Gas Accretion from the ISM onto Circumstellar Disks

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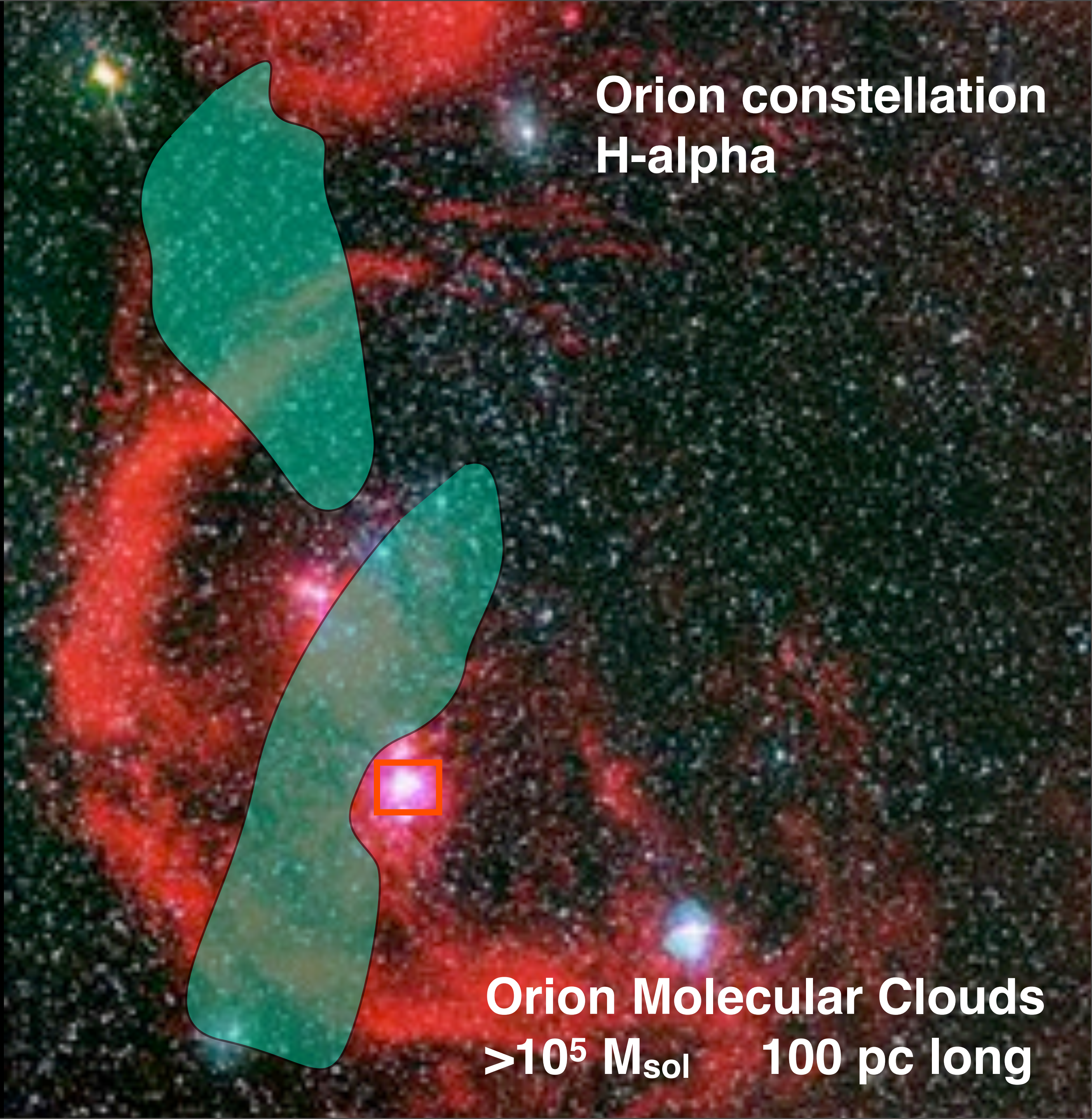
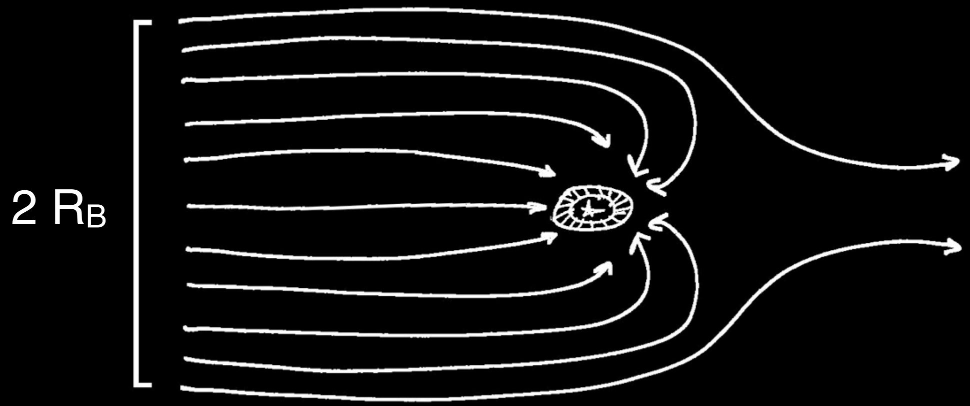
Orion Constellation
(visible light)


Orion constellation
H-alpha


Orion constellation
H-alpha
Orion Molecular Clouds
>10^5 M_{sol} 100 pc long

Bondi-Hoyle Accretion



- Gravitational accretion onto a moving body
- Cool molecular H_2 from cluster ISM accretes onto disks
- Accretion flow is **onto disk**, not star.
- Accretion is robust against stellar winds, radiation pressure, turbulence.
- This accretion is not considered by existing Solar System formation models!

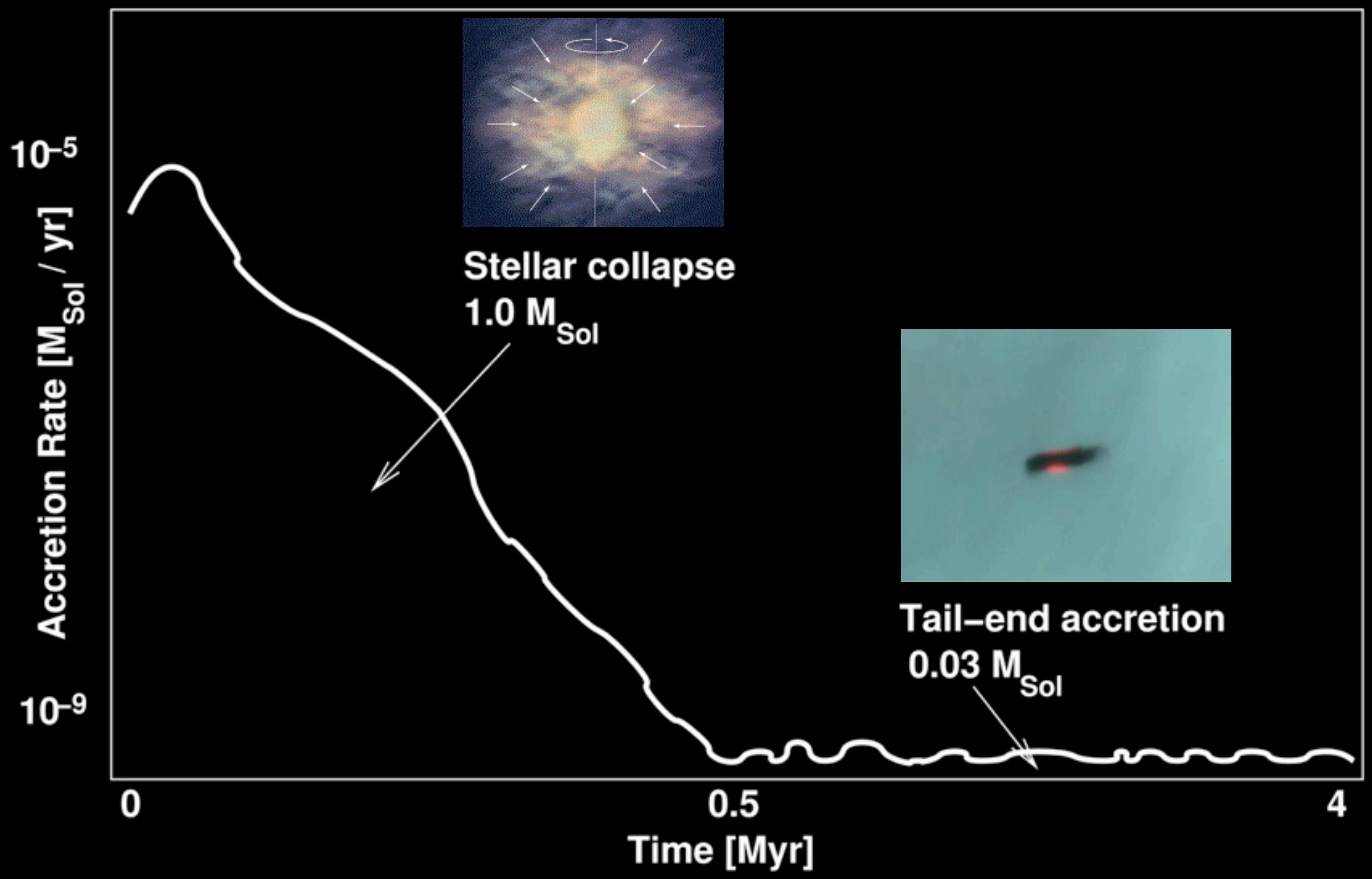
$$R_\mathrm{B} = \frac{2\,G\,M}{(v^2 + c_s^2)}$$

Accretion radius ~ 1000 AU

$$\dot{M}_\mathrm{B} = \frac{4\pi\,G^2 M^2}{(v^2 + c_s^2)^{3/2}}\quad n\,m_h$$

Accretion rate ~ 1 MMSN / Myr

Timescale of Star Formation



Gas Accretion + N-Body Cluster Simulations

NBODY6 code (Aarseth 2003)

Stars:

- N=1000
- M_{star} = 500 M_{sun}
- Kroupa IMF
- R_0 = 0.5 pc

Gas:

- M_{gas} = 500 M_{sun}
- R_0 = 0.5 pc
- Disperses with timescale 2 Myr

Throop & Bally 2008

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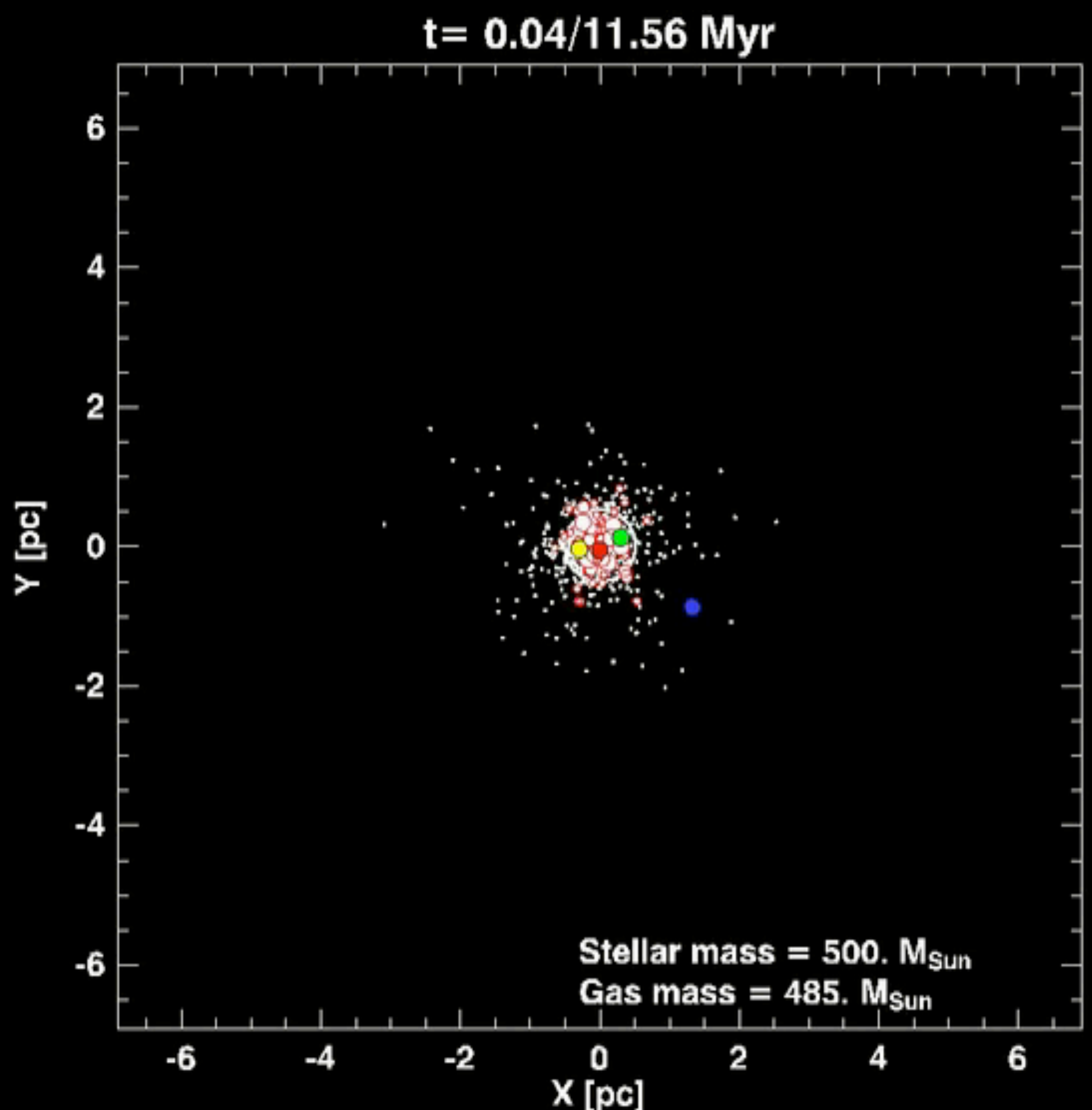

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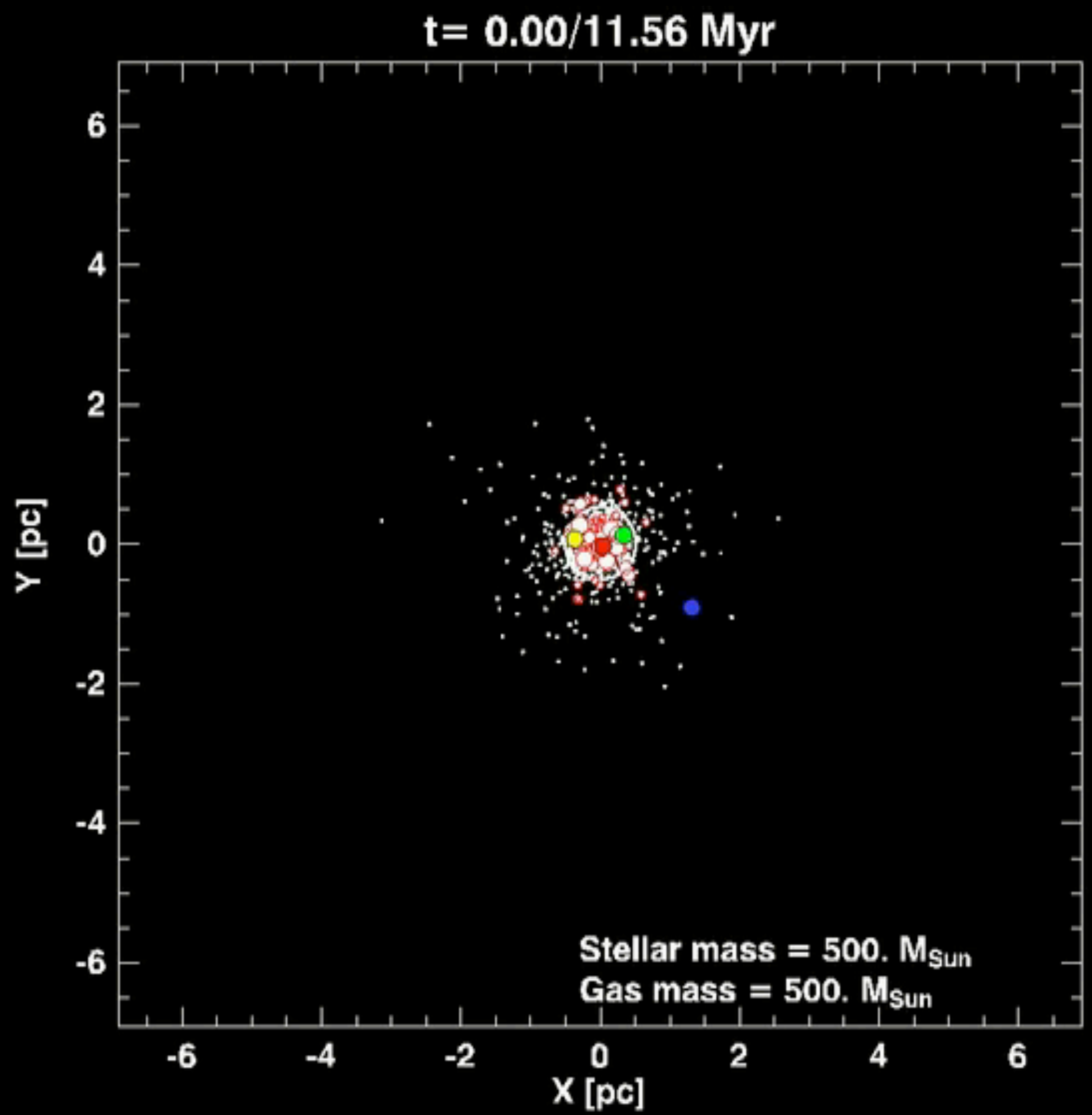

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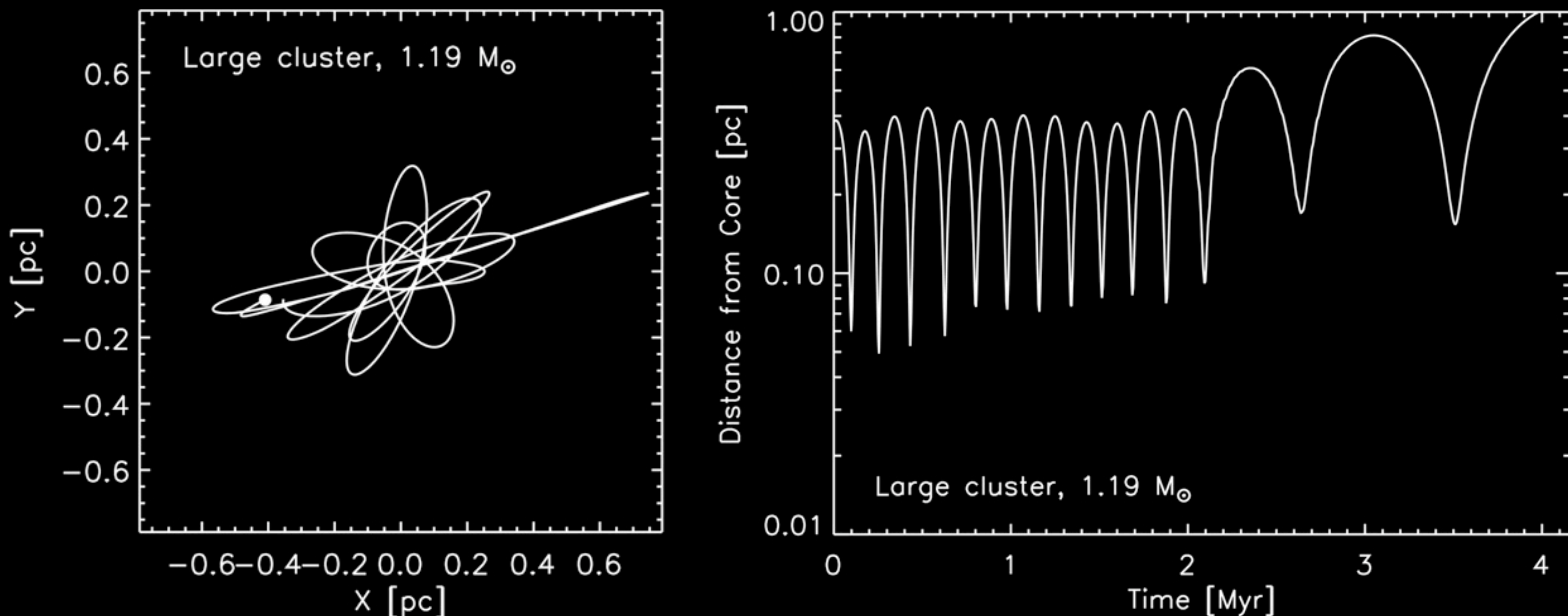
BH Accretion: History of individual star



Following trajectory of one star of 3000 from N-body simulation...

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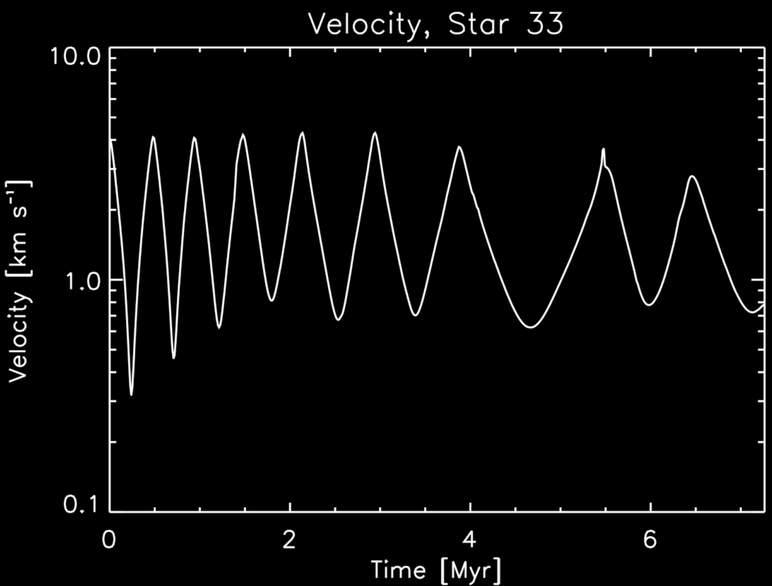
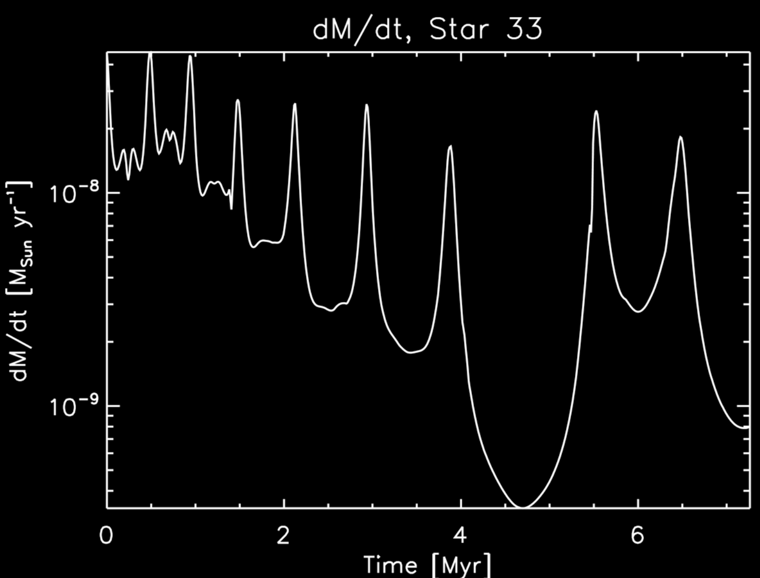
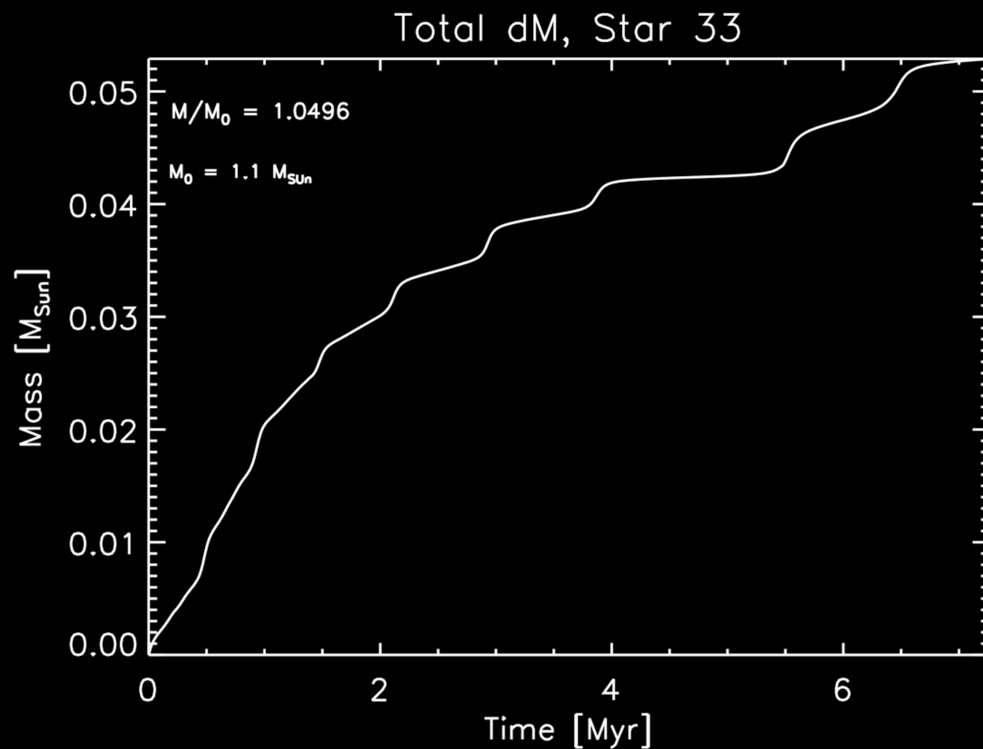




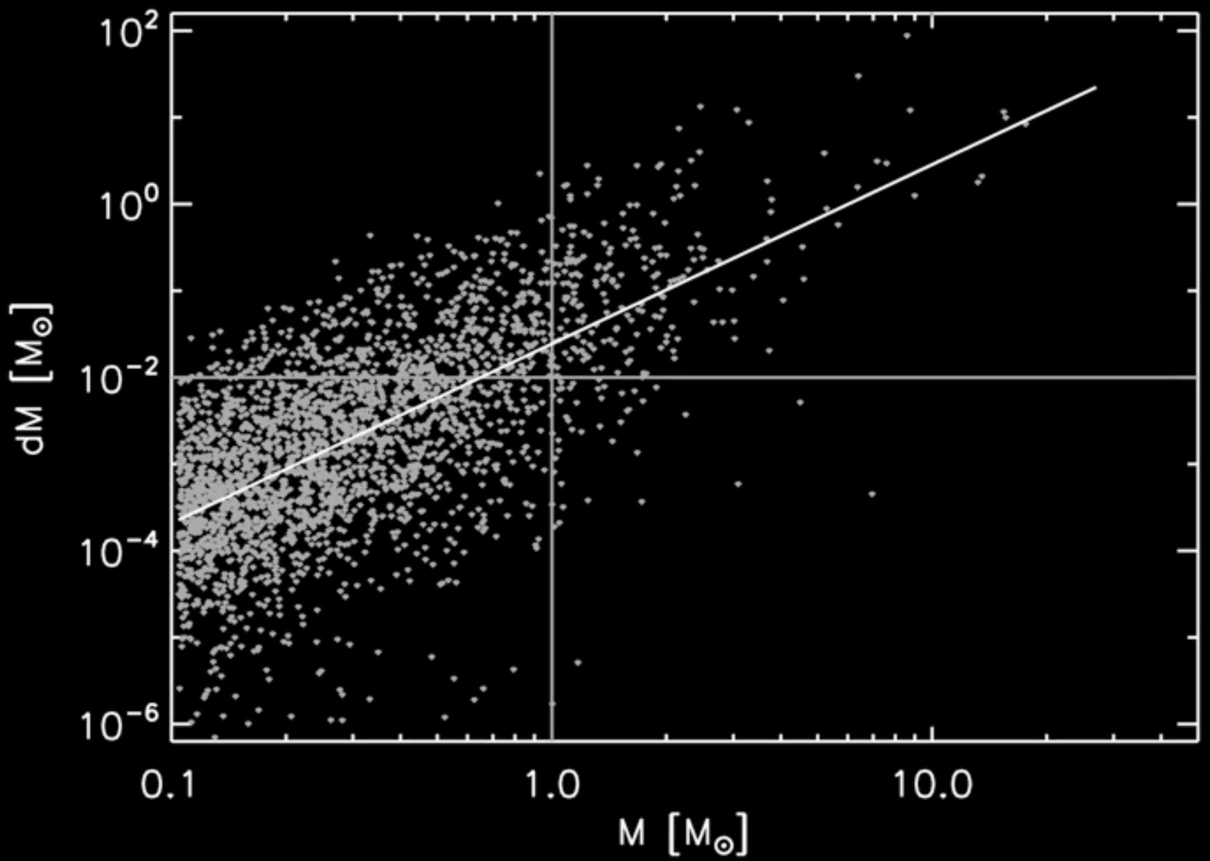


Star+disk accretes 5% of own mass in 5 Myr.

Accretion is episodic

- Highest at core: High velocity but high density

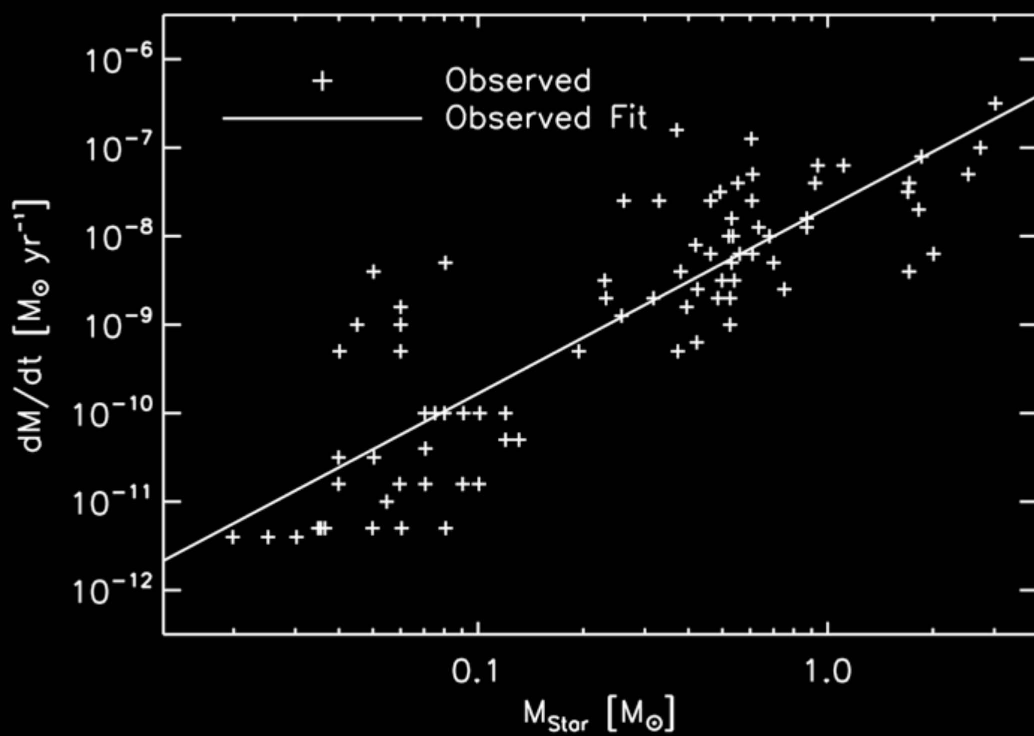
Results of N-Body sims



- Typical mass accreted by disks surrounding Solar-mass stars is 1 MMSN per Myr
- Accretion occurs for several Myr, until cluster disperses or cloud is ionized

Observations of accretion in young stars

- Accretion observed onto hundreds young stars in molecular clouds varies with stellar mass: $dM/dt \sim M^2$
  - Natta et al 2006, Muzerolle et al 2005, etc
- Accretion is $\sim 0.01\ M_\odot\ \mathrm{Myr}^{-1}$
- There is no accepted physical explanation for this relationship.



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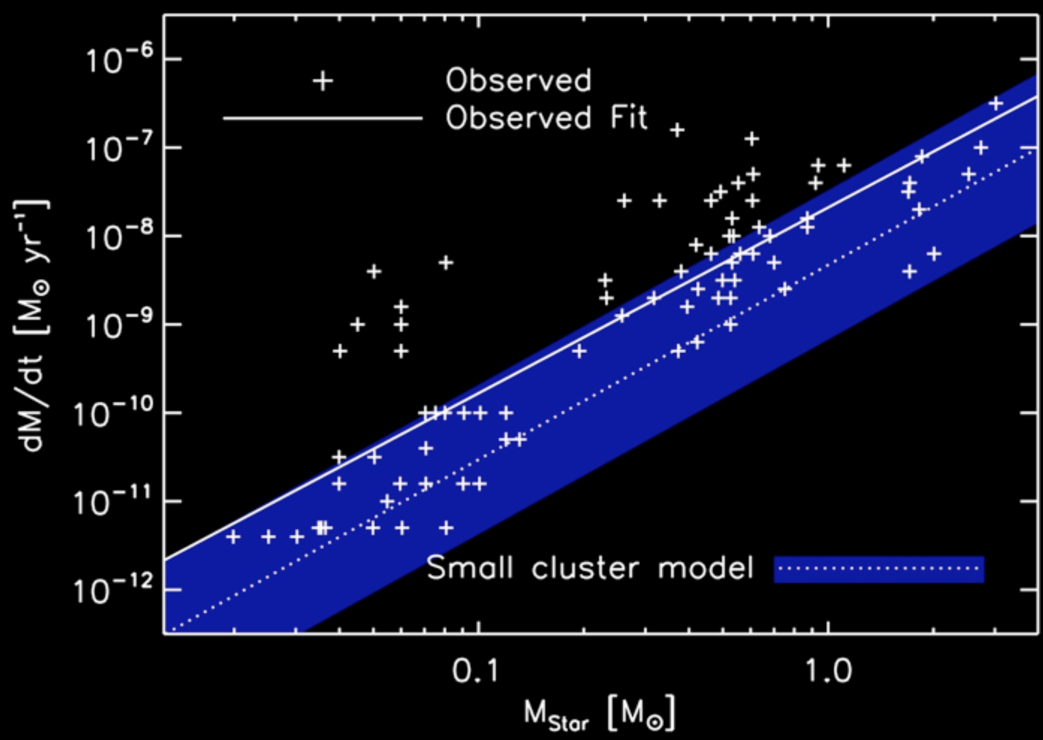
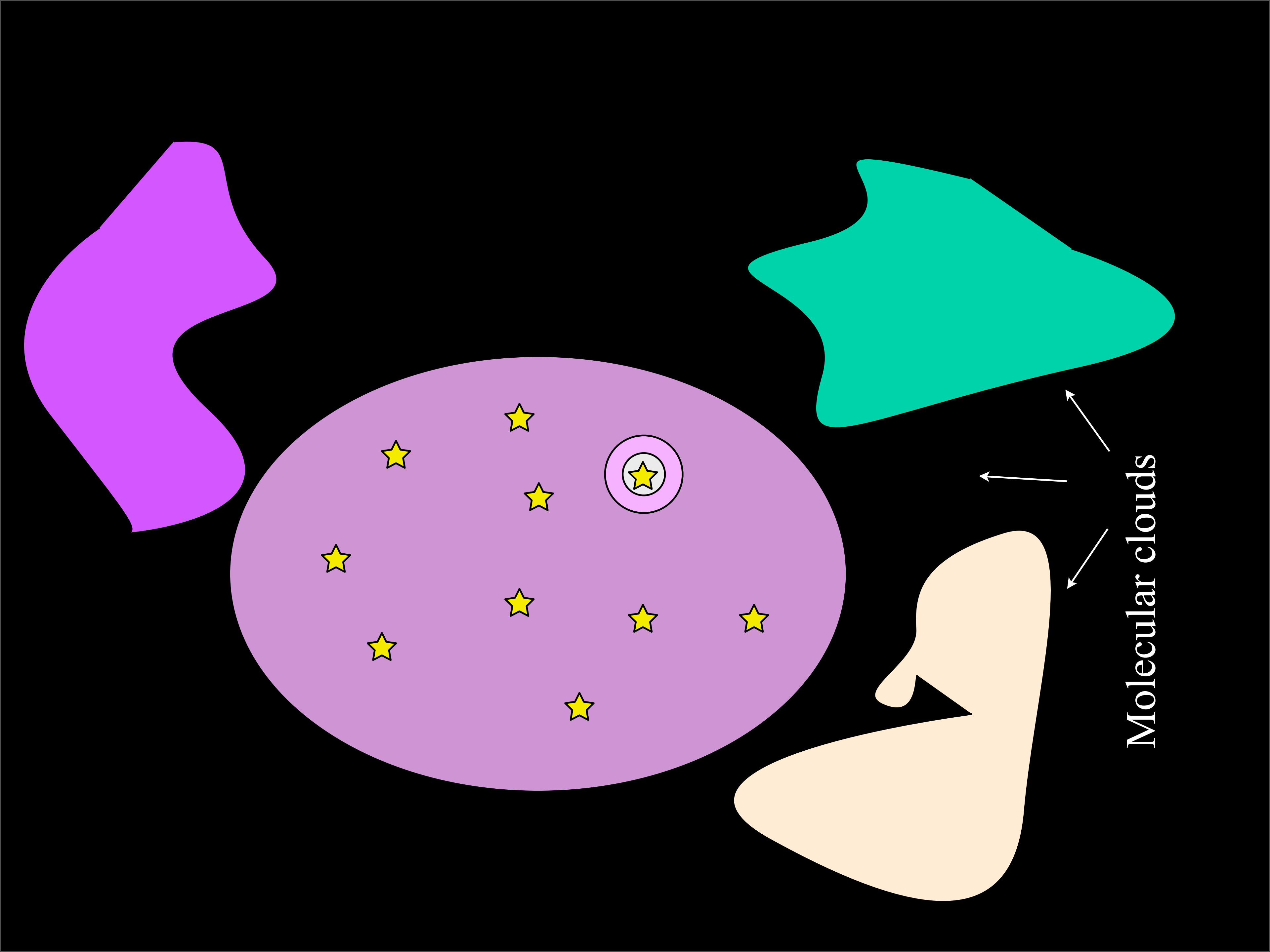
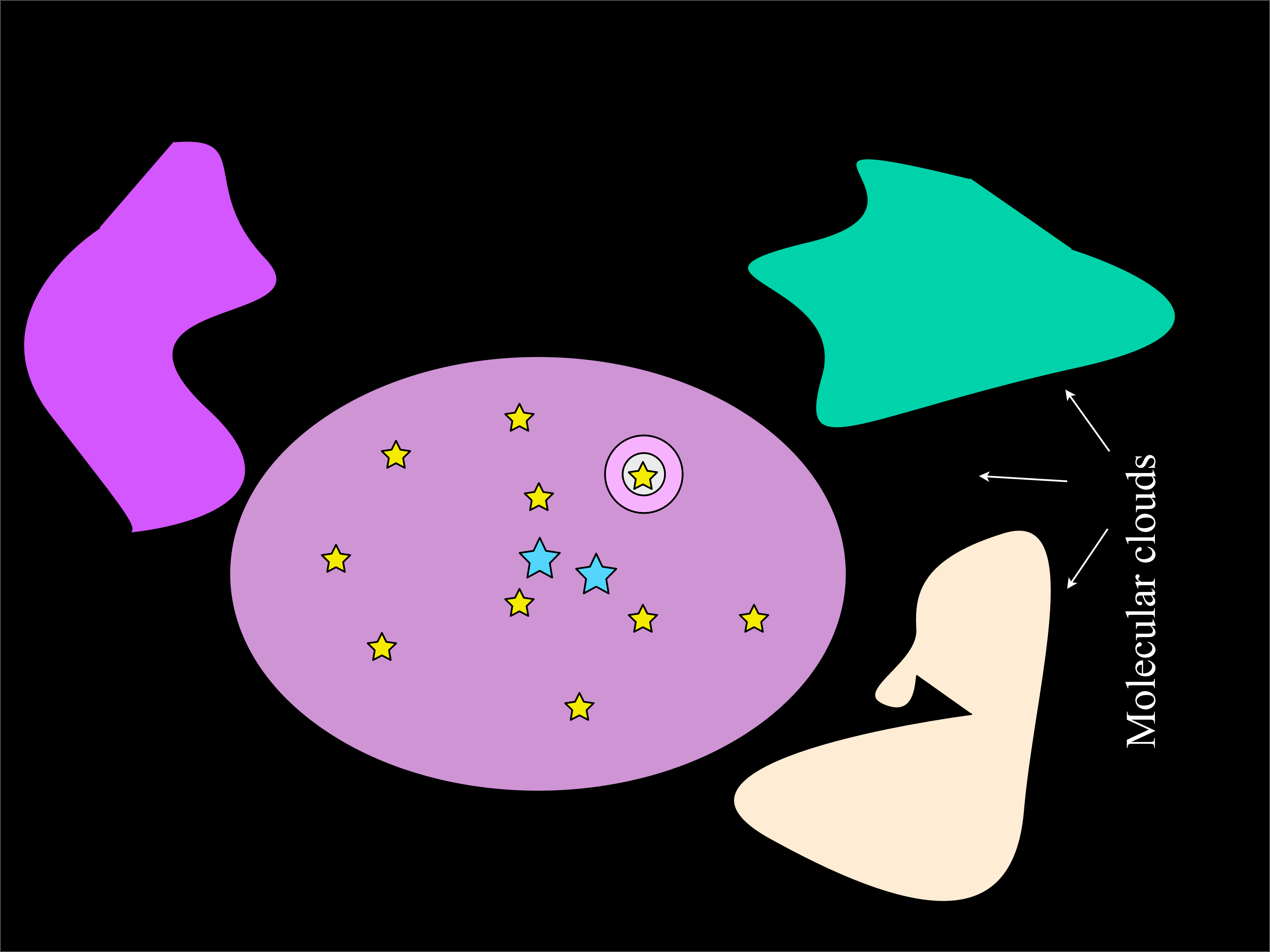


Accretion onto young stars may be a consequence and confirmation of ISM accretion onto their disks


Molecular clouds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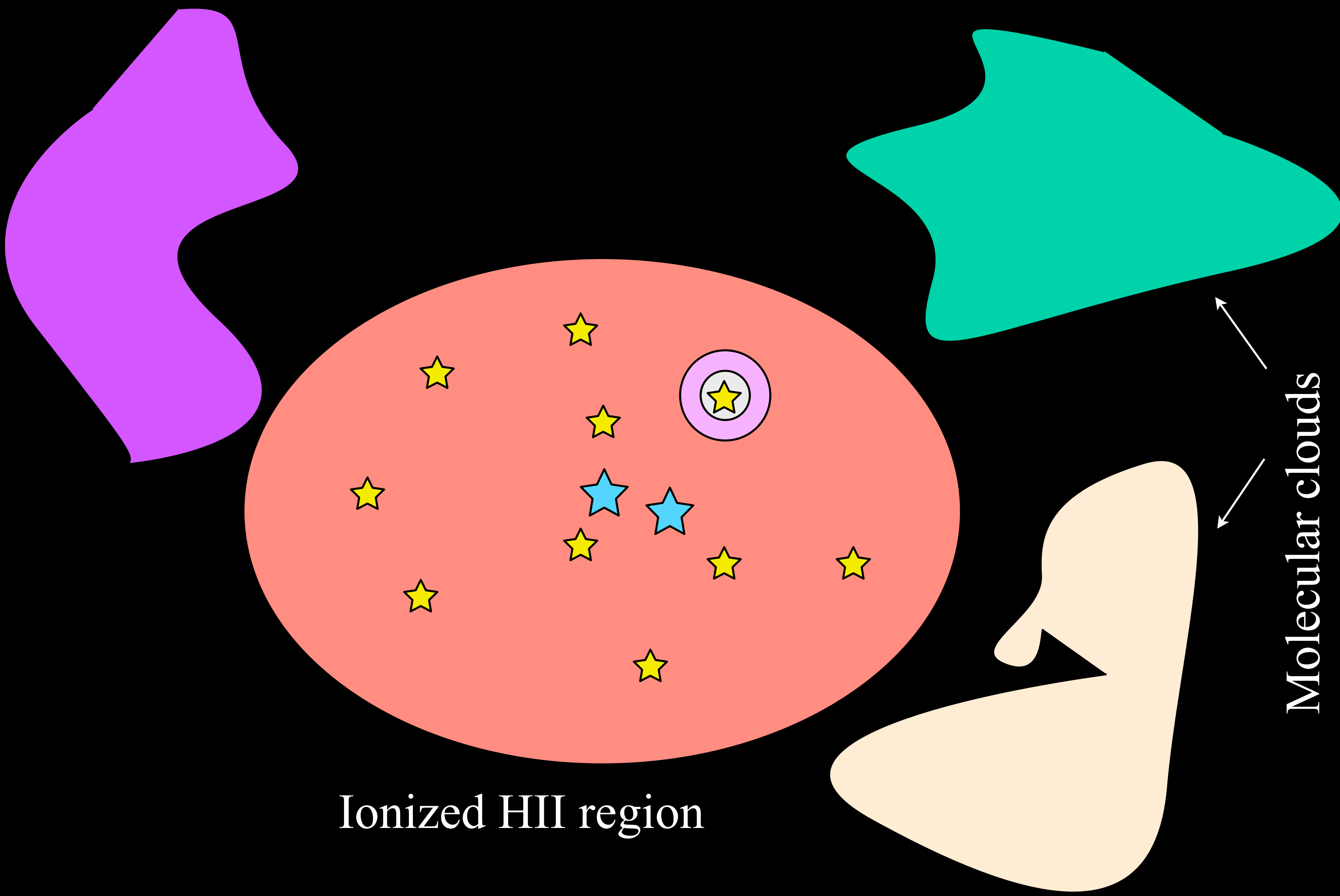
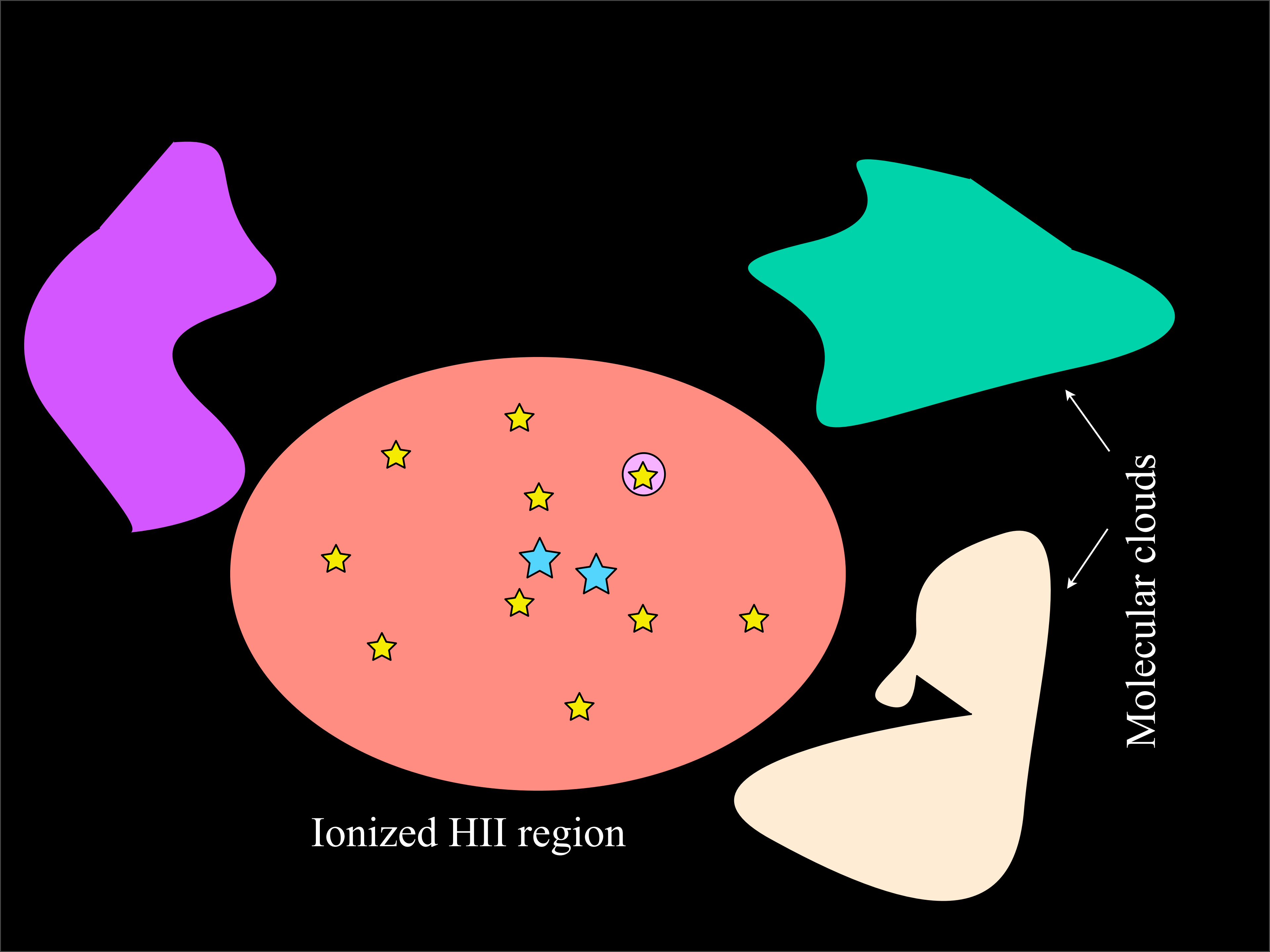

Ionized HII region
Molecular clouds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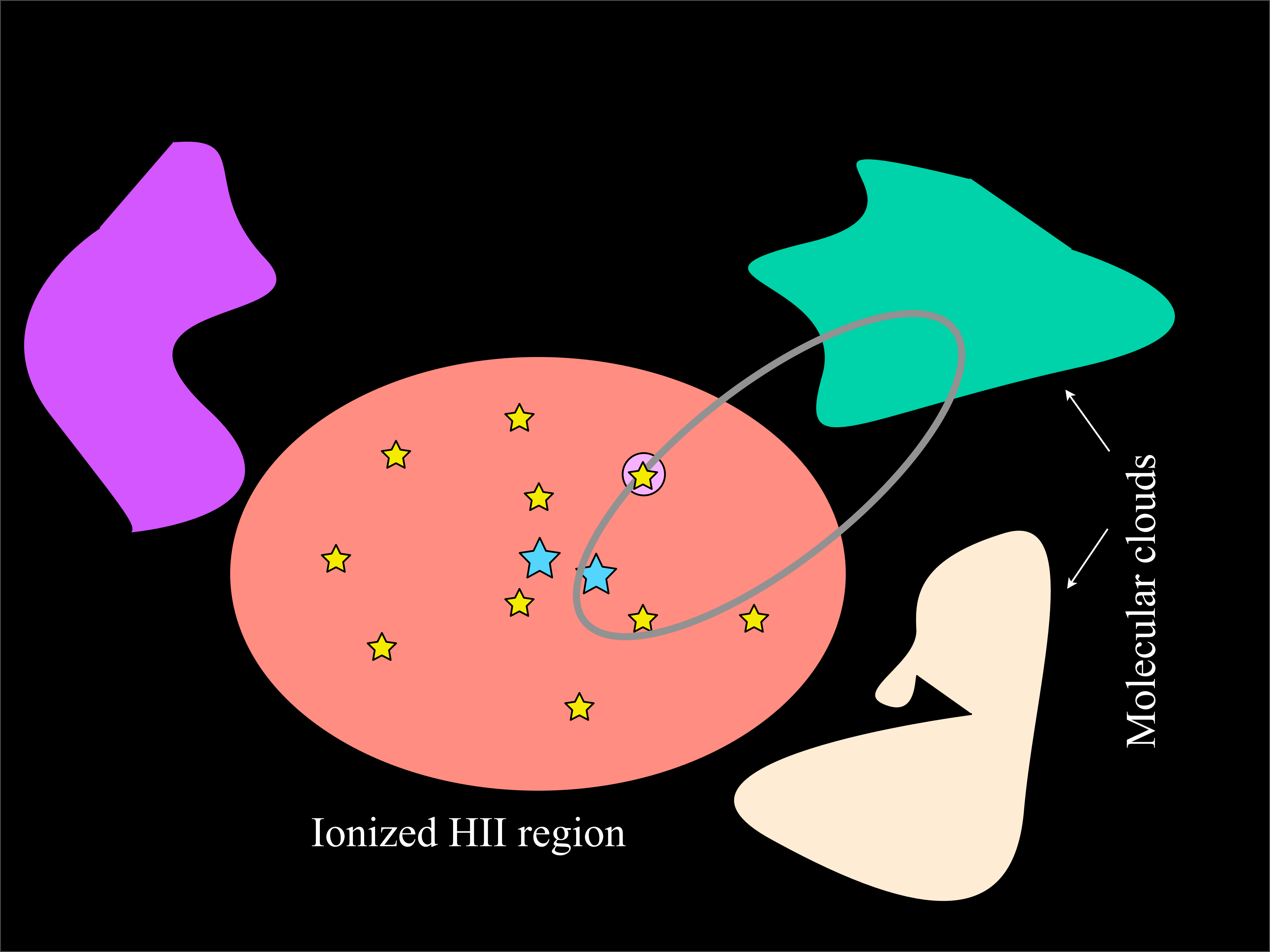

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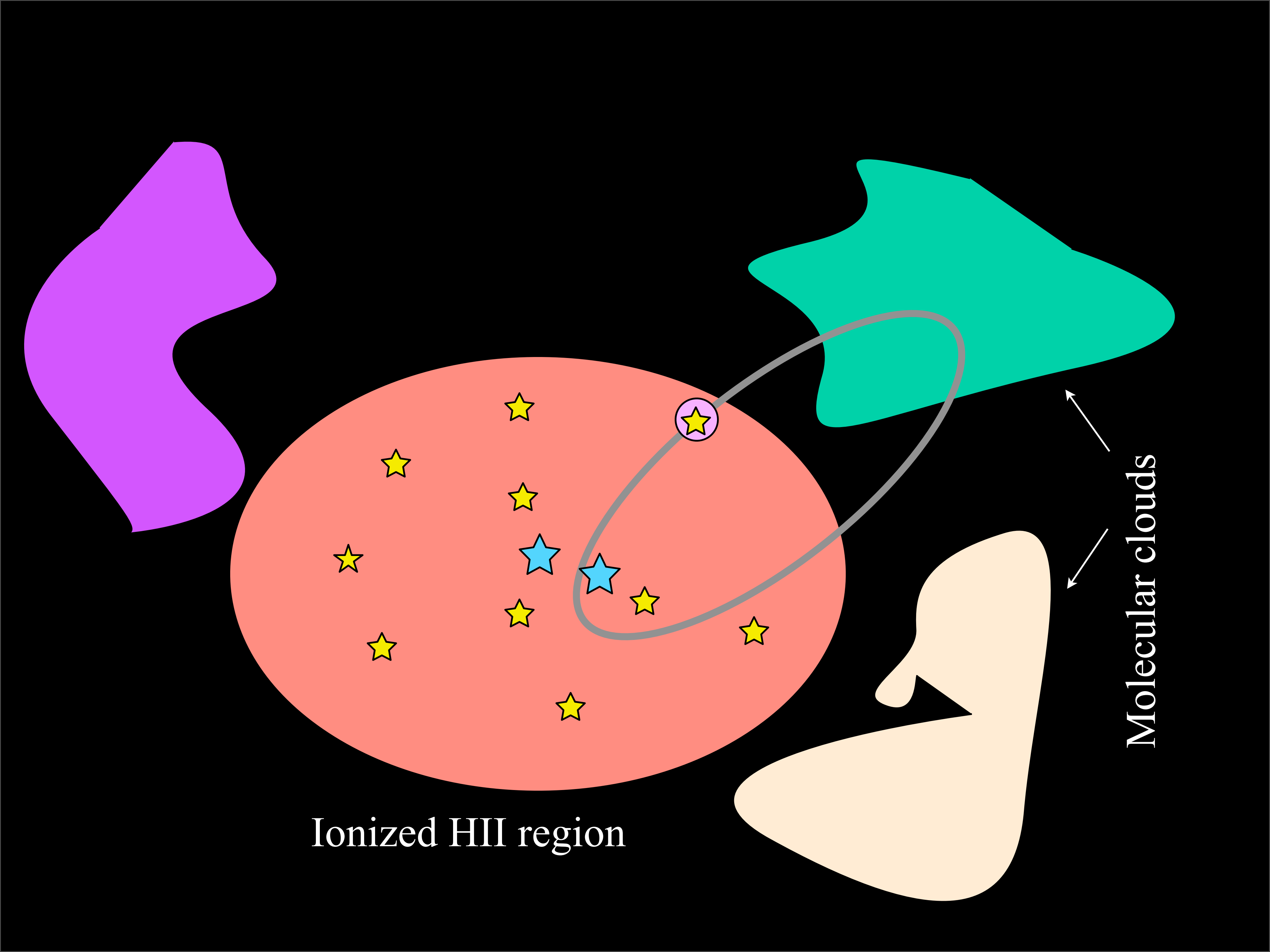
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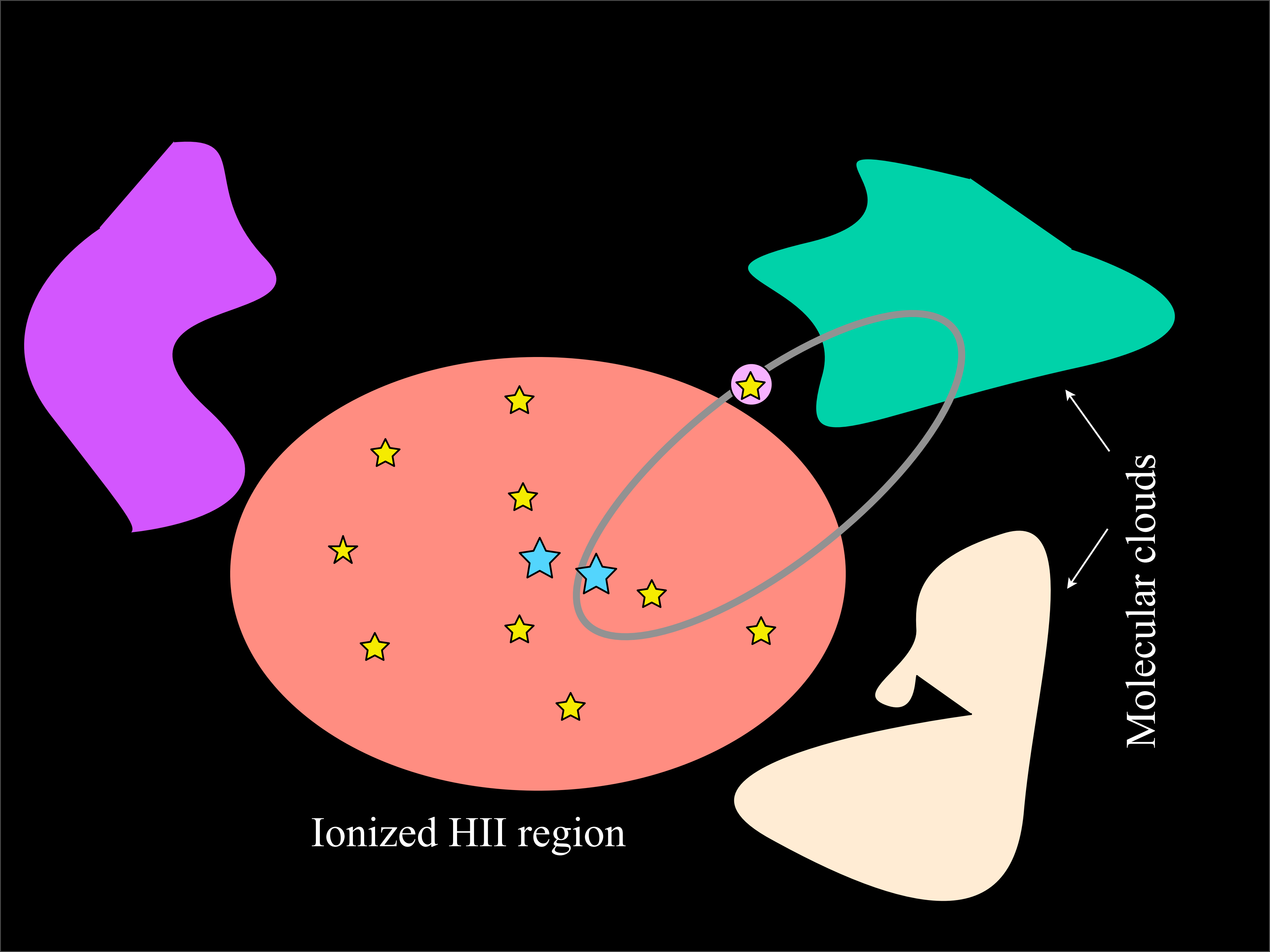
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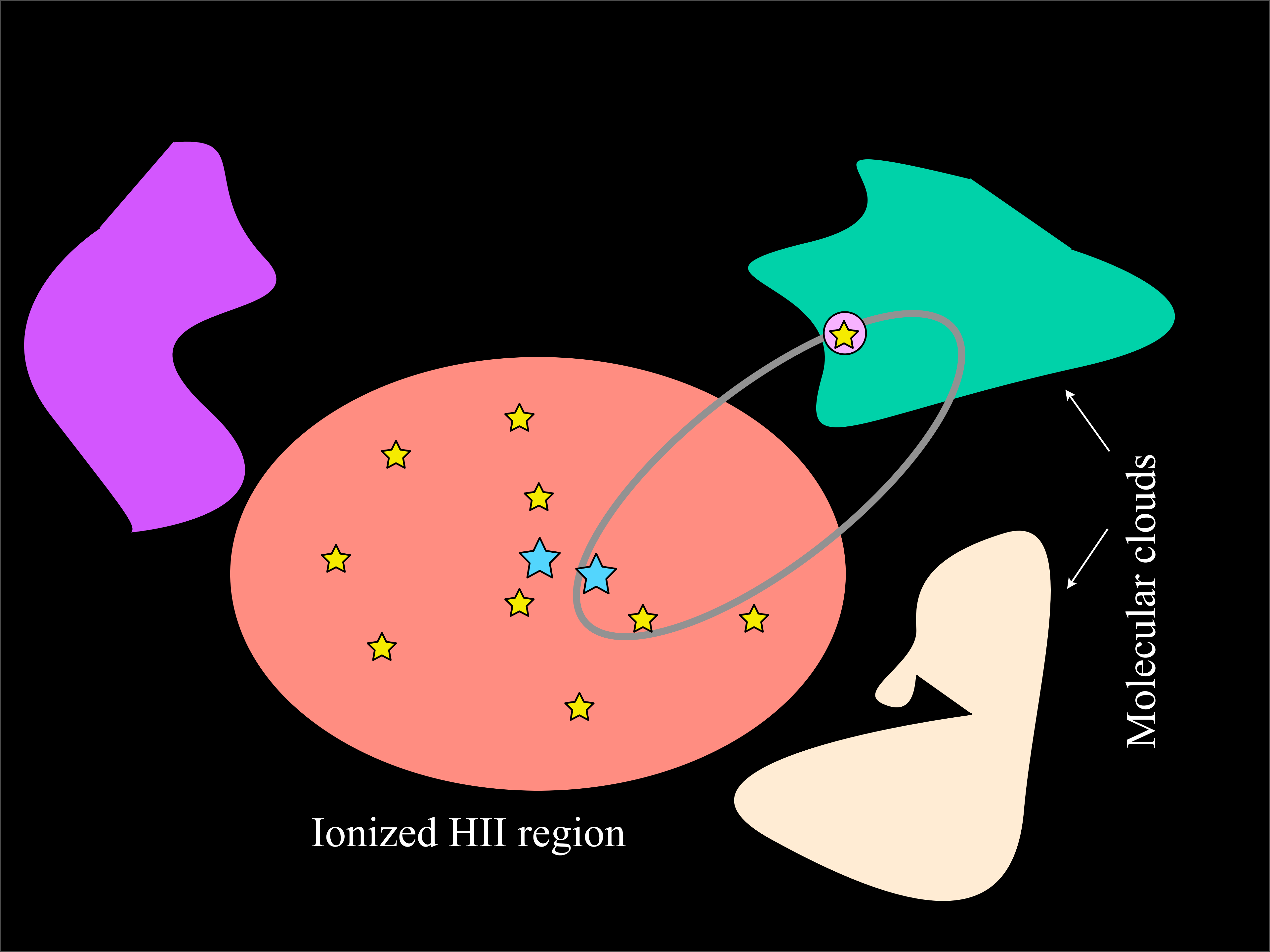

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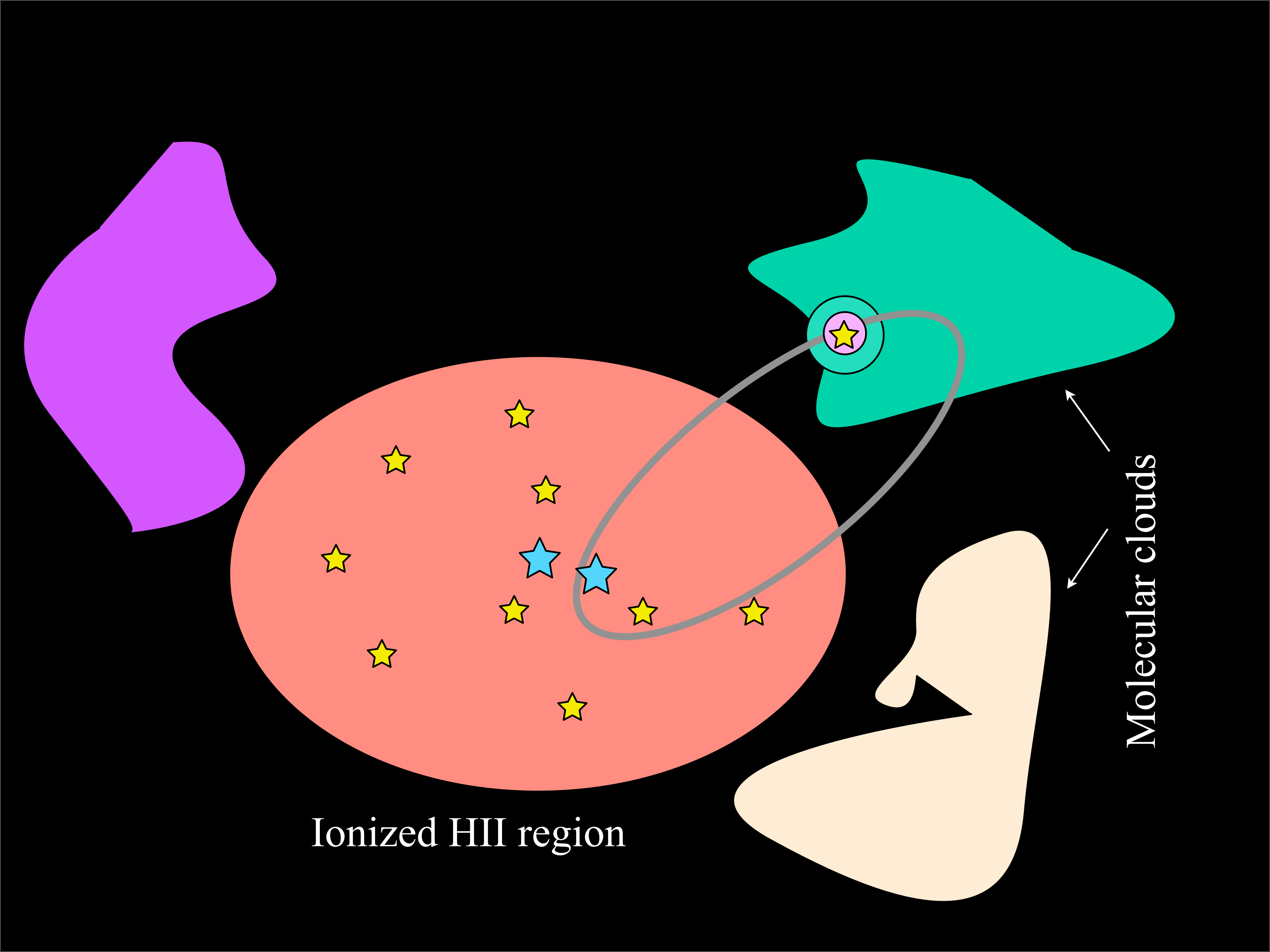
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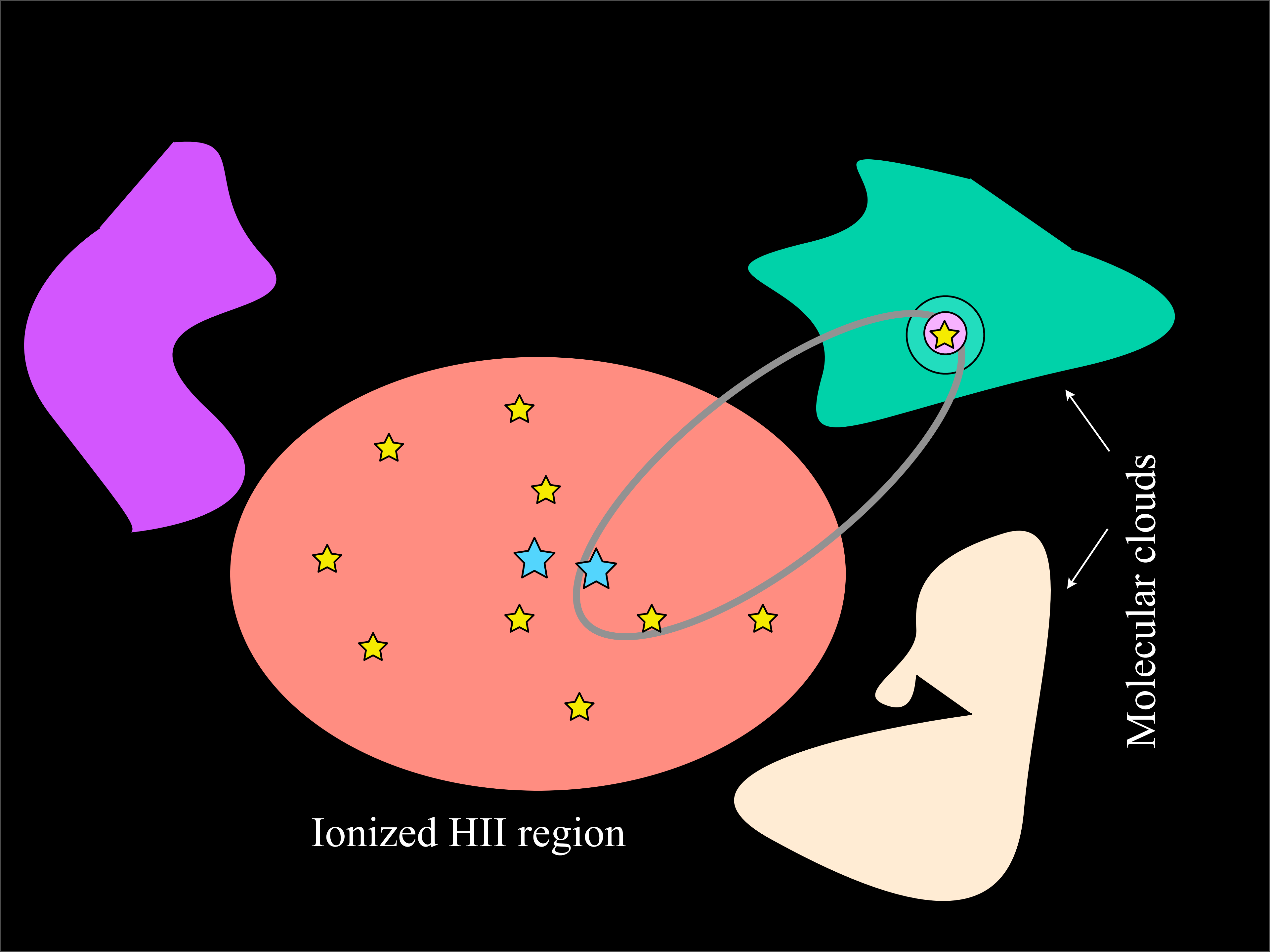
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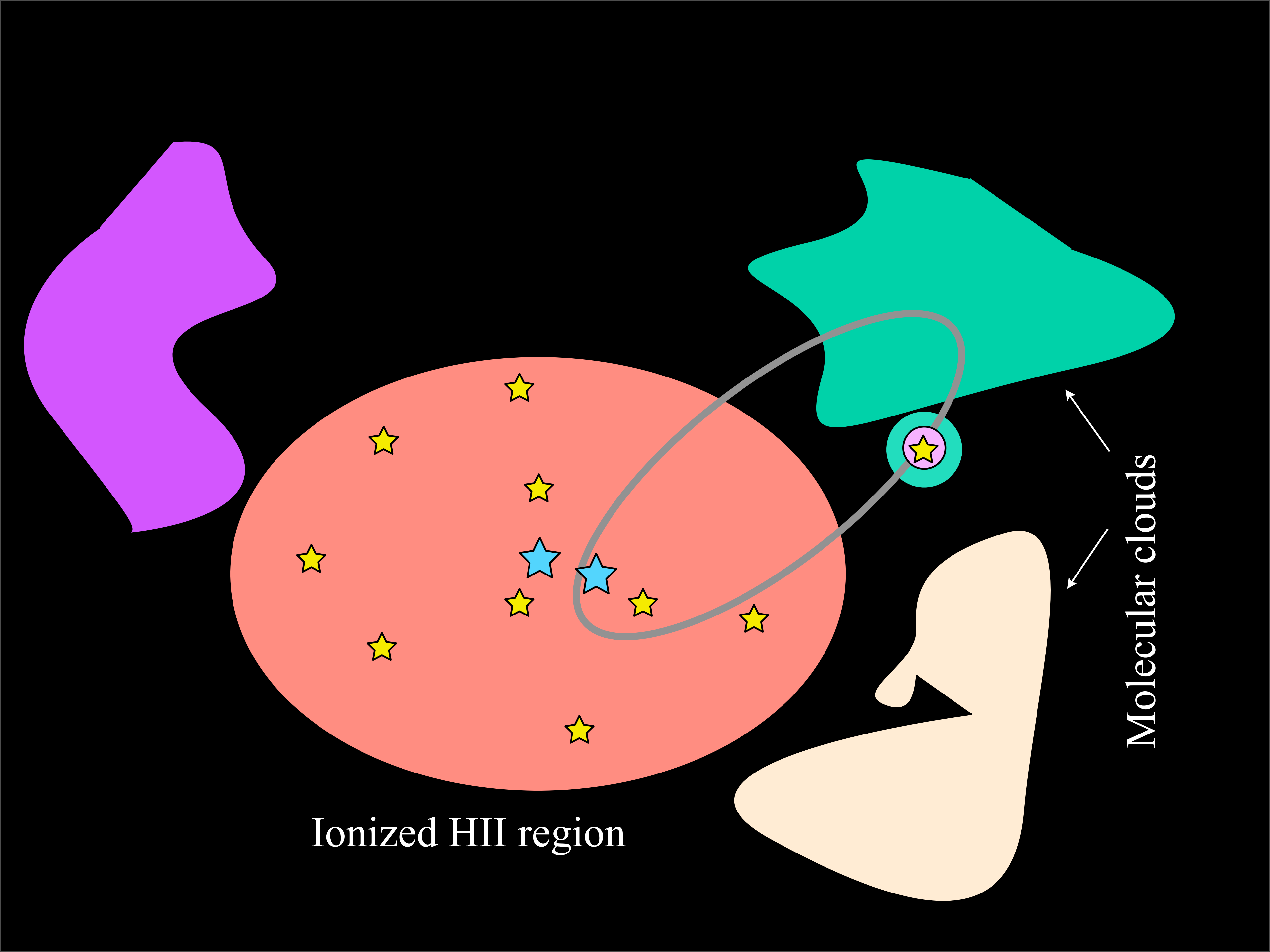
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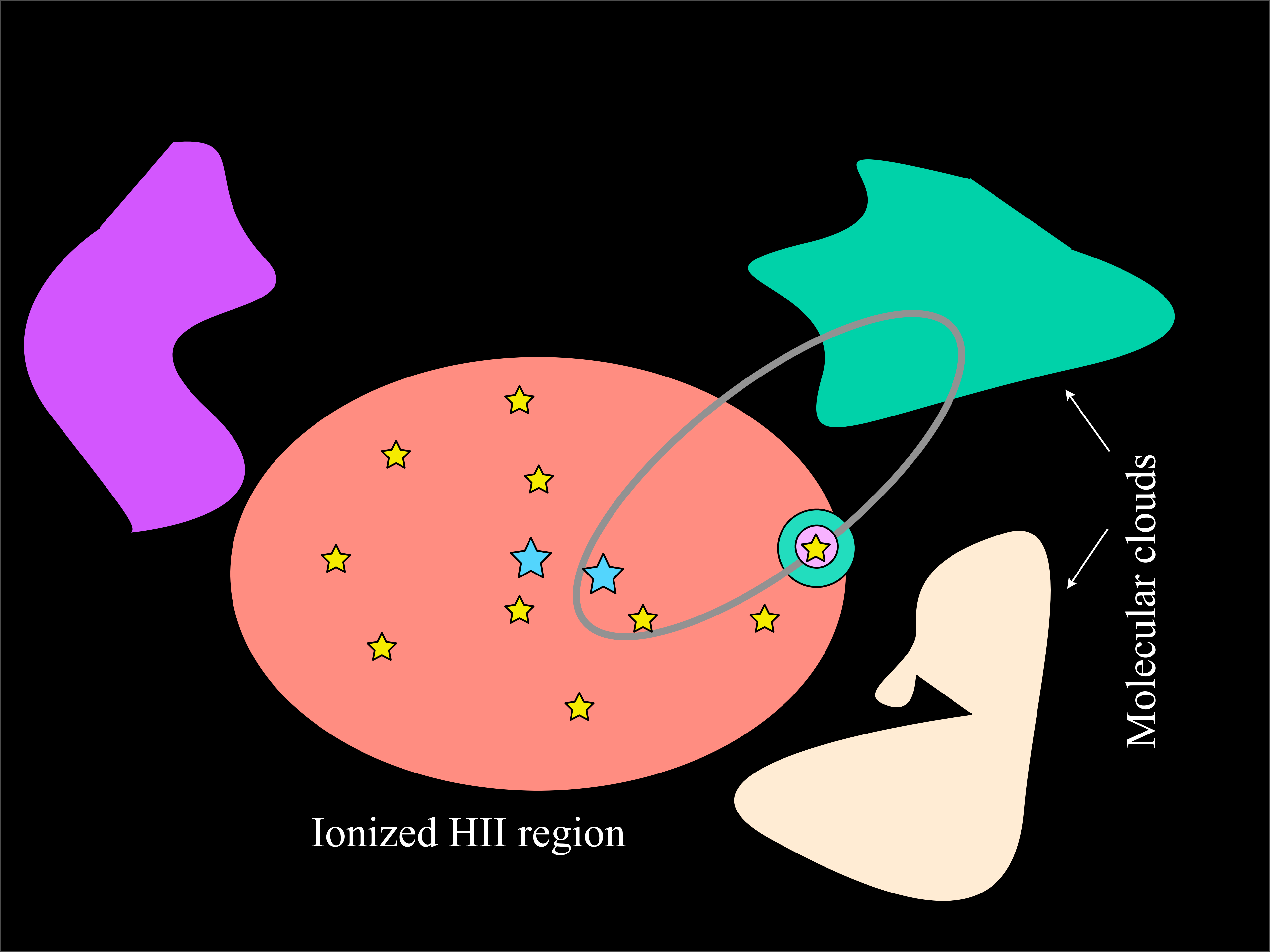
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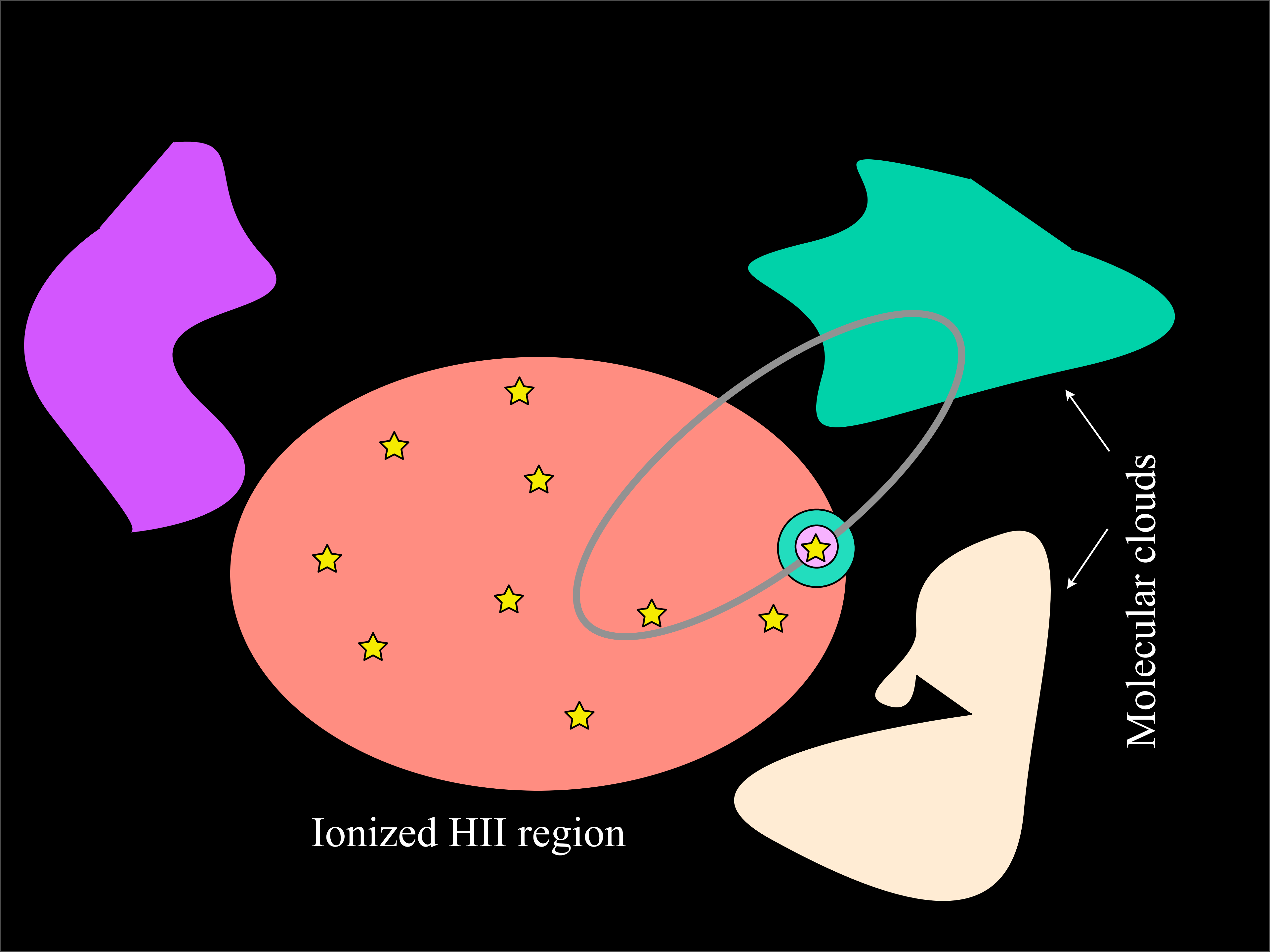
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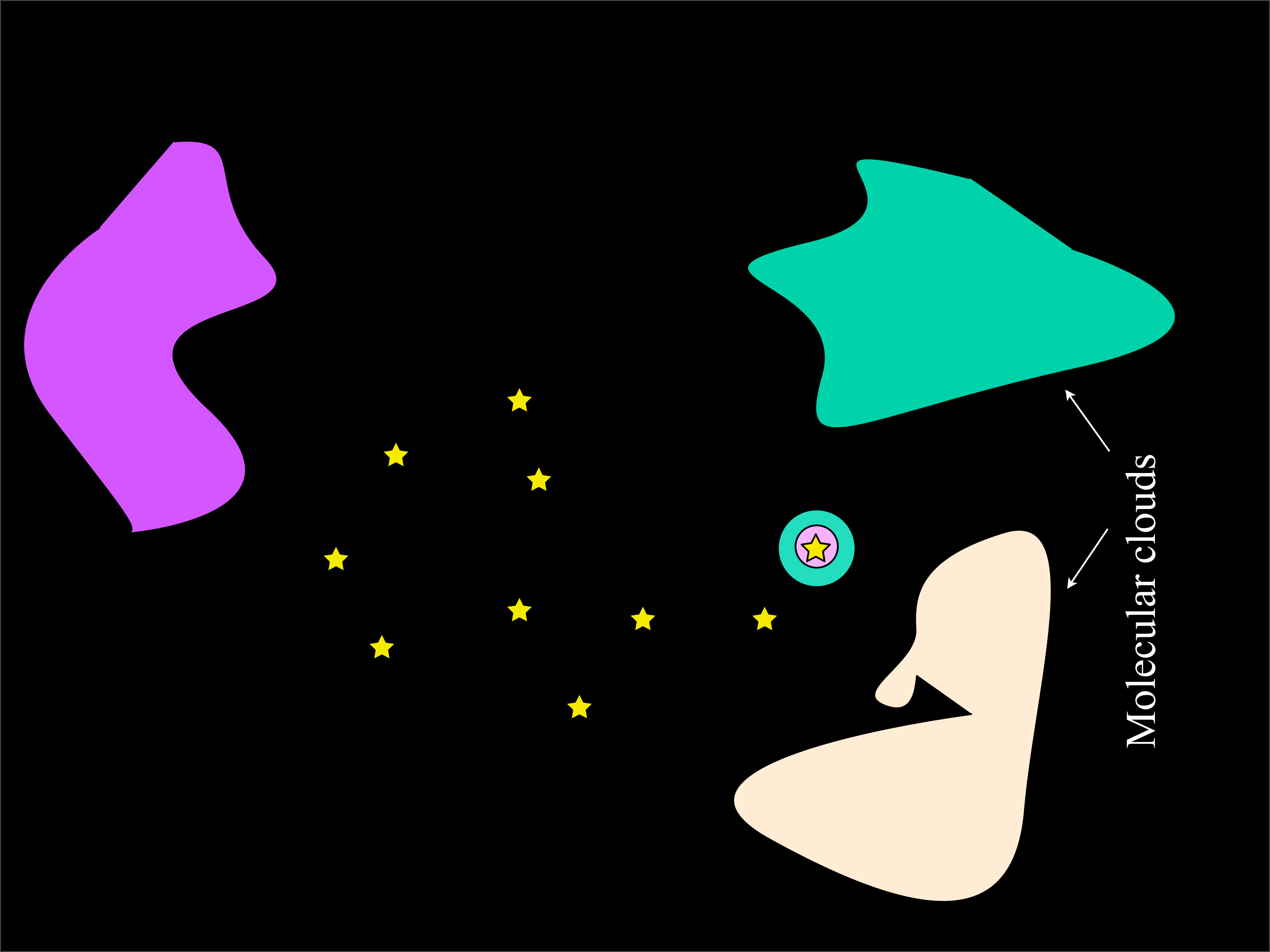
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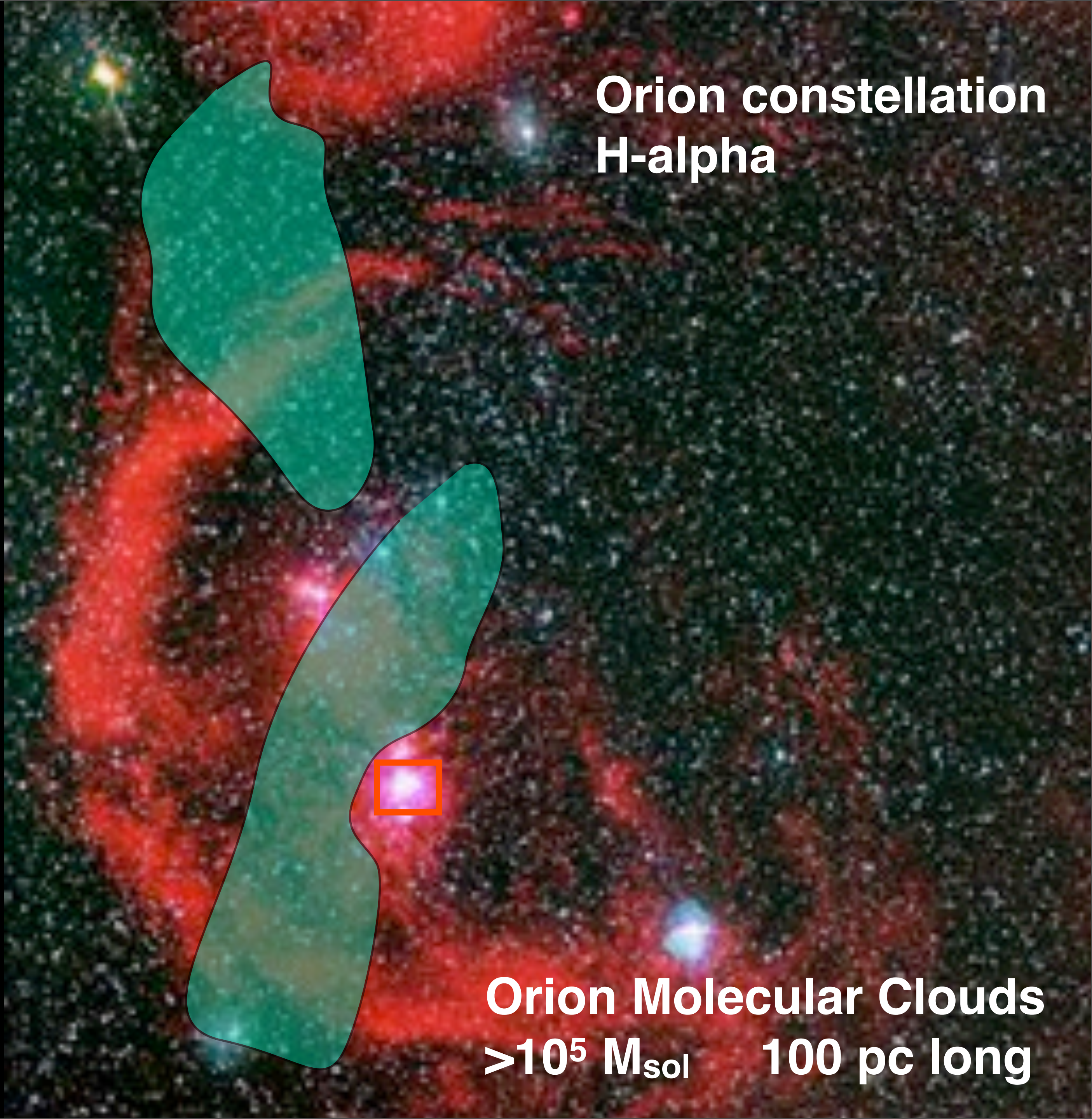
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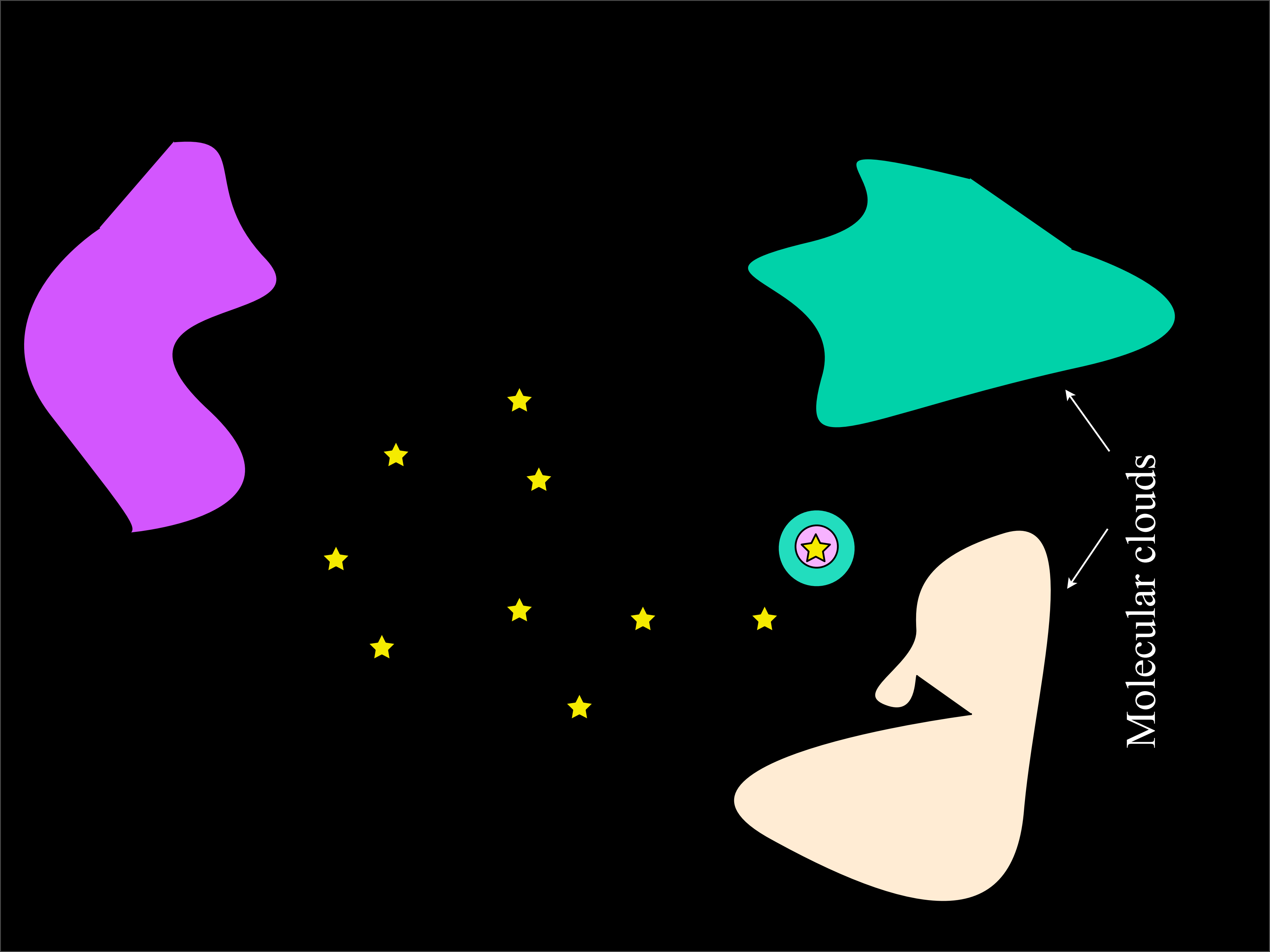
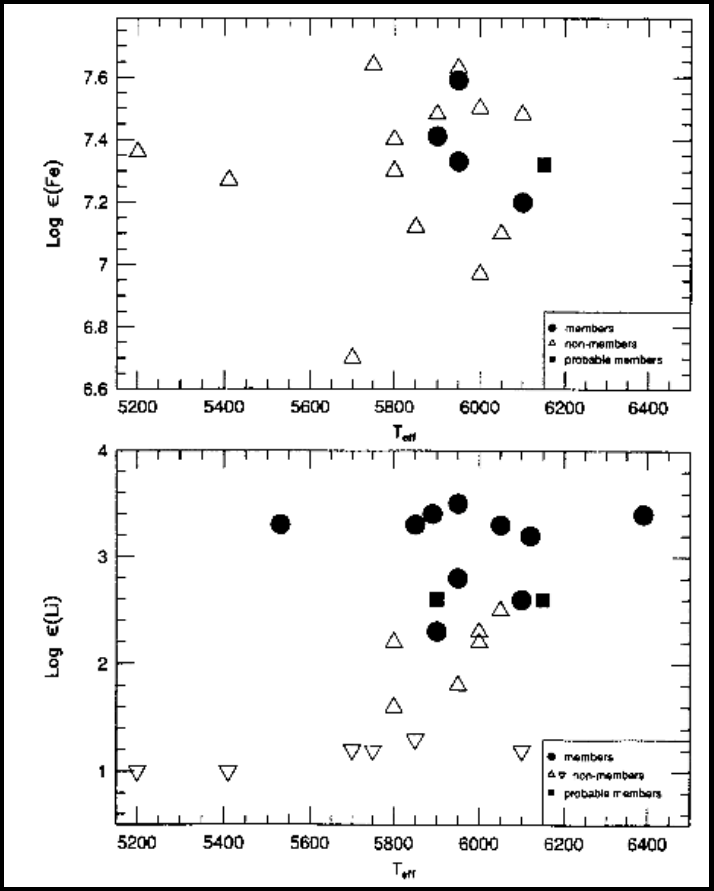

Molecular clouds

Accretion of 'polluted' ISM

- Stars of same age/position/type in Orion show metallicities that vary by up to 4x in Fe, O, Si, C (Cunha et al 1998)
- Could stars have accreted metallic 'veneers' by passing through nearby molecular clouds?
- Molecular clouds contaminated in metals by SN ejecta.



A Crazy idea for forming Jupiters?

1. Star and disk forms in a young cluster
2. Jupiter's rocky core forms slowly
3. Disk gas is photo-evaporated before Jupiter can form
4. Disk gas is rejuvenated by passage through molecular cloud
5. Jupiter forms its atmosphere from new disk

A solution to the ^{60}Fe problem?

- ^{60}Fe is created in supernovae -> Solar System formed in large cluster
- But, in order to directly implant ^{60}Fe into disk we need:
  - Solar System formed in an OB association
  - Solar System was close to an O star, $d < 0.2$ pc
  - But not too close!
  - And this happened at just the right time, as SN explodes
- Odds of this happening: < 1% (Gounelle + Meibom 2008)

We propose instead:

1. Sun forms in molecular cloud
2. O star forms ~ 10 pc away and explodes
3. SN ejecta mixes with ISM, distributes ^{60}Fe
4. Solar System disk accretes ^{60}Fe from ISM

Consequences of Tail-End Accretion

- Total disk mass accreted: ~ 1 MMSN per Myr for 1 M_{sol}
- Disk may still be accreting mass at >5 Myr, after planetesimals form
- Disk may be 'rejuvenated' after being partially lost
- Final composition of disk may be different than star

- Process is robust, and occurs in molecular clouds of all sizes (e.g., Taurus to Orion)

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Astro-ph 8404.0438

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‘Tail-end’ Bondi-Hoyle Accretion in Young Star Clusters: Implications for Disks, Planets, and Stars

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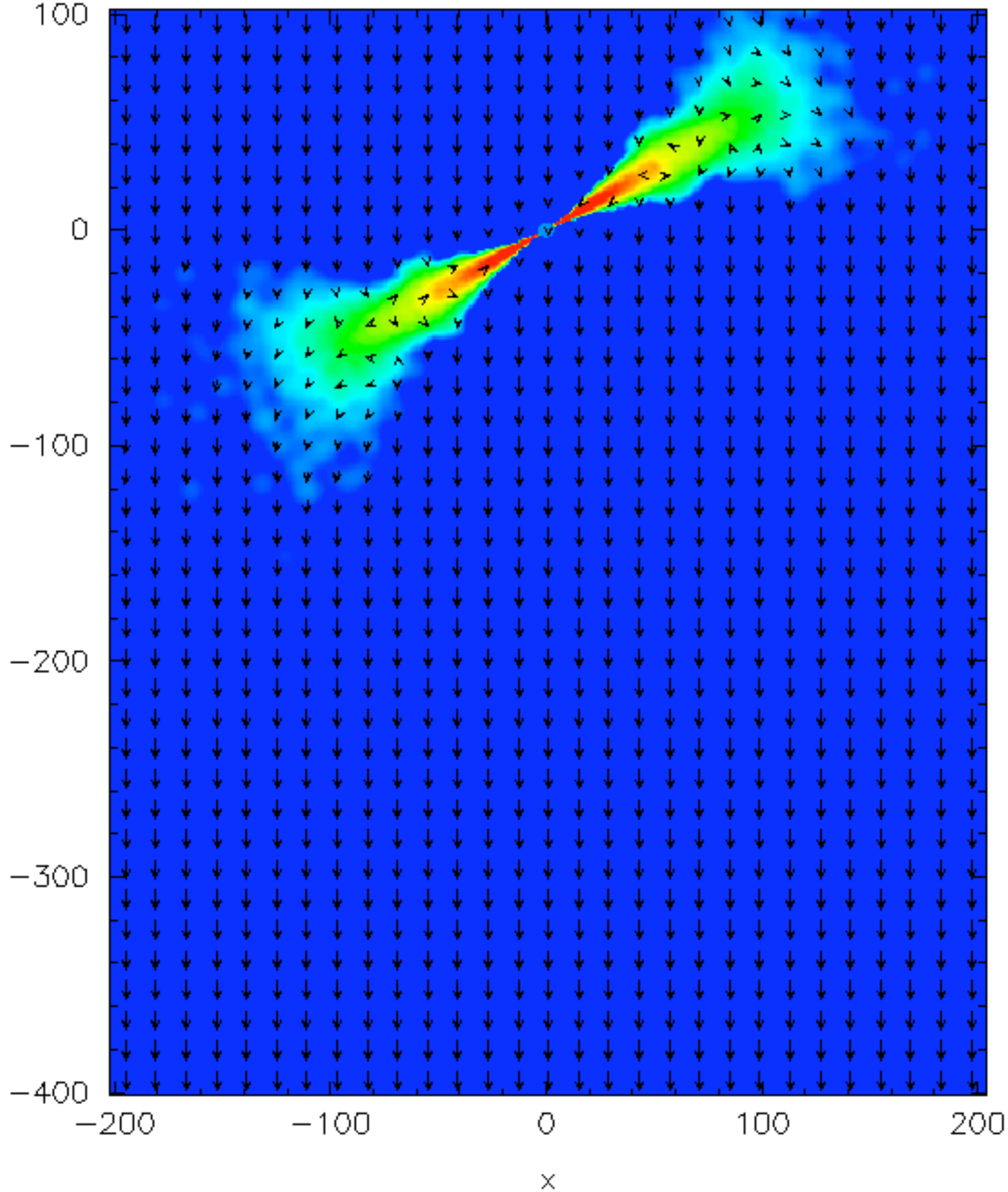
ABSTRACT

Young stars orbiting in the gravitational potential well of forming star clusters pass through the cluster's dense molecular gas and can experience Bondi-Hoyle accretion from reservoirs outside their individual protostellar cloud cores. Accretion can occur for several million years after the stars form, but before the cluster disperses. This accretion is predominantly onto the disk and not the star. N-body simulations of stars orbiting in three young model clusters containing 30, 300, and 3000 stars are presented. The simulations include the gravitational potential of the molecular gas which smoothly disperses over time. The clusters have a star formation efficiency of 33% and a radius of 0.22 pc. We find that the disks surrounding solar-mass stars in the N=30 cluster accretes ~ 0.01 $M_\odot$ (1 minimum-mass solar nebula, MMSN) per Myr, with a 1σ width of 50 times due to variations in initial stellar positions and velocities within the cluster. The accretion rate scales as $M^{2.1\pm0.1}$ for stars of mass M. The accretion rate is ~ 5 times lower for N=3000 cluster, due to its higher stellar velocities and higher temperature. The Bondi-Hoyle accretion rates onto the disks are ~ 5 times lower than accretion rates observed directly onto young stars (*e.g.*, Muzerolle et al. 2005): these two accretion rates follow the same M^2 behavior and may be linked, or may be unrelated. Nevertheless, the accreted disk mass is large enough that it may have


The
End



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