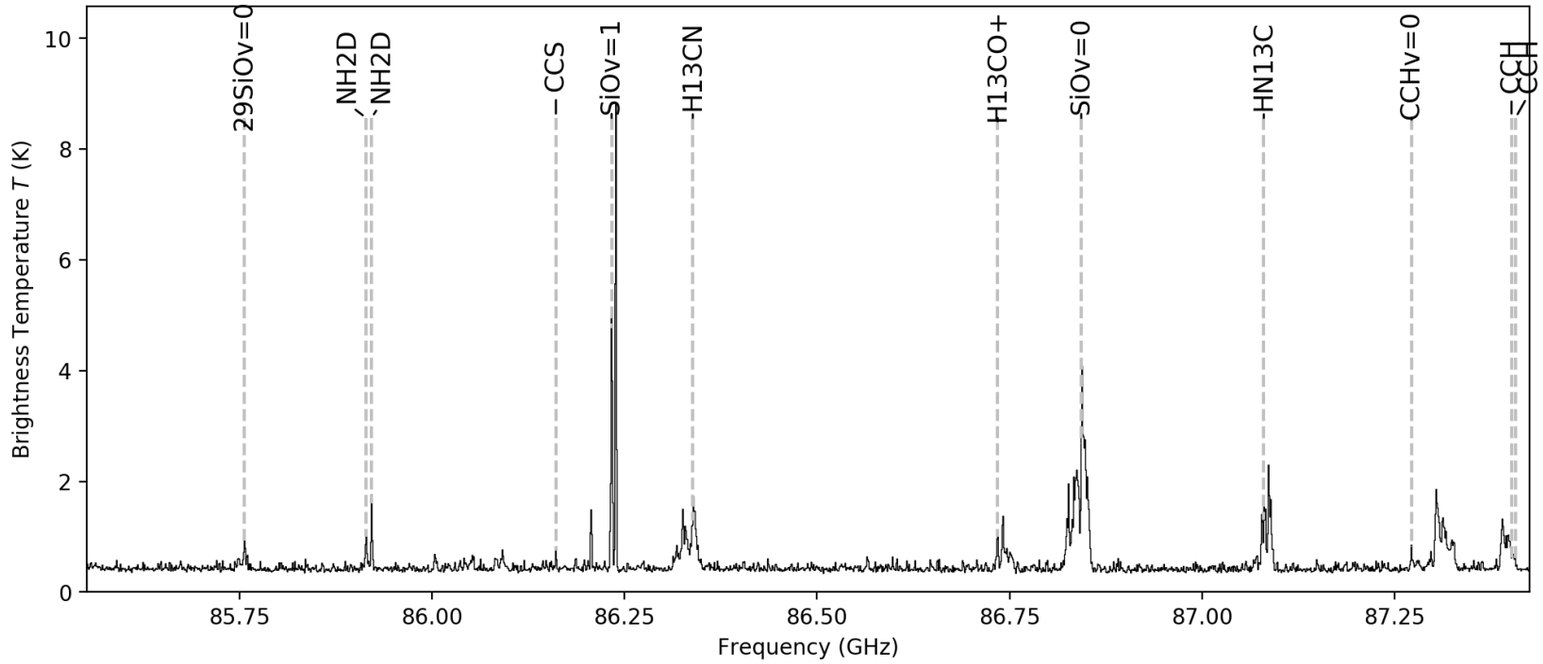
Used to validate spectral setup of ACES ALMA Large program

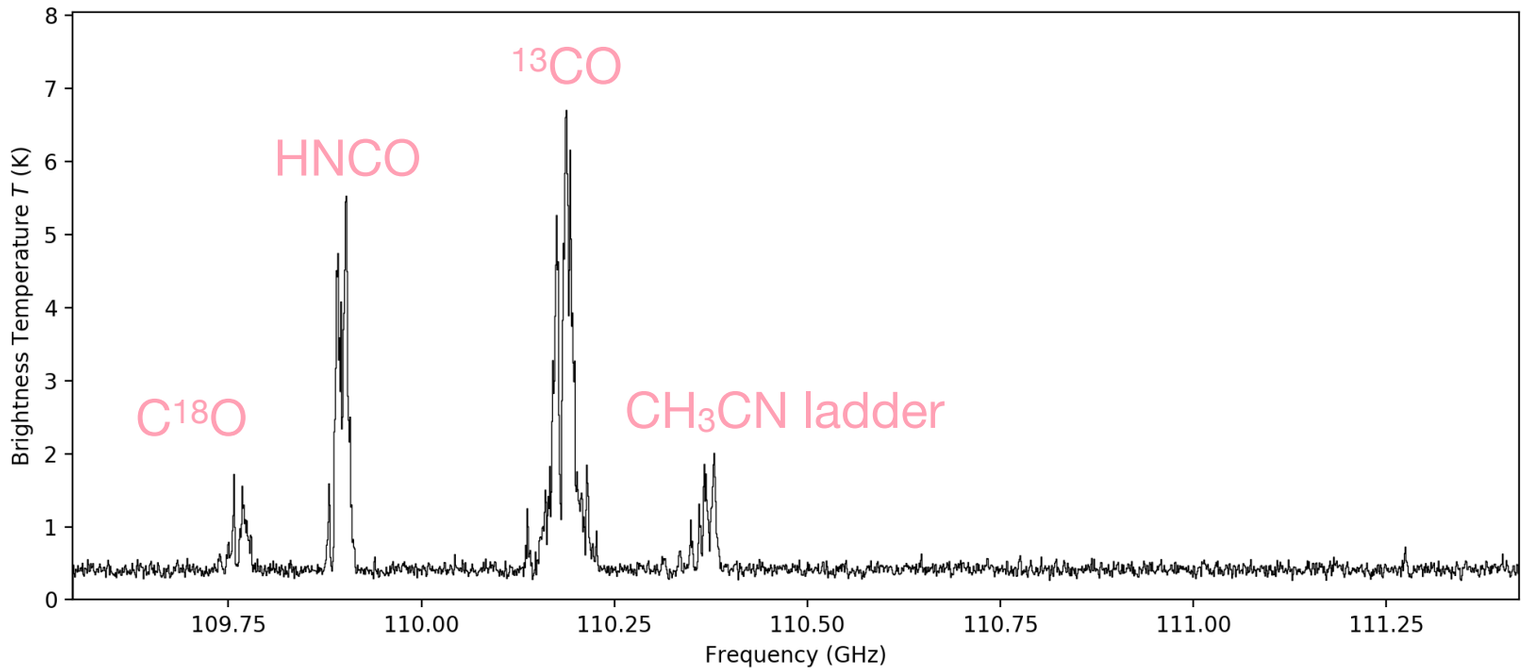
Hope to cover entire bandwidth (incl. missing portion) w/ ACA obs.

Identifying Spectral Lines

Which lines are in The Brick?

- "Max" spectra
- Small molecules and isotopologues
  - $H^{13}CN$, $H^{13}CO+$, $HN^{13}C$, CCH, H_2CS, NH_2D
- CH_3CCH, CS, CO, HNCO
- Masers (SiO v=1, class I methanol)
- Collaborating w/ Katharina Immer (Leiden) to cover all spectral windows

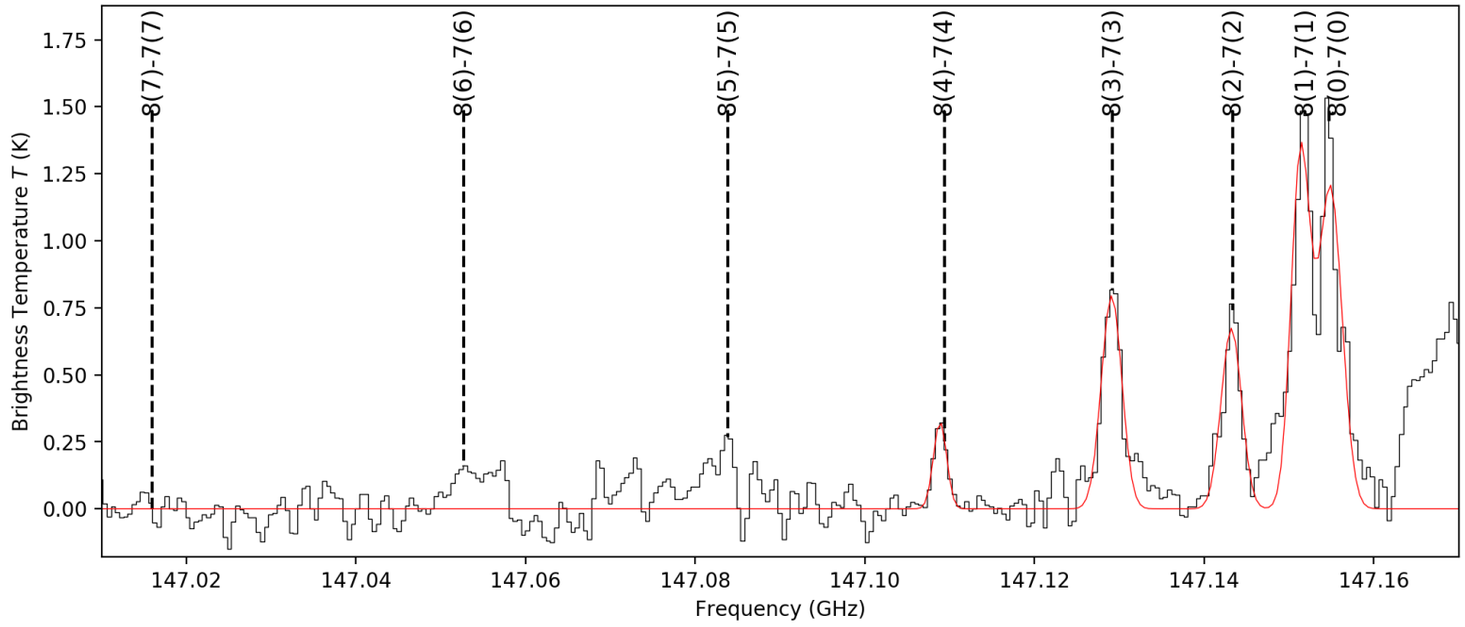


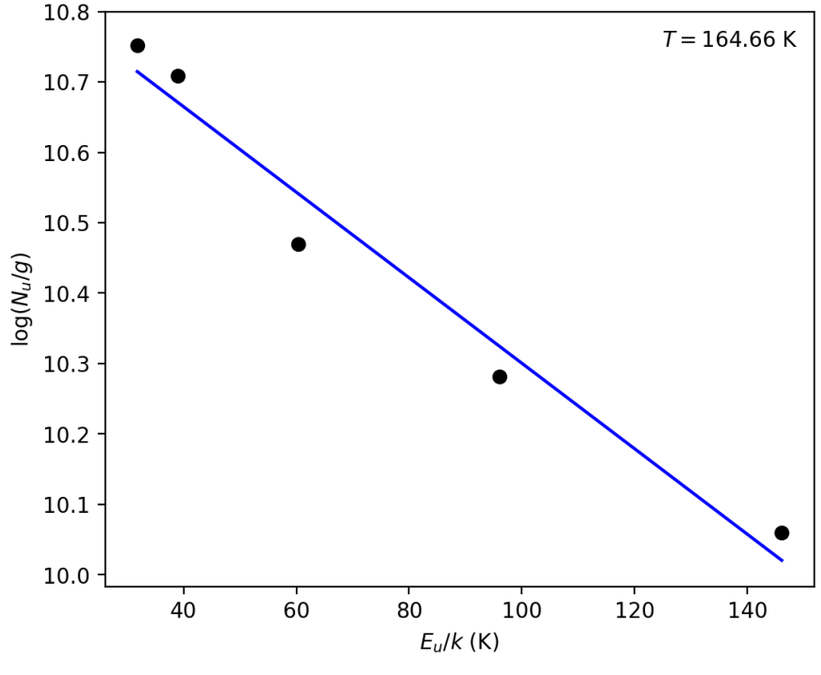


Rotational Diagrams

How do temperature and density vary in The Brick?

- Seven CH_3CN ladders in delivered data
  - Other temperature-sensitive molecules: CH_3OH, CH_3CCH, etc.
- $J = 8$ ladder, $T \sim 165$ K (same pointing from Walker+2021: 167 K)
- Repeat for other J ladders, repeat across cloud (**map**)
- Constrain cloud properties:
  - Temperature
  - Column density
  - Volume density





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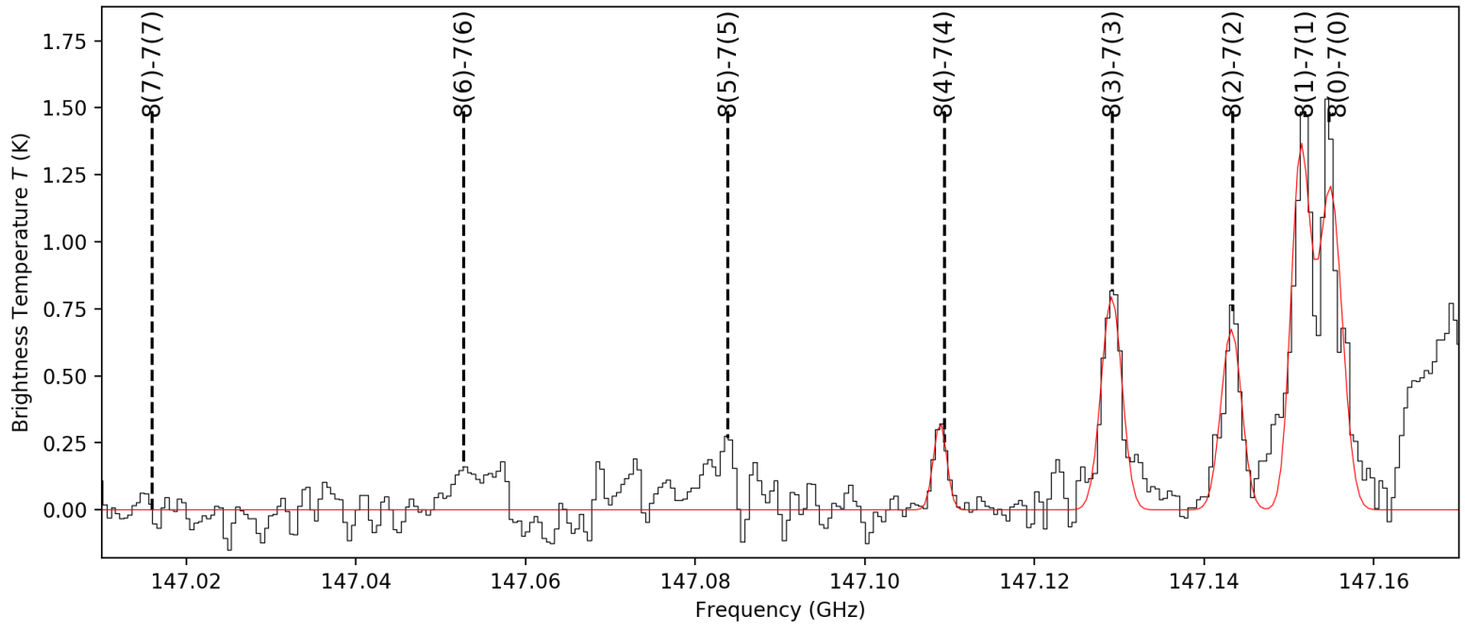
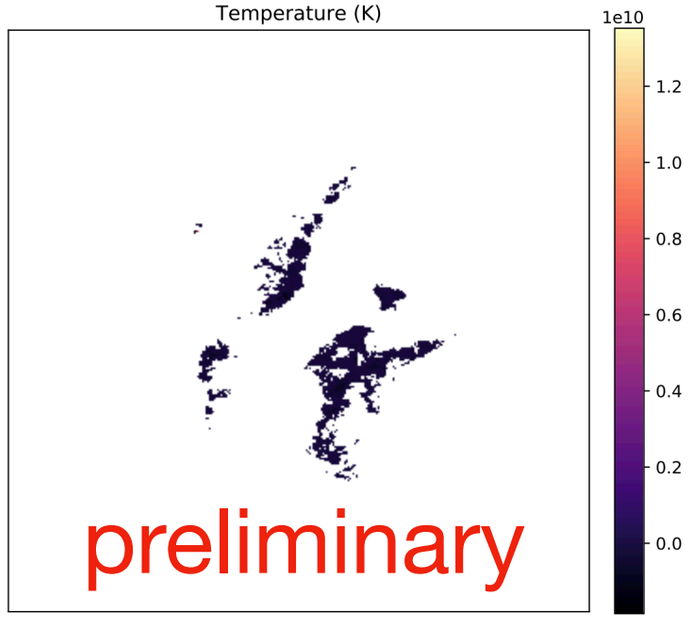
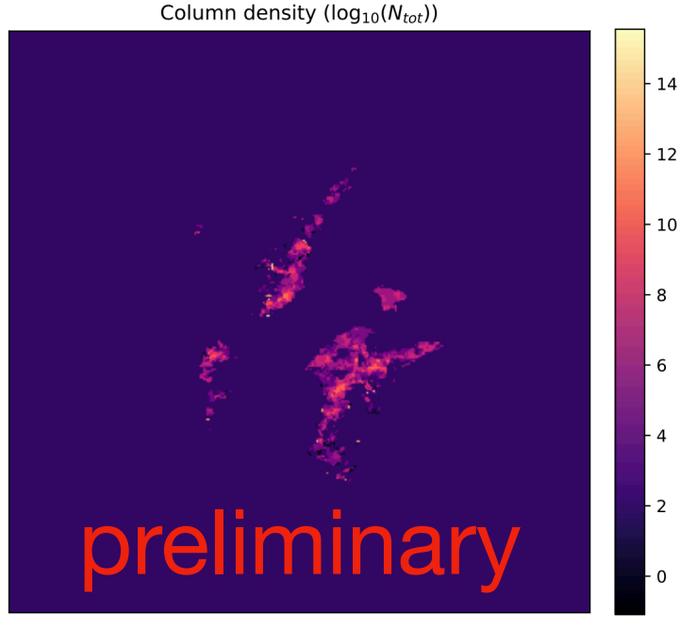


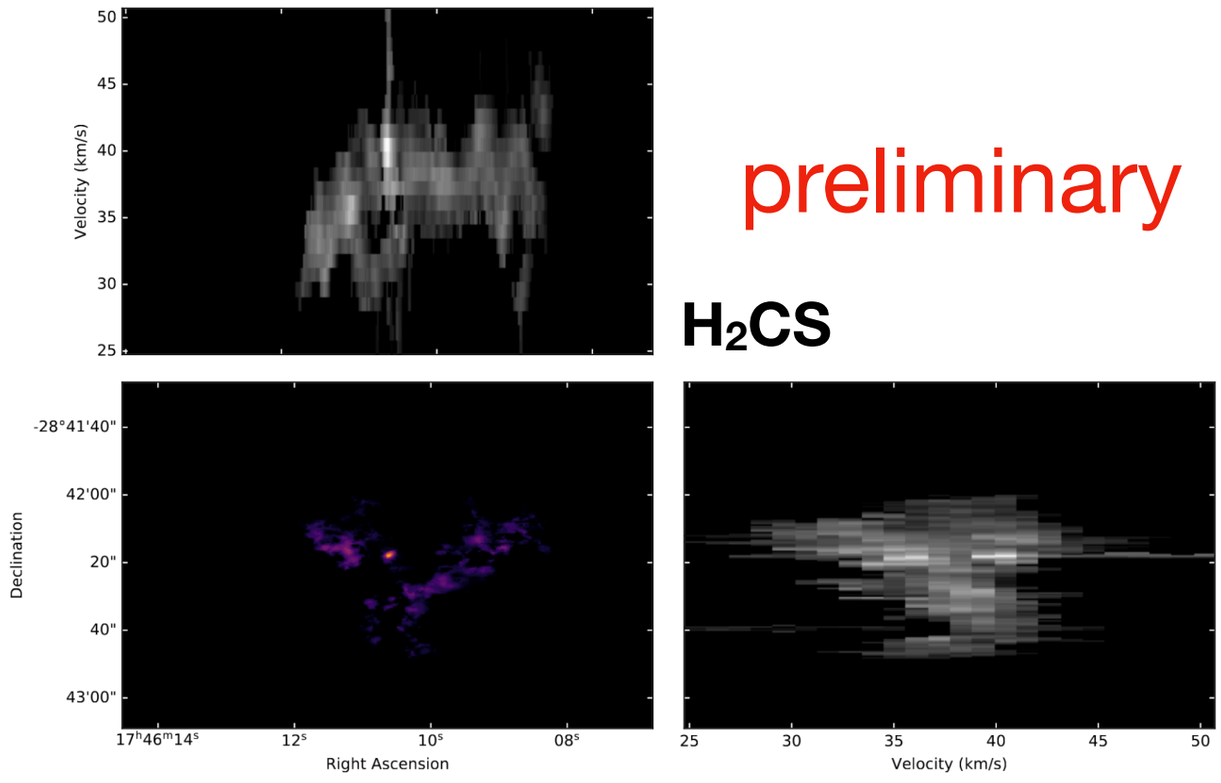




Future Work

What are the next steps?

- "First results" paper
  - Line identification
  - Fix temperature/density map
- Moment maps
  - What structures can we associate with certain molecules?
  - Compare w/ Petkova+2021 simulated obs. of The Brick
- Defining regions
  - What structures are associated with known cores, outflows, shocks, and regions of diffuse gas (and what unique tracers do we see there?)



preliminary

H_2CS

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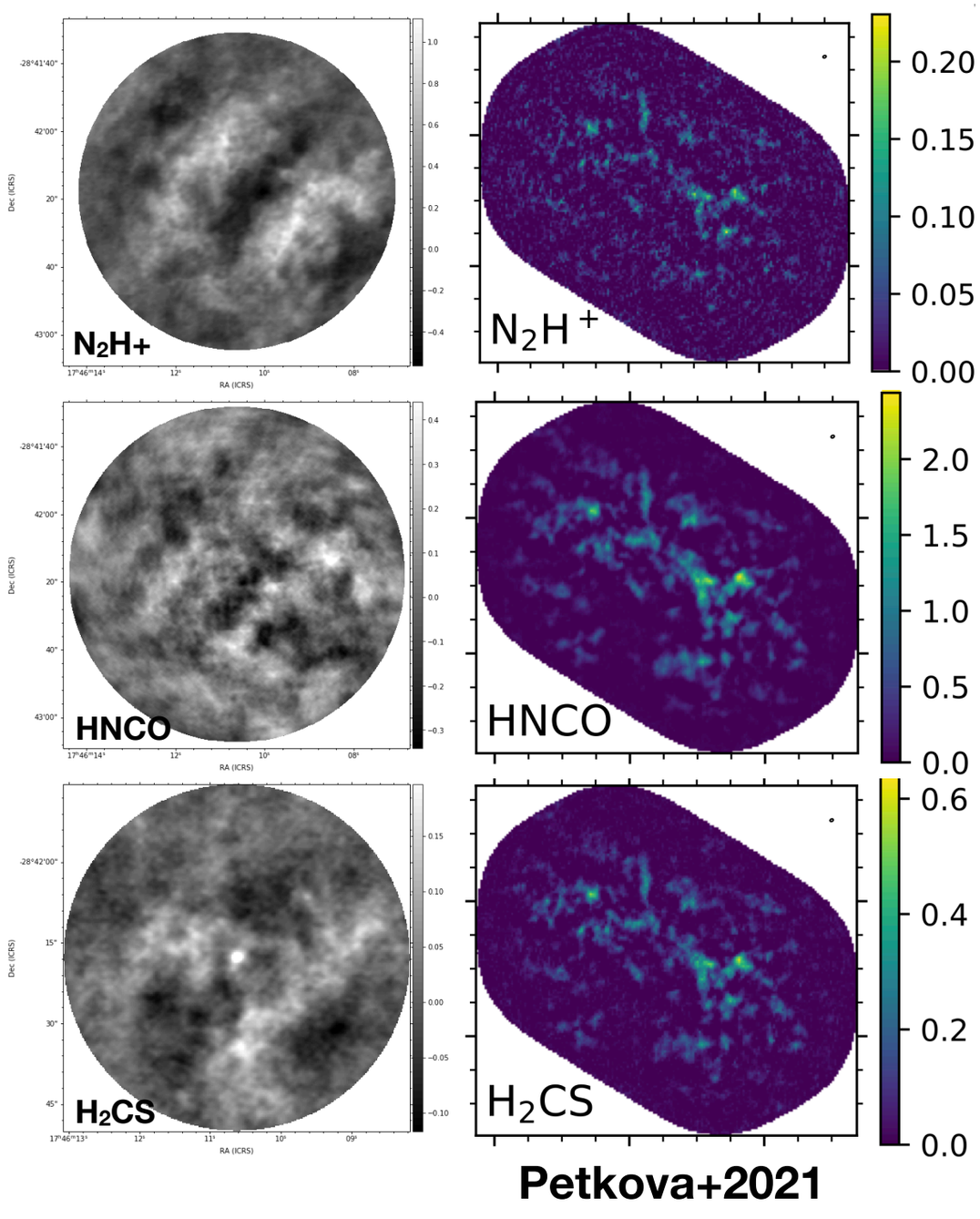

Thank you!

The Brick (Spitzer IRAC/MIPS)
Image credit: NASA, JPL-Caltech, and S.V Ramirez (NExScI/Caltech)

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- Brick (Spitzer): https://webbtelescope.org/contents/news-releases/2020/news-2020-14
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