Billowing Hydrogen
Simulating Turbulence in HII Regions

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HII Regions

- ▶ What is an HII Region?
- ▶ Physical Traits
  - ▶ Powered by hot stars
  - ▶ Can range from AU to parsecs
  - ▶ A type of nebulae

Image of an HII region, the Trifid Nebula.
Nebula image: M20 — Trifid Nebula HII Region in Sagittarius 6° from Kaus Borealis (top of the teapot) taken by R Jay GaBany
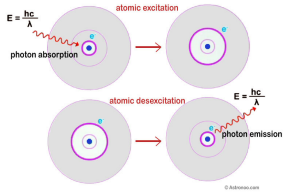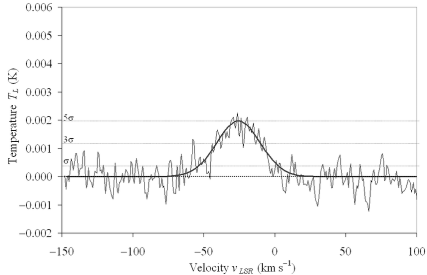
Emissions

Image 2: Process in which radio recombination lines are created.

Radio recombination lines: https://astronoo.com/images/lumiere/absorption-et-emission.jpg

▶ A way we observe HII regions

▶ Why use radio?

▶ Radio recombination lines (RRLs)

Emissions

Typical radio recombination line spectrum. 1051 erg less: the Galactic H II region OA 184 - Scientific Figure on ResearchGate. Available from:
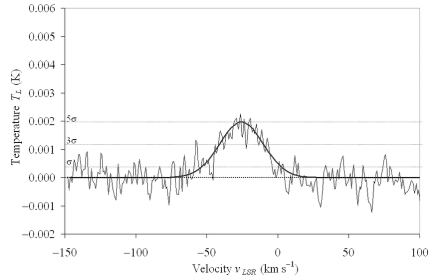
https://www.researchgate.net/figure/Radio-recombination-line-emission-from-OA-184-This-is-a-composite-spectrum-of-seven_fig1_44090151

[accessed 17 Nov 2025]

▶ A way we observe HII regions

▶ Why use radio?

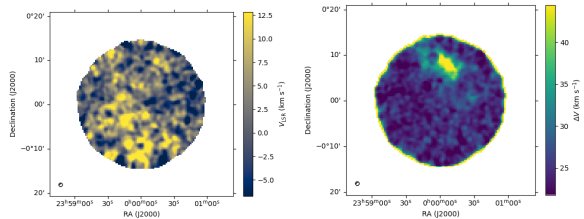▶ Radio recombination lines (RRLs)

Radio Imaging

- ▶ Multiple frequencies
- ▶ Doppler shift
- ▶ Velocity compared to Local Standard of Rest (VLSR)
- ▶ Velocity line width

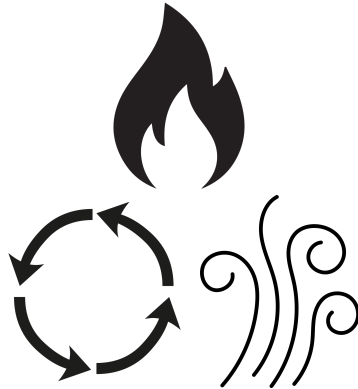Radio recombination line to discuss how velocity is mapped.

Radio Imaging

- ▶ Multiple frequencies
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- ▶ Velocity line width

First and second moment maps of an HII region.

Emission Line-Broadening

- Thermal motion
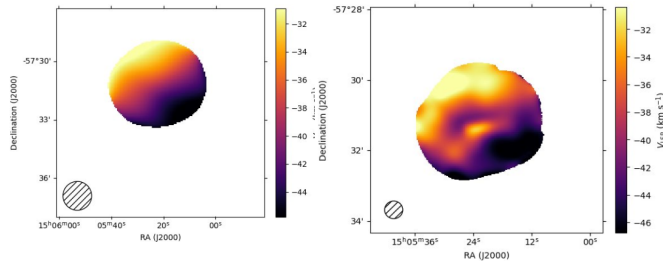- Bulk motion
  - Outflow
  - Expansion
  - Rotation
- Turbulence

Fire Image Source Here

Cycle: https://www.vecteezy.com/png/18723264-roundabout-directional-arrow-sign-on-transparent-background

Wind: https://www.vecteezy.com/png/22183351-hand-drawn-doodle-vaporize-icon

Motivations

▶ Previous work had shown what looked like rotation

▶ Later observations show a more complex story

▶ Can turbulence explain this behavior?

Showing the how the same object can act differently based on the beam width.
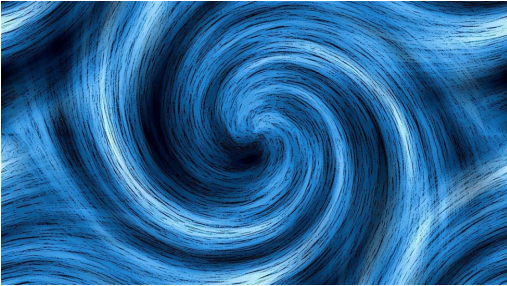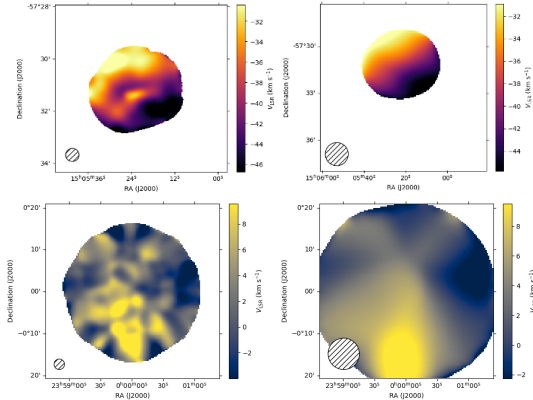
Turbulence

- ▶ Hard to model
- ▶ Not well understood
- ▶ But can be predicted to a degree!

Project Goals

► Simulate turbulence in HII regions
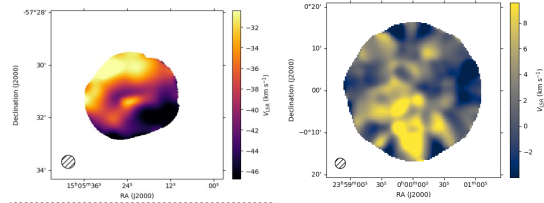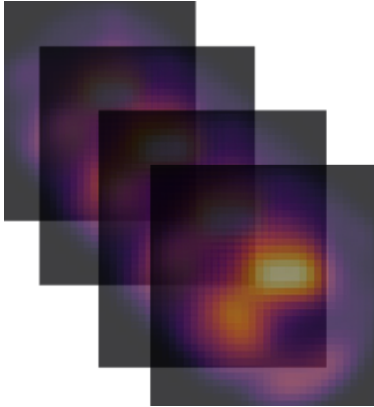► Test different turbulence parameters
► Compare to reality

Comparing the effects of a higher resolution on the first moment map.

- Similarity to reality
  - Turbulence looking like angular momentum
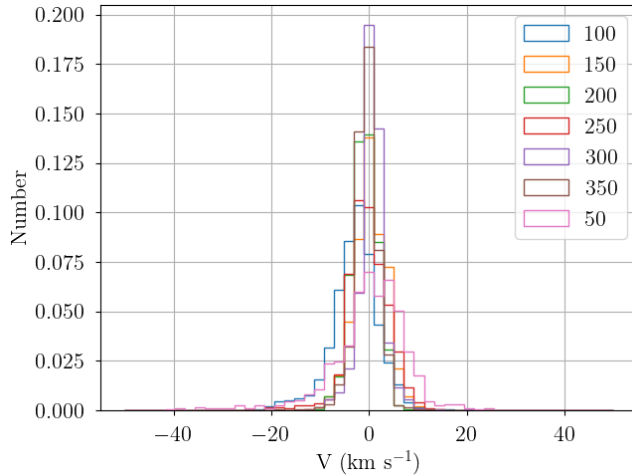 - Similar velocity scales

Future Work

- ▶ Comparing with more radio data
- ▶ Develop new analyses

Pipeline

- ▶ Generate and truncate turbustat data
  - ▶ Creates cubes to represent density and velocity in 3d space
- ▶ Calculate emission measure for each physical "voxel" of HII region
- ▶ Calculate RRL strength for each pixel
  - ▶ Gaussian treating velocity cube as line centers
  - ▶ Add free-free emission afterwards

Resolution Dependance

Demonstrating that the resolution dependance is negligible past 300 pixels.