

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

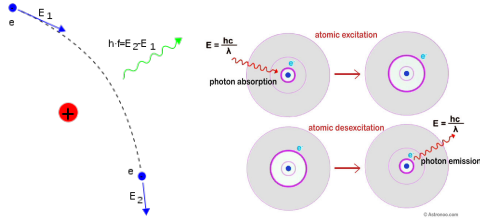


Image 1: Process in which the free-free continuum is created.

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

Free-free emission: <https://en.wikipedia.org/wiki/Bremsstrahlung#/media/File:Bremsstrahlung.svg>

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

- ▶ A way we observe HII regions
- ▶ Why use radio?
- ▶ Free-free continuum
- ▶ Radio recombination lines (RRLs)



Radio Imaging

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

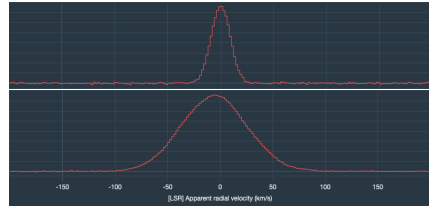
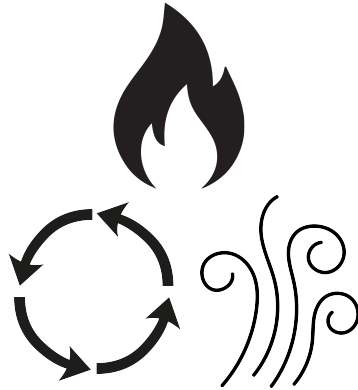


Image 3: Spectrum without any motion compared to a spectrum with motion.



Emission Line-Broadening

- ▶ Thermal motion
- ▶ Rotation
- ▶ Turbulence



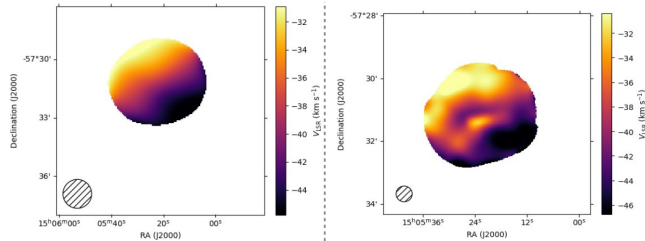
Fire: <https://www.vecteezy.com/png/19787026-fire-icon-on-transparent-background>
Cycle: <https://www.vecteezy.com/png/18723264-roundabout-directional-arrow-sign-on-transparent-background>

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?

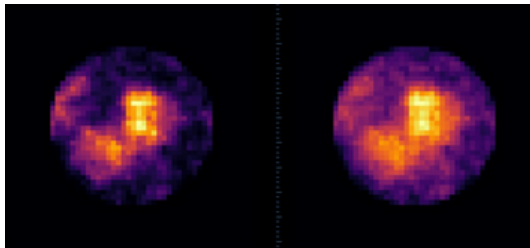


Showing the how the same object can act differently based on the beam width.



Motivations

- ▶ Similar programs don't use RRLs



Comparing optically thin tracers, one of density (right) and one of density squared (left).



Turbulence

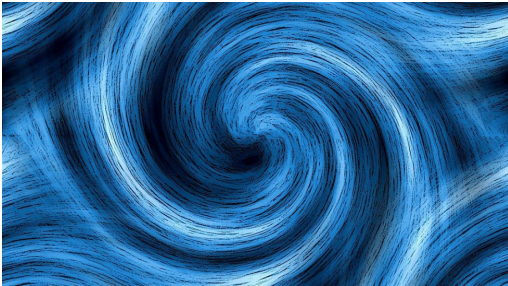


Image attribution: https://www.advancedsciencenews.com/wp-content/uploads/2023/07/swirl-g52ac5d4ac_1280.jpg

- ▶ Not just swirls
- ▶ Subsonic and supersonic
- ▶ Ways of flowing

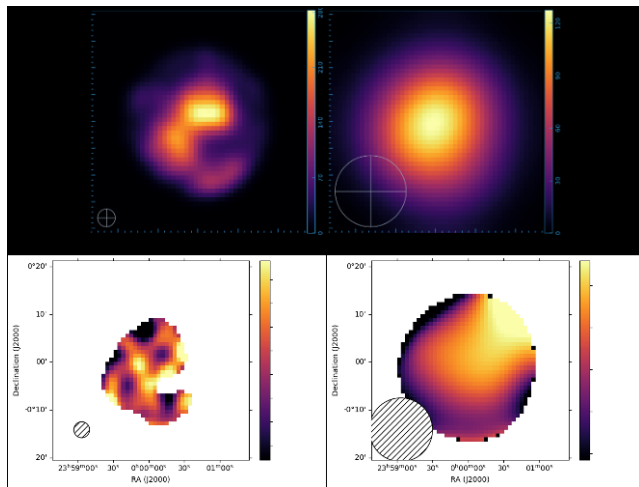


Project Goals

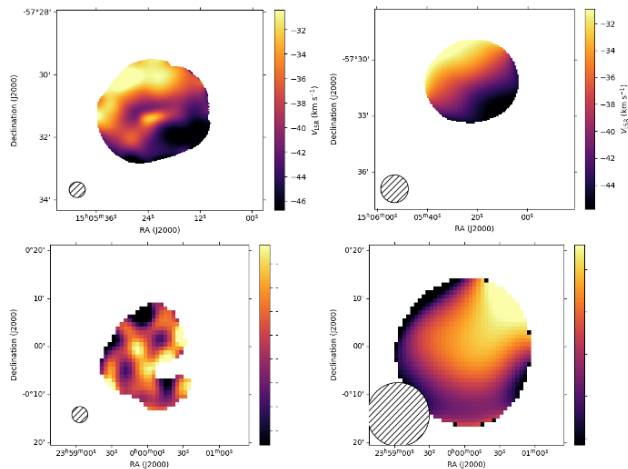
- ▶ Simulate turbulence in HII regions
- ▶ Test different turbulence parameters
- ▶ Comparing to reality



Results

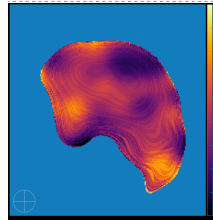
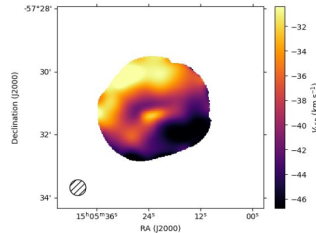


Results

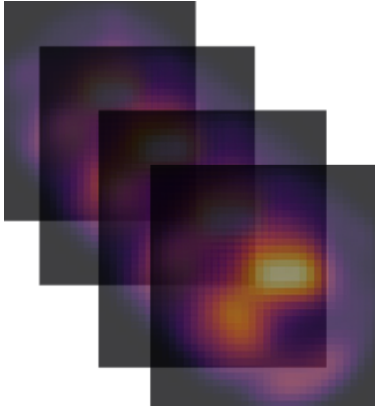


Results

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



Future Work



- ▶ Comparing with more radio data
- ▶ Refining simulation
- ▶ Testing under various conditions



Conclusion

- ▶ Could turbulence explain HII region behavior?
- ▶ Tested with simulation
- ▶ At first glance, it is a viable model

