

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), University of Florida

PI: Adam Ginsburg

Co-Is: John Bally, Ashley Barnes, Cara Battersby, Yanett Contreras,
Jonathan Henshaw, Katharina Immer, Desmond Jeff, Jens Kauffmann,
Diederik Kruijssen, Steven Longmore, David Meier, Elisabeth Mills,
Juergen Ott, Erik Rosolowsky, Alvaro Sanchez-Monge, Daniel Walker

May 13, 2021
ISM 2021

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), University of Florida

PI: Adam Ginsburg

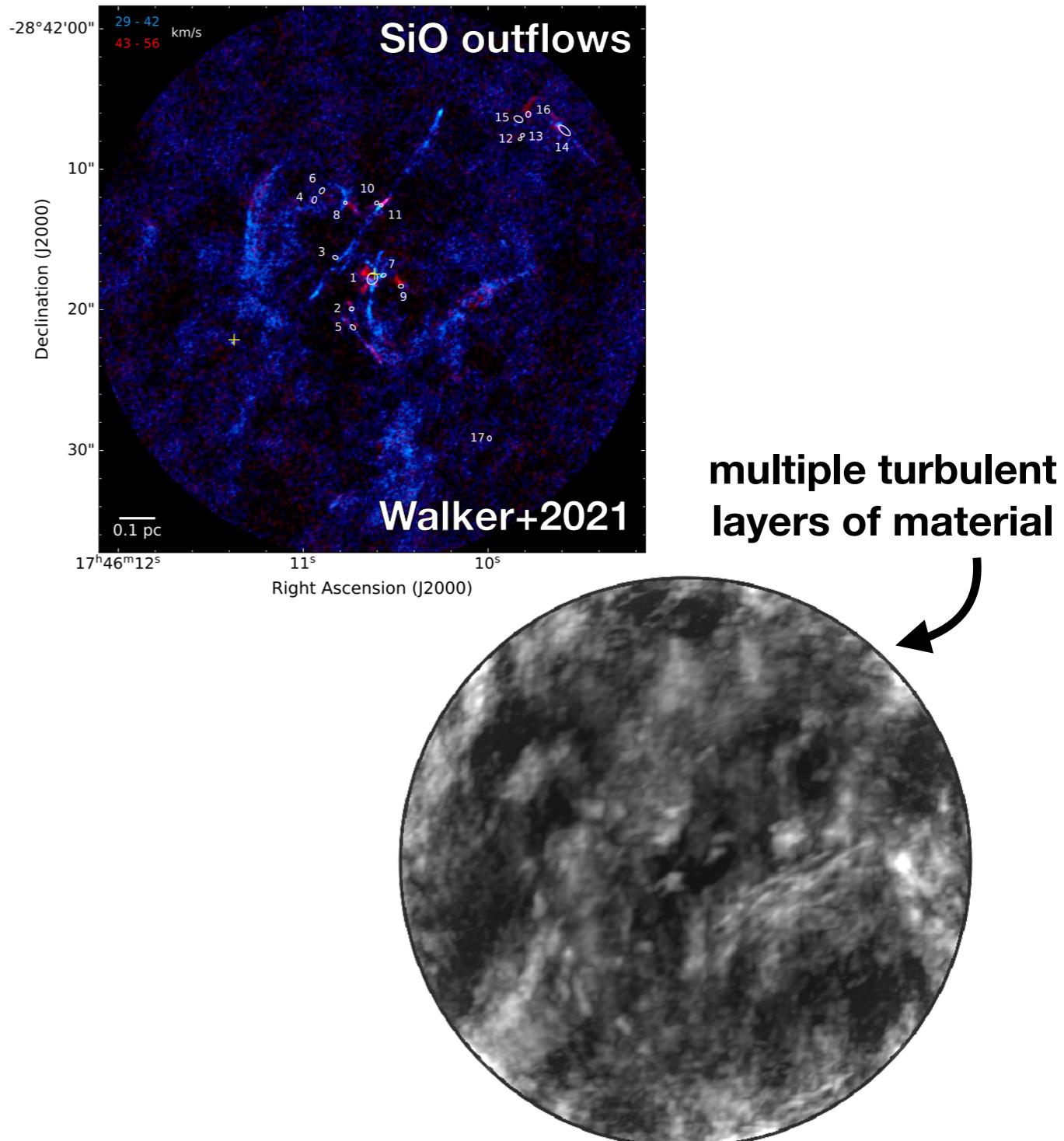
Co-Is: John Bally, Ashley Barnes, Cara Battersby, Yanett Contreras, Jonathan Henshaw, Katharina Immer, Desmond Jeff, Jens Kauffmann, Diederik Kruijssen, Steven Longmore, David Meier, Elisabeth Mills, Juergen Ott, Erik Rosolowsky, Alvaro Sanchez-Monge, Daniel Walker

May 13, 2021
ISM 2021

Molecular Fingerprints

Where do our "rules of thumb" fail?

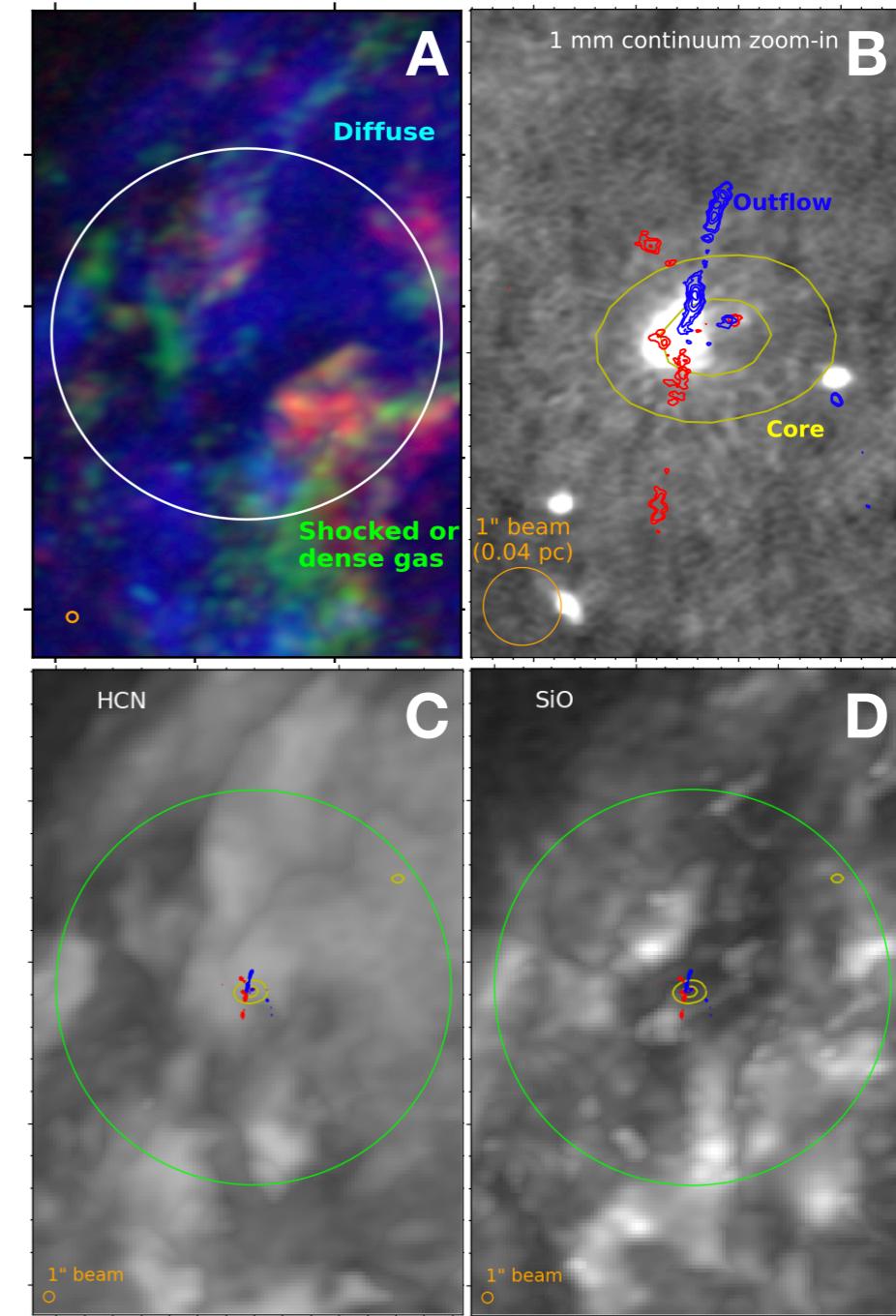
- Several molecules are widely used as heuristic tracers for different ISM processes
 - Outflows: CO, SiO
 - Hot cores: CH₃OH, CH₃CN
 - Shocks: SiO, HNCO
 - Dense gas: HCN, HCO+
- **Problem:** all of these molecules are *widespread* in the Central Molecular Zone
 - These molecules don't uniquely trace processes... they trace everything!



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

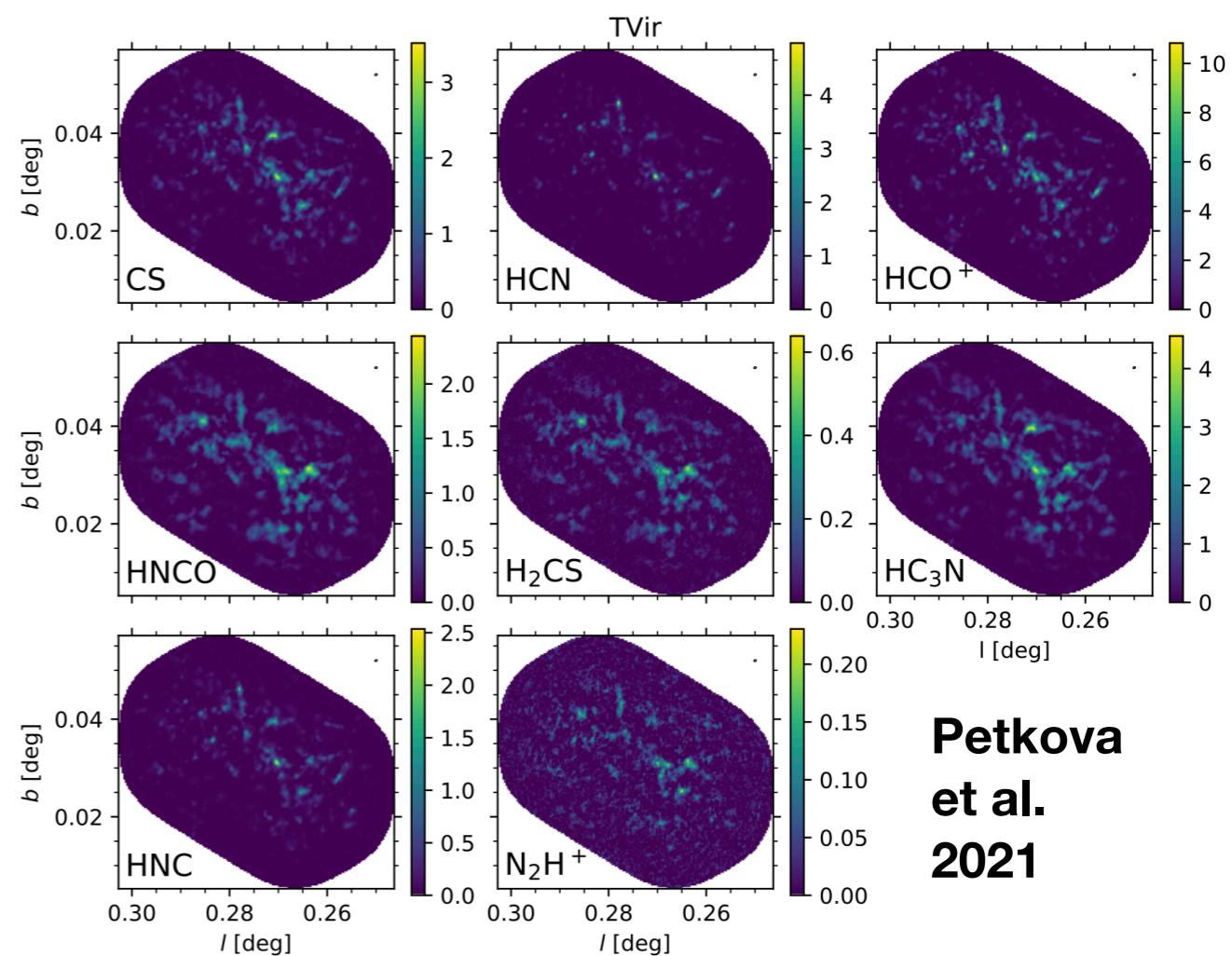


Rathborne+2015 and Walker+2021

The CMZ and The Brick

The Brick is the prototypical dense but low-SF cloud

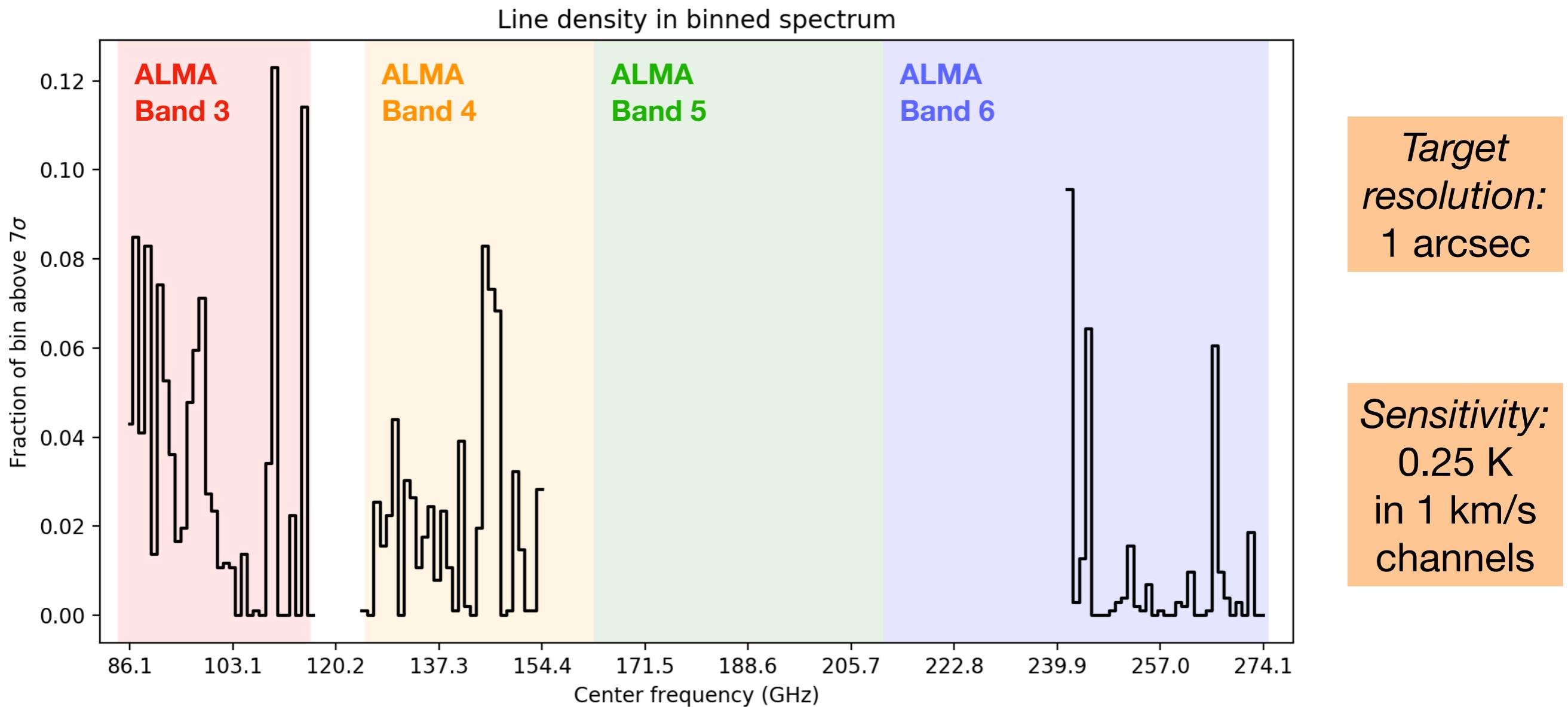
- Petkova et al. 2021 (submitted)
 - Compared ALMA observations to simulations of common molecules in The Brick
 - CS, HCN, HCO+, HNC trace compact structures
 - HNCO, H₂CS, HC₃N, N₂H+ trace diffuse gas
 - Simulations are a good starting point for comparison w/ line survey



Petkova
et al.
2021

Spectral Line Density

How many lines are in the delivered data?

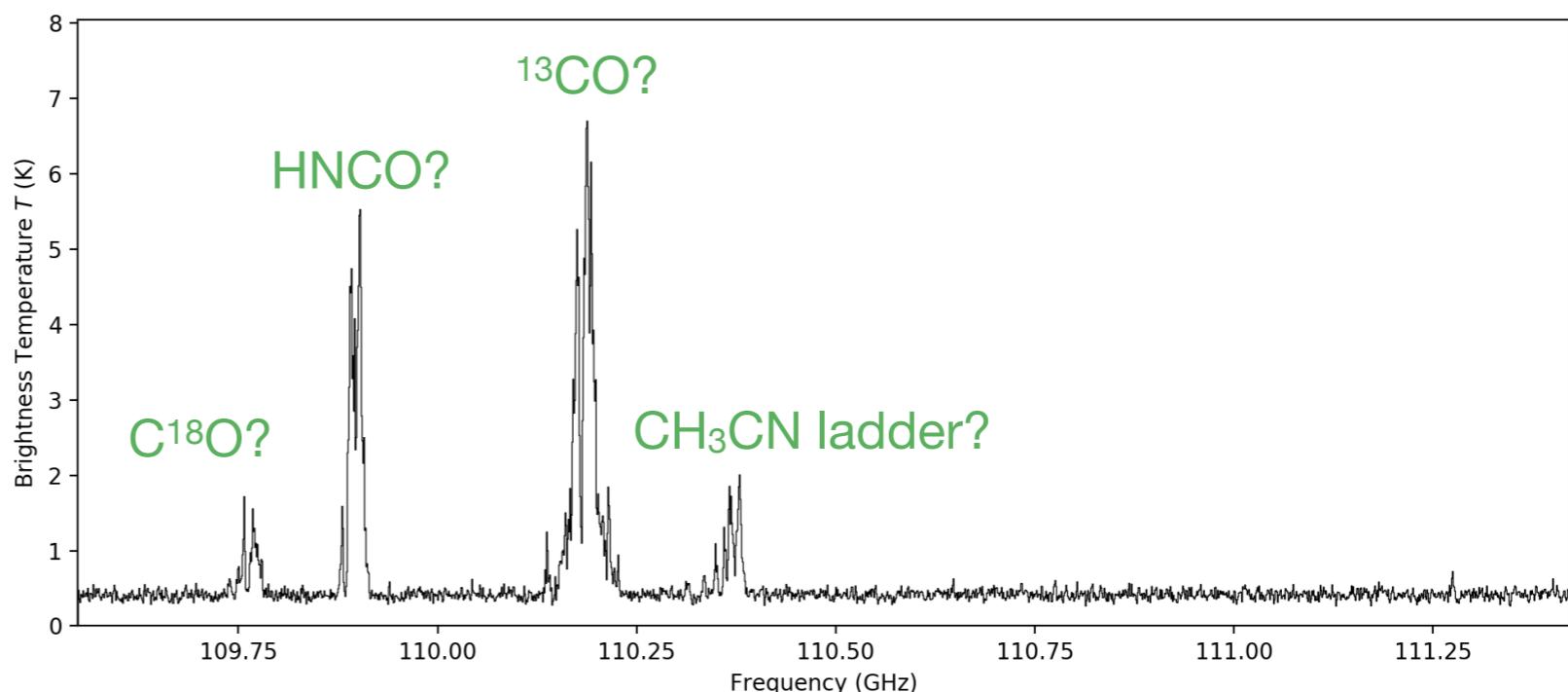
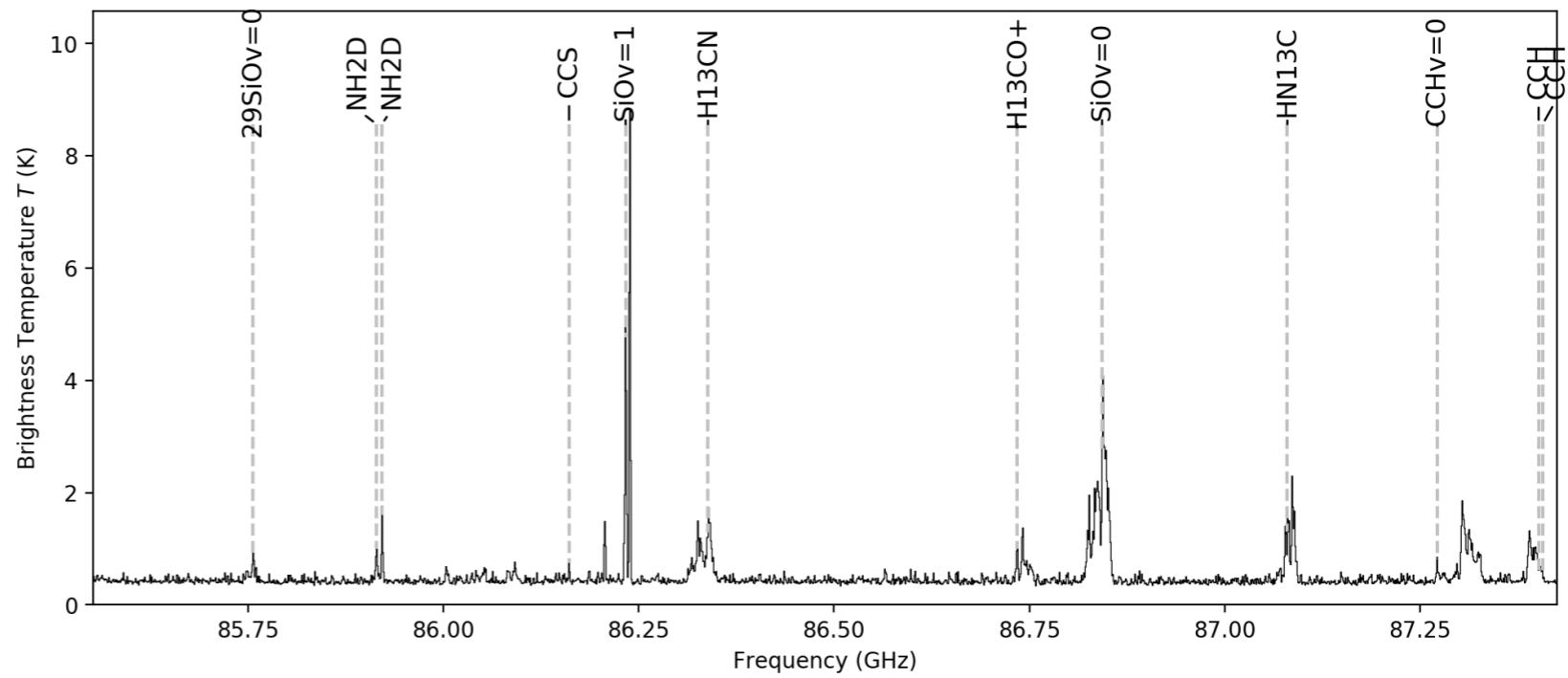


Used to validate spectral setup of ACES ALMA Large program

Identifying Spectral Lines

Which lines are in The Brick?

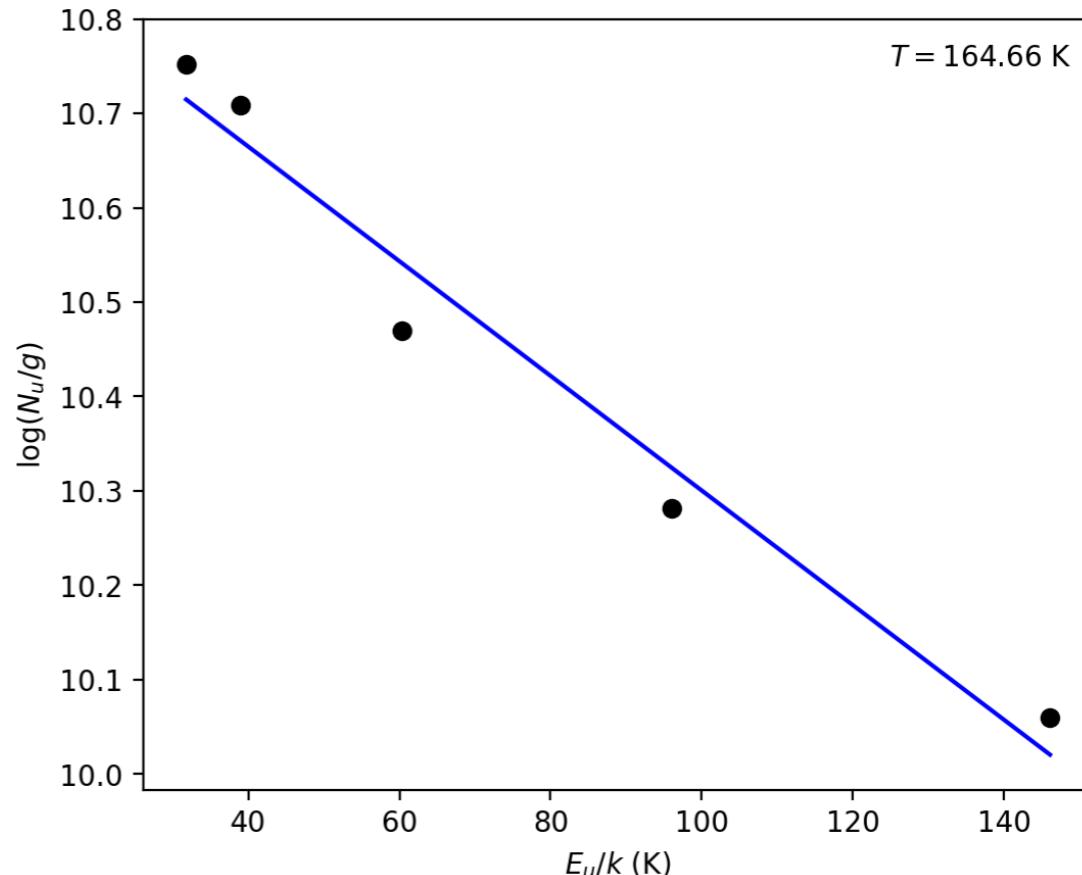
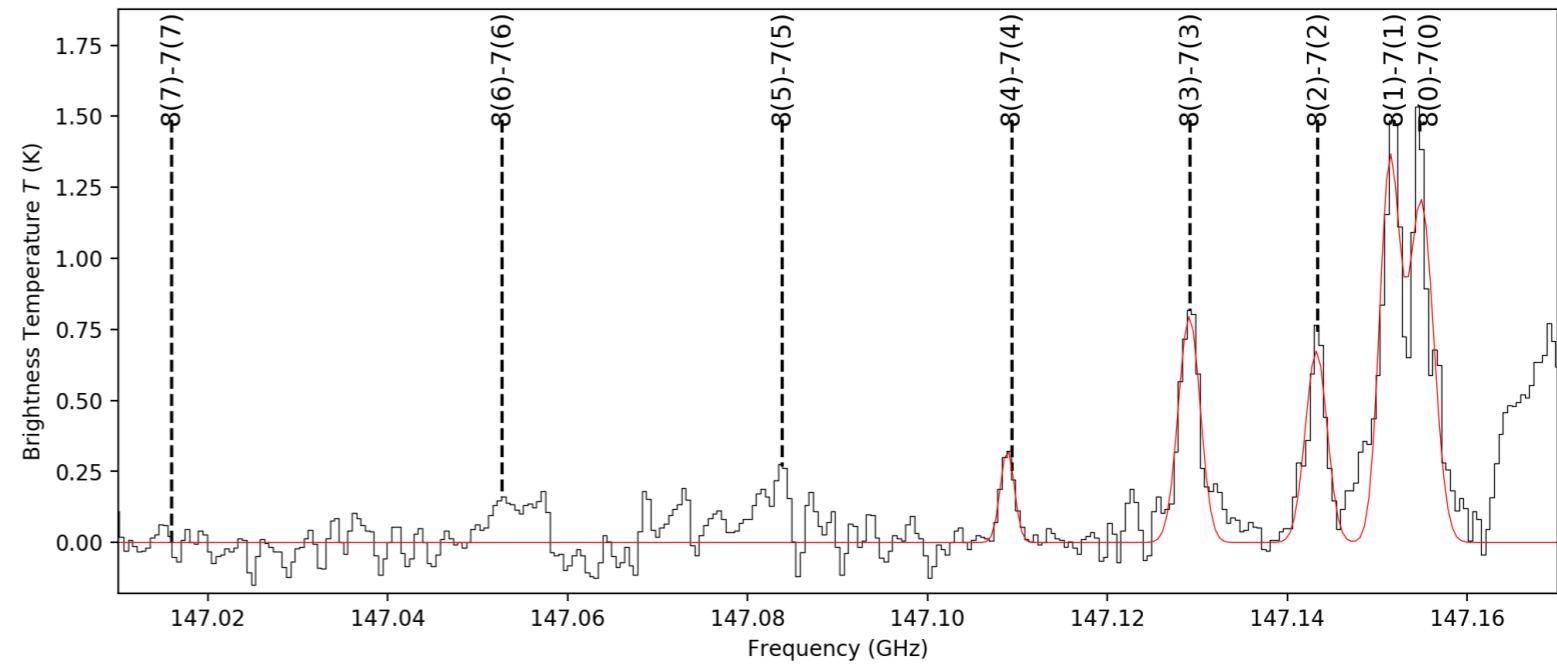
- "Max" spectra
- Small molecules and isotopologues
 - H^{13}CN
 - H^{13}CO^+
 - HN^{13}C
 - CCH
 - H_2CS
 - NH_2D
- CH_3CCH , CS, CO, HNCO
- Masers ($\text{SiO } \nu=1$, class I methanol)



Rotational Diagrams

How do temperature and density vary in The Brick?

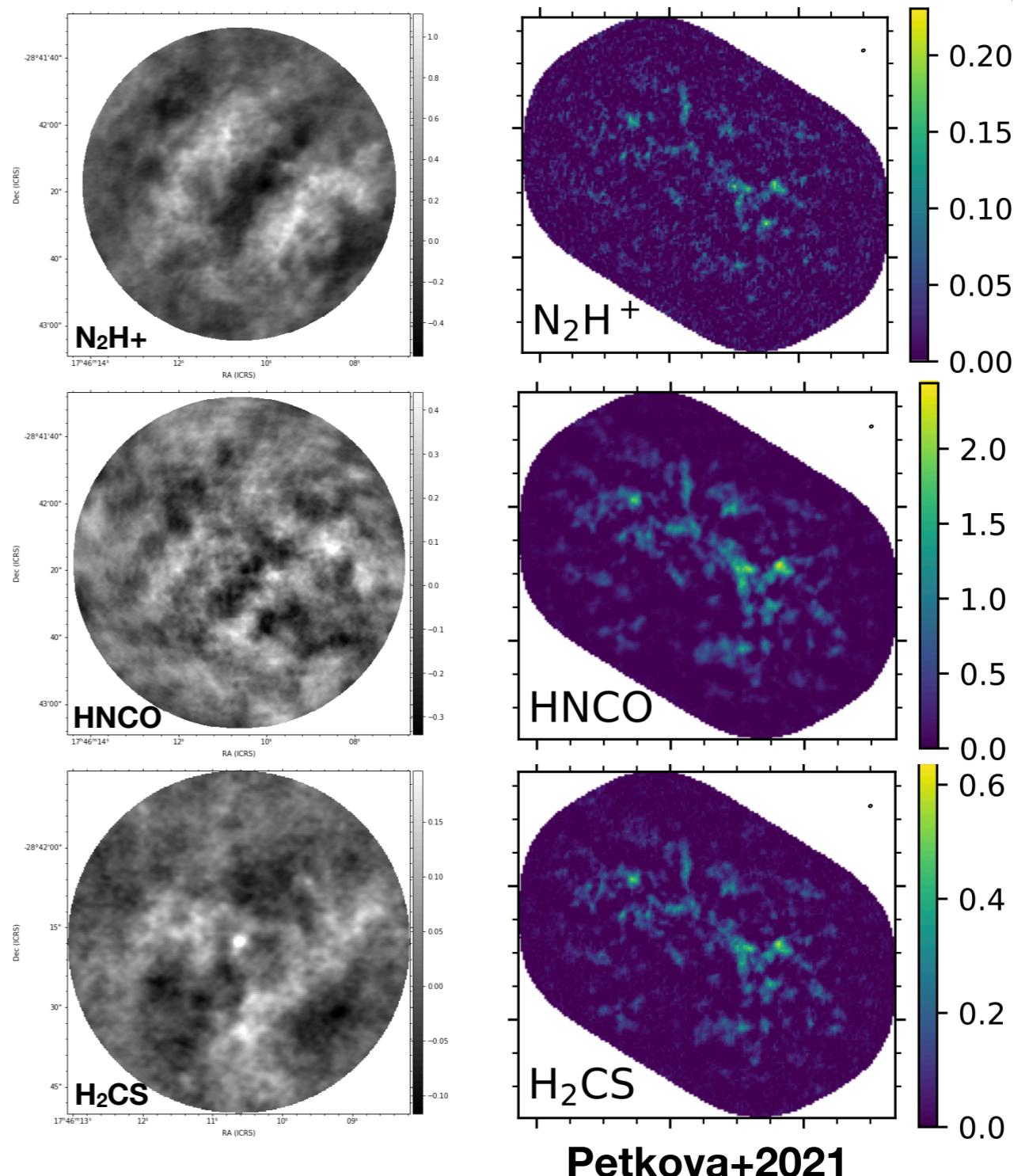
- Seven CH₃CN ladders in delivered data
 - Other temperature-sensitive molecules: CH₃OH, CH₃CCH, etc.
- $J = 8$ ladder, $T \sim 165$ K (same pointing from Walker+2021: 167 K)
- Repeat for other J ladders, repeat across cloud ([map](#))
- Constrain [cloud properties](#):
 - Temperature
 - Column density
 - Volume density



Future Work

What are the next steps?

- Temperature maps
- Moment maps
 - What structures can we associate with certain molecules?
 - Compare w/ Petkova+2021, share outflow tracers
- Defining regions
 - What structures are associated with known cores, outflows, shocks, and regions of diffuse gas (and what unique tracers do we see there?)



Thank you!

Contact email:
abulatek@ufl.edu

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

References

- Petkova, M. A., Kruijssen, J. M. D., Kluge, A. L., et al. 2021, [arXiv:2104.09558](https://arxiv.org/abs/2104.09558)
- Rathborne, J. M., Longmore, S. N., Jackson, J. M., et al. 2015, ApJ, 802, 125. [doi:10.1088/0004-637X/802/2/125](https://doi.org/10.1088/0004-637X/802/2/125)
- Walker, D. L., Longmore, S. N., Bally, J., et al. 2021, MNRAS, 503, 77. [doi:10.1093/mnras/stab415](https://doi.org/10.1093/mnras/stab415)
- Center of the Milky Way (Spitzer): https://www.nasa.gov/multimedia/imagegallery/image_feature_1439.html
- ALMA Receivers: <https://www.eso.org/public/teles-instr/alma/receiver-bands/>
- Brick (Spitzer): <https://webbtelescope.org/contents/news-releases/2020/news-2020-14>