Investigating Flux Densities and Polarization of Methanol Masers in the Orion Nebula

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Western Illinois University

NASA, Hubble Space Telescope

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- ACCESS

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Background

- VLA (Very Large Array)
  - Radio Telescope
  - New Mexico, U.S.
- VOLS (VLA Orion-A Large Survey)
- 20 Epochs
- From April 3, 2022
- To July 1, 2022

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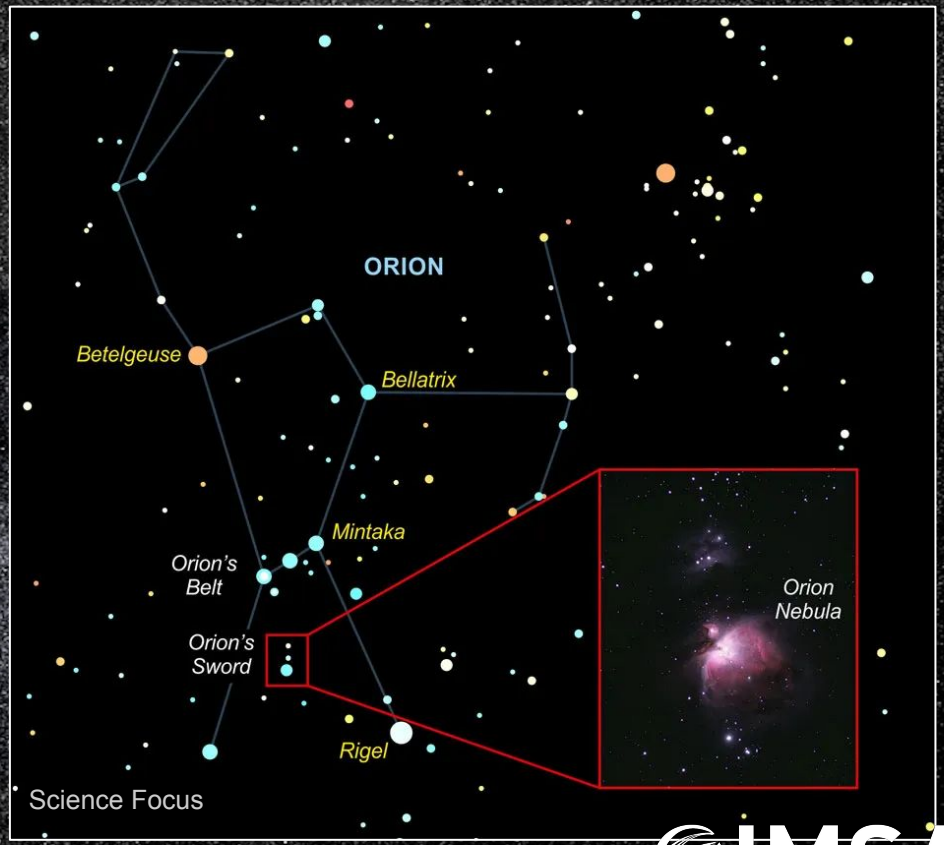
Background

- Orion Nebula



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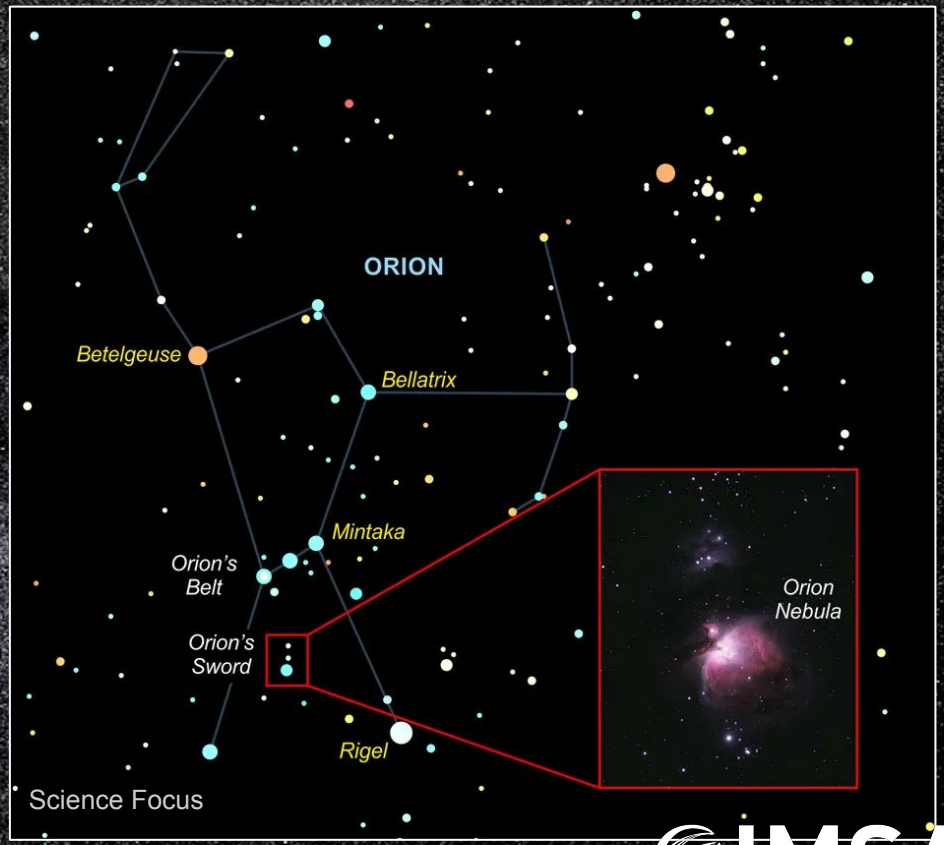
Background

- Orion Nebula
- Pointings



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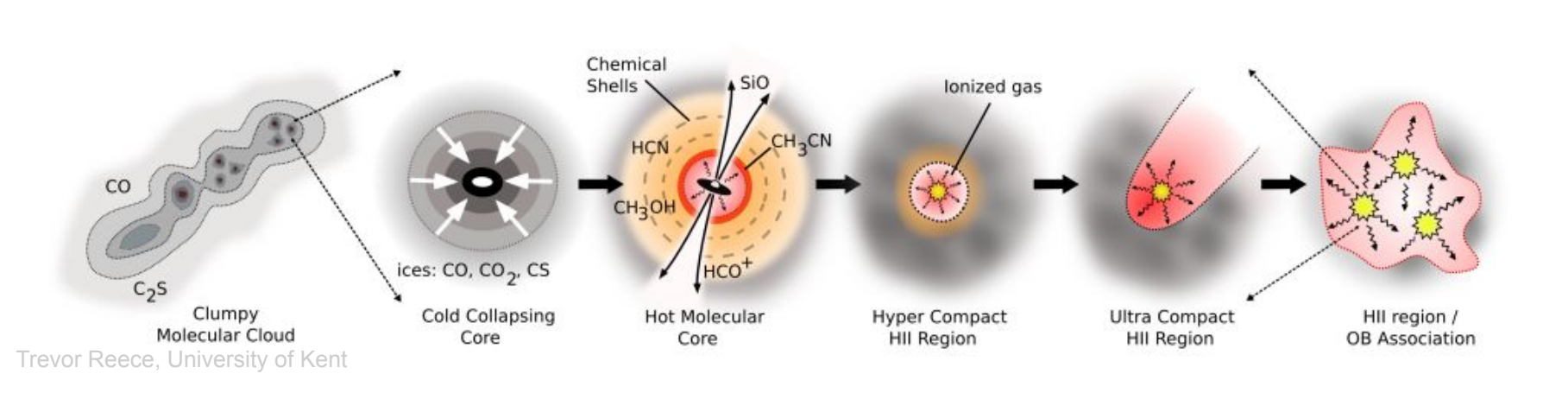
Background

- High Mass Star Formation



Trevor Reece, University of Kent

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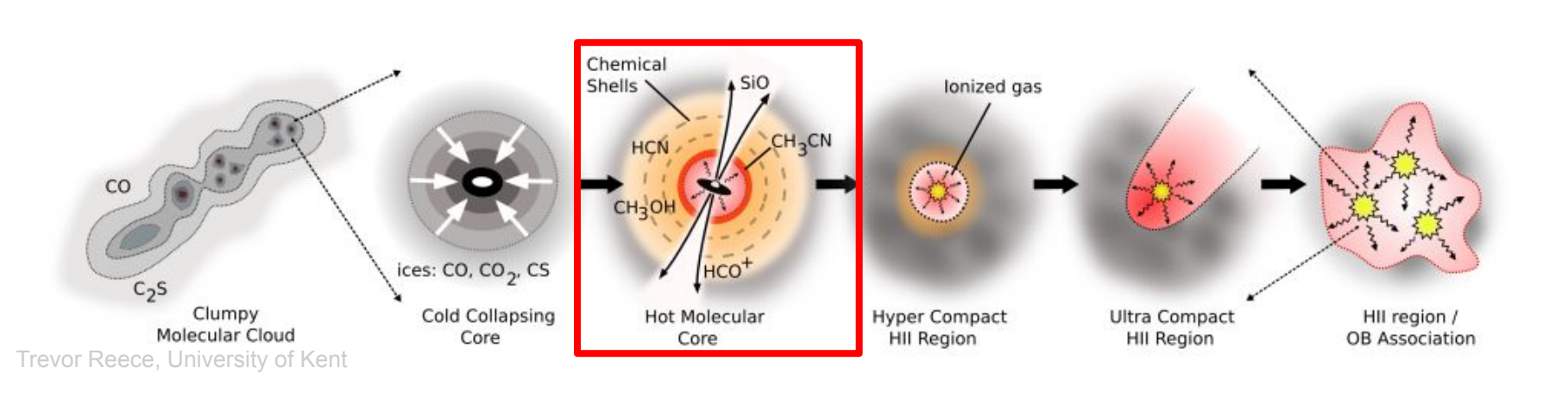
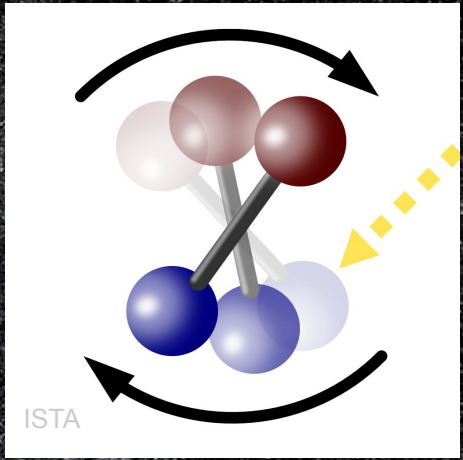
Background

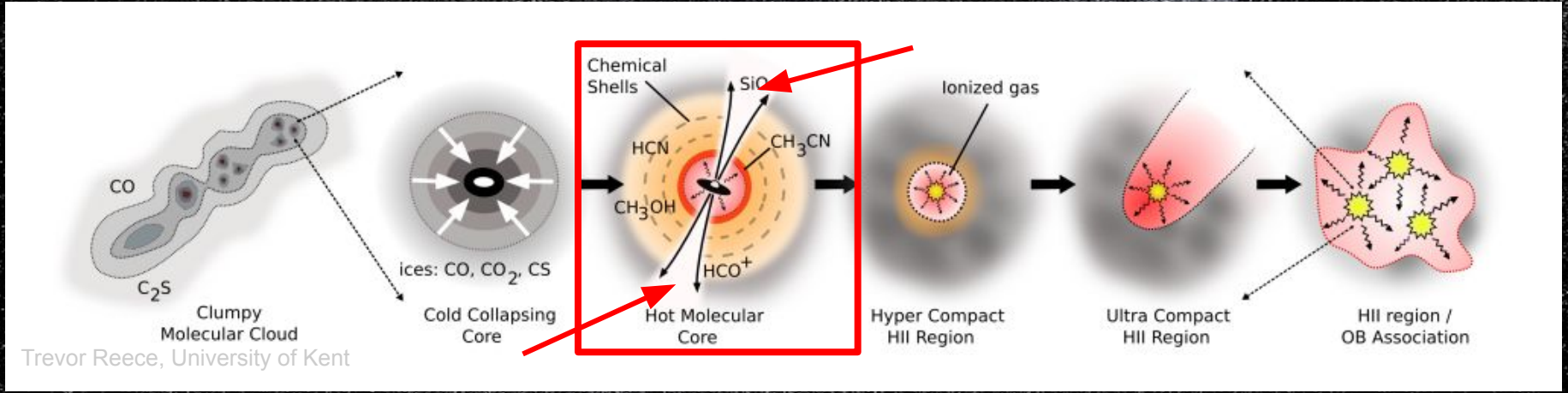
- High Mass Star Formation
  - Molecular Outflow



Background

- High Mass Star Formation
  - Molecular Outflow
  - Masers





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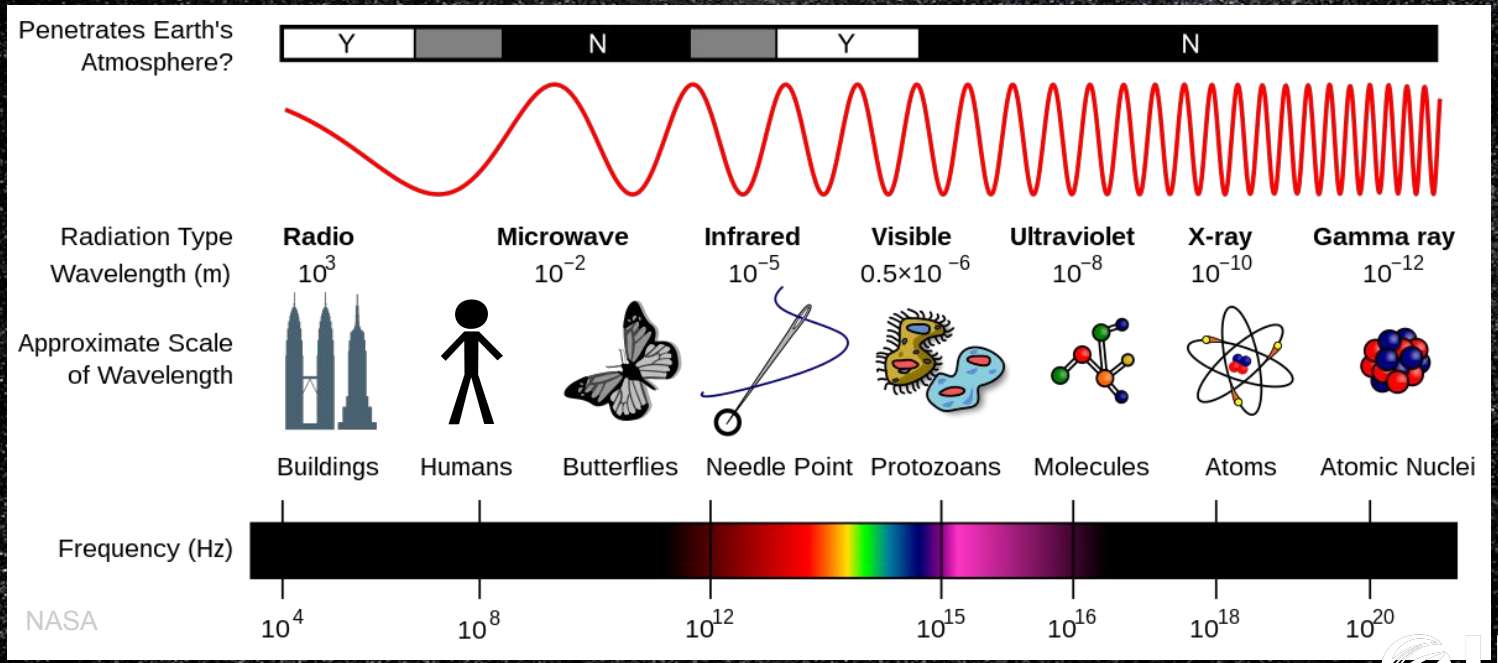
Background

- Microwave Radiation
- Flux Density

$$1\ Jy = 10^{-26}\ \frac{W}{m^2 Hz}$$



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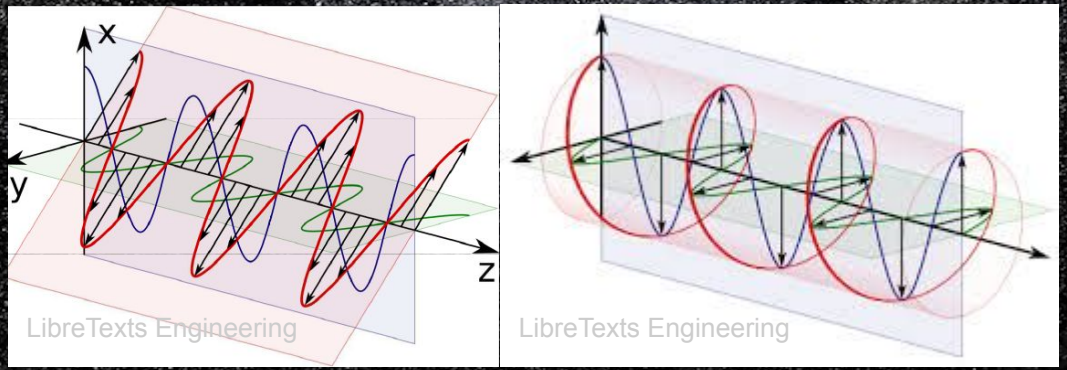
Background

- Light Wave Polarization
  - Stokes Intensity - IQUV
  - I - Overall Signal Intensity
  - Q, U - Linear Polarization, 45 degree increments
  - V - Circular Polarization, Left/Right-Hand



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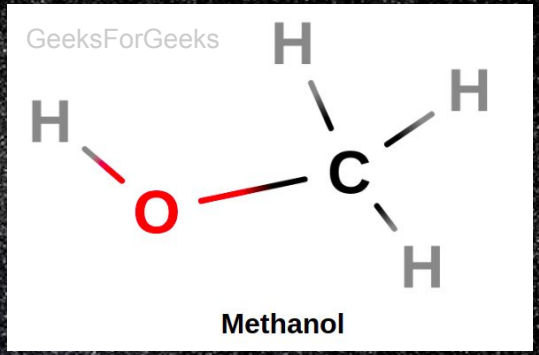
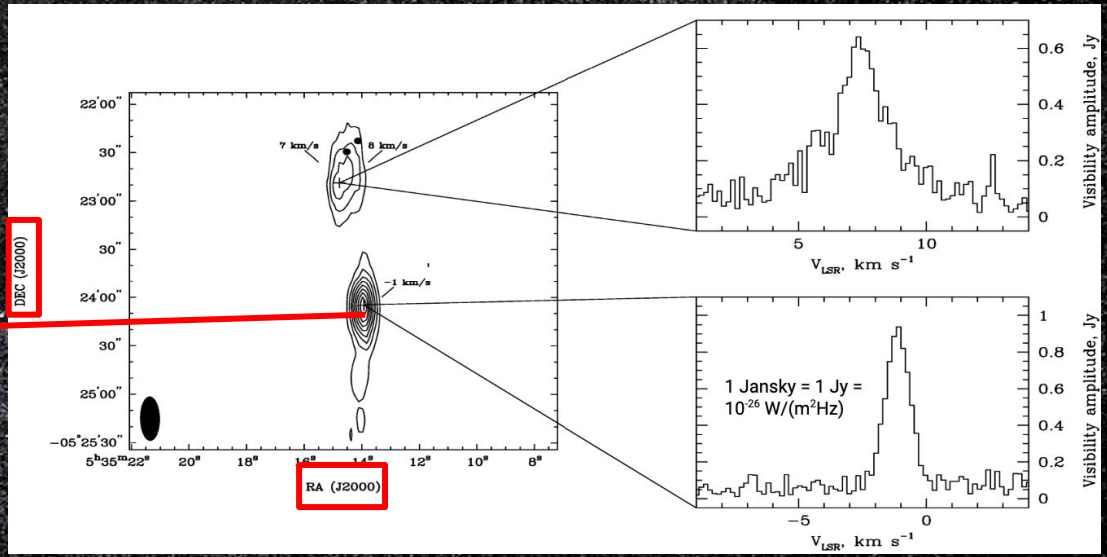
Background

- Methanol (CH_3OH) Masers in Orion



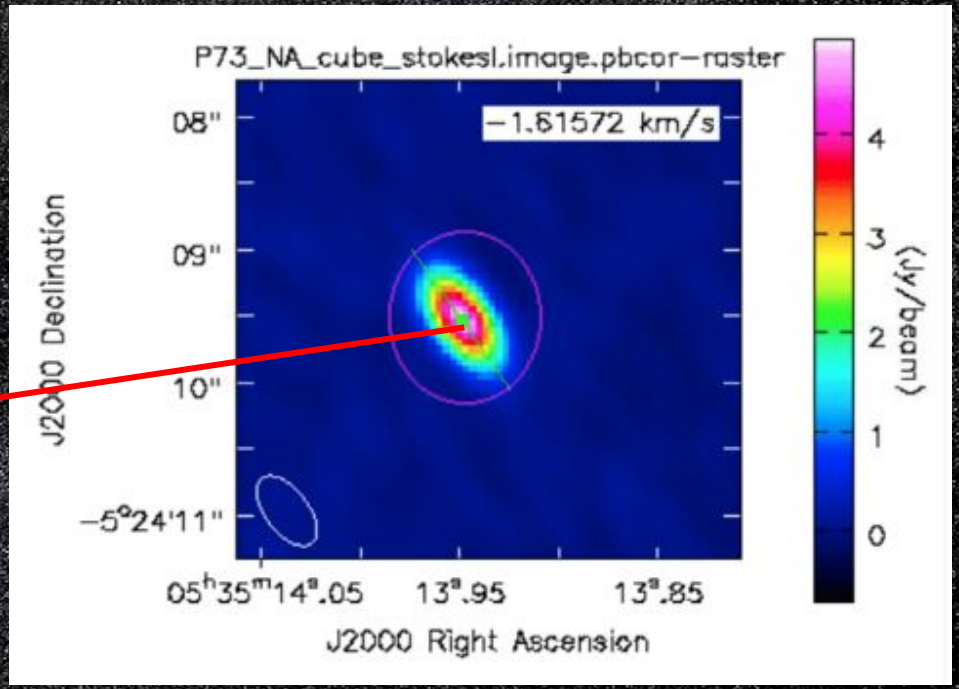
Voronkov et al. (2005, MNRAS 362, 995)



- Right Ascension, Declination => x, y in the Night Sky

Background

- Methanol (CH_3OH) Masers in Orion



Sojka et al. (2024, AAS 244, 302.06)

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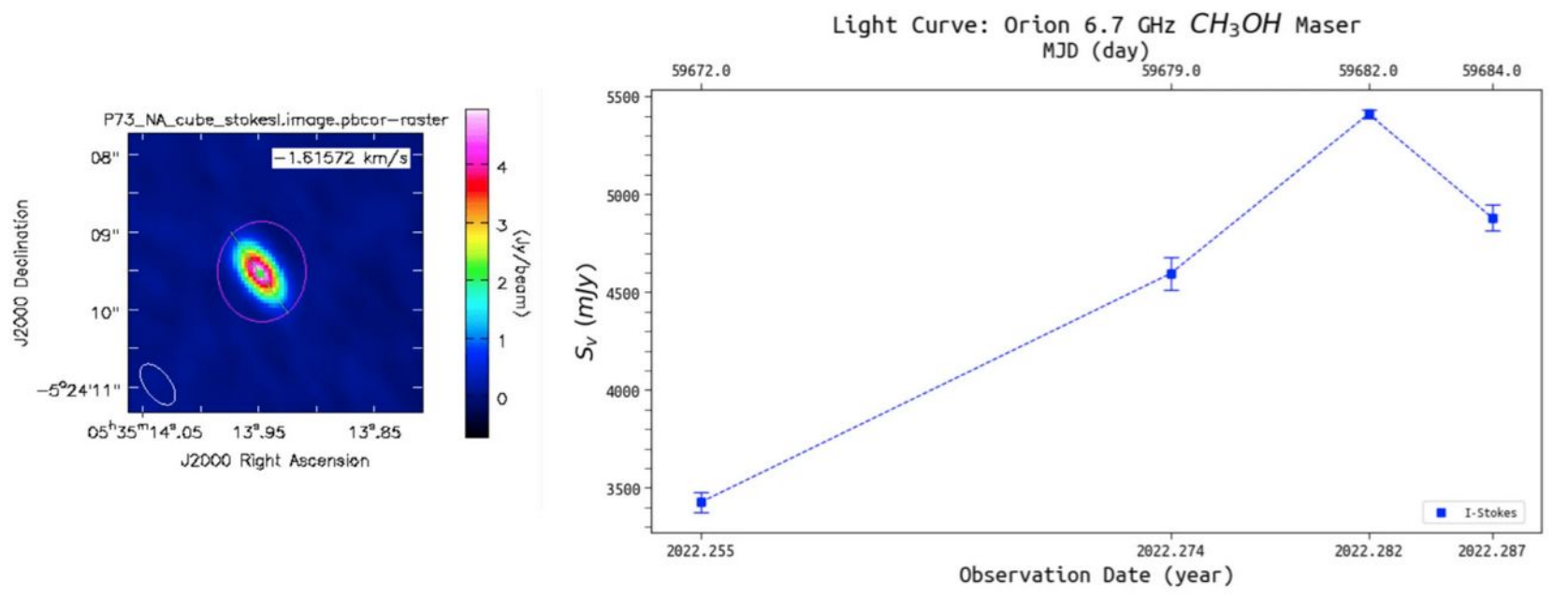

Sojka et al. (2024, AAS 244, 302.06)

Objectives

- Obj 1: Confirmation using pointings in the night sky

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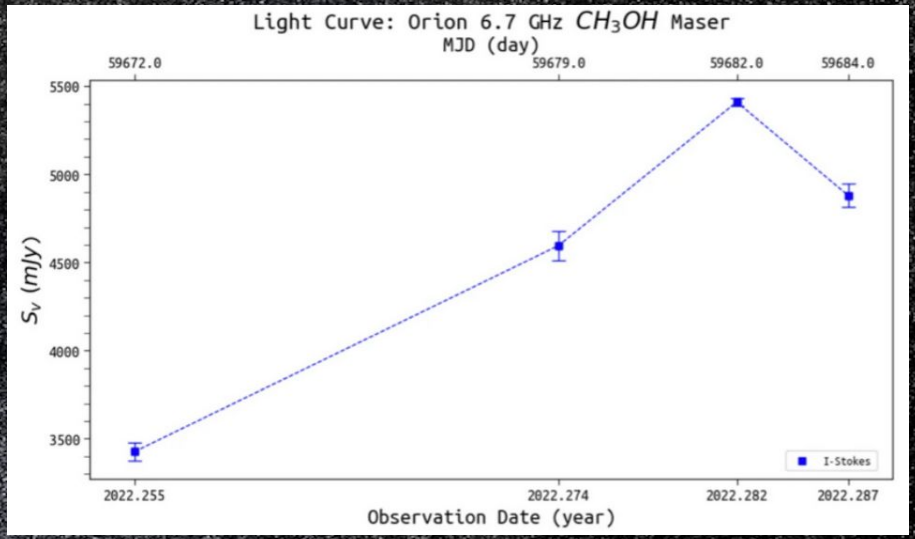
Objectives

- Obj 1: Confirmation using pointings in the night sky
- Obj 2: Look for fast variability in the maser



Sojka et al. (2024, AAS 244, 302.06)

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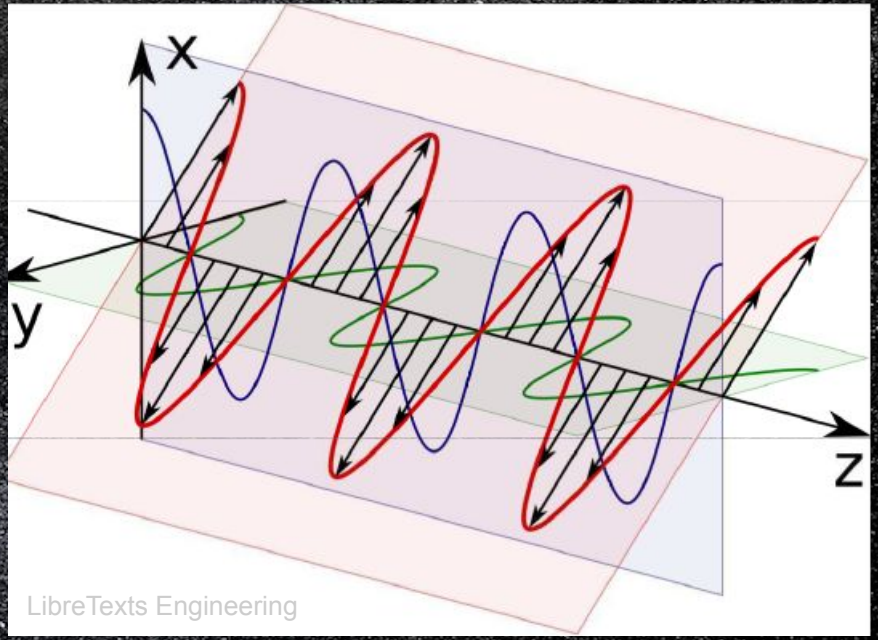
Objectives

- Obj 1: Confirmation using pointings in the night sky
- Obj 2: Look for fast variability in the maser
- Obj 3: Check for linear polarization (as well as circular polarization)



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Methodology

- NSF ACCESS, Jetstream2, University of Indiana
- CASA (Common Astronomical Software Applications)

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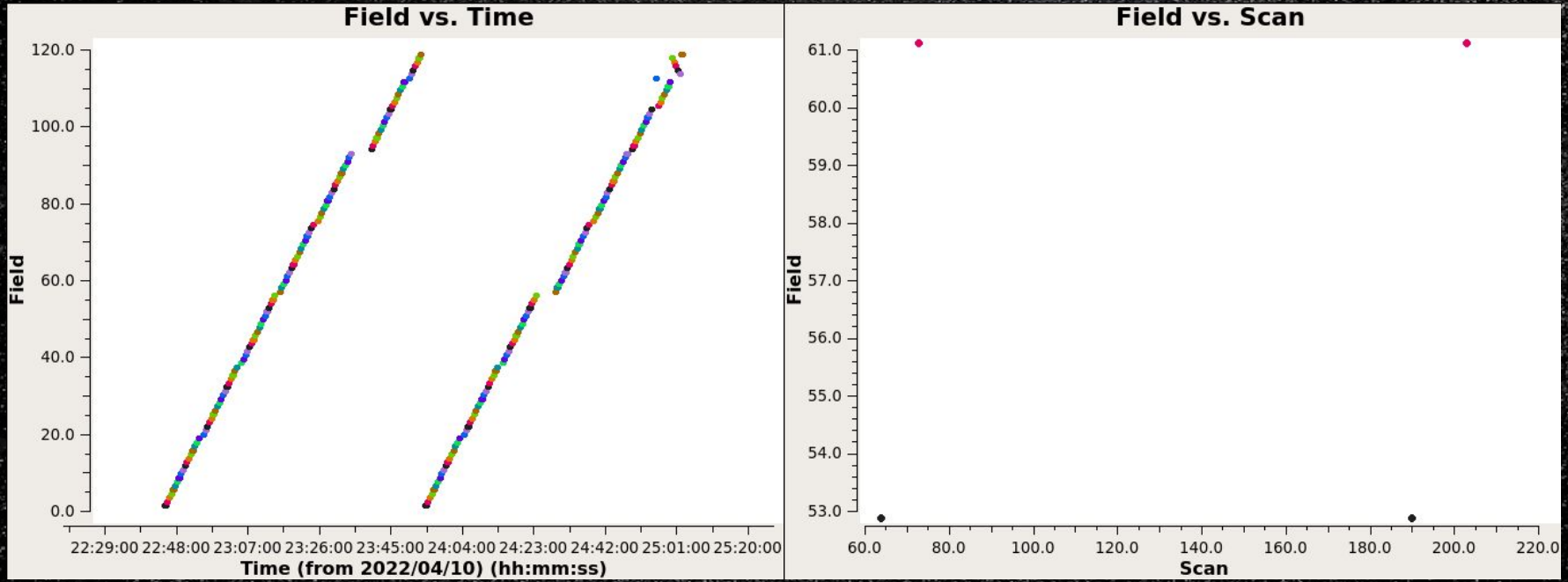
Methodology

Epoch 2

- Sky Scanning



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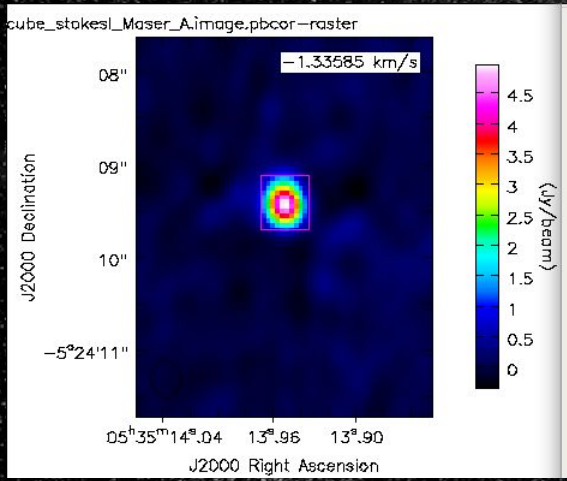
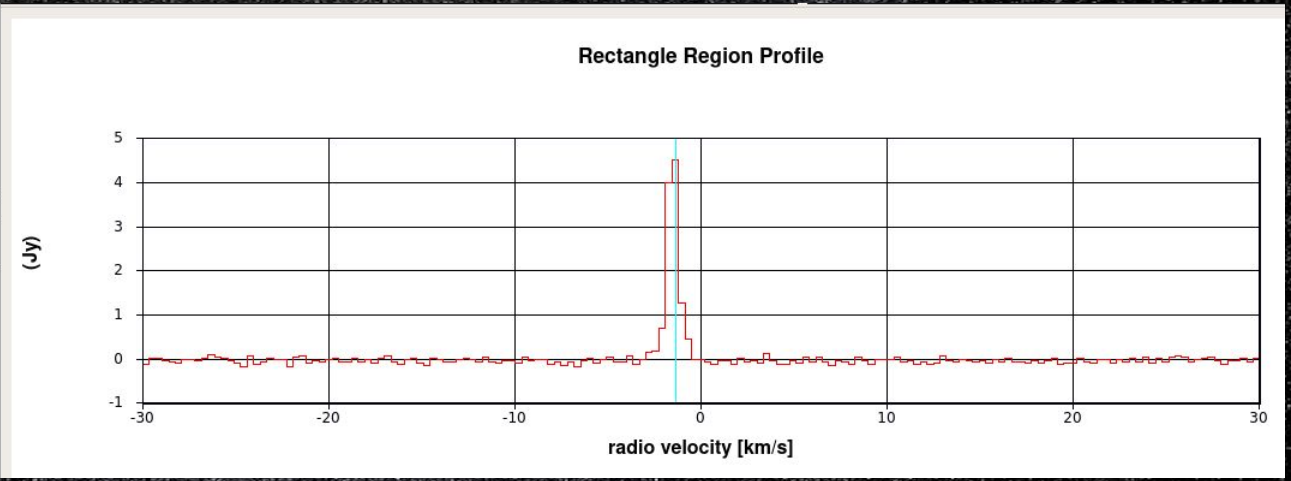
Methodology

Epoch 2, Pointing 73

- Spectral Imaging
- Spectral Lines





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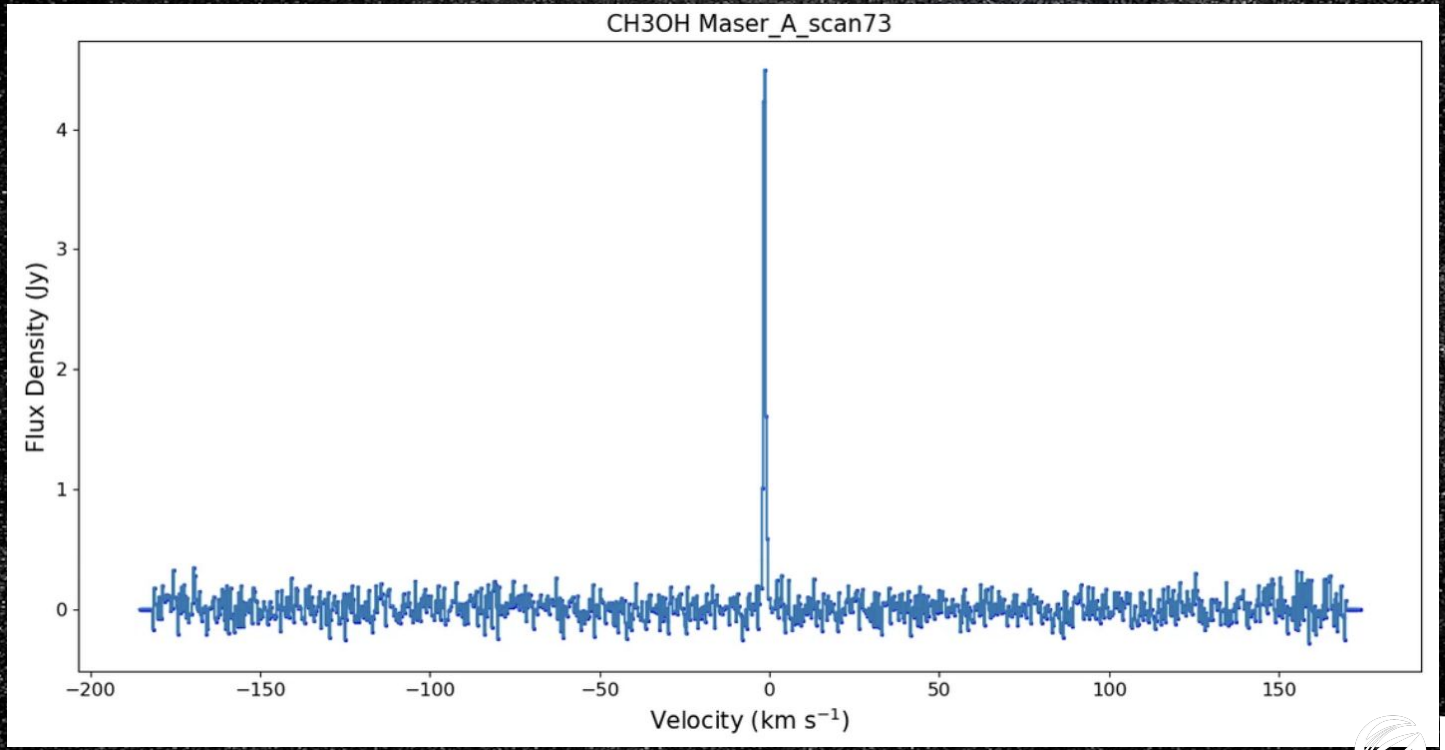
Methodology

Epoch 2, Scan 73

- Examples of Signal and Noise Graphs



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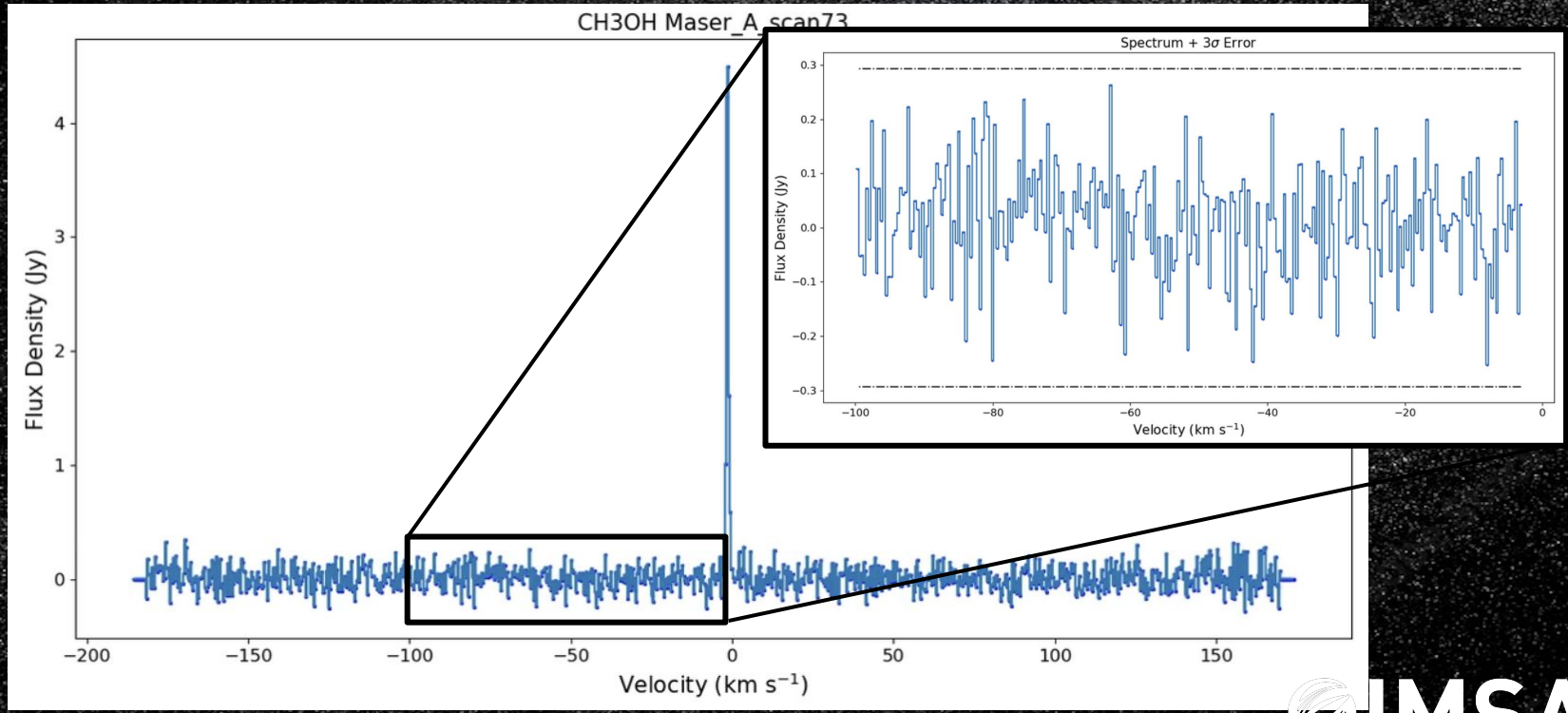
Methodology

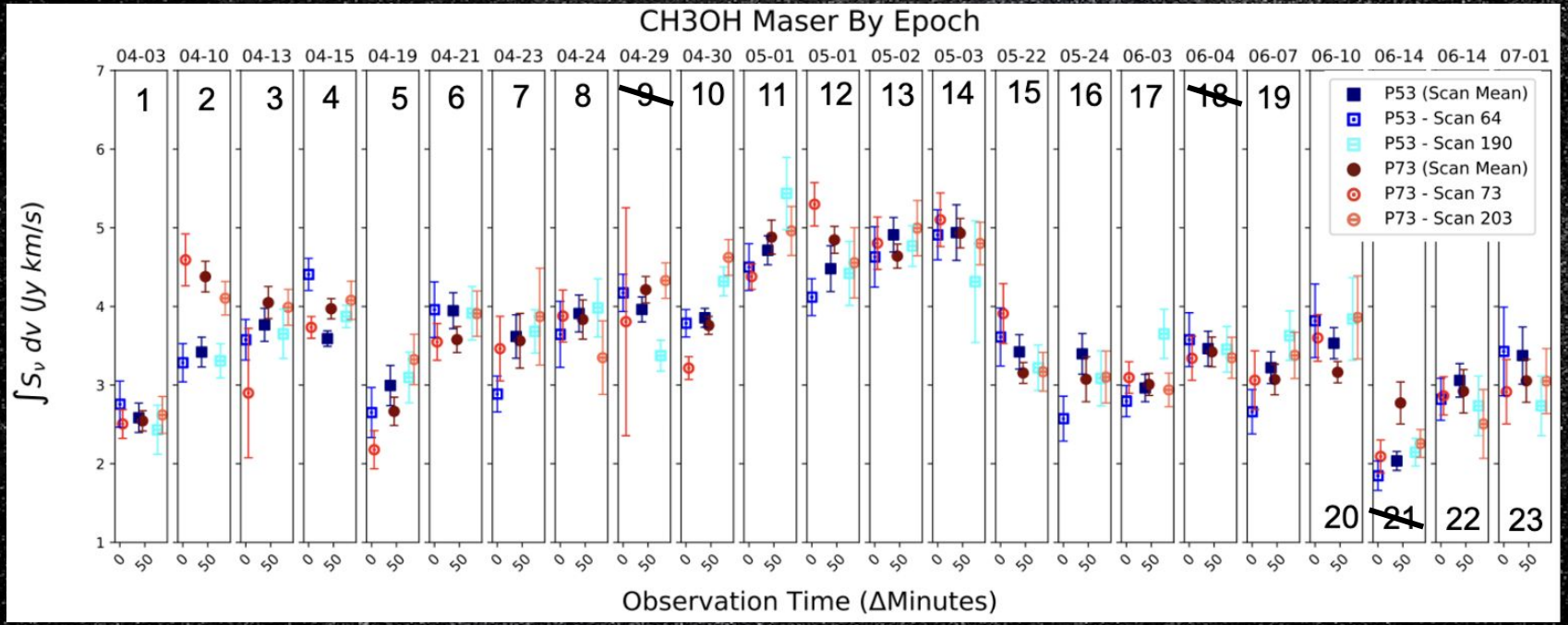
Epoch 2, Scan 73

- Examples of Signal and Noise Graphs



Results and Discussion

- Combined Light Curve of 23 epochs



All Epochs

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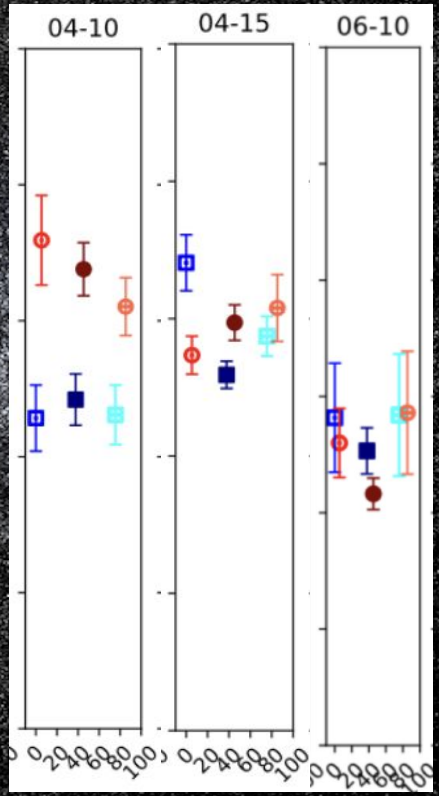
Objective 1

Epoch 2, Epoch 4

- Overall Findings
  - Flux densities consistent between different pointings for all epochs except epochs 2, 4, and 20
  - General consistency for 17/20 epochs => general maser consistency

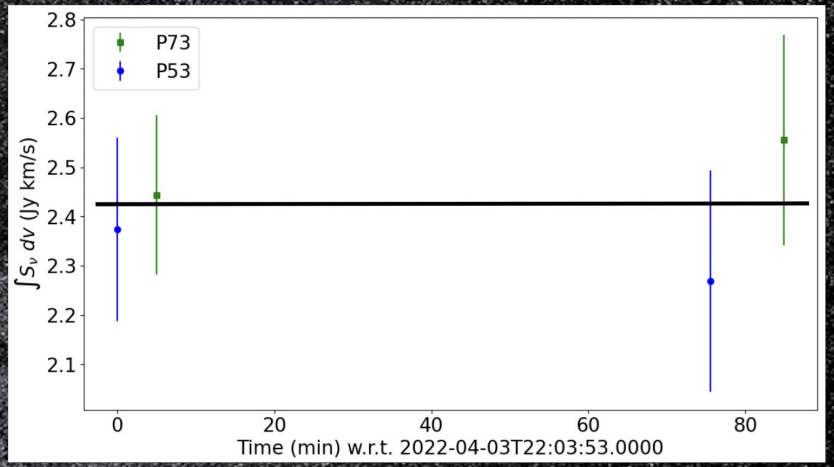


E2 E4 E20

Objective 2

Epoch 1

- Overall Findings
  - Possible evidence of fast variability in epochs with general trends
  - Generally similar scan values for most epochs
  - Offset scans in some epochs due to lack of telescope data or high noise



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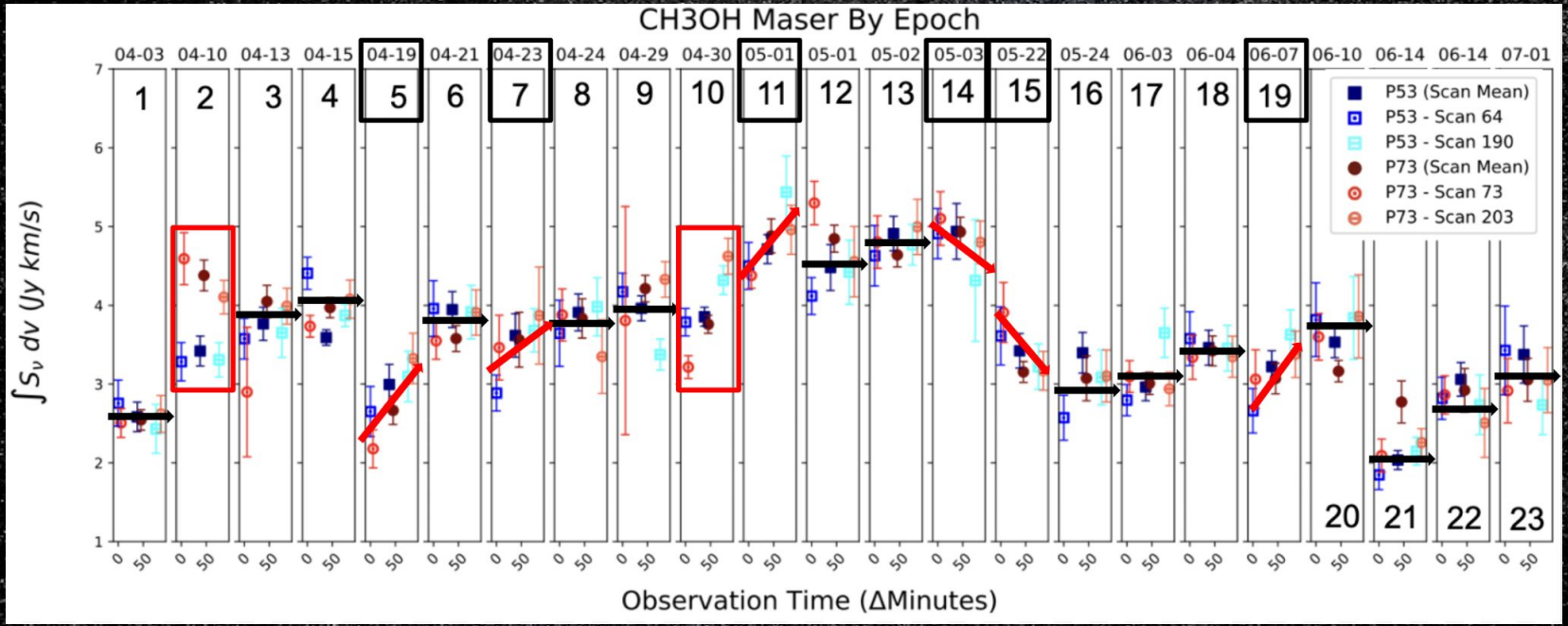
Objective 2

- Fast Variability in the 20 Epochs



All Epochs

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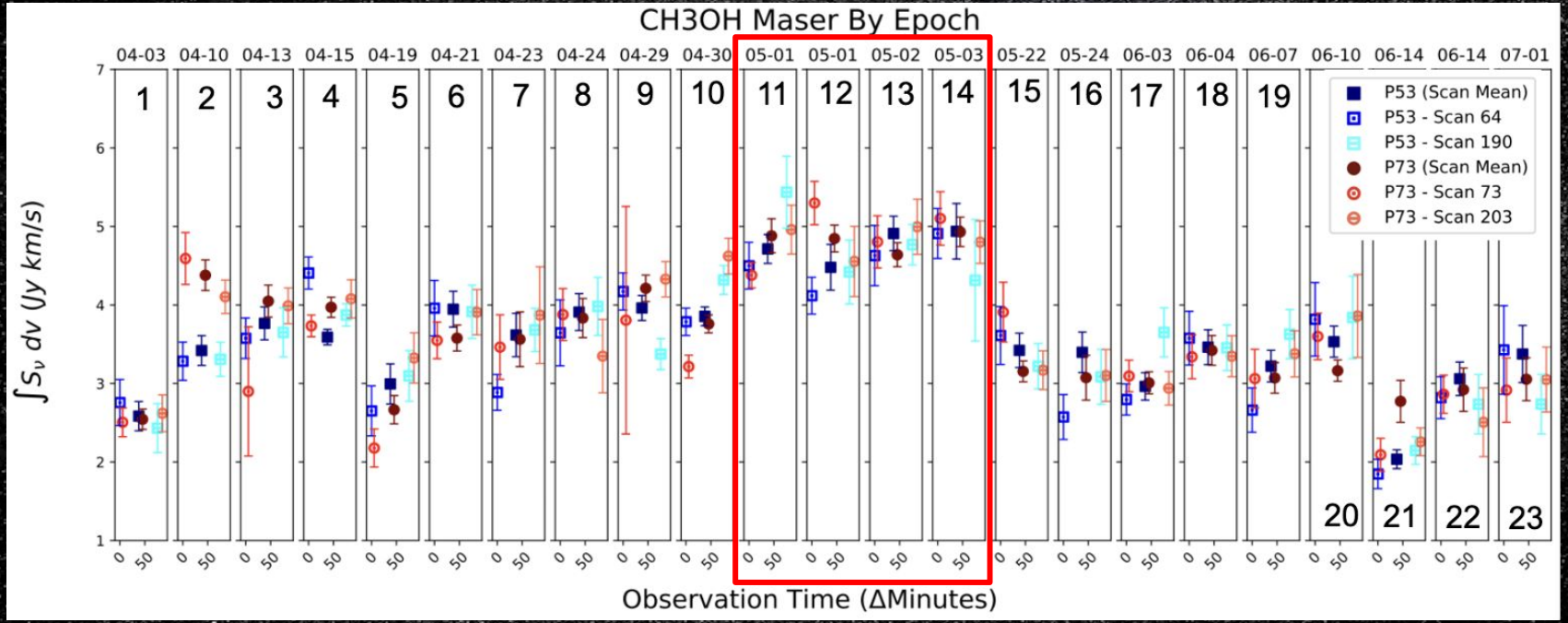
Discrepancy

- May 1st to 3rd Flare



Epochs 11-14

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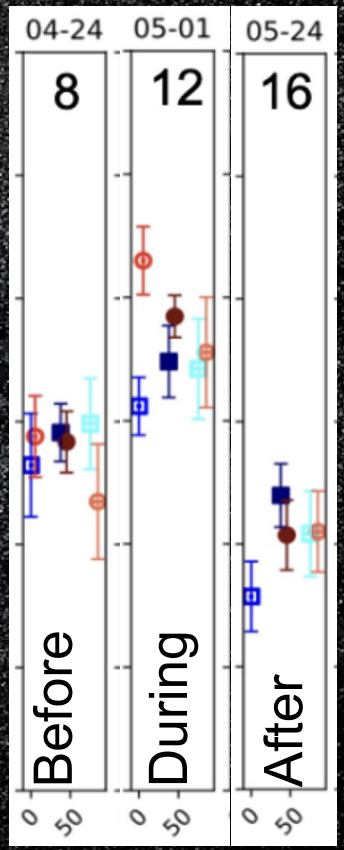
Discrepancy

Epochs 8, 12, 16



- May 1st to 3rd Flare
  - Significant increase in flux density in epochs 11 through 14
  - Possible Causes:
    - Nearby young stellar object's accretion disk grows, leading to a larger radiation field affecting maser
    - Shockwave front passes through maser

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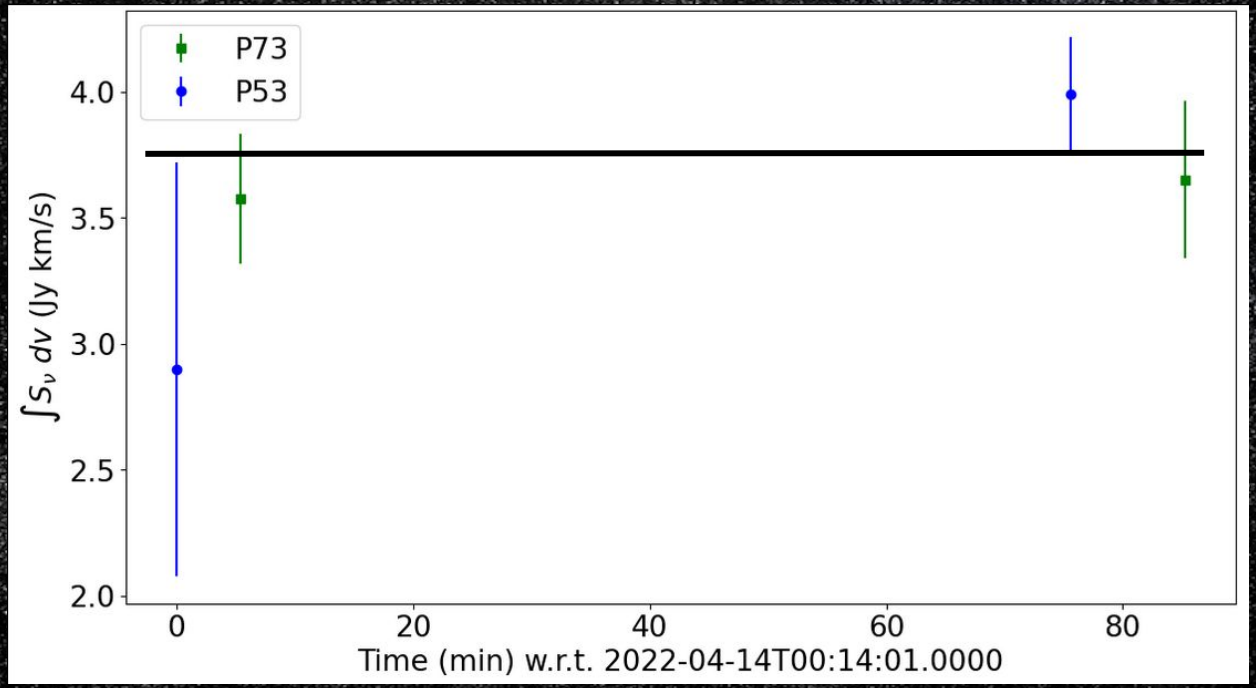
Discrepancy

Epoch 3

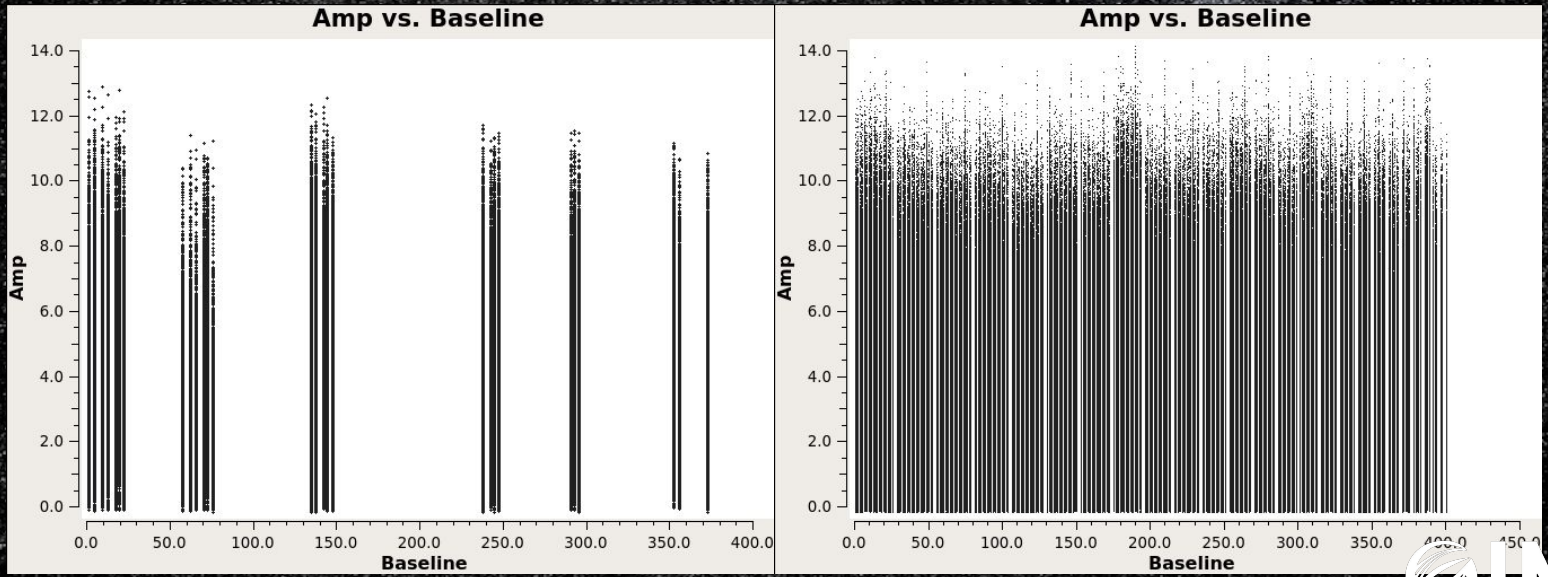
- Comparing Pointings
  - Epoch 3 pointings are consistent, but one scan is offset



Discrepancy

Epoch 3, Scan 73

- Lack of data
  - Not all telescopes took a reading
  - Left: Scan 73, Right: Scan 203



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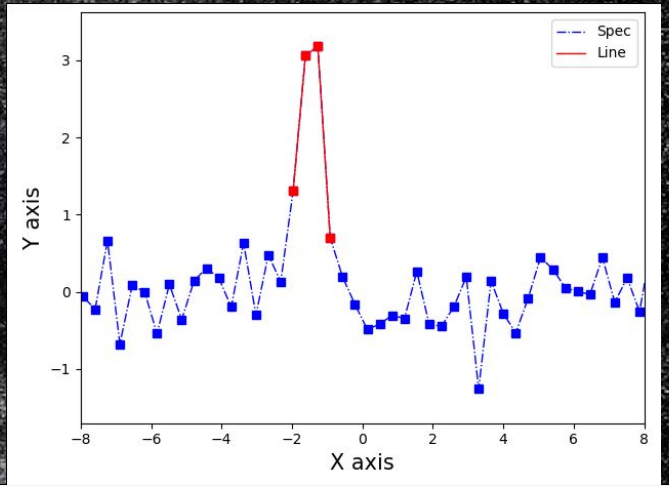
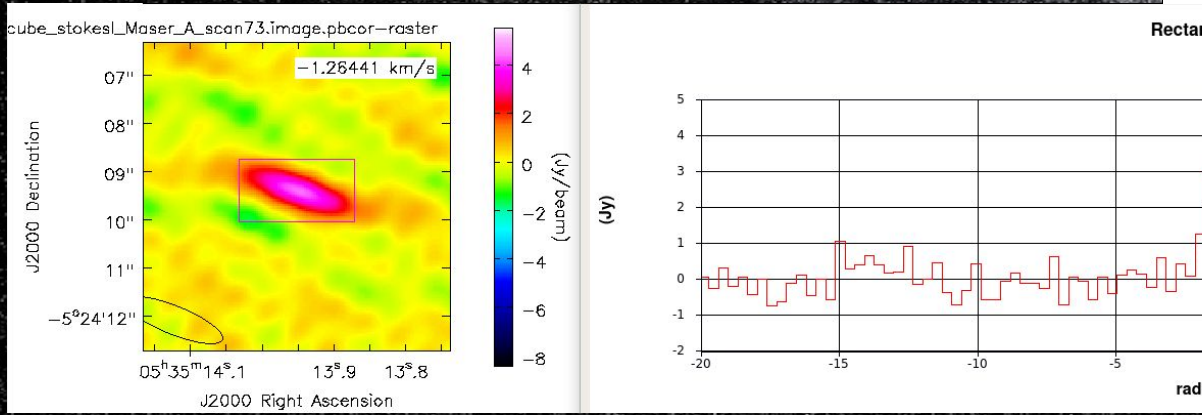
Discrepancy

Epoch 3, Scan 73

- Scan 73
  - More noise
  - Less signal
  - Lower signal-to-noise ratio

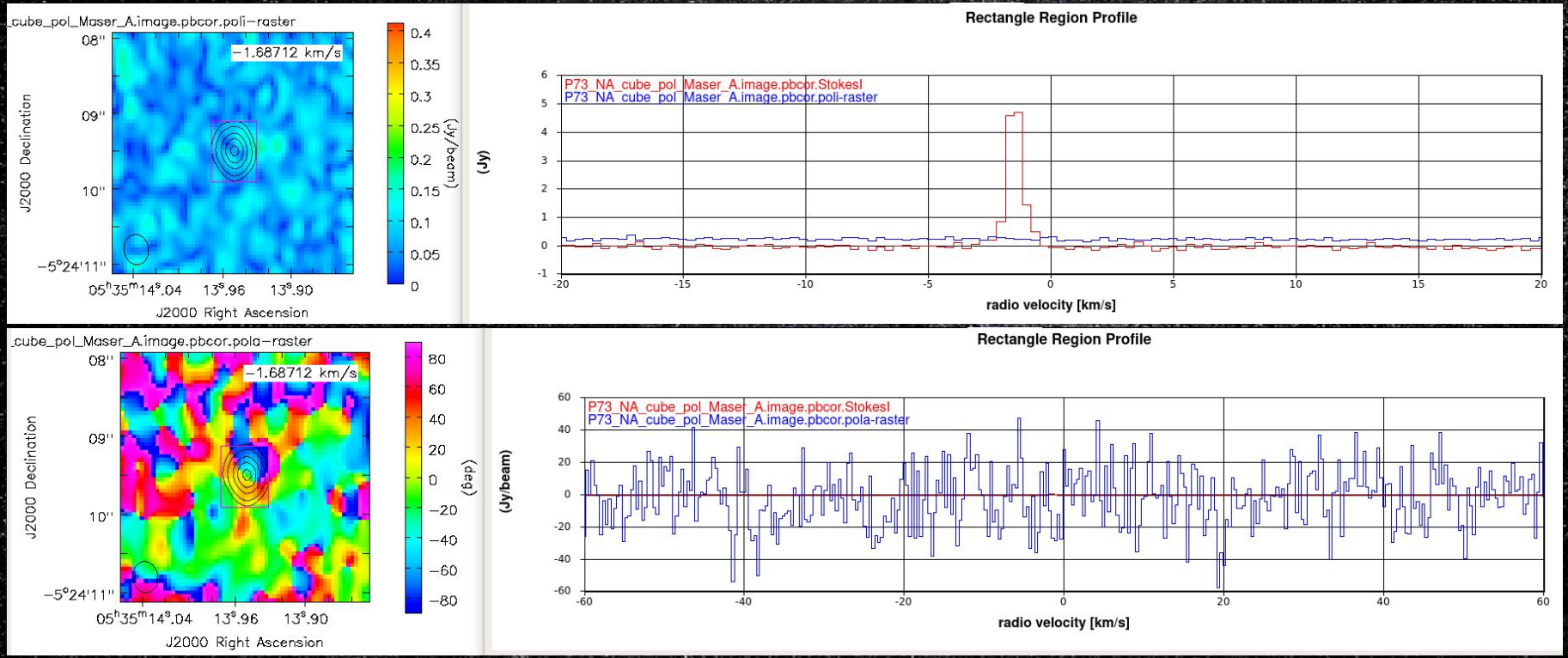




Objective 3

Epoch 2

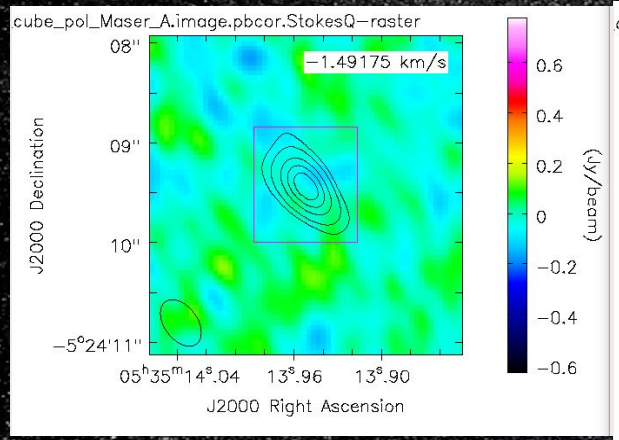
- Lack of Polarization, Mix of Photonic Angles

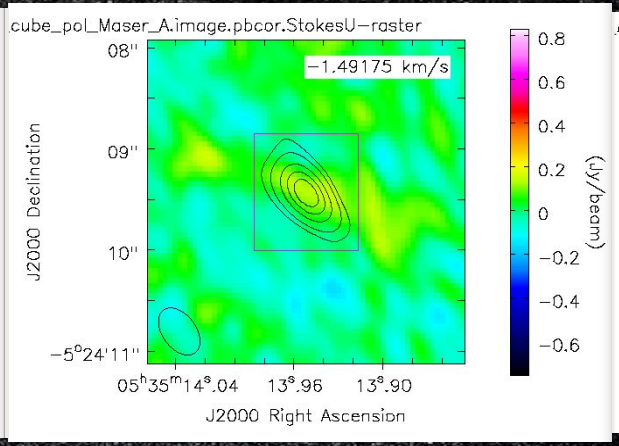


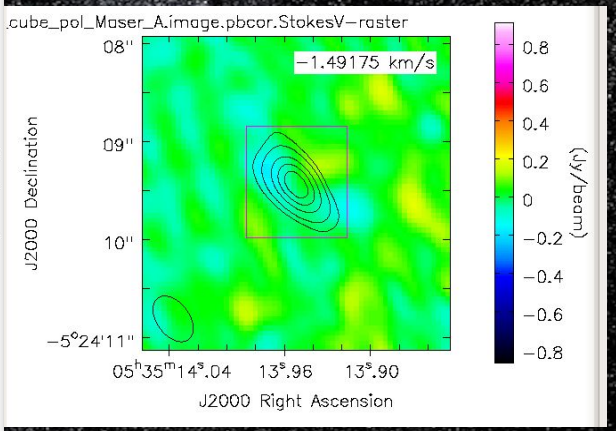
Objective 3

Epoch 9

- No dominant linear nor circular polarization found for any of the 20 epochs







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Summary

- Constructed light-curve to investigate short-term maser variability
- General consistency for pointing averages and scans for most epochs
- Some evidence of fast variability, no evidence of polarization

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Acknowledgements

- Thank you to:
  - My advisor Dr. Araya for mentoring me
  - WIU Undergrad Mr. Sojka and WIU Grad Mr. VanZuiden for collaboration on the project
  - Dr. Dong, Dr. Trimm, and the rest of the SIR department

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References

- Araya, E. D., Hofner, P., Goss, W. M., Kurtz, S., Richards, S., Linz, H., L. Olmi, & M. Sewiło. (2010). Quasi-periodic Formaldehyde Maser Flares in the Massive Protostellar Object IRAS 18566+0408. The Astrophysical Journal Letters, 717(2), L133–L137. https://doi.org/10.1088/2041-8205/717/2/l133
- Motte, F., Bontemps, S., & Louvet, F. (2018). High-Mass Star and Massive Cluster Formation in the Milky Way. Annual Review of Astronomy and Astrophysics, 56(1), 41–82. https://doi.org/10.1146/annurev-astro-091916-055235
- Sanchez-Tovar, E., Araya, E. D., Rosero, V., Hofner, P., & Kurtz, S. (2023). Broadband VLA Spectral-line Survey of a Sample of Ionized Jet Candidates. The Astrophysical Journal Supplement Series, 267(2), 43. https://doi.org/10.3847/1538-4365/acdb5e
- Sojka, G., VanZuiden, K., Araya, E., Busquet, G., Girart, J. M., Hofner, P., Fernández-López, M., Teixeira, P., Sánchez-Monge, A., Carrasco-González, C., Tobin, J., Rodríguez, T., & VOLS. (2024). Changes in the Spectral Zoo: Preliminary Results of Molecular Maser Variability in VOLS. Bulletin of the AAS, 56(7). https://baas.aas.org/pub/2024n7i302p06/release/1
- Voronkov, M. A., Sobolev, A. M., Ellingsen, S. P., & Ostrovskii, A. B. (2005). The 6.7- and 25-GHz methanol masers in OMC-1. Monthly Notices of the Royal Astronomical Society, 362(3), 995–1005. https://doi.org/10.1111/j.1365-2966.2005.09374.x