Temperature of Gases at the Center of Our Galaxy

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Introduction

Super massive black holes (SMBHs) are of particular interest into how galaxies and the universe develop over time.

- As gas from a galaxy accretes onto a SMBH it responds through feedback mechanisms; like radiative pressure, jets, and winds, changing and forming the galaxy around it
- The closest SMBH is Sagittarius A* (Sgr A*) located at the center of the Milky Way.

Only recently was cold molecular gas observed near Sgr A* [1] [2] [3] [5].

- Want to determine how the black hole influences the nearby environment.
- Gas disrupted by radiation and tidal interactions will be hotter.

Methods

Observe the data of ^{12}CO(J = 2 − 1), rest frequency 230.538 GHz, [3] and ^{12}CO(J = 3 − 2), rest frequency 345.8 GHz. [2]

- This data is presented in "cubes"
  - 2 spatial axes (RA and Dec.) and 1 spectral axis (Hz or km s^{-1})
- Collected via the Atacama Large Millimeter Array (ALMA) consisting of 66 radio telescopes.
- Observations with ALMA were smoothed to 1.065'' x 0.710'', 83.569° and 25 km s^{-1}.

To get an idea of the temperature of different regions at specific velocities we must look at a ratio of the two data cubes.

- Using Boltzmann distribution and optically thin assumptions the ratio of the 3-2 data over the 2-1 data gives a good idea at the temperature distribution throughout the cube.

$$\frac{N_{32}}{N_{21}} = \frac{g_{32}}{g_{21}} \exp\left(-\frac{E_{32} - E_{21}}{k_B T}\right)$$

- Masking techniques were used to eliminate artifacting caused by noise.
  - All data was masked below 10σ.

To get a map of Rotation Temperature we have to consider the integrated flux maps of each cube

- An integrated flux map (moment 0) sums the intensities over the spectral axis to get a total intensity along the line of sight.
- We can then take a ratio of both these maps and, after performing a specific transform, we get a Rotation Temperature map (Fig. 1, Left).

Results Summary

The head of the OH stream [4] [6] is much hotter than the surrounding gas. (Fig. 1)

- Indicates likely interaction with Sgr A*.
- Great for further observation and study to understand how matter is actually accreted onto a black hole.

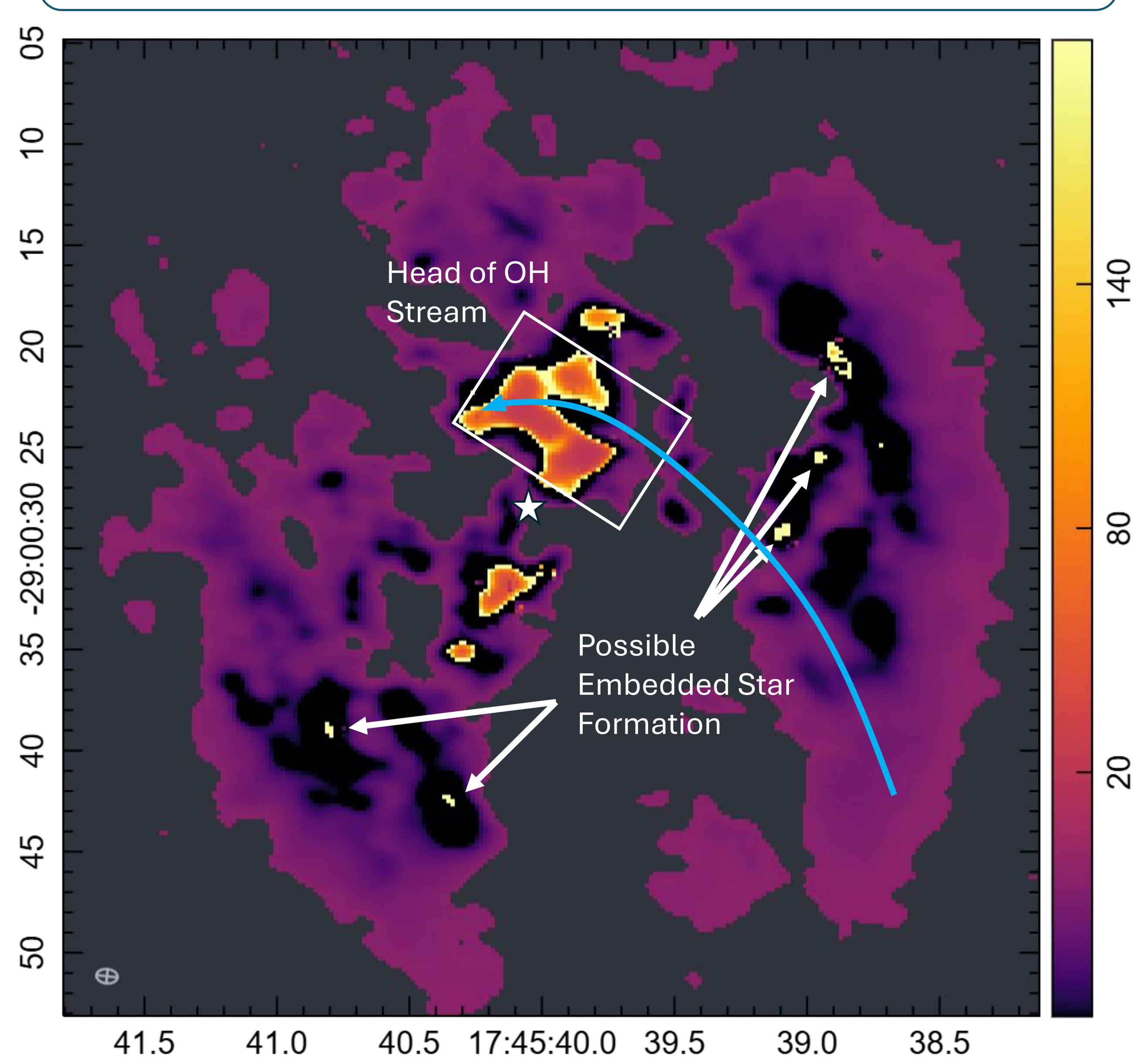
An interesting stream of gas seen at -20 km s^{-1} south of Sgr A* heating east to west. (Fig. 2)

- Indicates possible interaction with Sgr A*.

Unique pockets of cold gas with a hot core like center. (Fig. 1)

- Indications of star formation or heating due to tidal stress.

Rotation Temperature



Integrated Flux Map

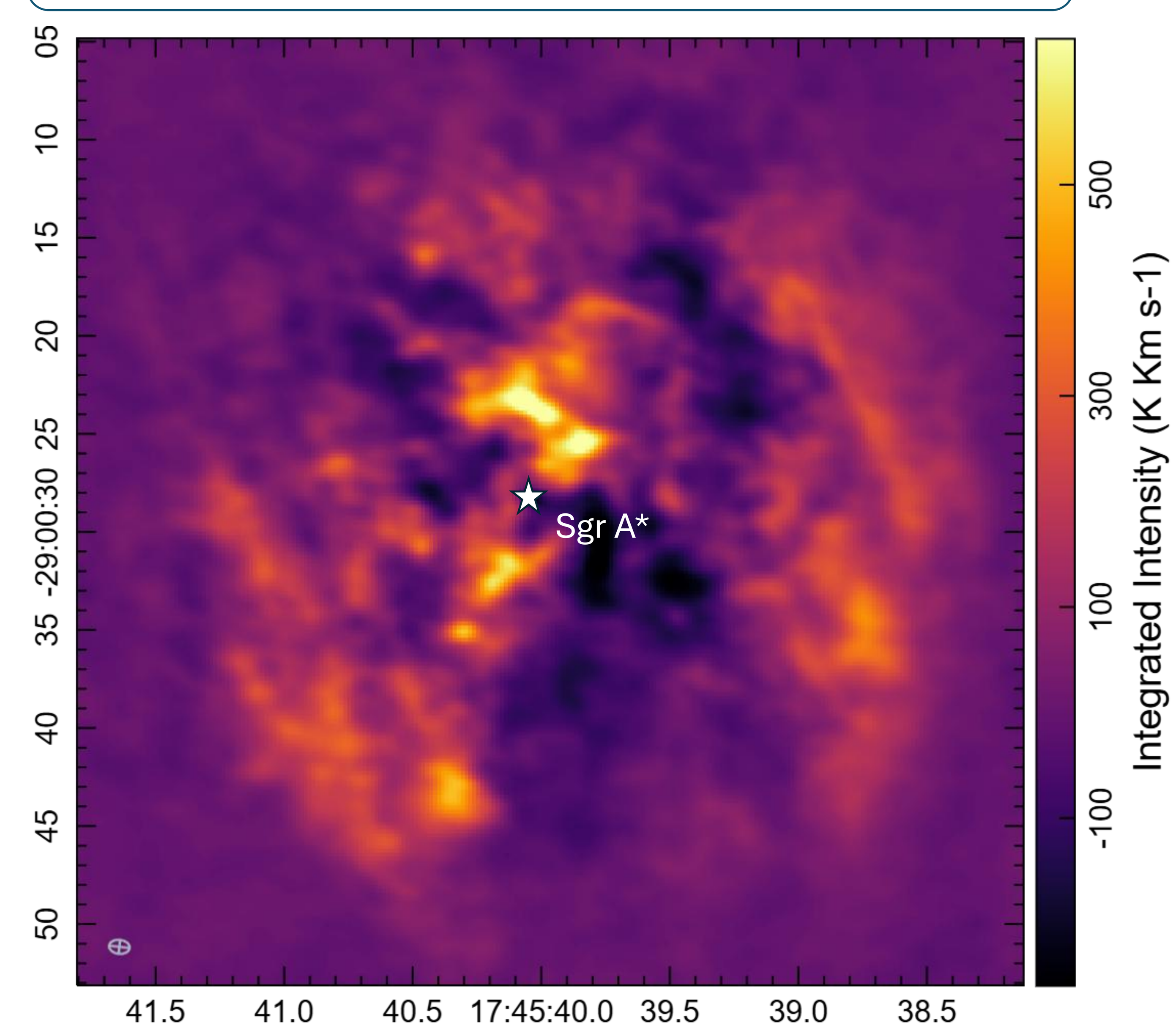


Figure 1. (Left) Masked rotation temperature map using ^{12}CO (J=3-2) and (J=2-1) lines. (Right) Integrated flux map for the ^{12}CO(J=2-1) line. ($\sigma_{\text{moment 0, 2−1}} \approx 0.71$ K km s^{-1}, $\sigma_{\text{moment 0, 3−2}} \approx 11.50$ K km s^{-1})

-20 km s^{-1} Slice of Ratio Cube

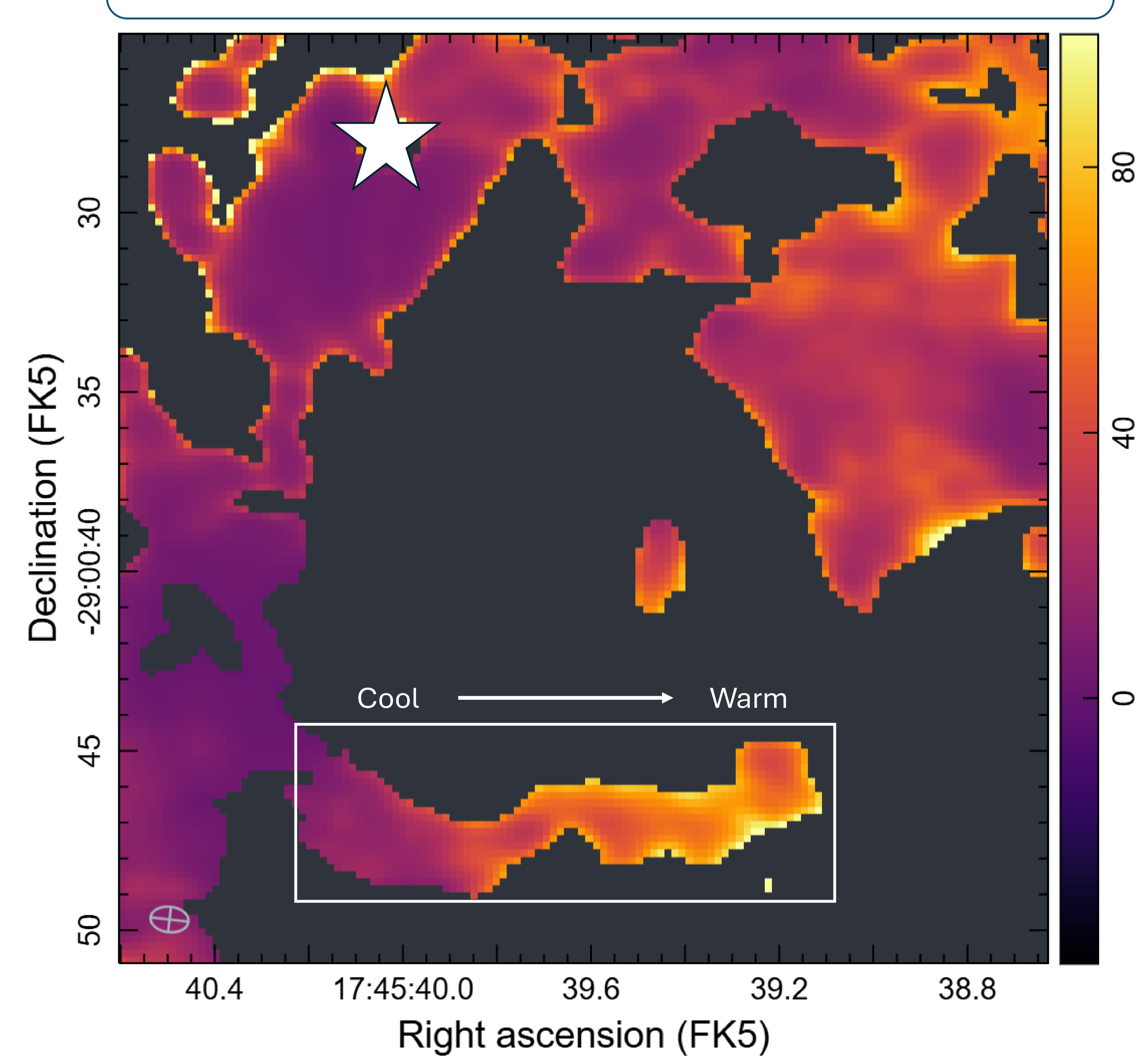


Figure 2. Masked slice of the ratio cube at -20 km s^{-1} depicting a stream of gas south of Sgr A* heating from east to west. ($\sigma_{2-1} \approx 0.004$ K, $\sigma_{3-2} \approx 0.065$ K)

Cold Molecular Gas Interacts With Sgr A*!

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Acknowledgements

I would like to thank CIERA for this opportunity to be able to do this research in the first place, and the great mentor Dr. Mark Gorski, without whom none of this would be possible.

This material is based upon work supported by the U.S. National Science Foundation (NSF) under Award Number AST-2446392. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the NSF.

This poster makes use of the following ALMA data: ADS/JAO.ALMA #2016.1.00870.S, #2017.1.00995.S, #2017.1.00040.S, and #2019.1.01559.S. ALMA is a partnership of ESO (representing its member states), NSF (USA) and NINS (Japan), together with NRC (Canada) and NSC and ASIAA (Taiwan) and KASI (Republic of Korea), in cooperation with the Republic of Chile. The Joint ALMA Observatory is operated by ESO, AUI/NRAO and NAOJ.

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