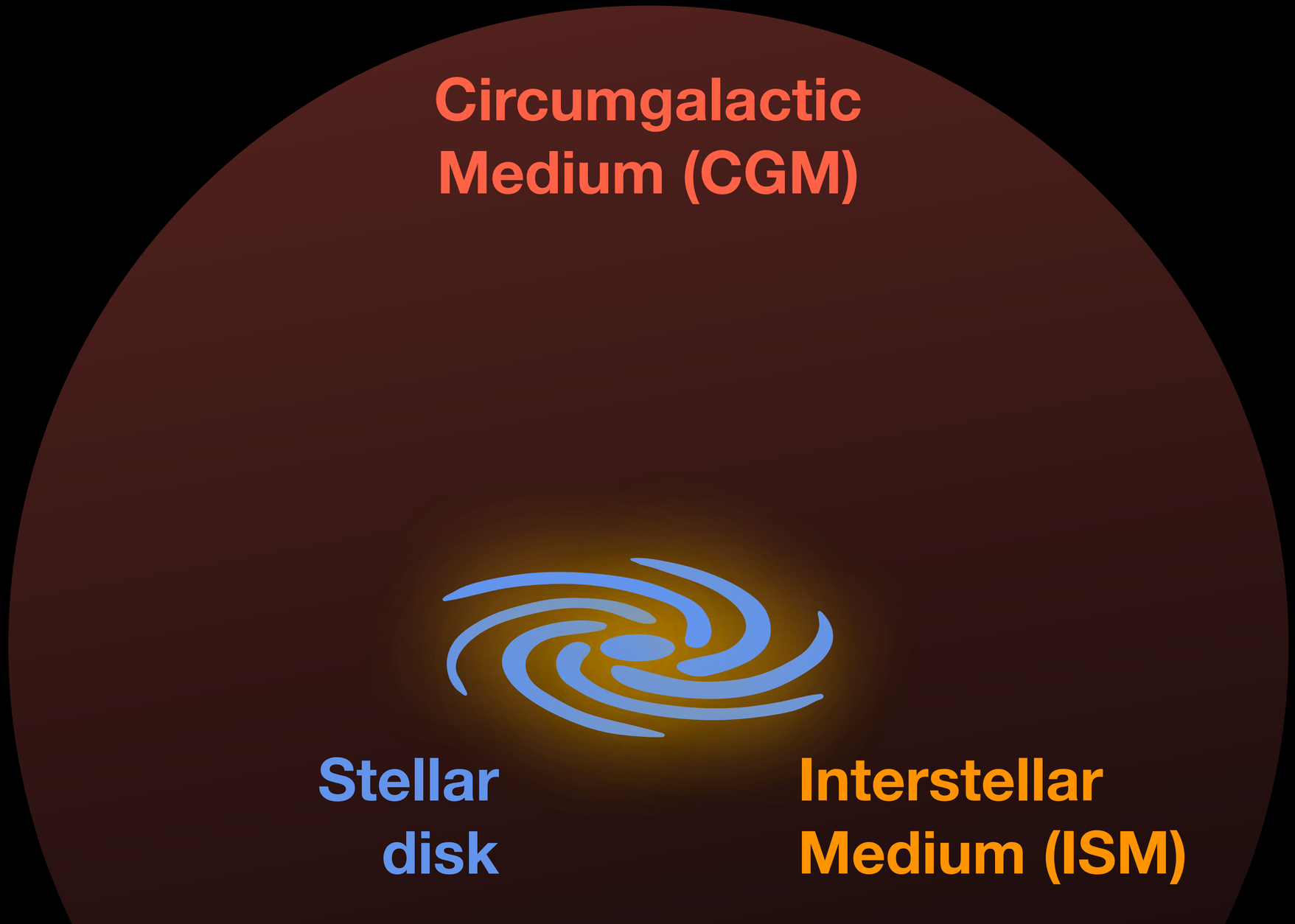
ALMA reveals extended cool gas and hot ionized outflows around a distant star-forming galaxy

Hollis Akins (*Grinnell College → UT Austin*)
S. Fujimoto, K. Finlator, D. Watson (*DAWN*)
K. Knudsen (*Chalmers U.*)
J. Richard (*U. Lyon*)

Akins et al. (2022), ApJ in press
iPoster 241.23: today, 5:30-6:30 pm PDT, hall A/B
hollis.akins@gmail.com **|** **(336) 681-8118**

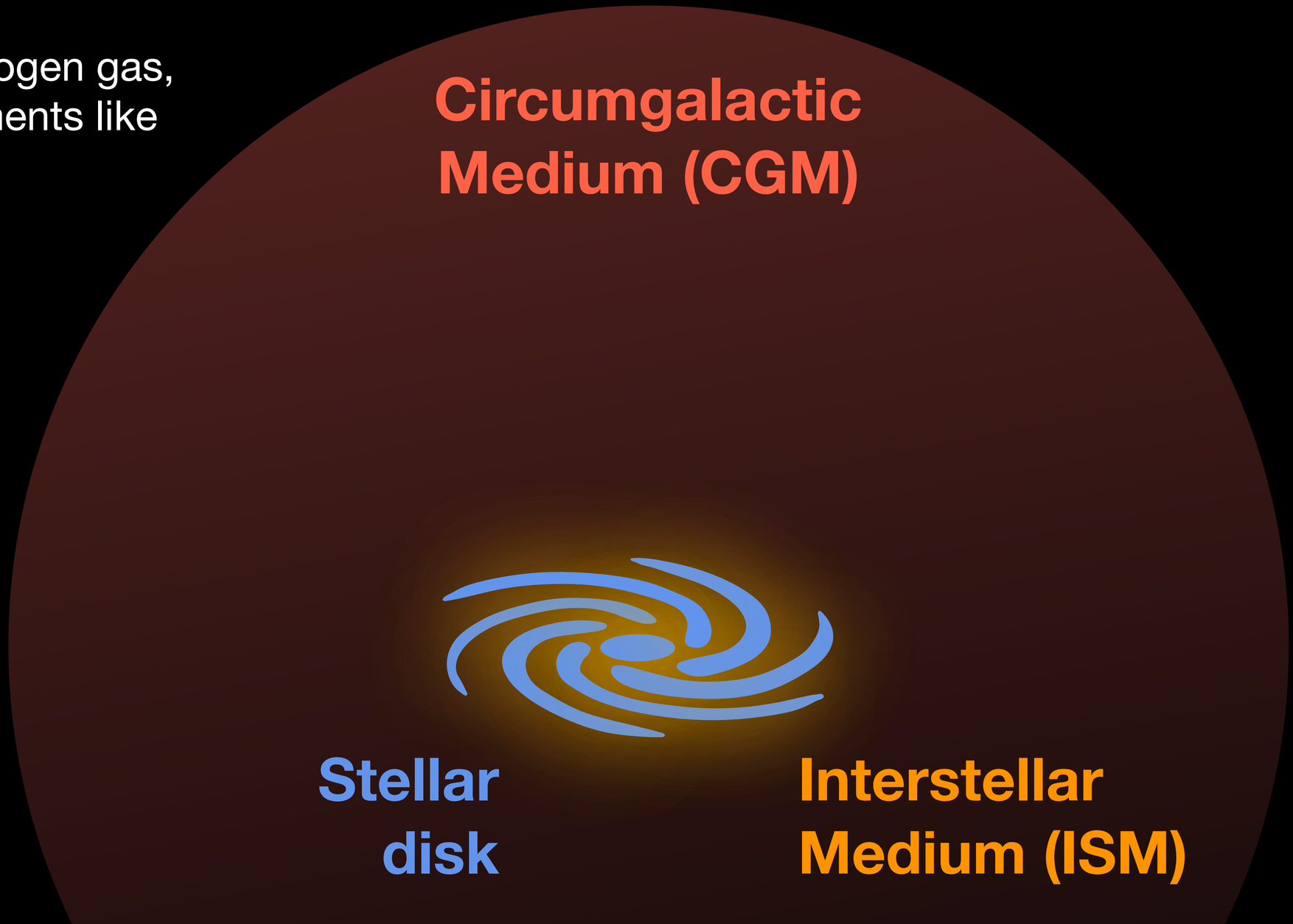
Background: *Hubble view of Abell 1689 (ESA/Hubble)*
Inset: *Artist's illustration of A1689-zD1 (B. Saxon/NRAO/AUI/NSF)*

The dynamic, multiphase interstellar medium



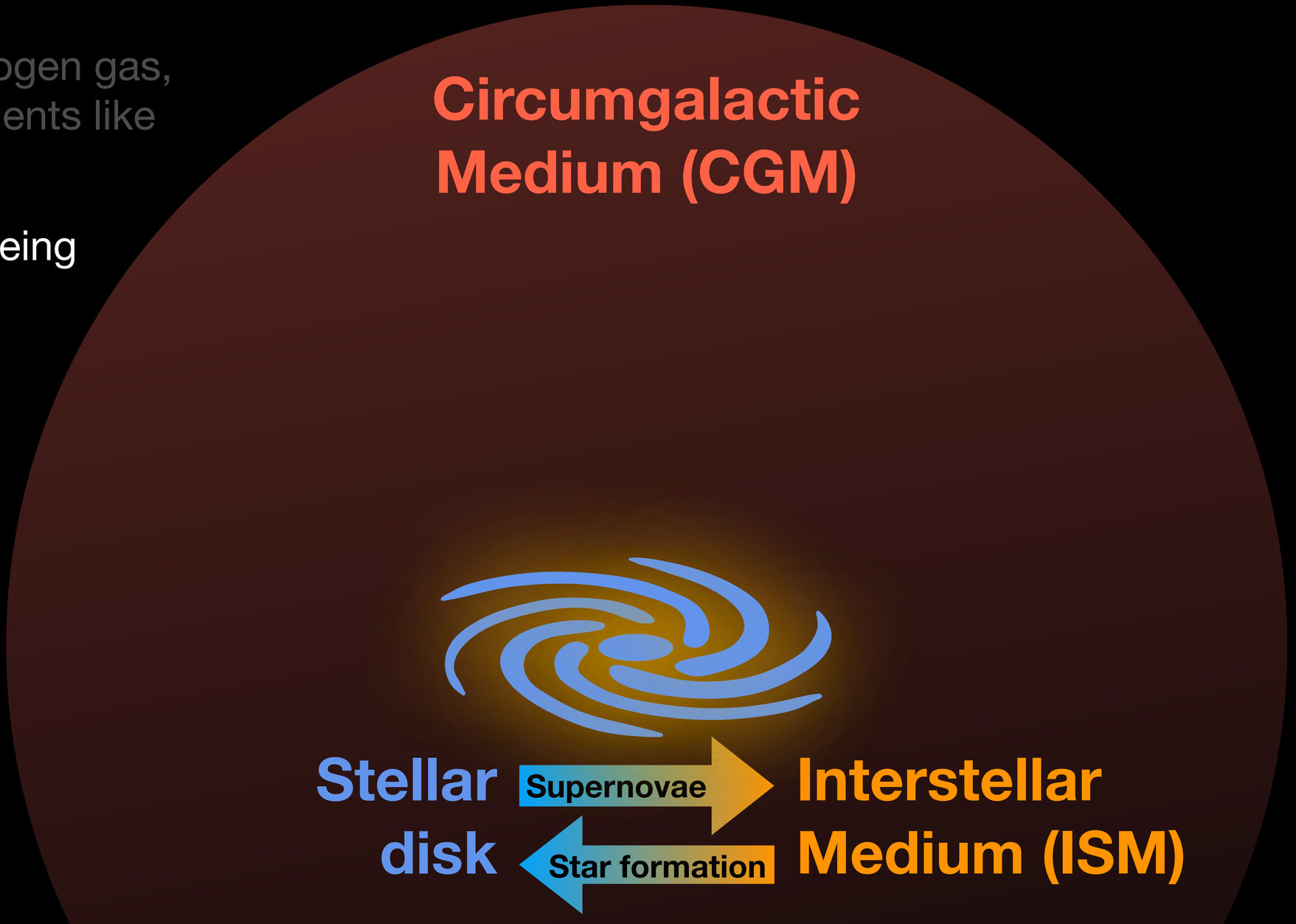
The dynamic, multiphase interstellar medium

- The ISM is mostly hydrogen gas, with some heavier elements like carbon or oxygen



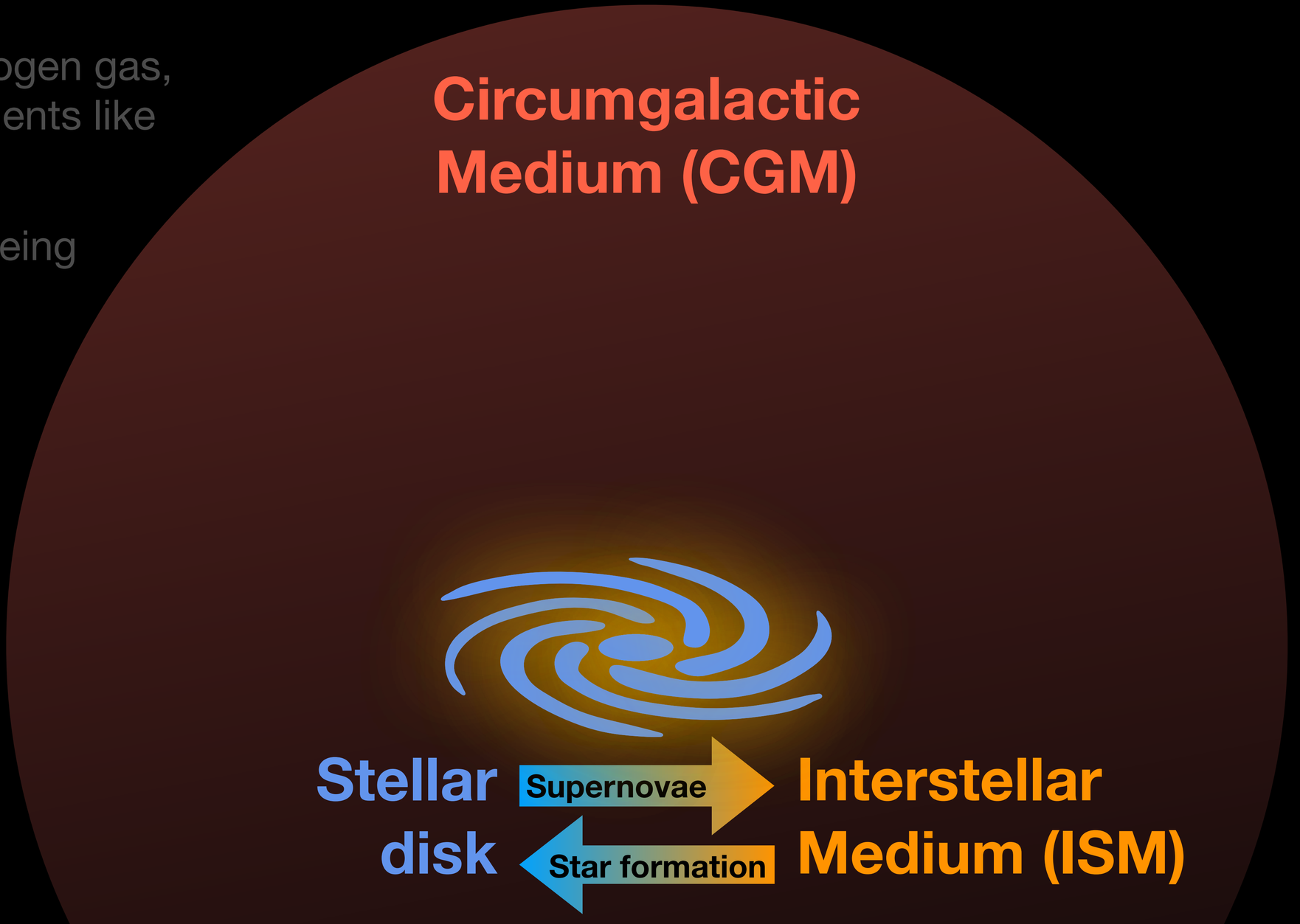
The dynamic, multiphase interstellar medium

- The ISM is mostly hydrogen gas, with some heavier elements like carbon or oxygen
- ISM gas is constantly being formed into stars/ replenished by supernovae



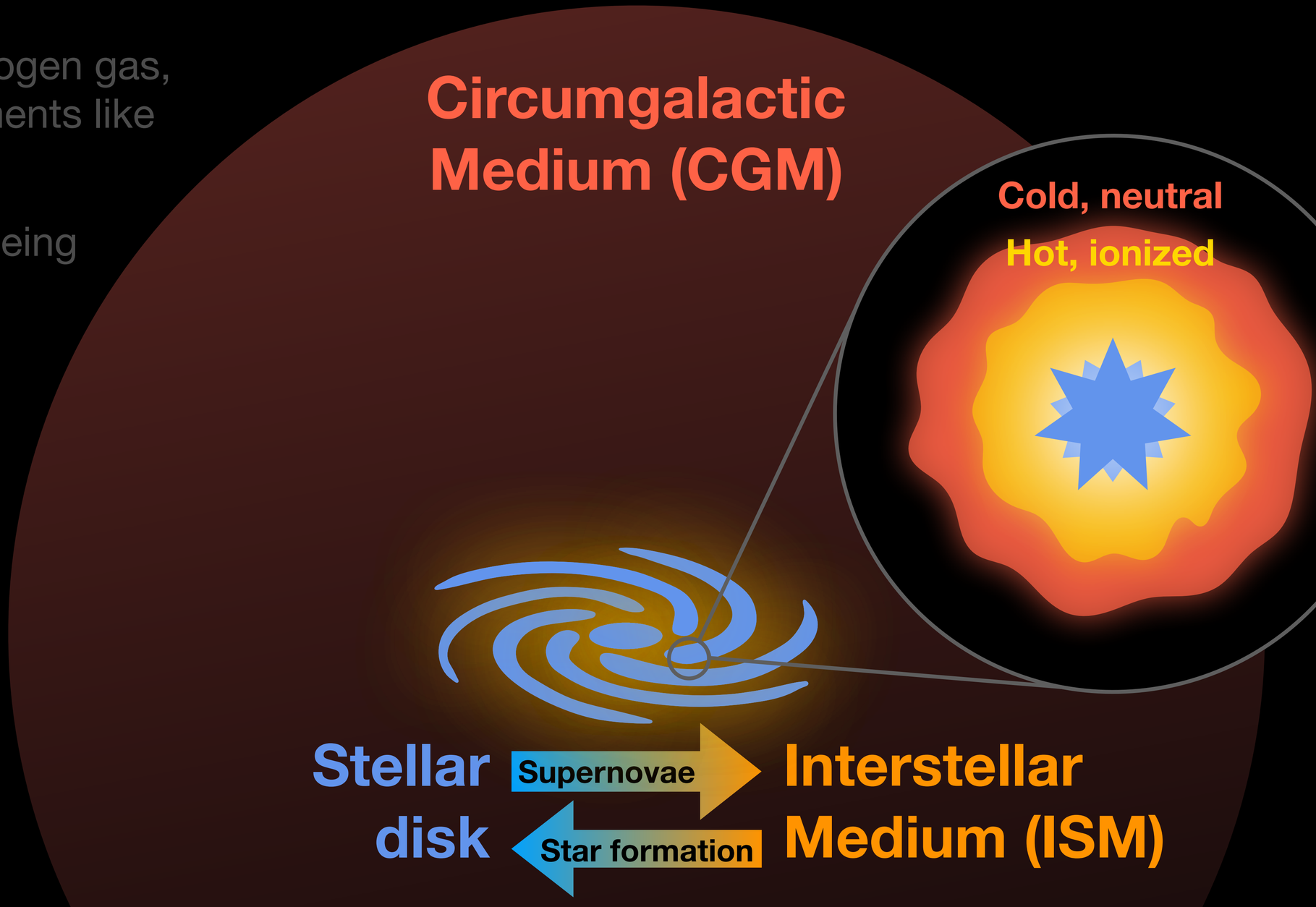
The dynamic, multiphase interstellar medium

- The ISM is mostly hydrogen gas, with some heavier elements like carbon or oxygen
- ISM gas is constantly being formed into stars/ replenished by supernovae
- The ISM can exist in many phases



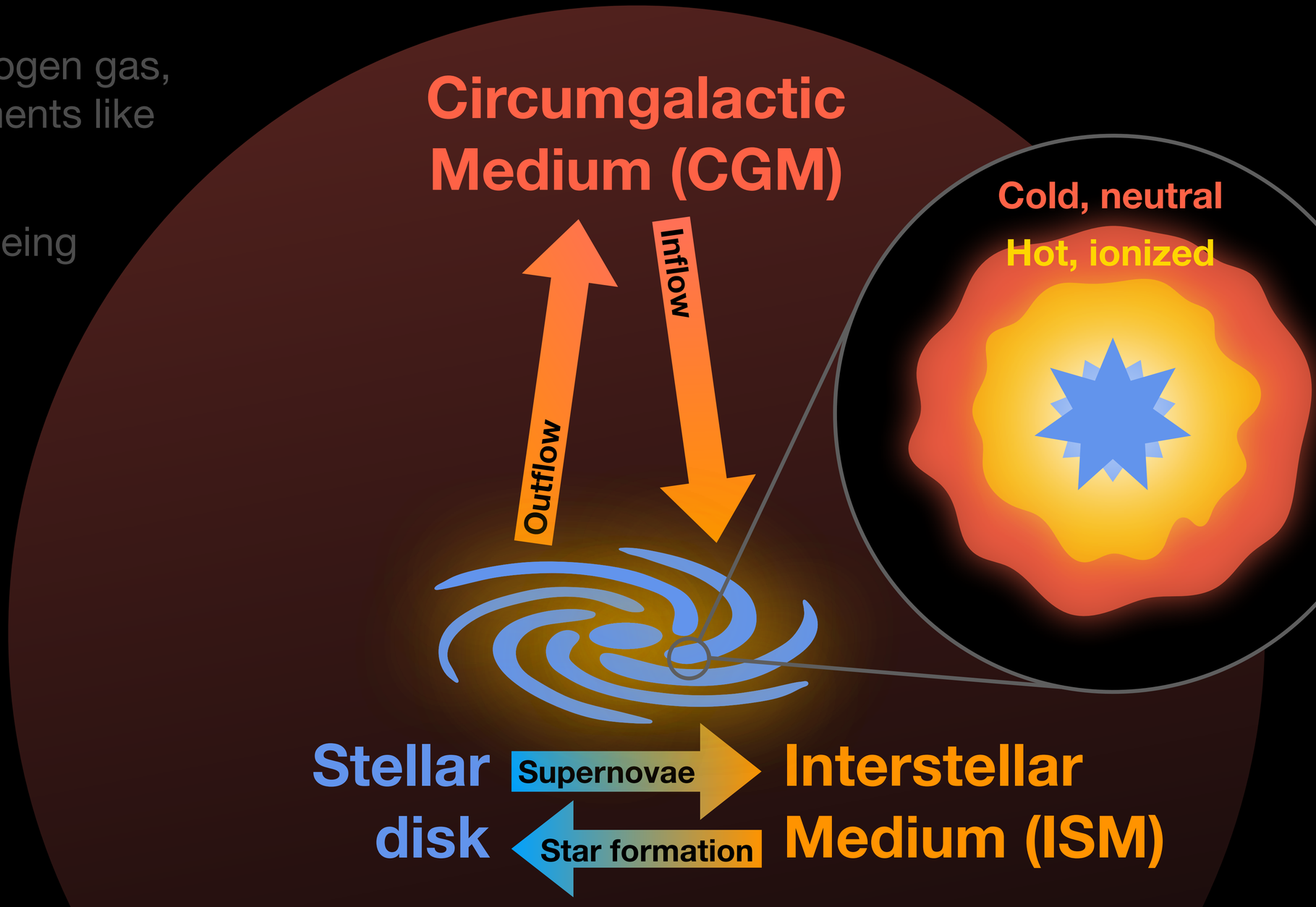
The dynamic, multiphase interstellar medium

- The ISM is mostly hydrogen gas, with some heavier elements like carbon or oxygen
- ISM gas is constantly being formed into stars/ replenished by supernovae
- The ISM can exist in many phases

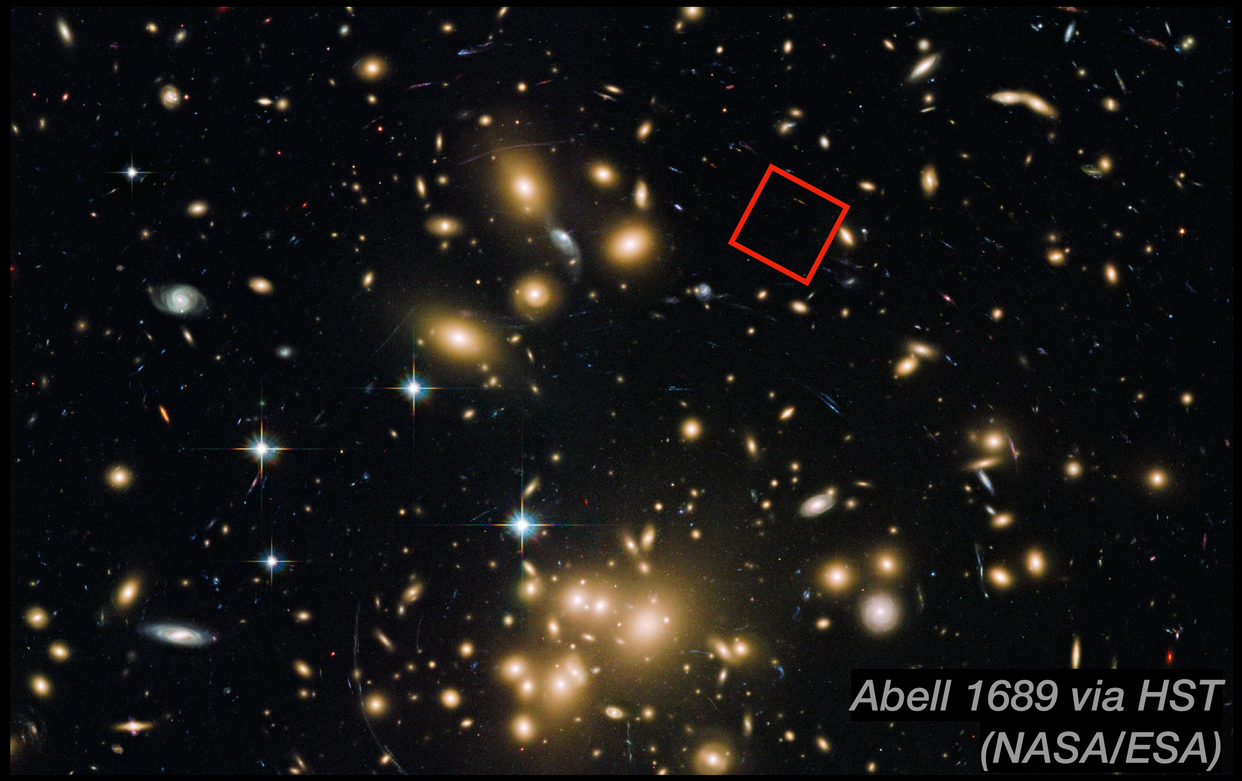


The dynamic, multiphase interstellar medium

- The ISM is mostly hydrogen gas, with some heavier elements like carbon or oxygen
- ISM gas is constantly being formed into stars/ replenished by supernovae
- The ISM can exist in many phases
- Gas can also be exchanged between the ISM and CGM



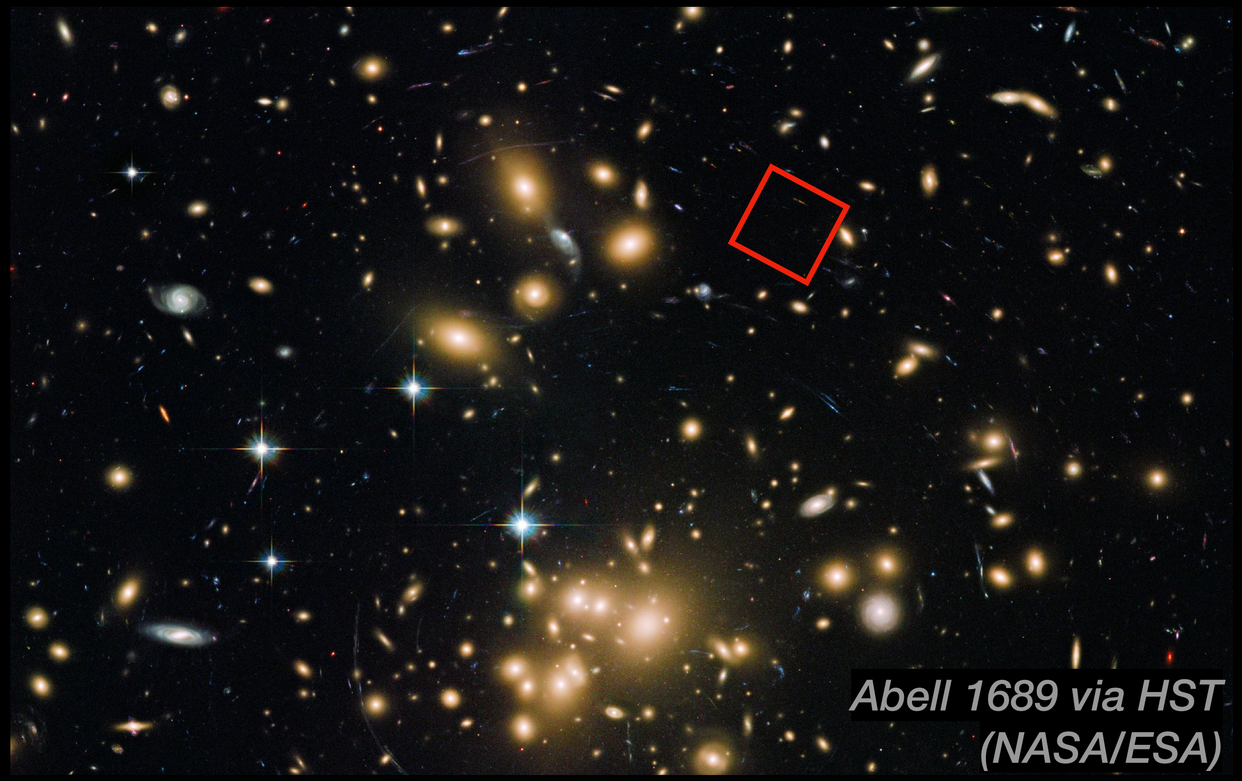
Observing A1689-zD1



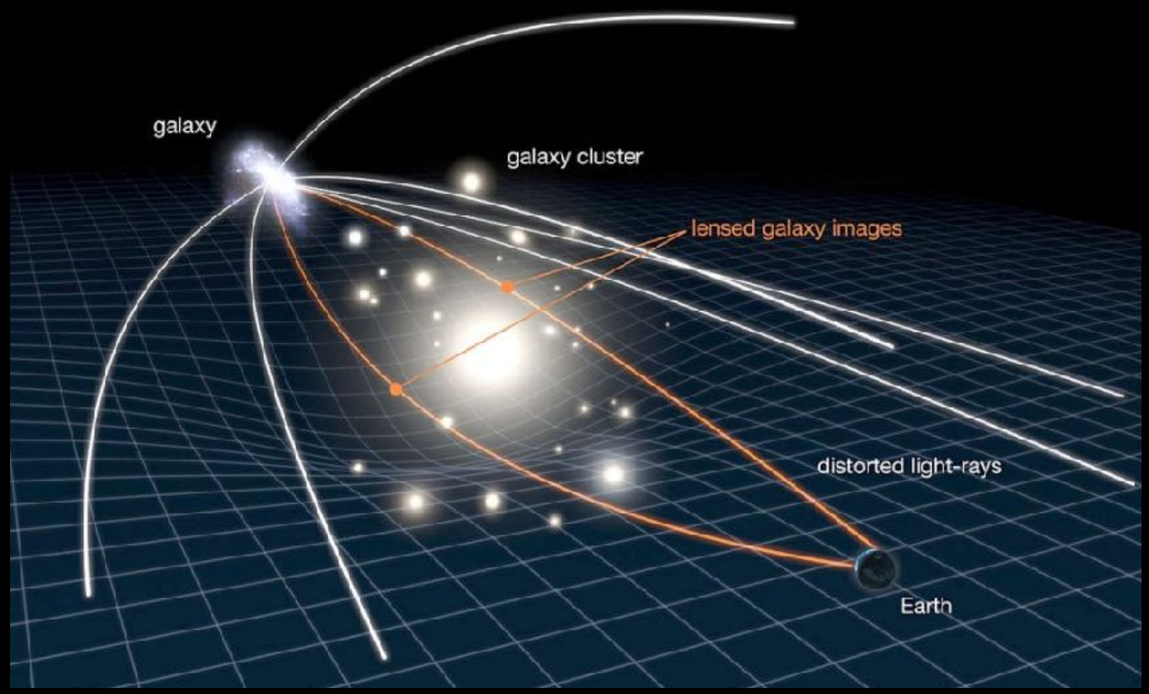
Abell 1689 via HST (NASA/ESA)

- A1689-zD1 is roughly 13 billion light years away

Observing A1689-zD1

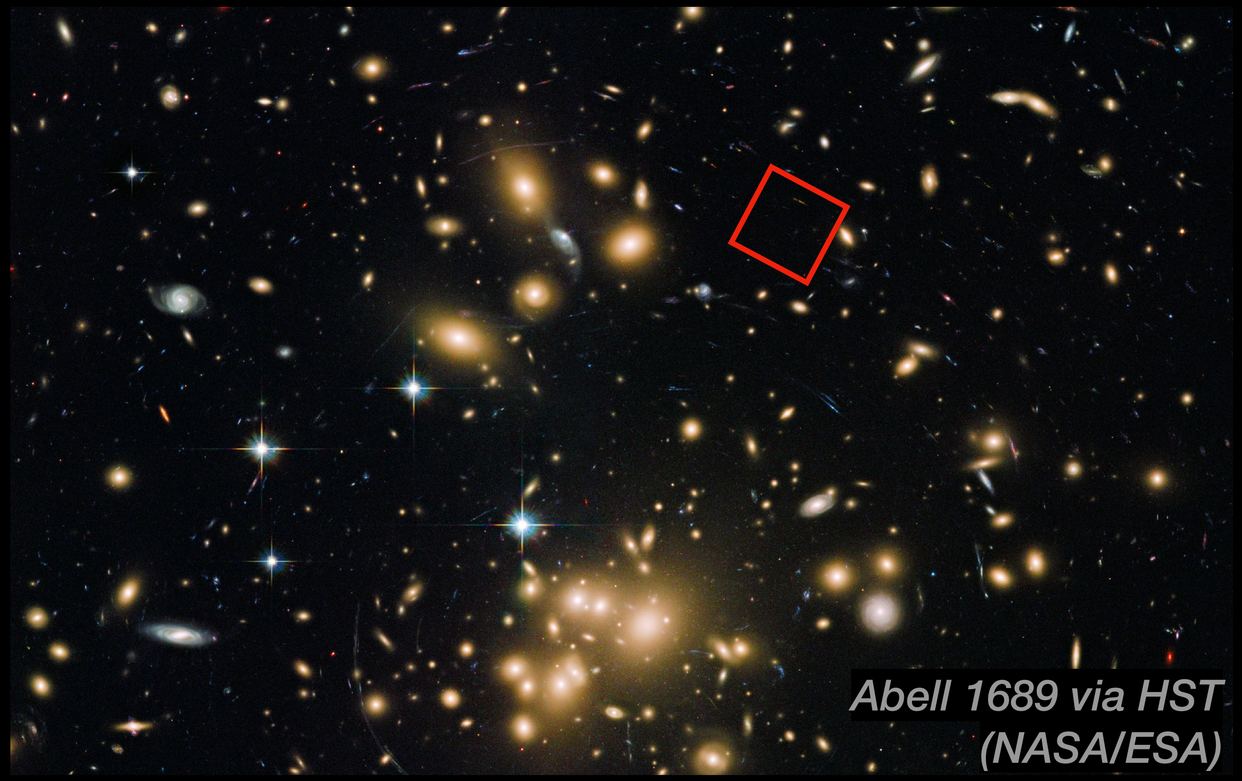


Abell 1689 via HST (NASA/ESA)

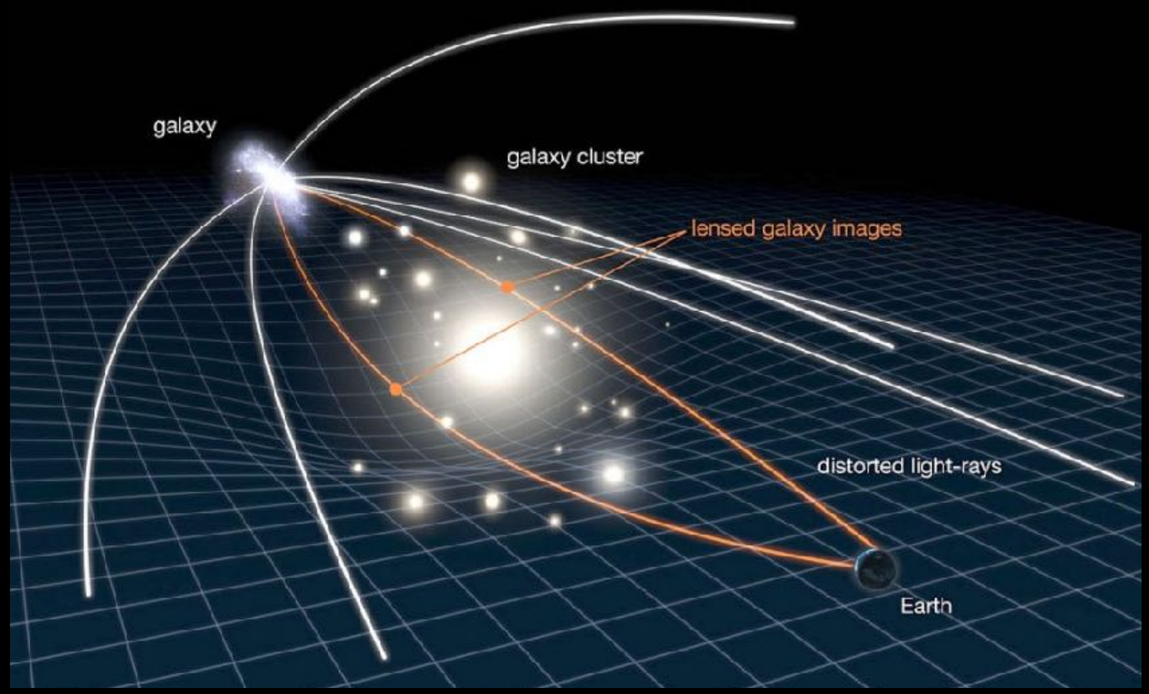


- A1689-zD1 is roughly 13 billion light years away
- The cluster Abell 1689 magnifies the galaxy by 10x

Observing A1689-zD1

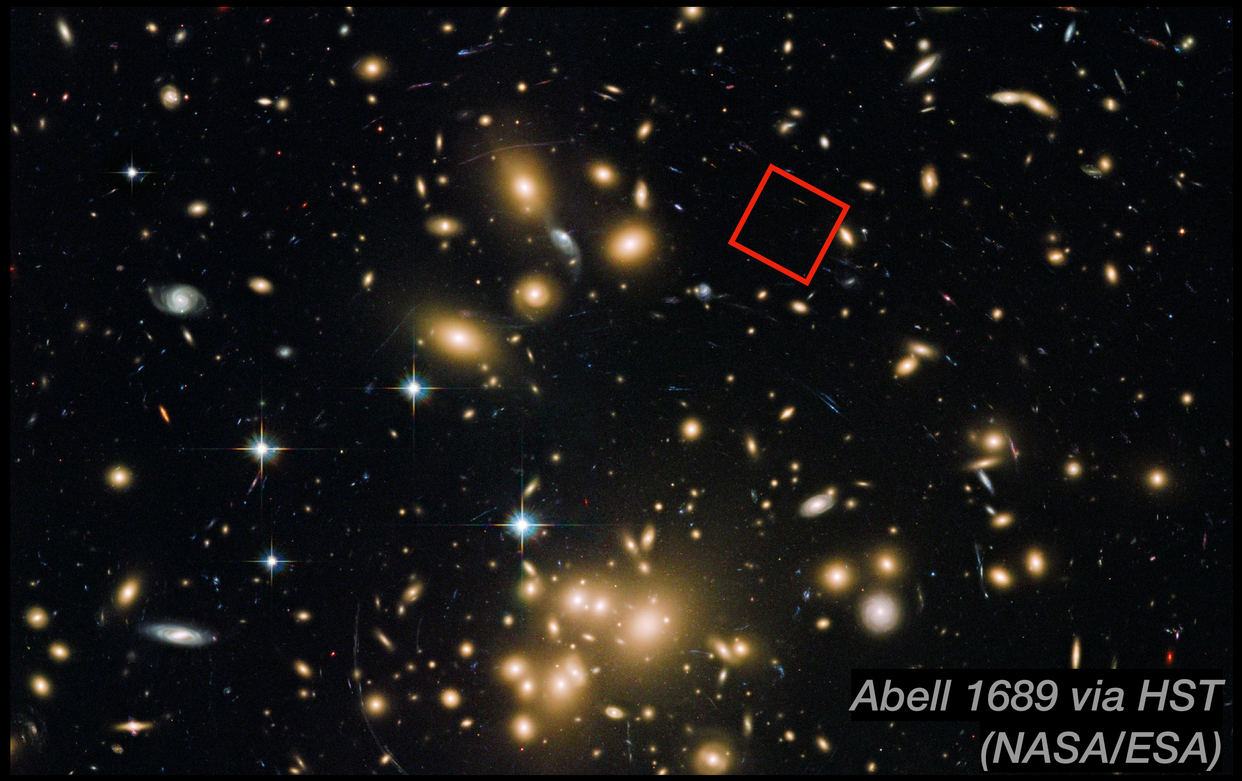


Abell 1689 via HST (NASA/ESA)

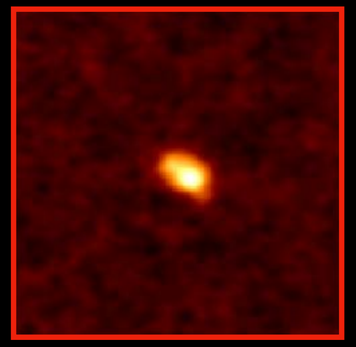


- A1689-zD1 is roughly 13 billion light years away
- The cluster Abell 1689 magnifies the galaxy by 10x
- Relatively “normal” galaxy

Observing A1689-zD1

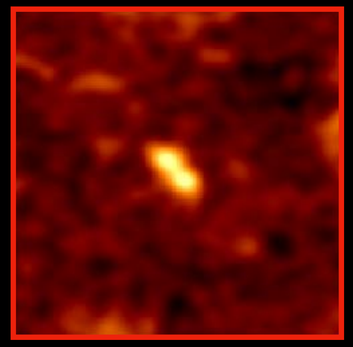


- A1689-zD1 is roughly 13 billion light years away
- The cluster Abell 1689 magnifies the galaxy by 10x
- Relatively “normal” galaxy
- We use new ALMA observations of [OIII] and [CII] to observe the ISM and archival HST data to observe the ultraviolet emission from the stars



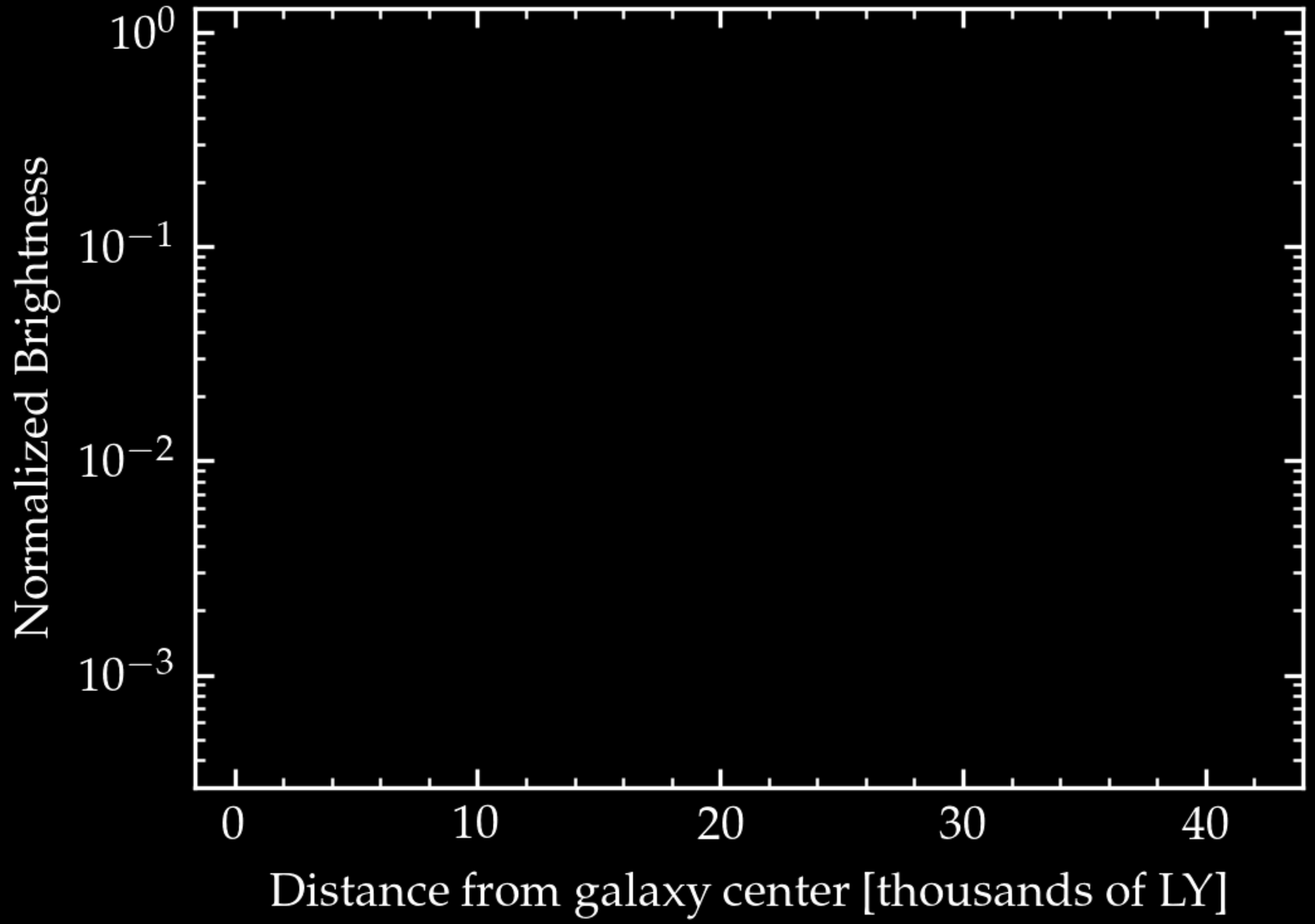
[OIII] emission (hot, ionized gas) via ALMA

[CII] emission (cold, neutral gas) via ALMA

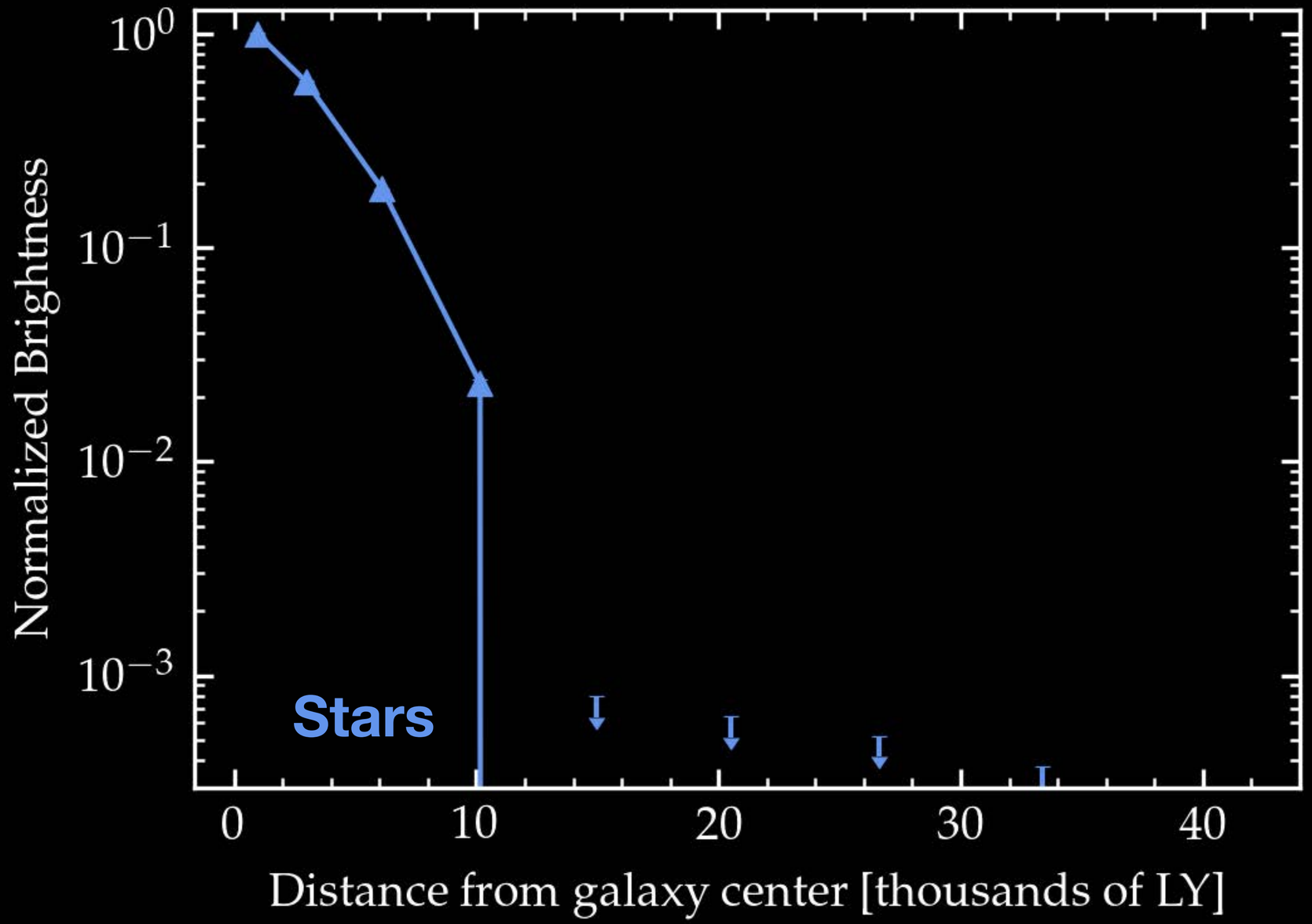


Ultraviolet emission (stars) via HST

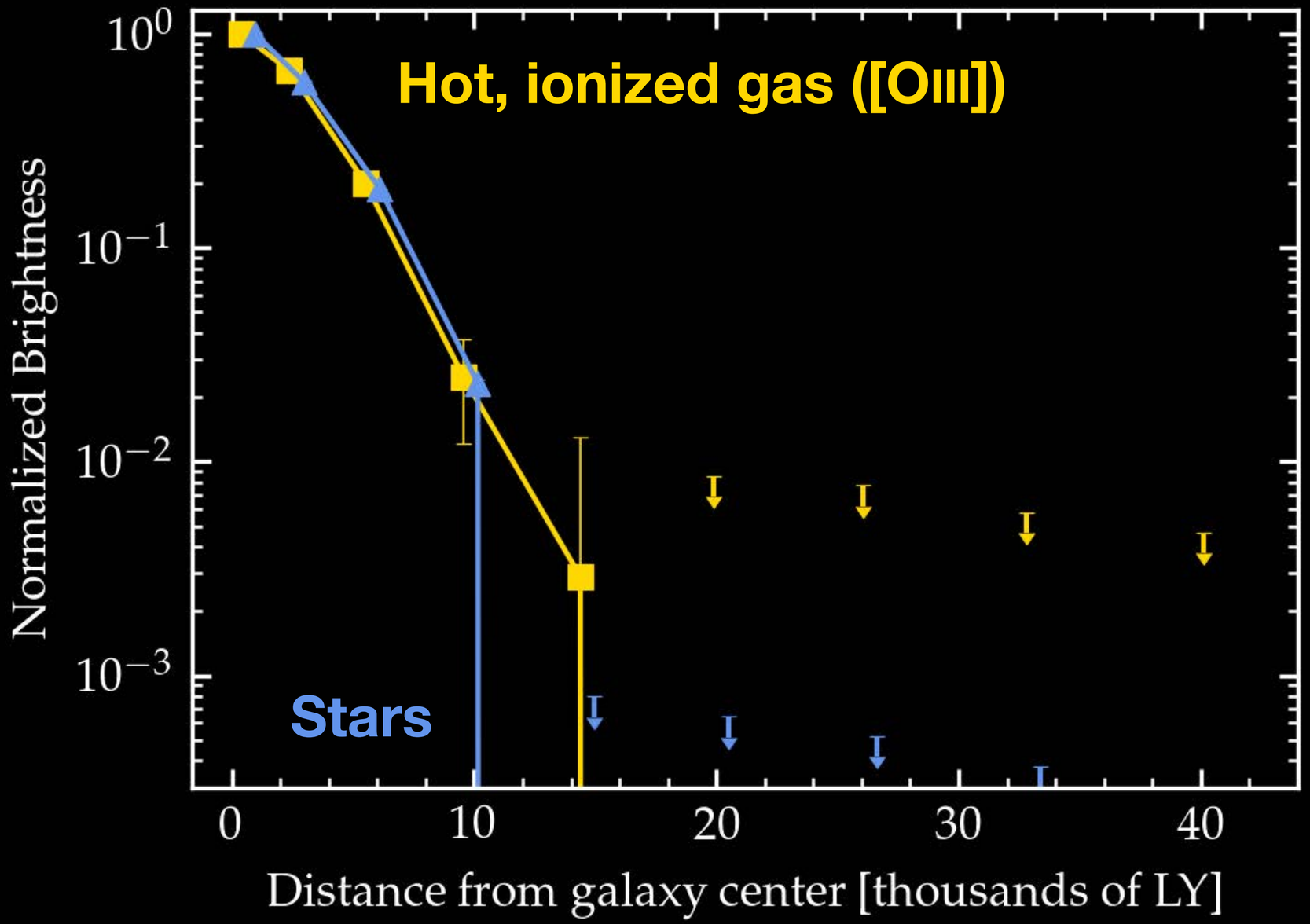
How is the gas distributed?



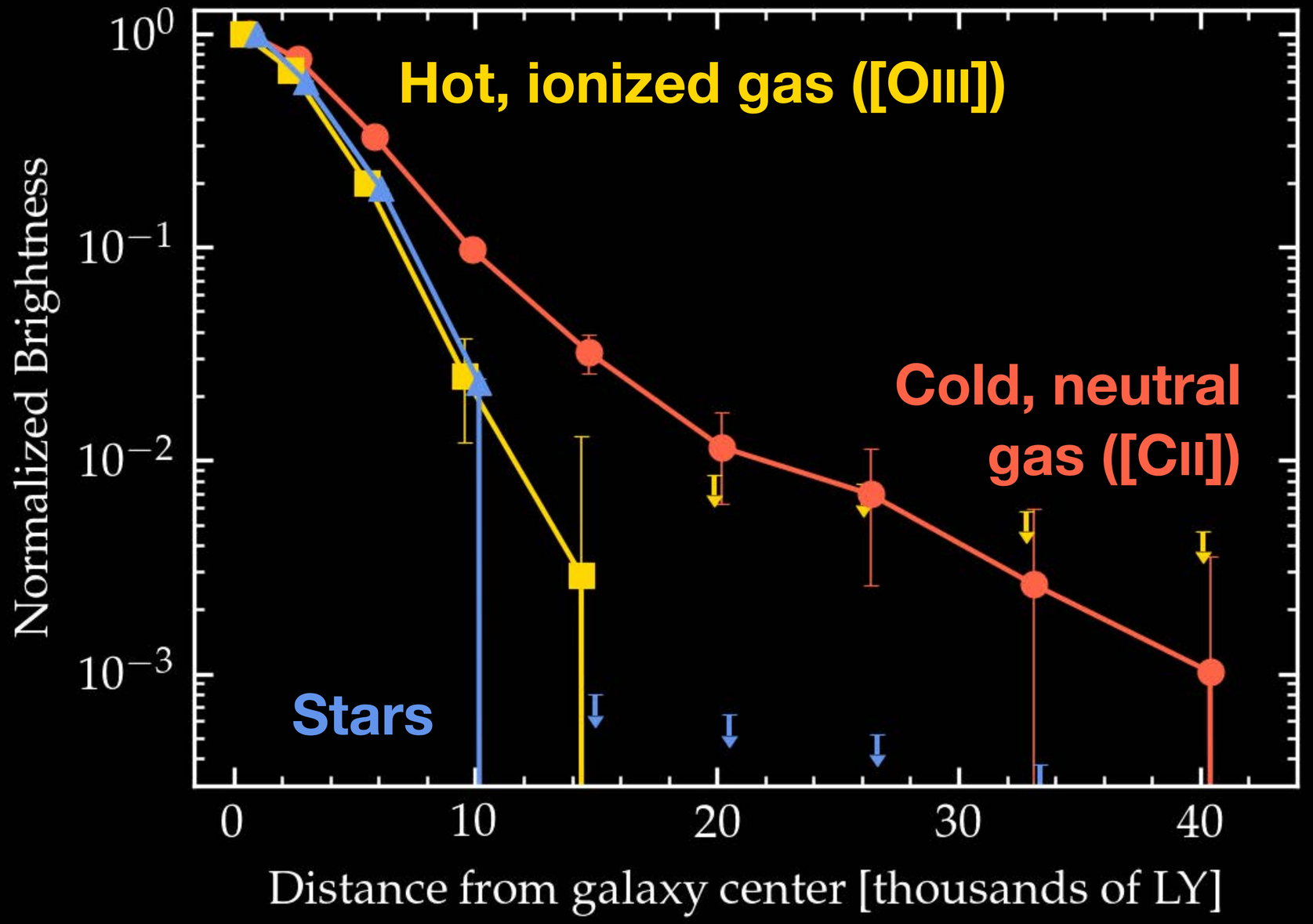
How is the gas distributed?



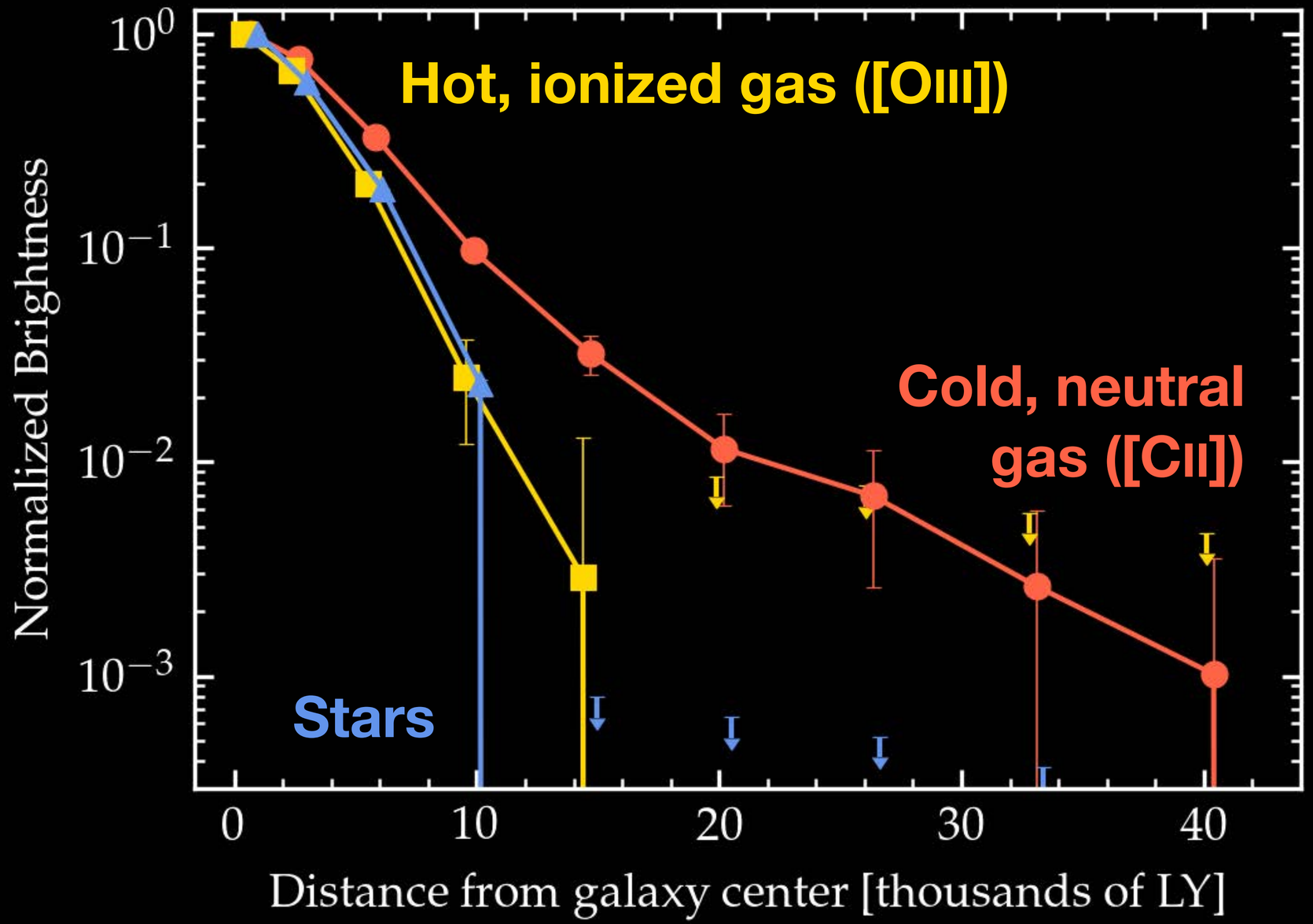
How is the gas distributed?



How is the gas distributed?

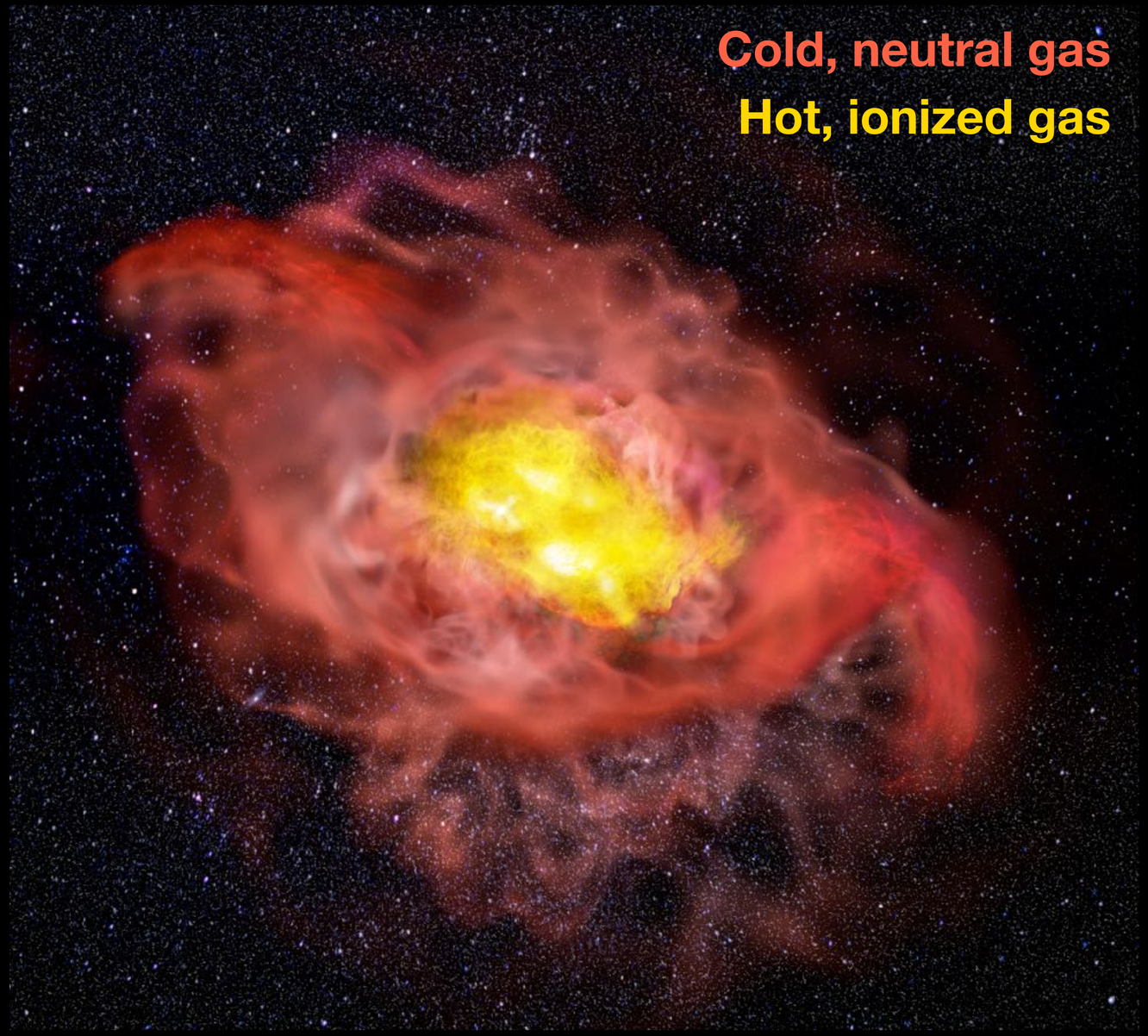


How is the gas distributed?



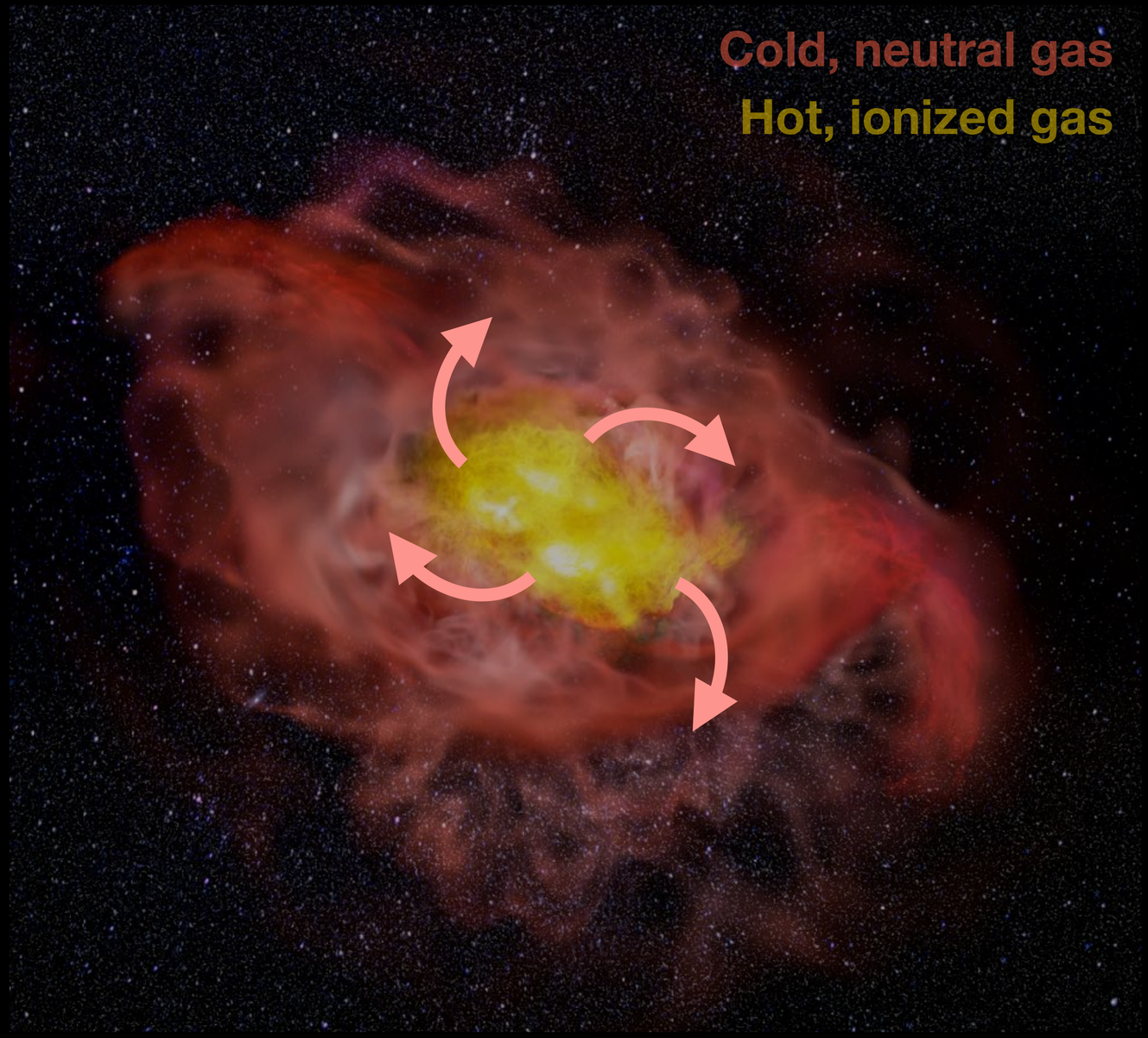
The cold, neutral gas extends significantly further than the stars or the hot, ionized gas

Why is the neutral gas extended?



Artist's illustration of A1689-zD1
(B. Saxon/NRAO/AUI/NSF)

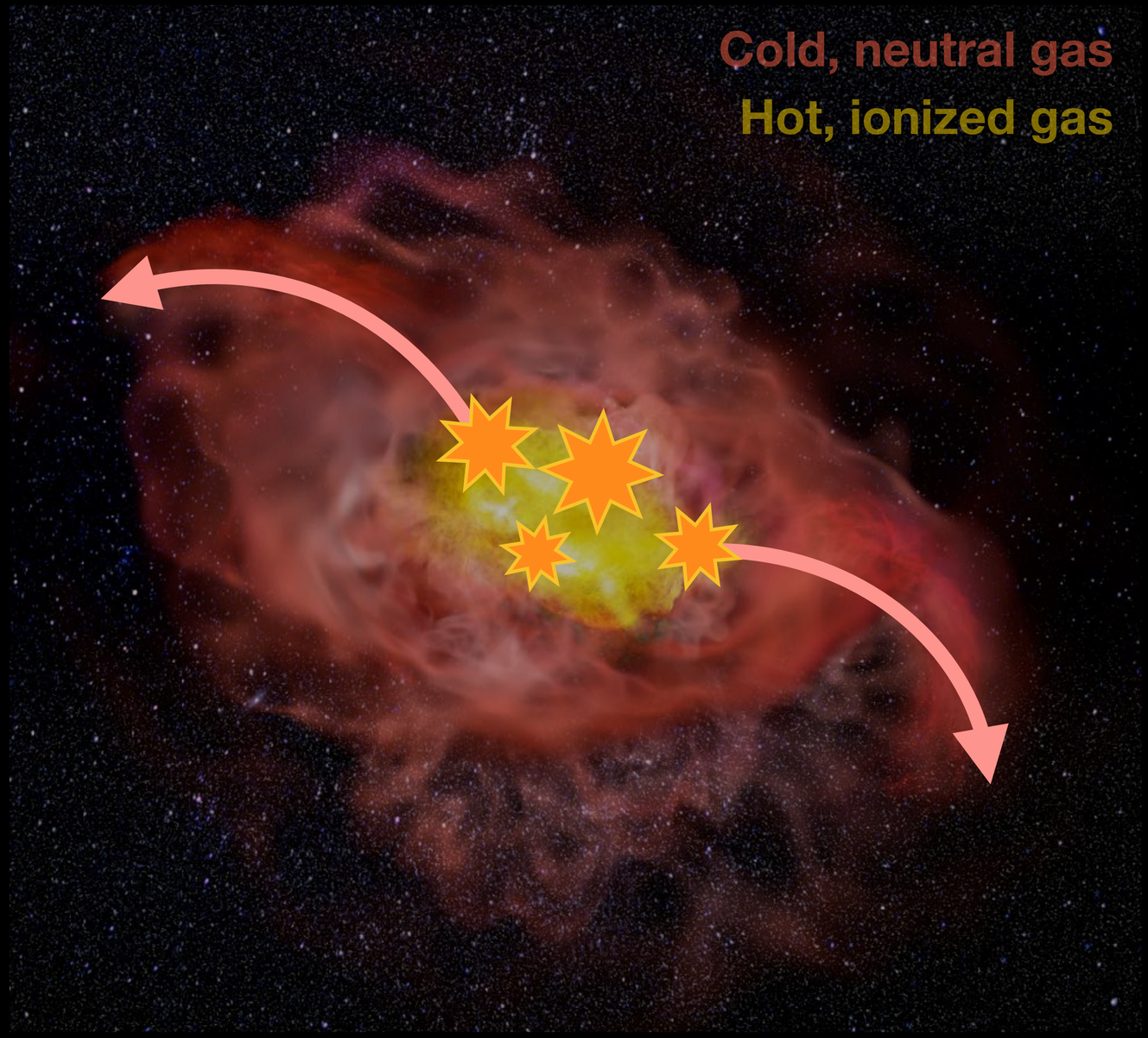
Why is the neutral gas extended?



1. Past mergers/ gravitational interactions with other galaxies

Artist's illustration of A1689-zD1 (B. Saxon/NRAO/AUI/NSF)

Why is the neutral gas extended?

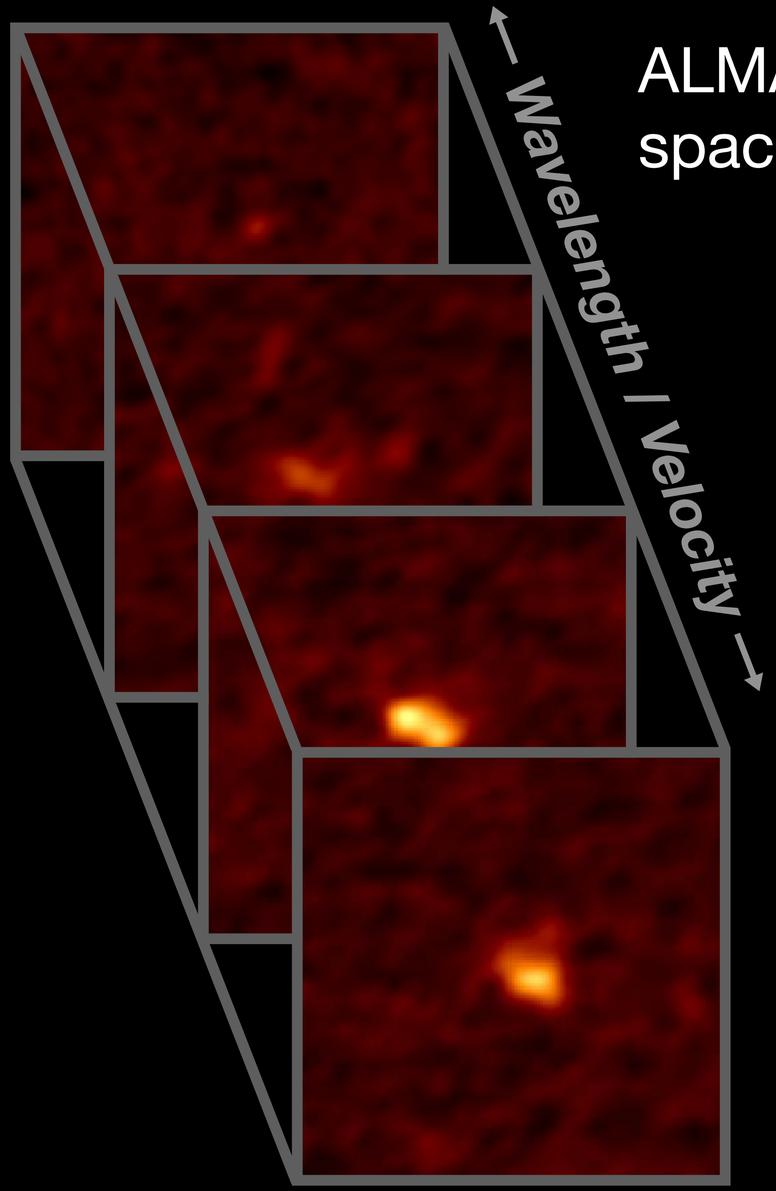


1. Past mergers/ gravitational interactions with other galaxies

2. Outflow of gas driven by galactic activity (supernovae, AGN)

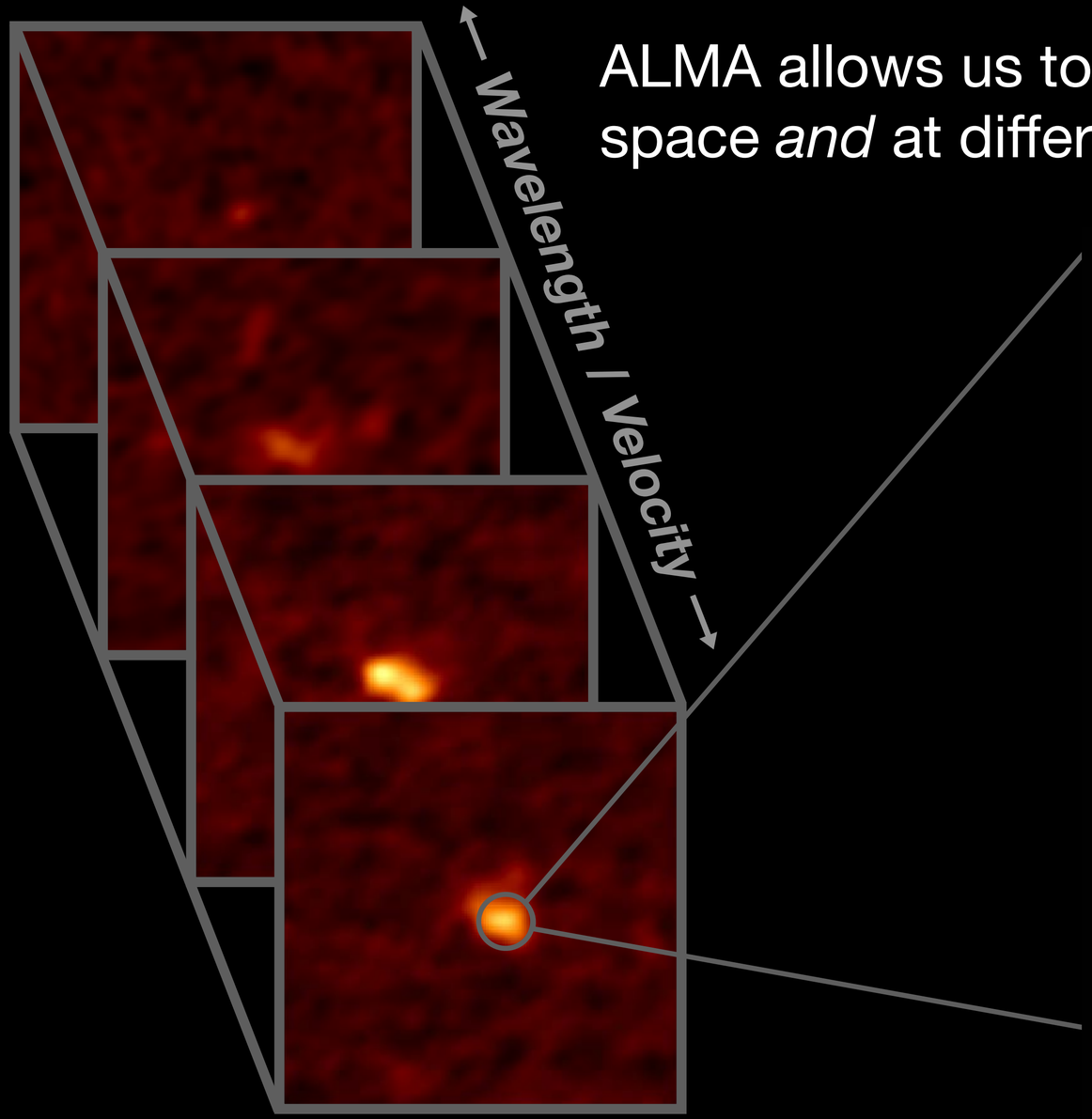
Artist's illustration of A1689-zD1
(B. Saxon/NRAO/AUI/NSF)

Evidence for outflowing gas

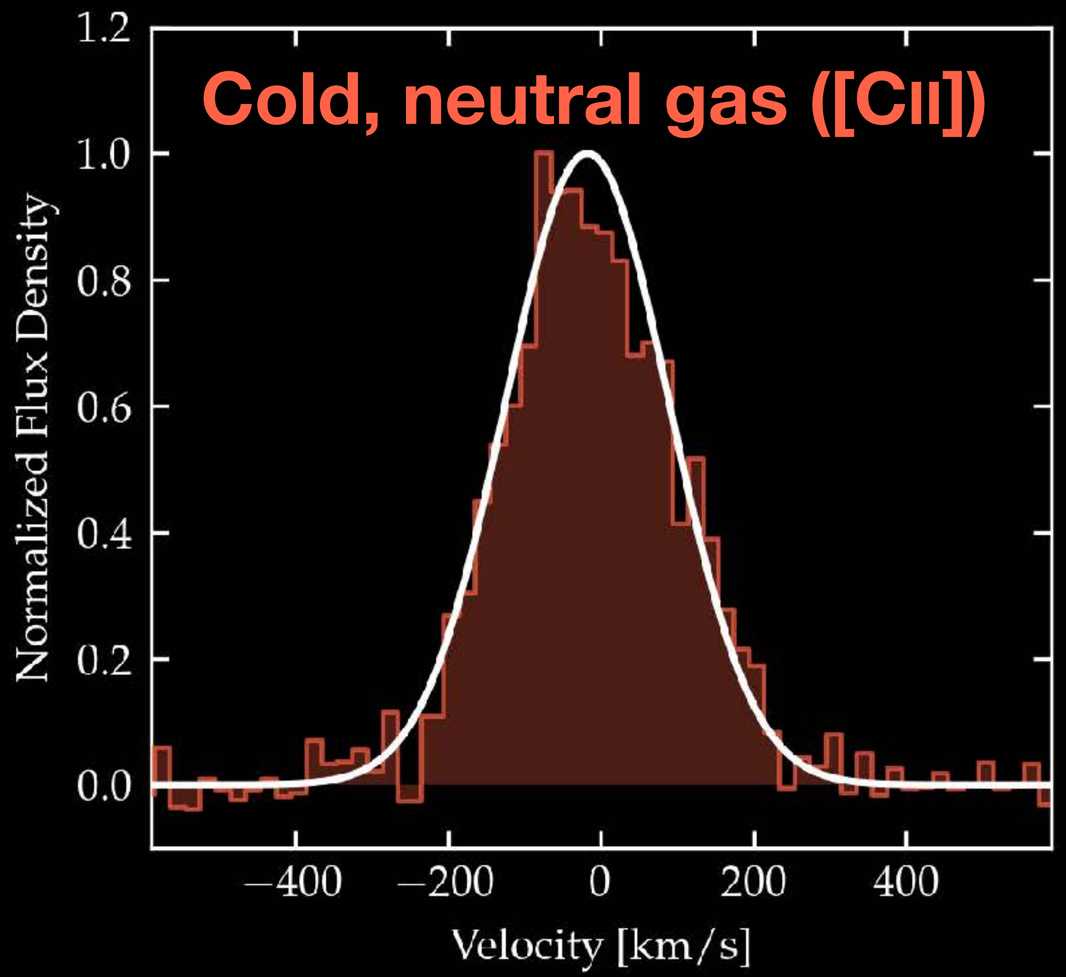


ALMA allows us to see matter at different locations in space *and* at different velocities, simultaneously

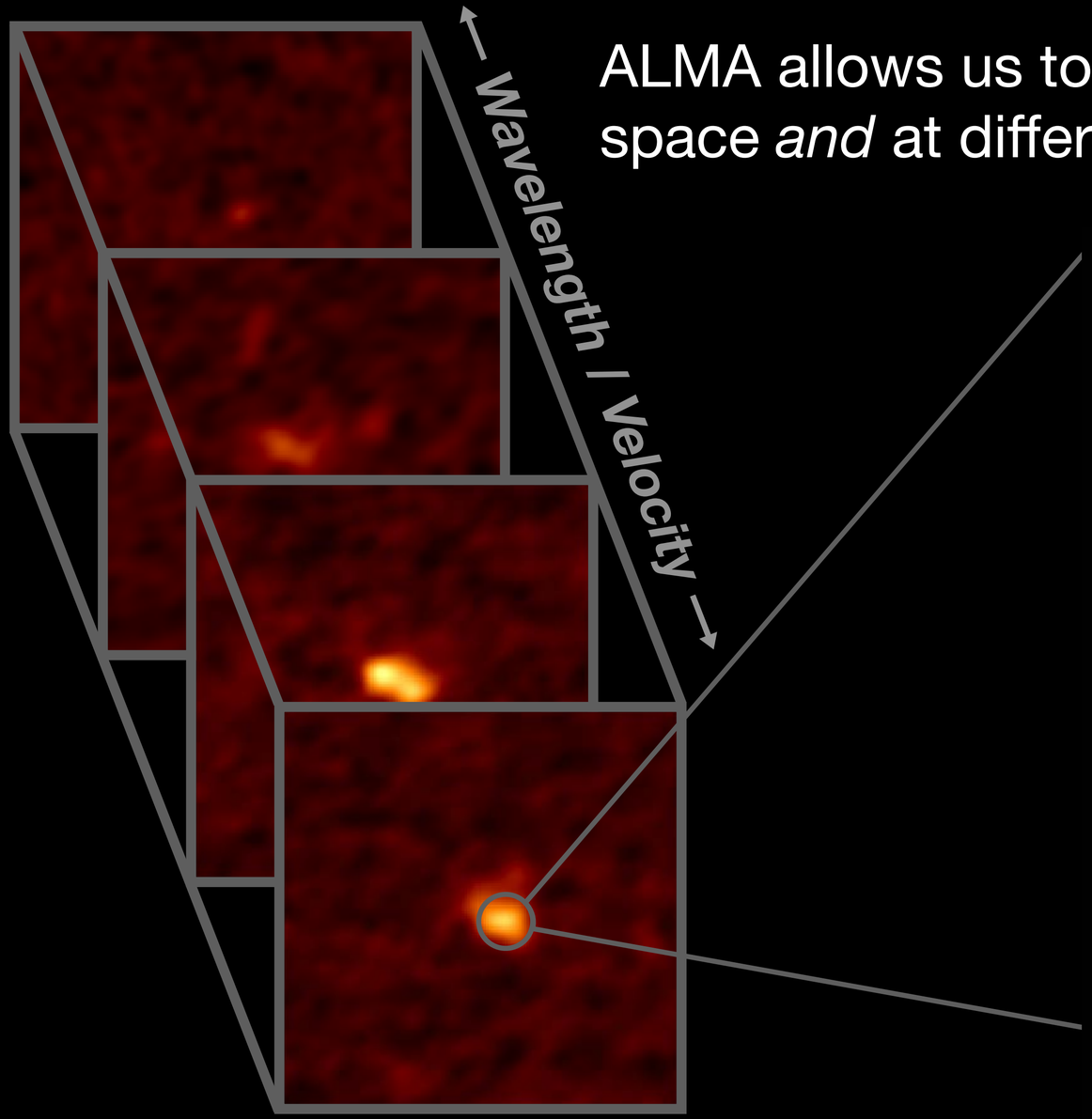
Evidence for outflowing gas



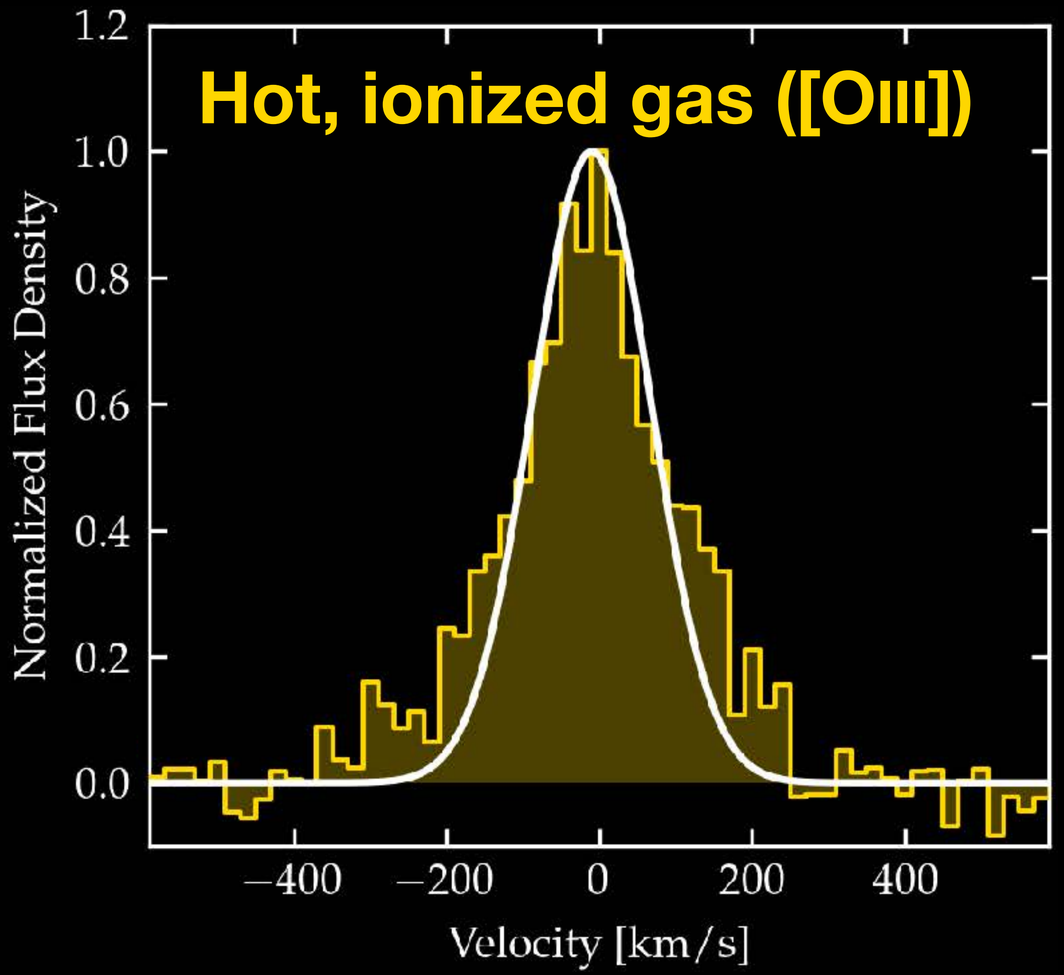
ALMA allows us to see matter at different locations in space *and* at different velocities, simultaneously



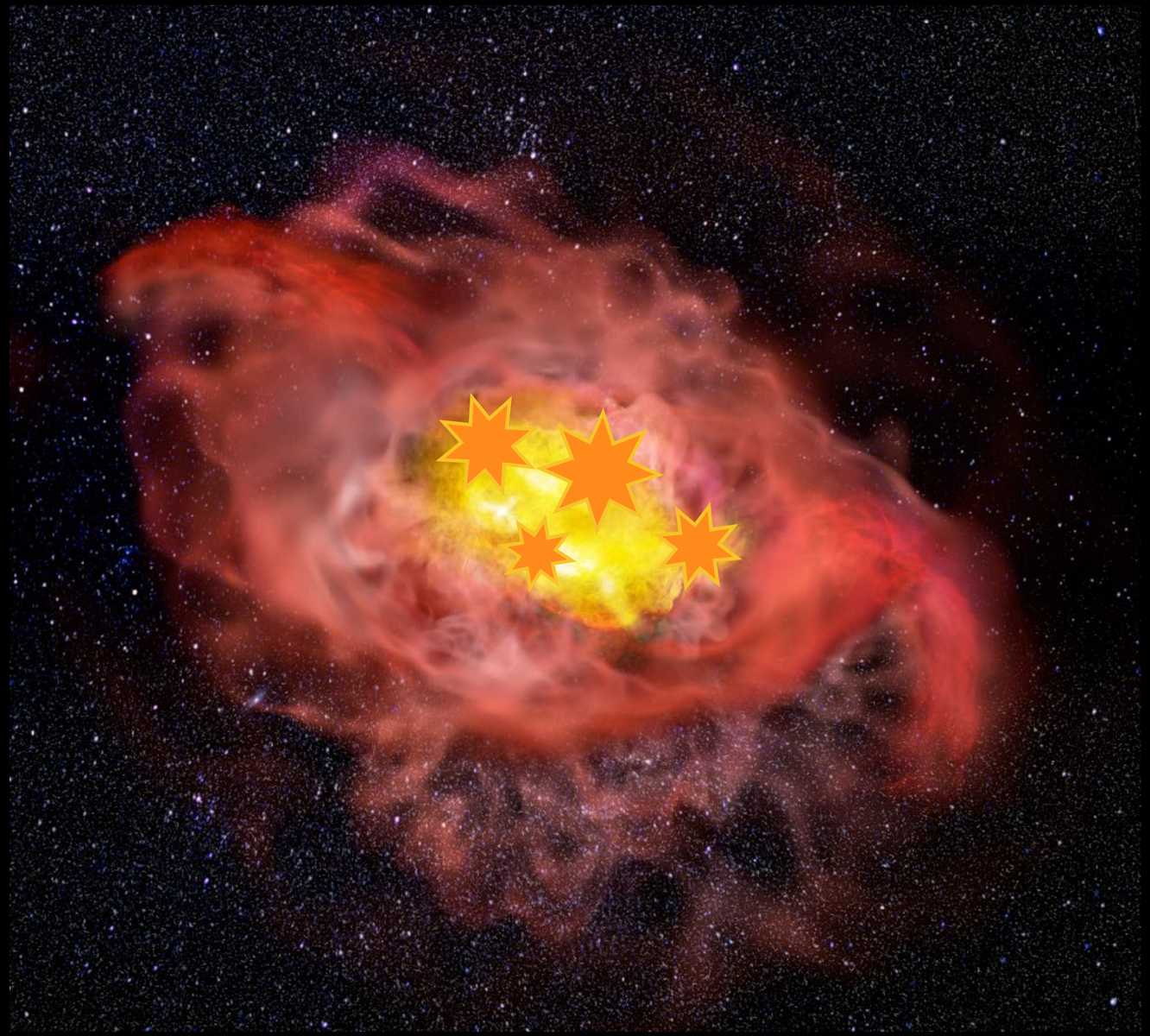
Evidence for outflowing gas



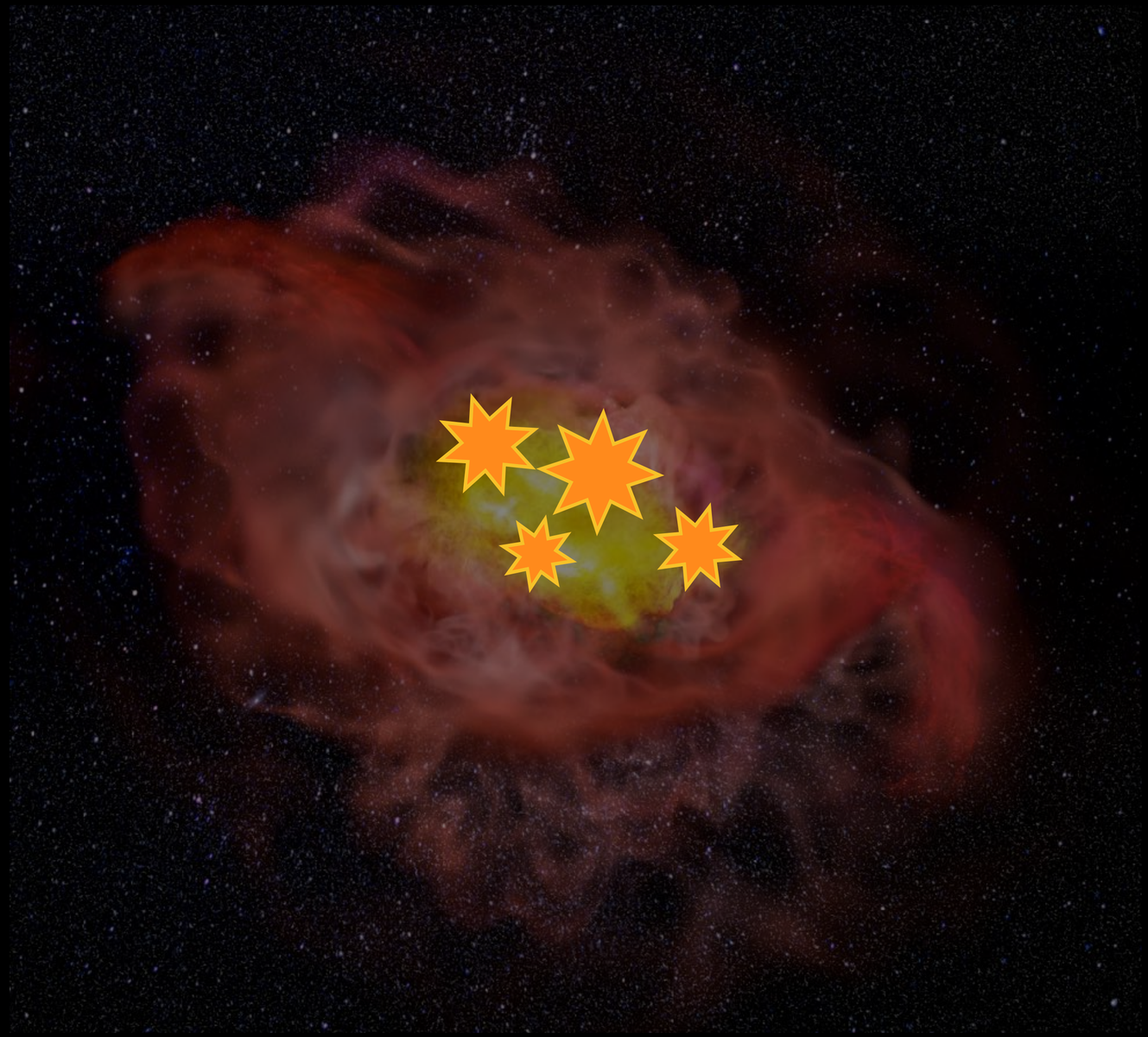
ALMA allows us to see matter at different locations in space *and* at different velocities, simultaneously



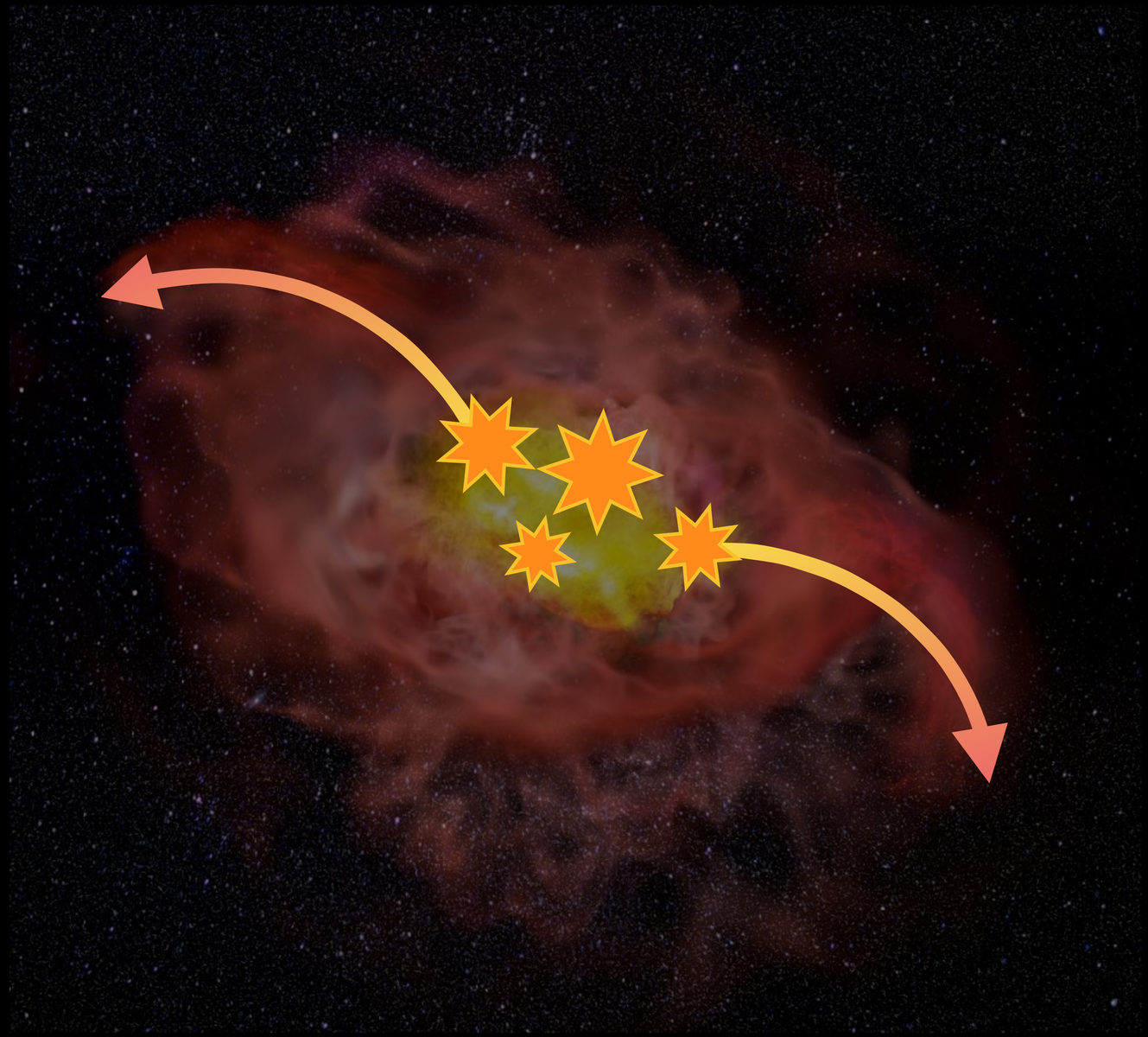
What’s going on in A1689-zD1?



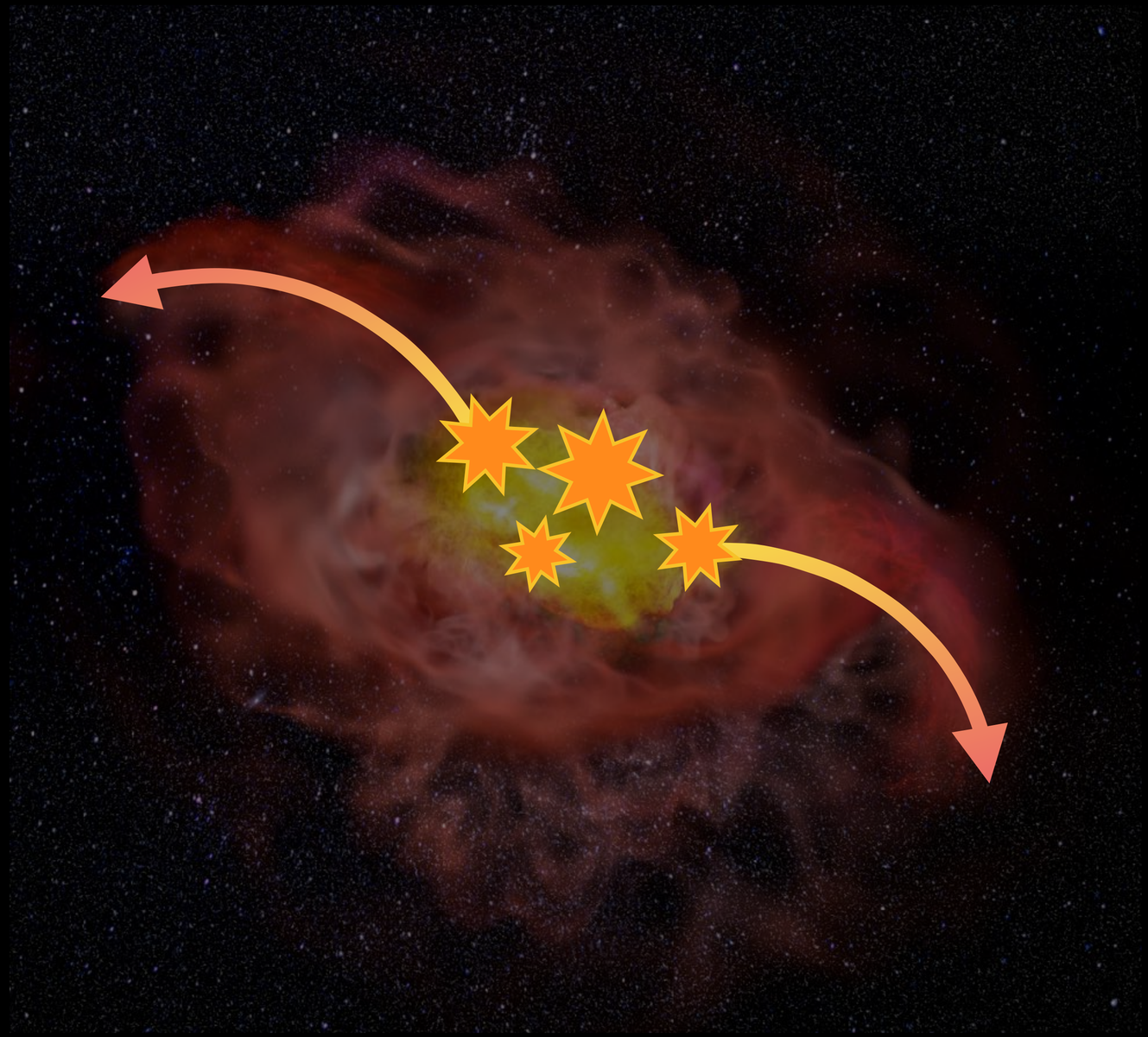
What’s going on in A1689-zD1?

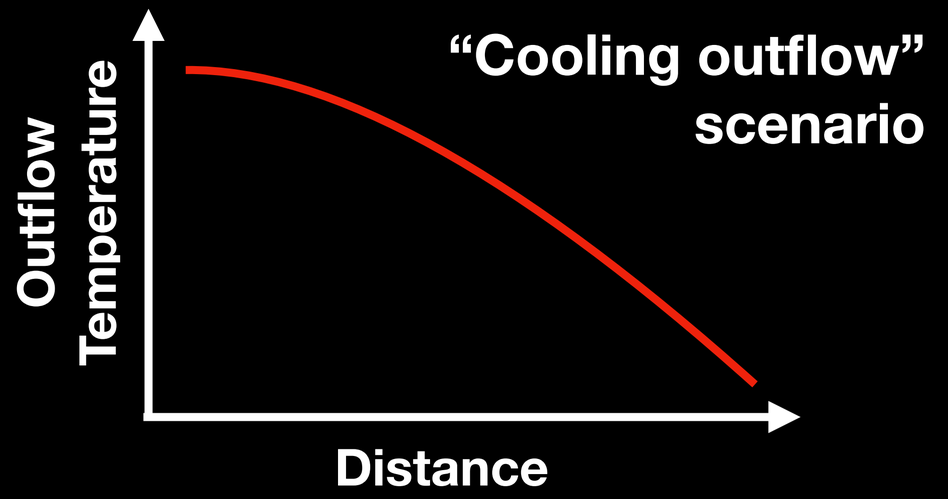


What’s going on in A1689-zD1?

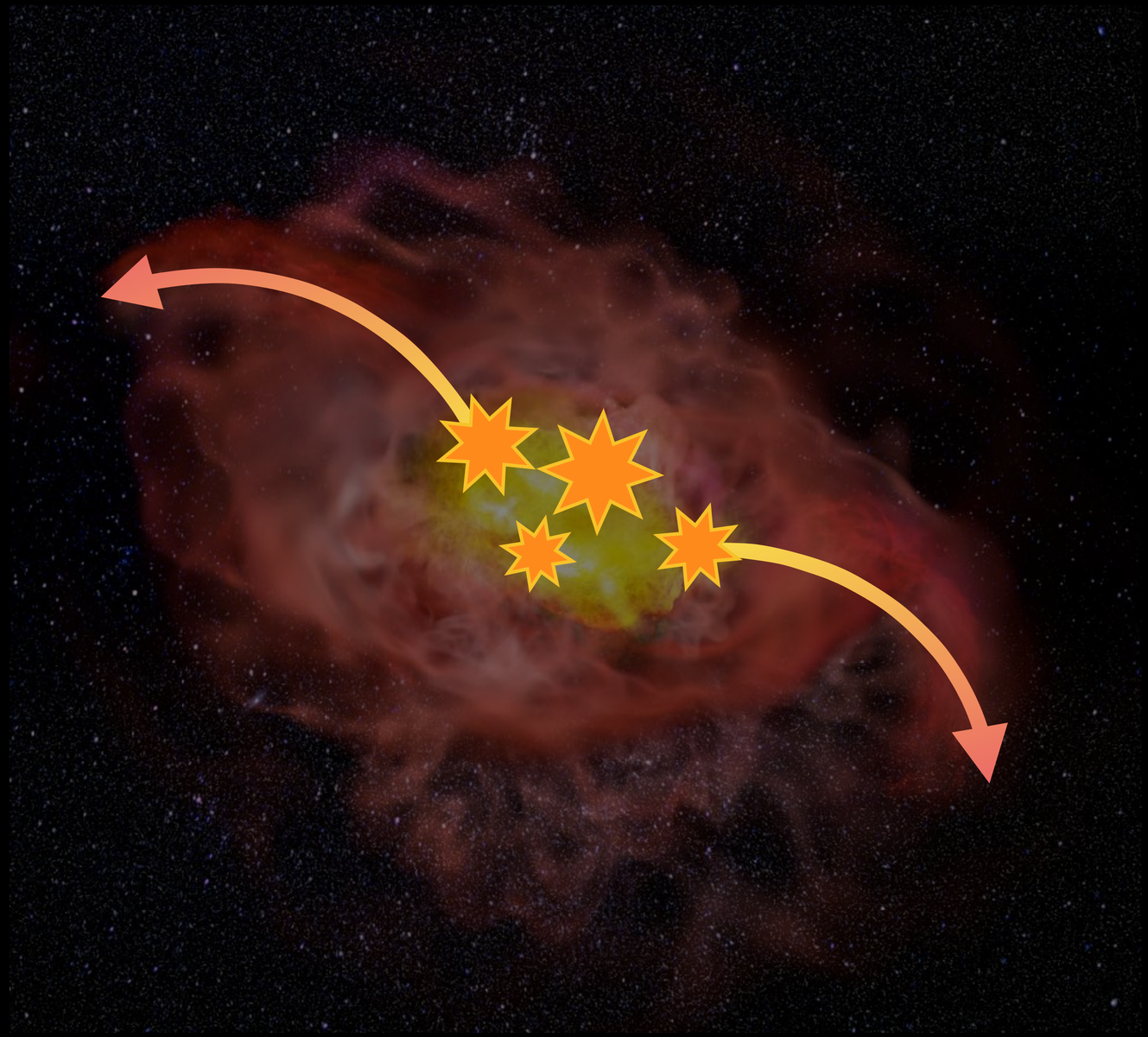


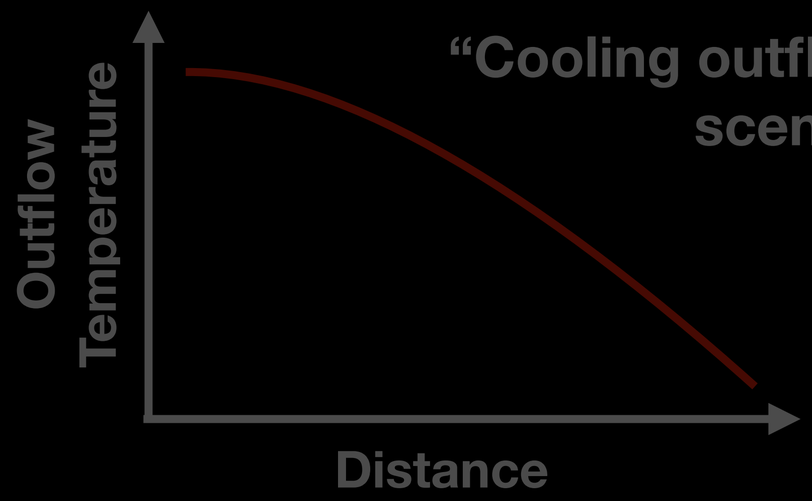
What’s going on in A1689-zD1?





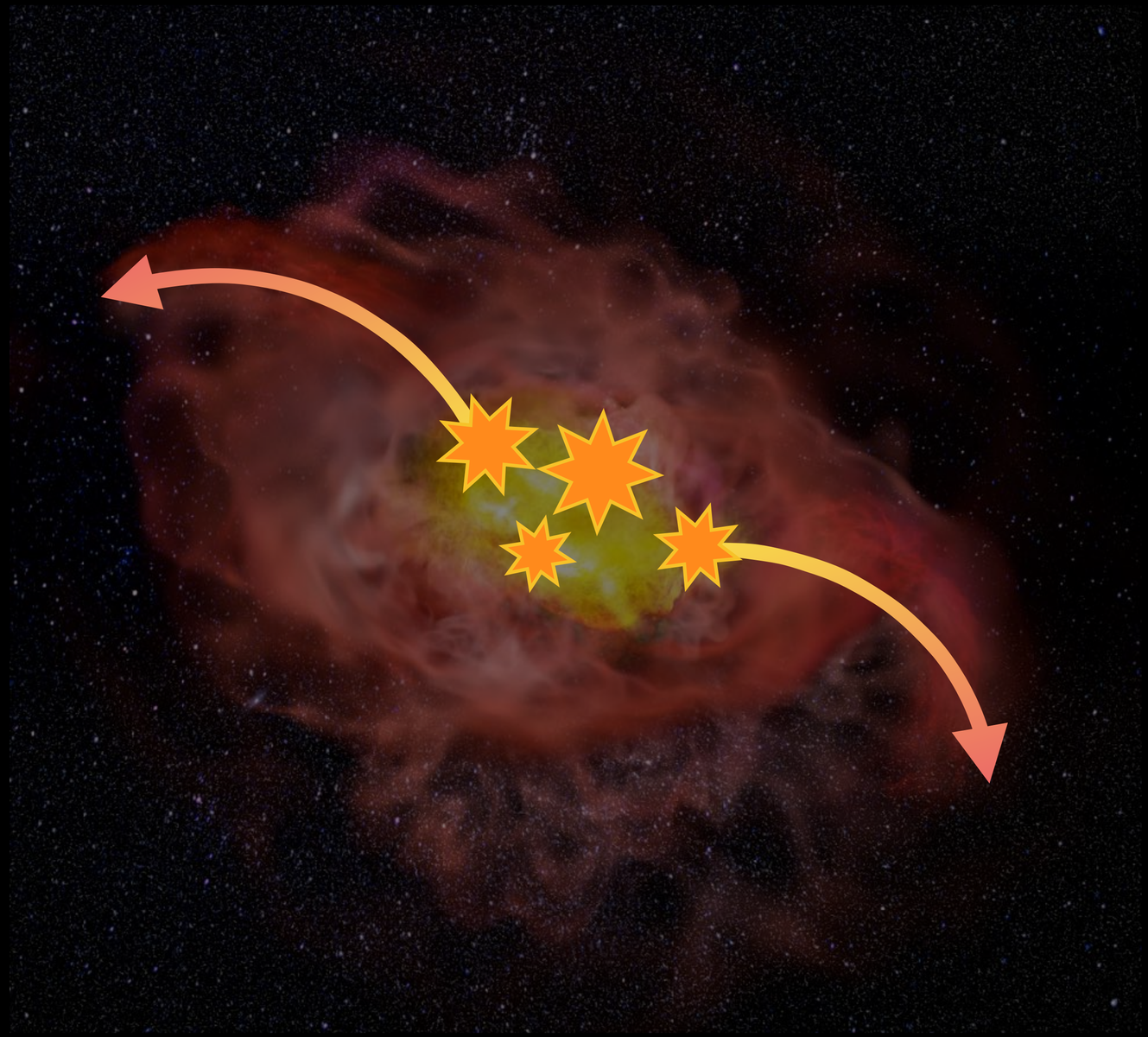
What’s going on in A1689-zD1?

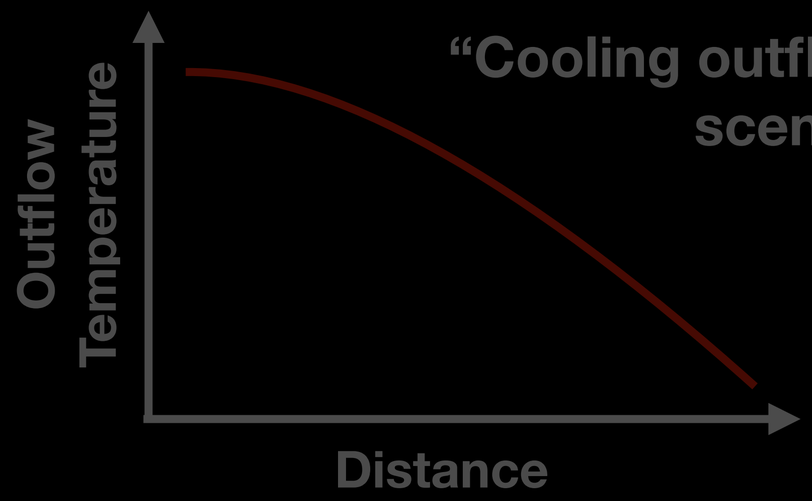




Key Takeaways

What’s going on in A1689-zD1?

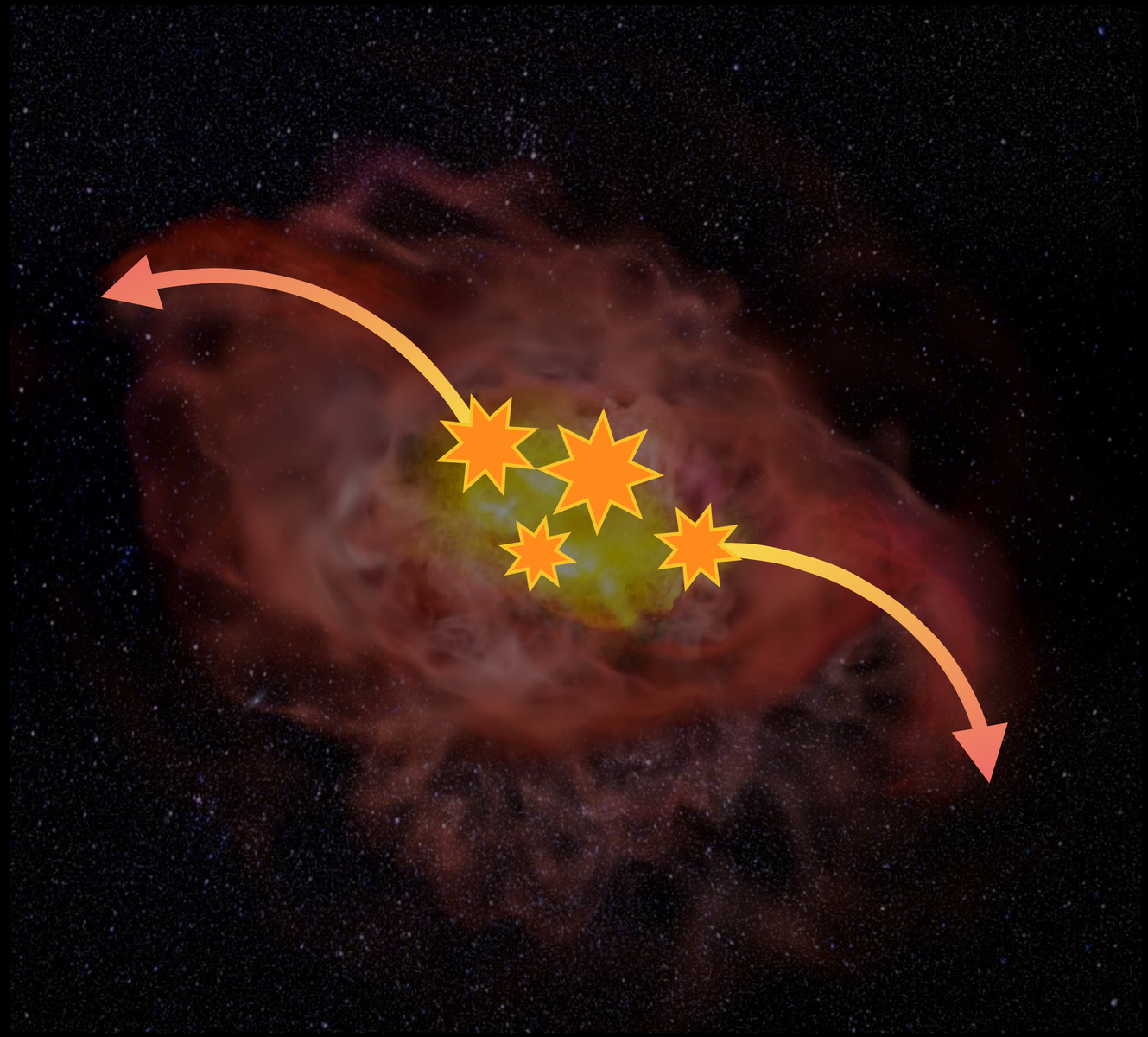


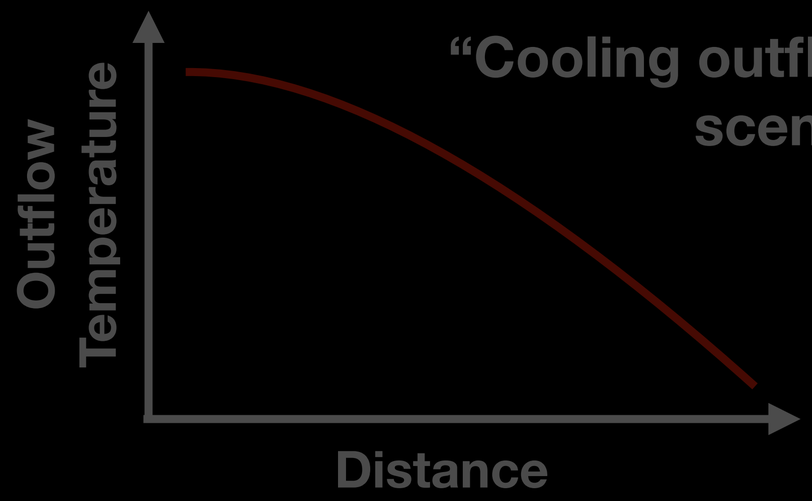


Key Takeaways

- Cooling outflows may be a critical part of the buildup of the CGM

What’s going on in A1689-zD1?





Key Takeaways

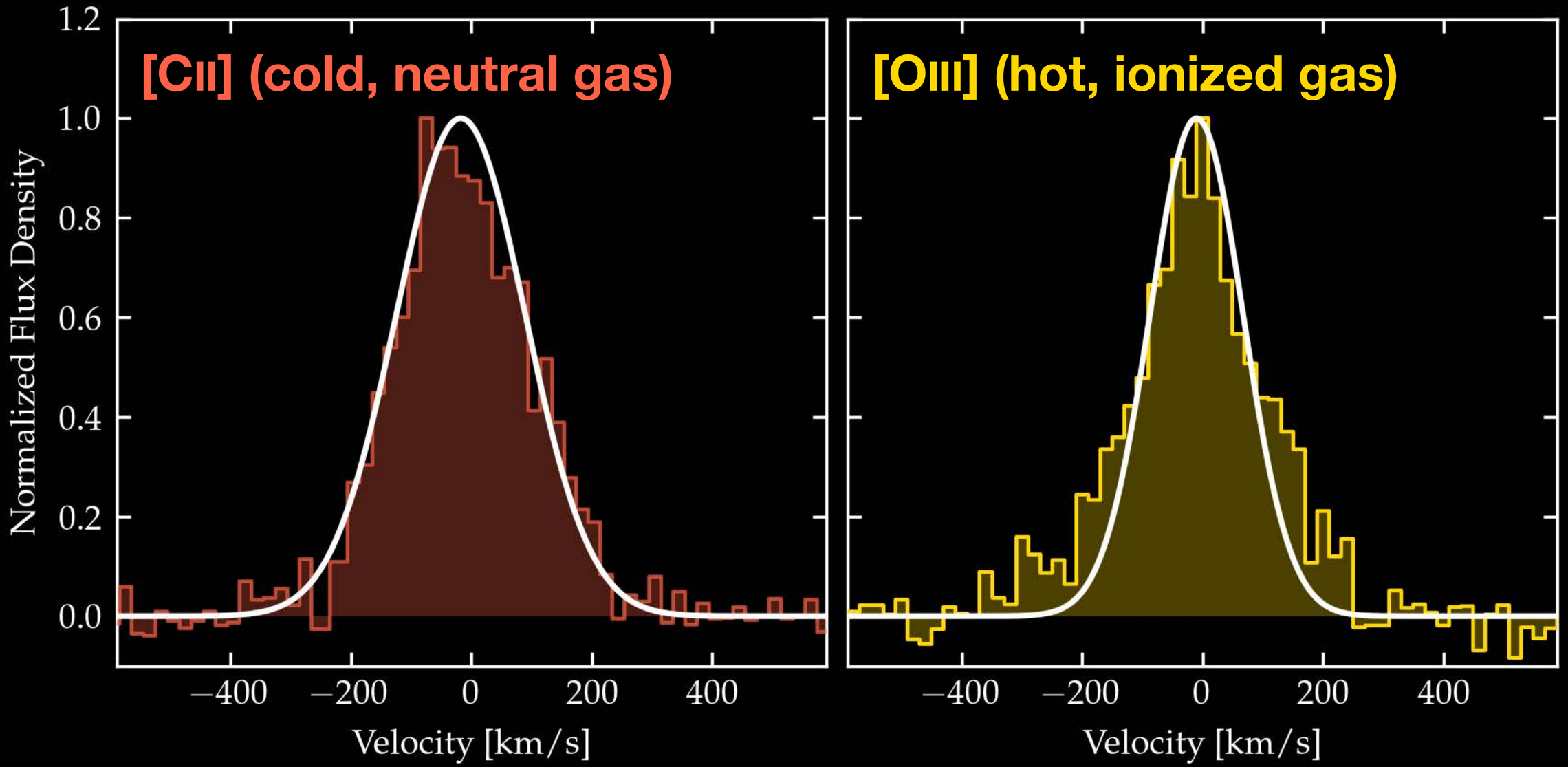
- Cooling outflows may be a critical part of the buildup of the CGM
- Outflow activity can shape galaxy evolution even in the early universe and in relatively “normal” galaxies

ALMA reveals extended cool gas and hot ionized outflows around a distant star-forming galaxy

Hollis Akins (*Grinnell College → UT Austin*)
S. Fujimoto, K. Finlator, D. Watson (*DAWN*)
K. Knudsen (*Chalmers U.*)
J. Richard (*U. Lyon*)

Akins et al. (2022), ApJ in press
iPoster 214.23: today, 5:30-6:30 pm PDT, hall A/B
hollis.akins@gmail.com **|** **(336) 681-8118**

Background: *Hubble view of Abell 1689 (ESA/Hubble)*
Inset: *Artist's illustration of A1689-zD1 (B. Saxon/NRAO/AUI/NSF)*


[CII] (cold, neutral gas)
[OIII] (hot, ionized gas)
Normalized Flux Density
1.2
1.0
0.8
0.6
0.4
0.2
0.0
−400
−200
0
200
400
Velocity [km/s]
−400
−200
0
200
400
Velocity [km/s]