Gas Accretion from the ISM onto Circumstellar Disks

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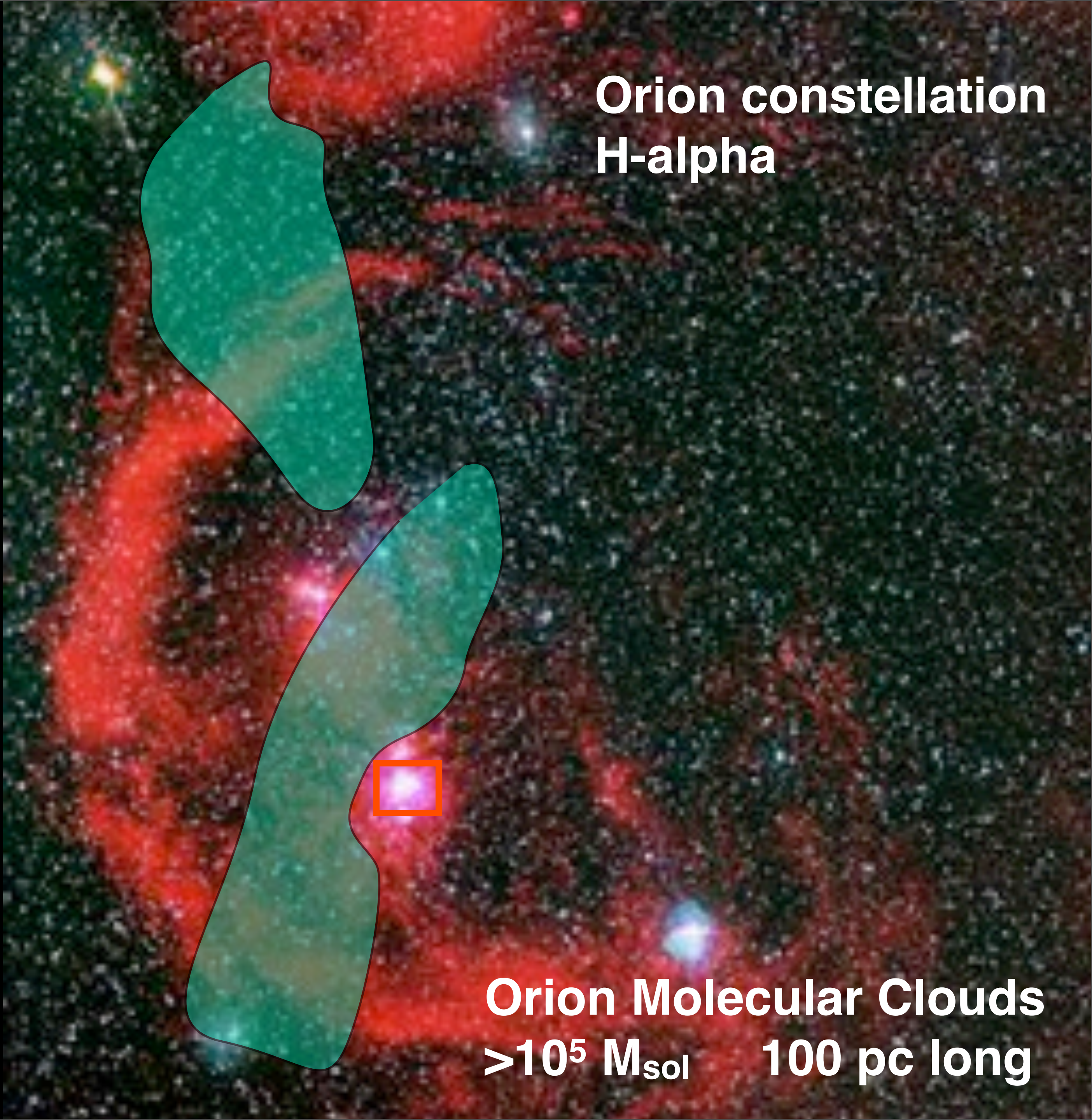
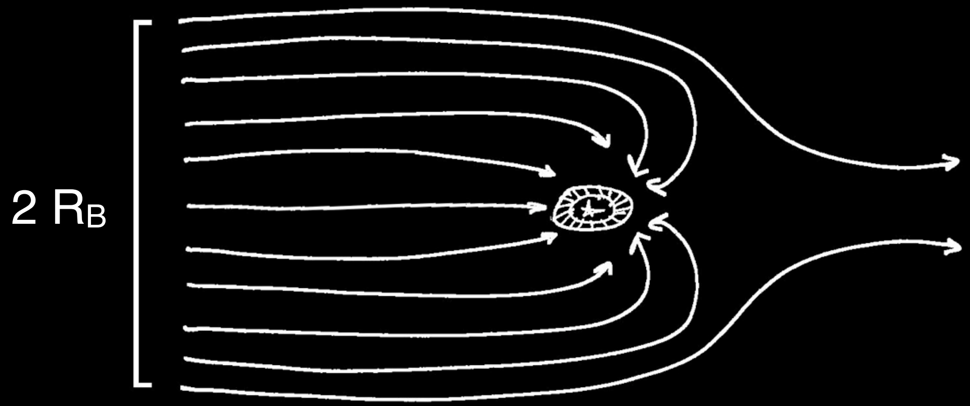
Orion Constellation
(visible light)


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!

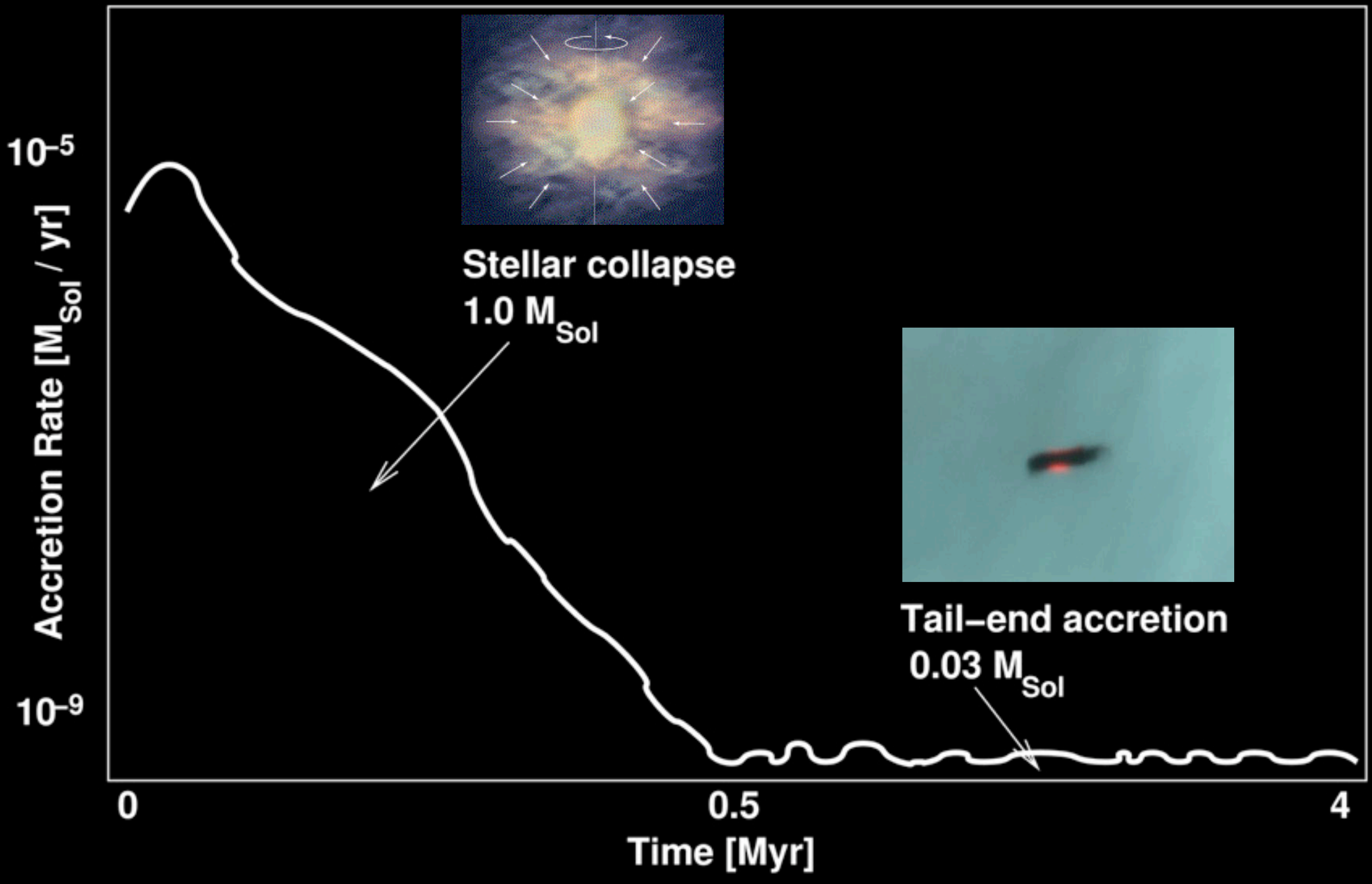
$$R_{\mathrm{B}} = \frac{2\,G\,M}{(v^2 + c_s^2)}$$

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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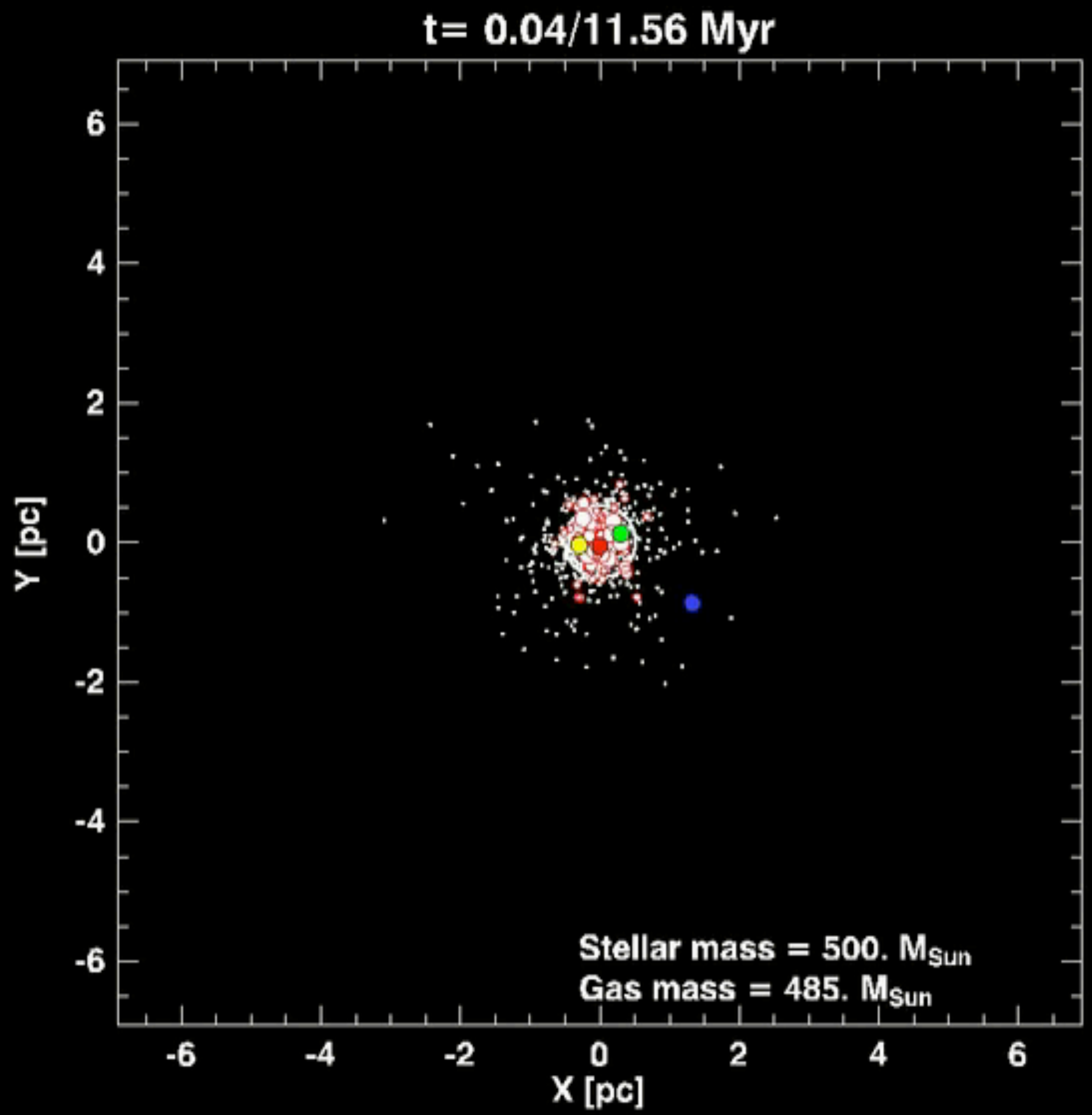

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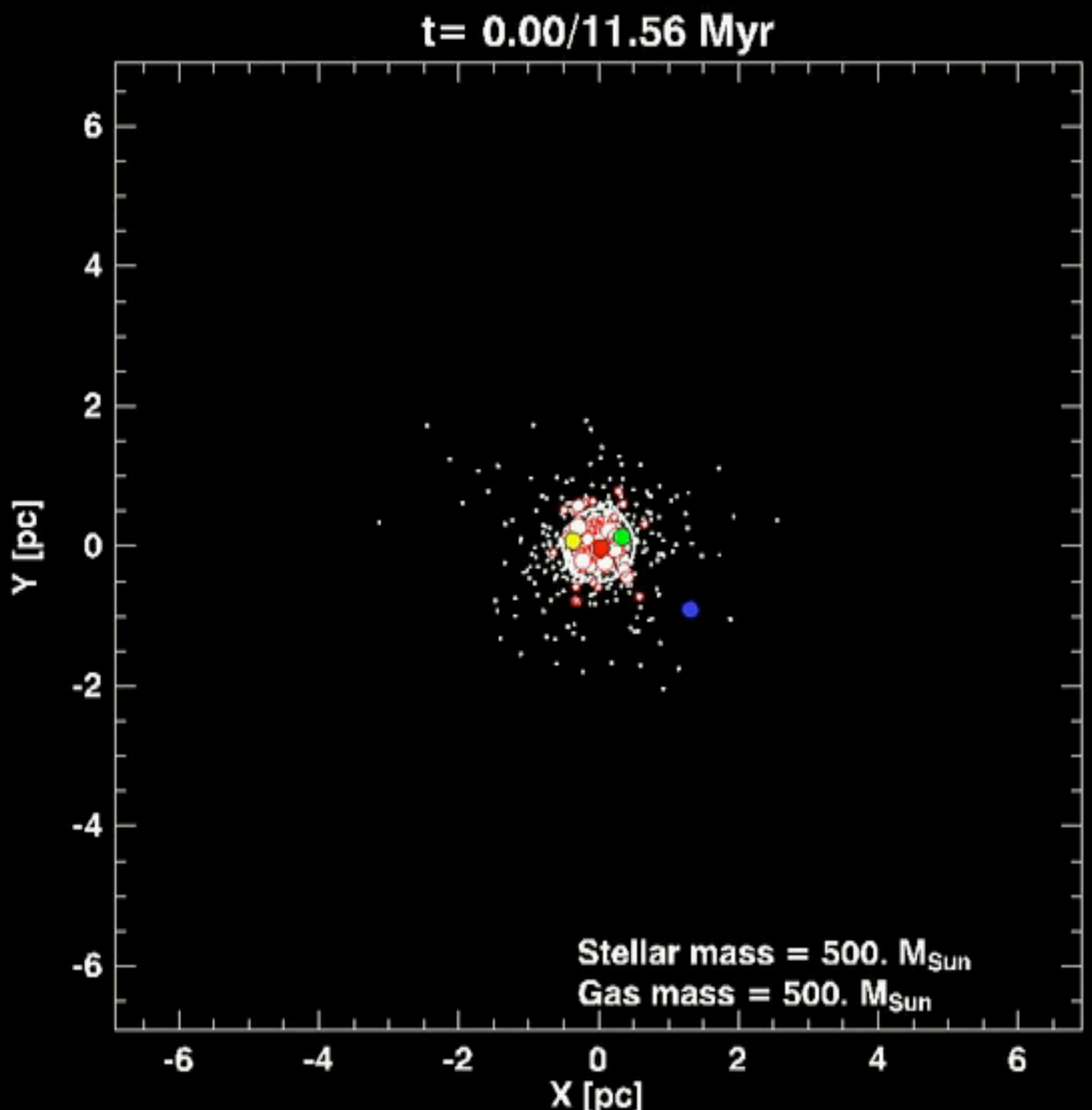

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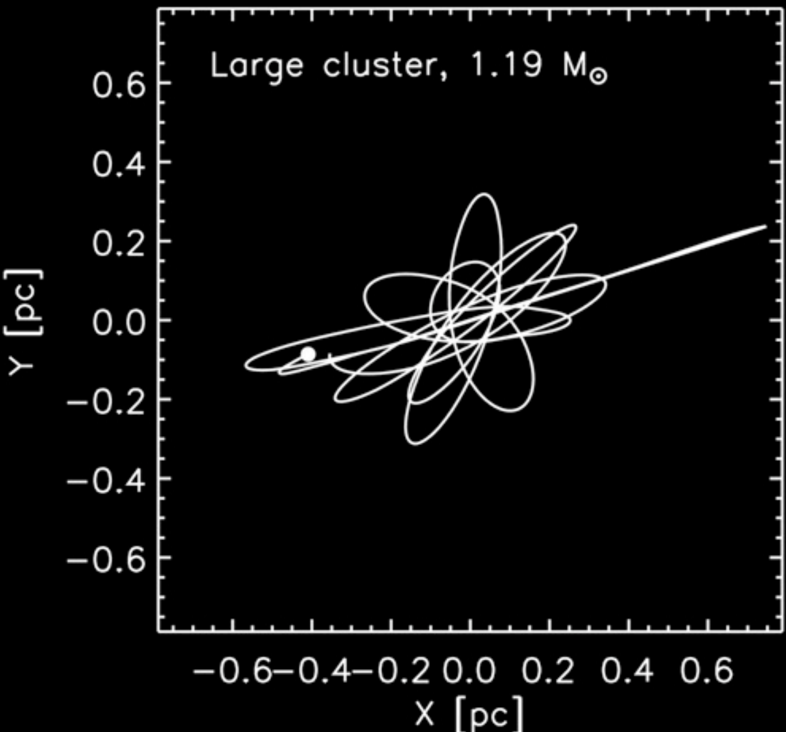
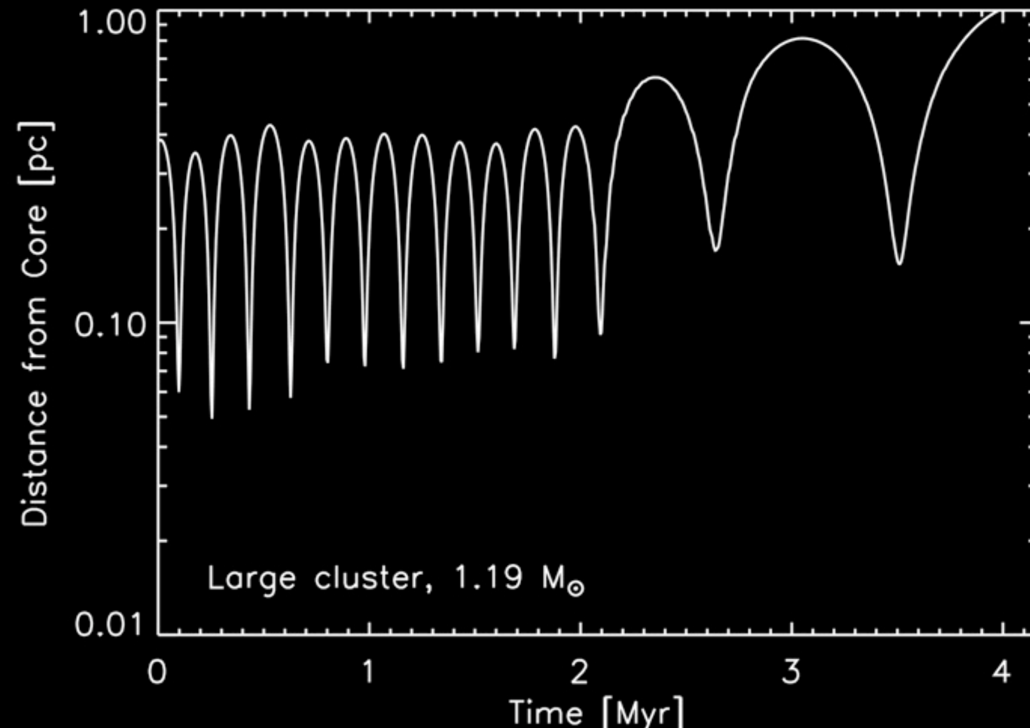
BH Accretion: History of individual star





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

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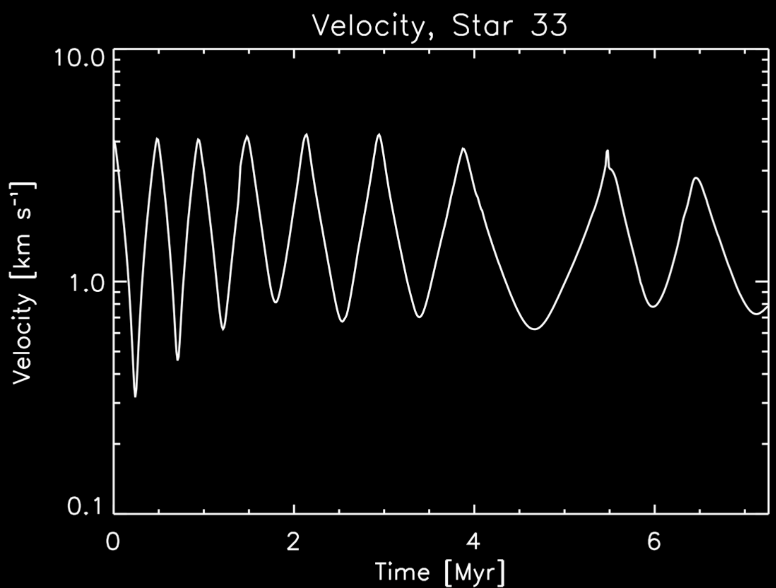
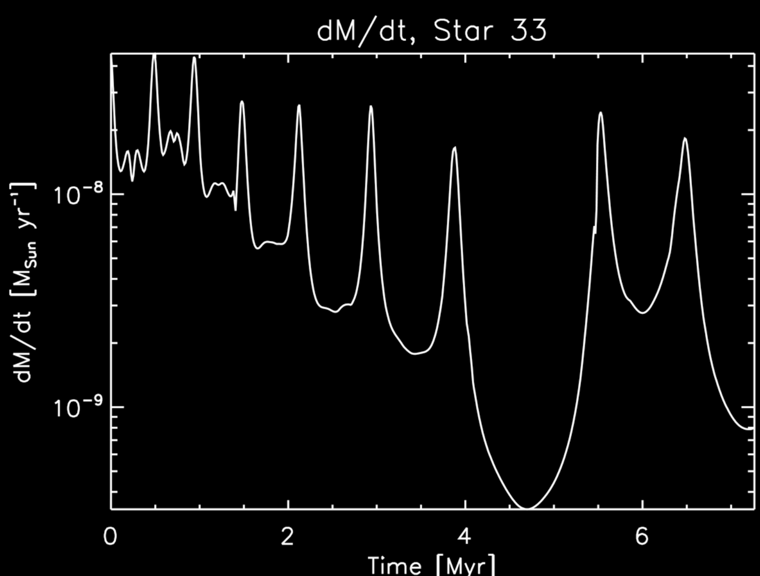
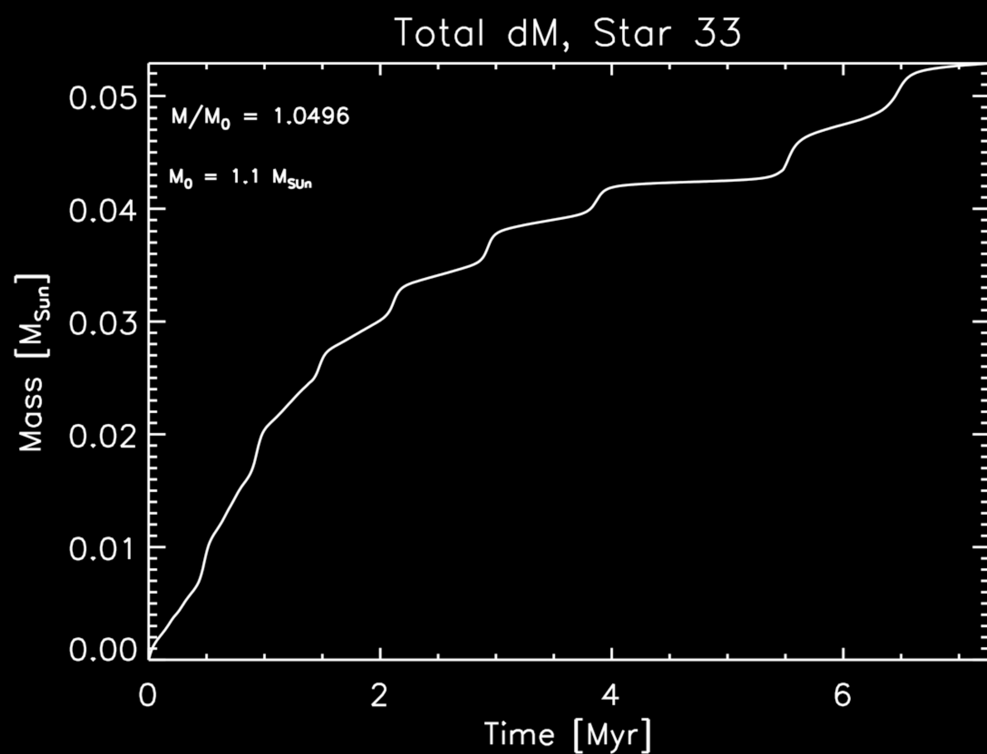




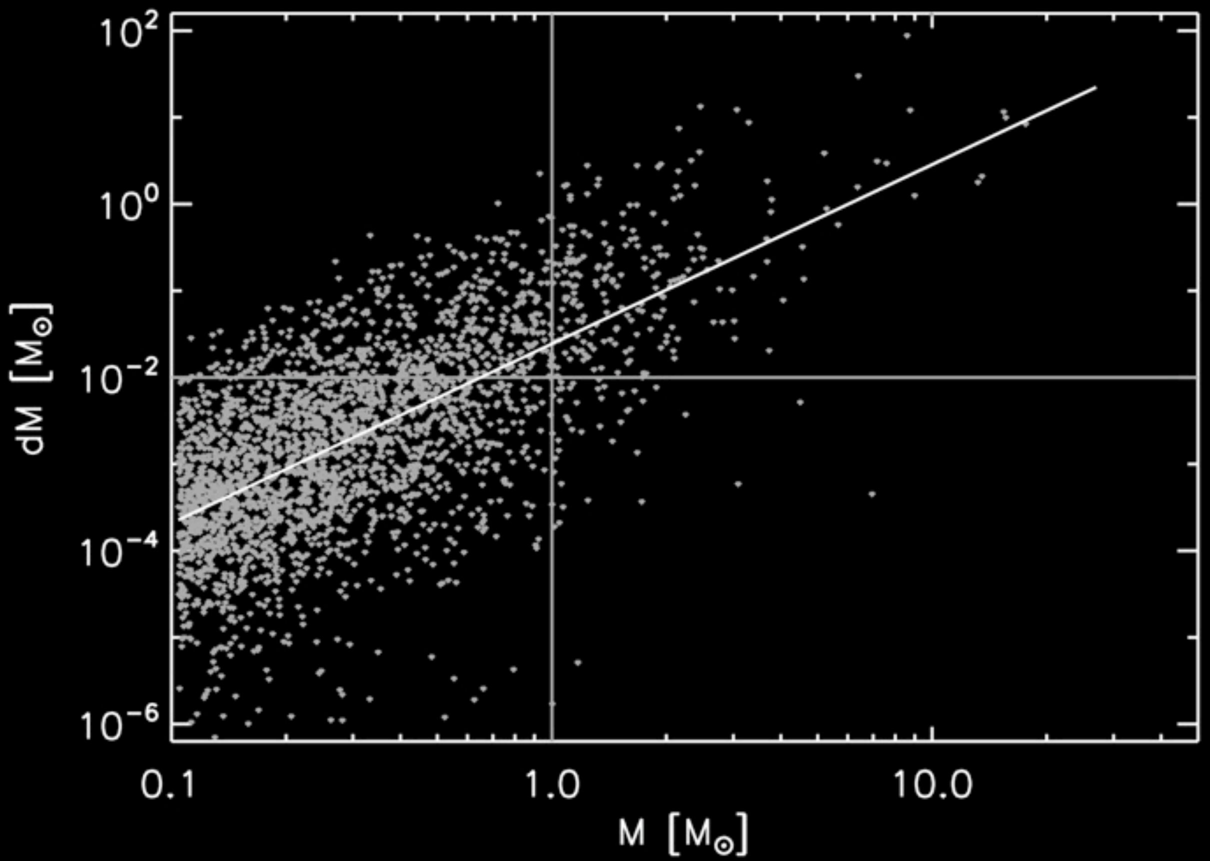


Star+disk accretes 5% of own mass in 5 Myr.

Accretion is episodic

- Highest at core: High velocity but high density

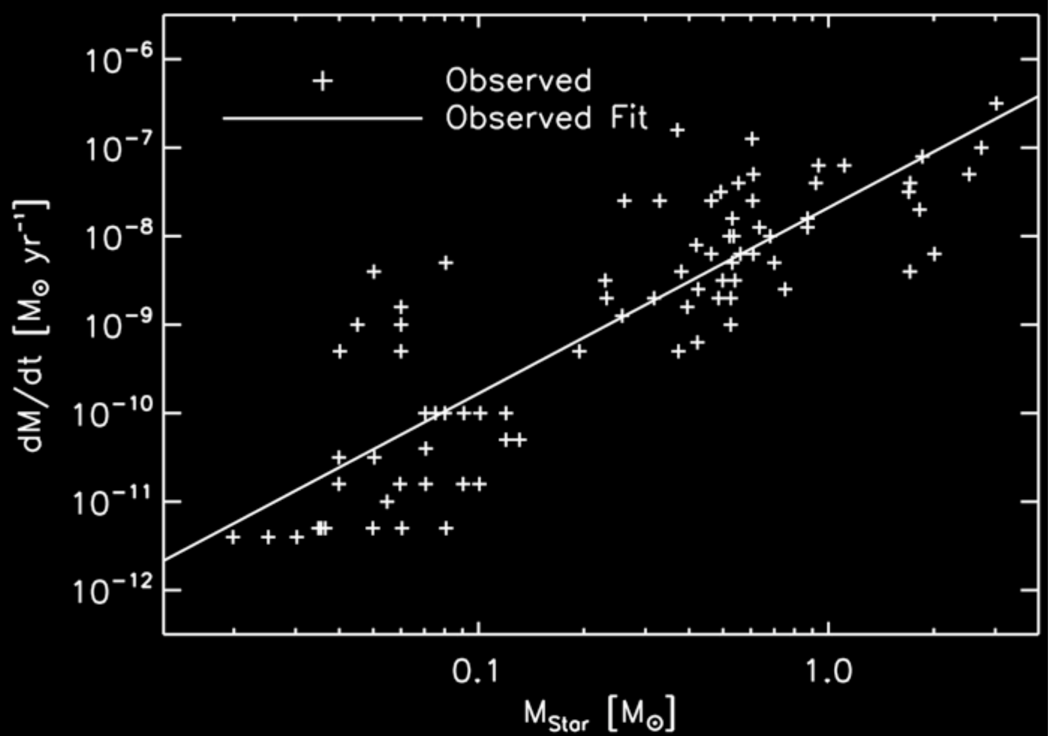
Results of N-Body sims



- 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 ~ M^2
  - Natta et al 2006, Muzerolle et al 2005, etc
- Accretion is ~ 0.01 $M_\odot$ Myr^{-1}
- There is no accepted physical explanation for this relationship.



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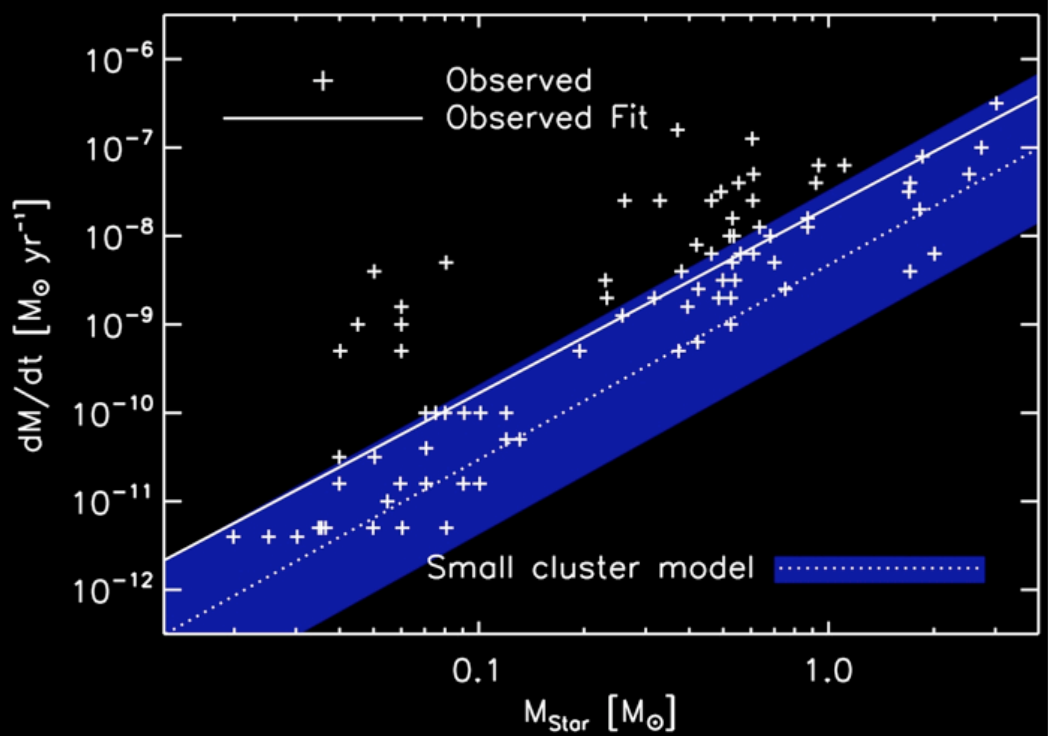
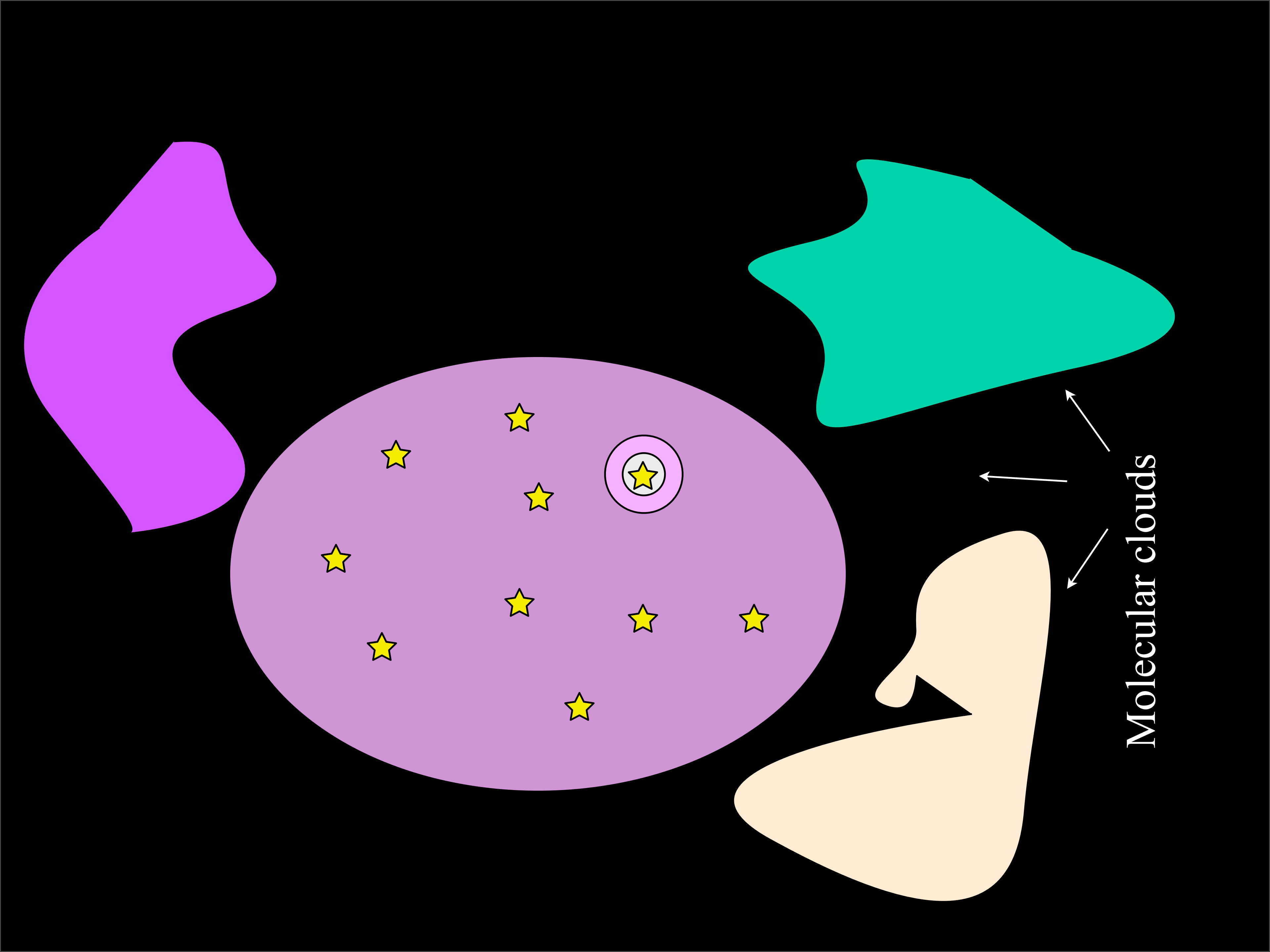
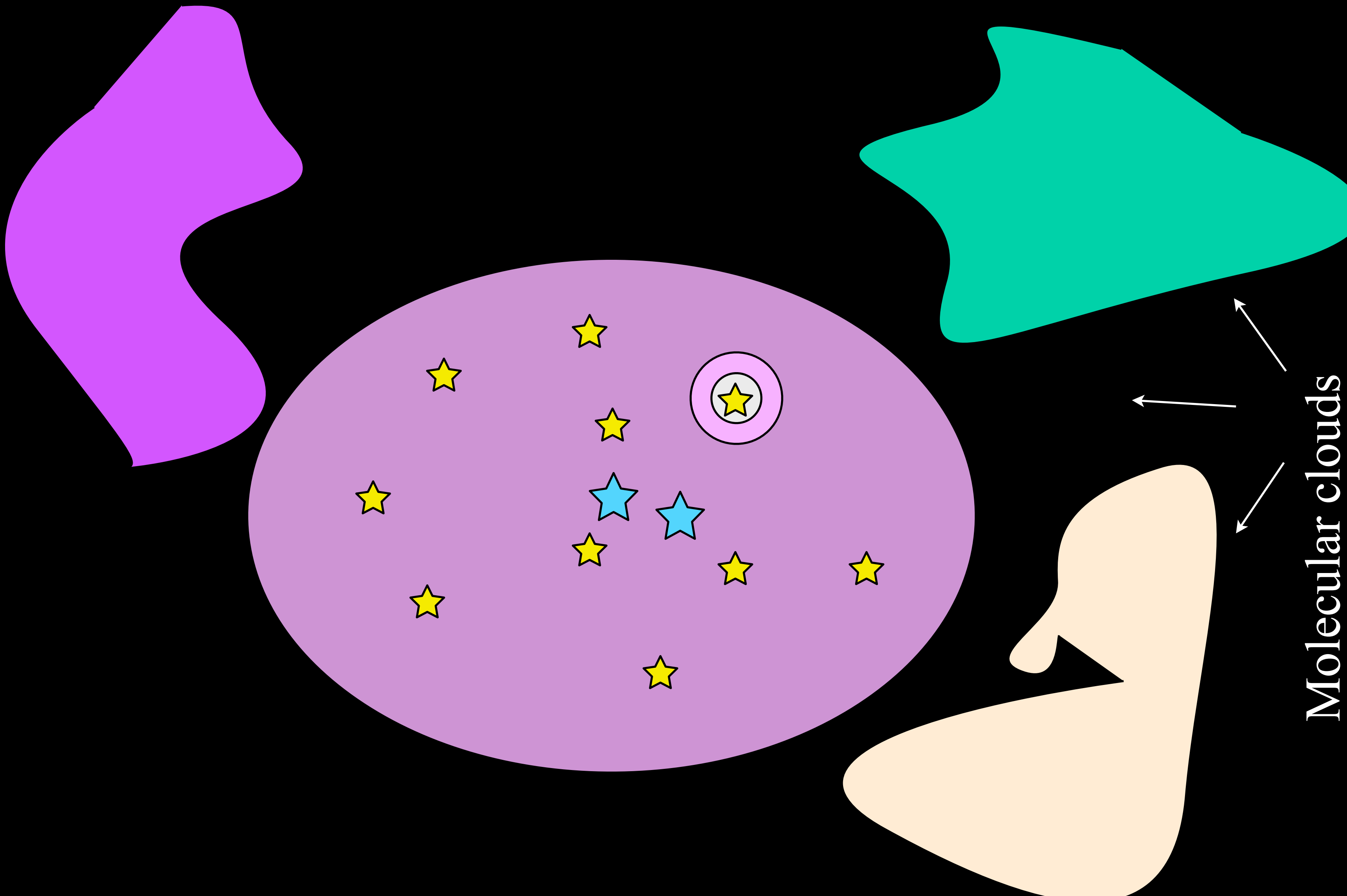


Accretion onto young stars may be a consequence and confirmation of ISM accretion onto their disks


Molecular clouds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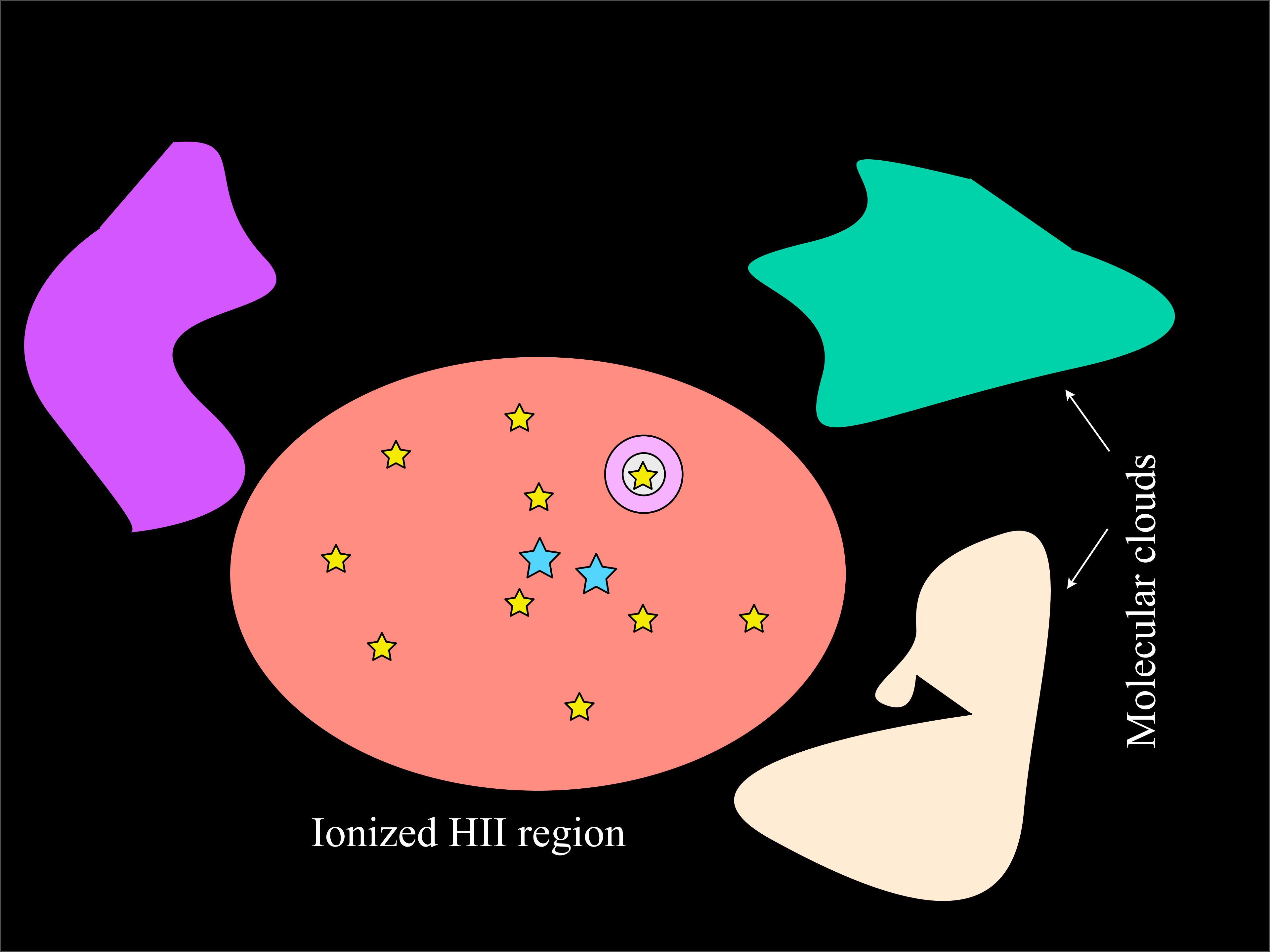
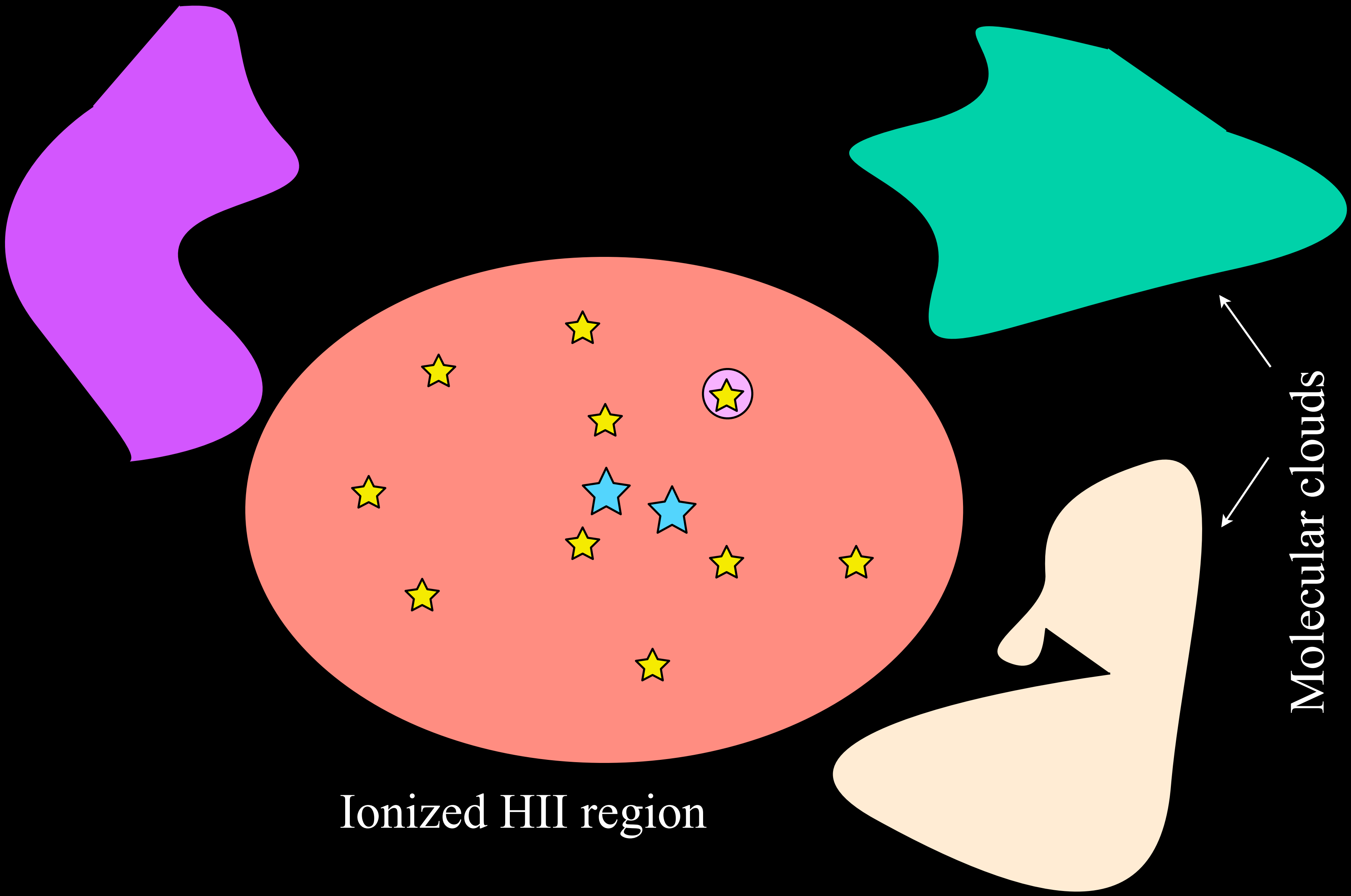

Molecular clouds
Ionized HII region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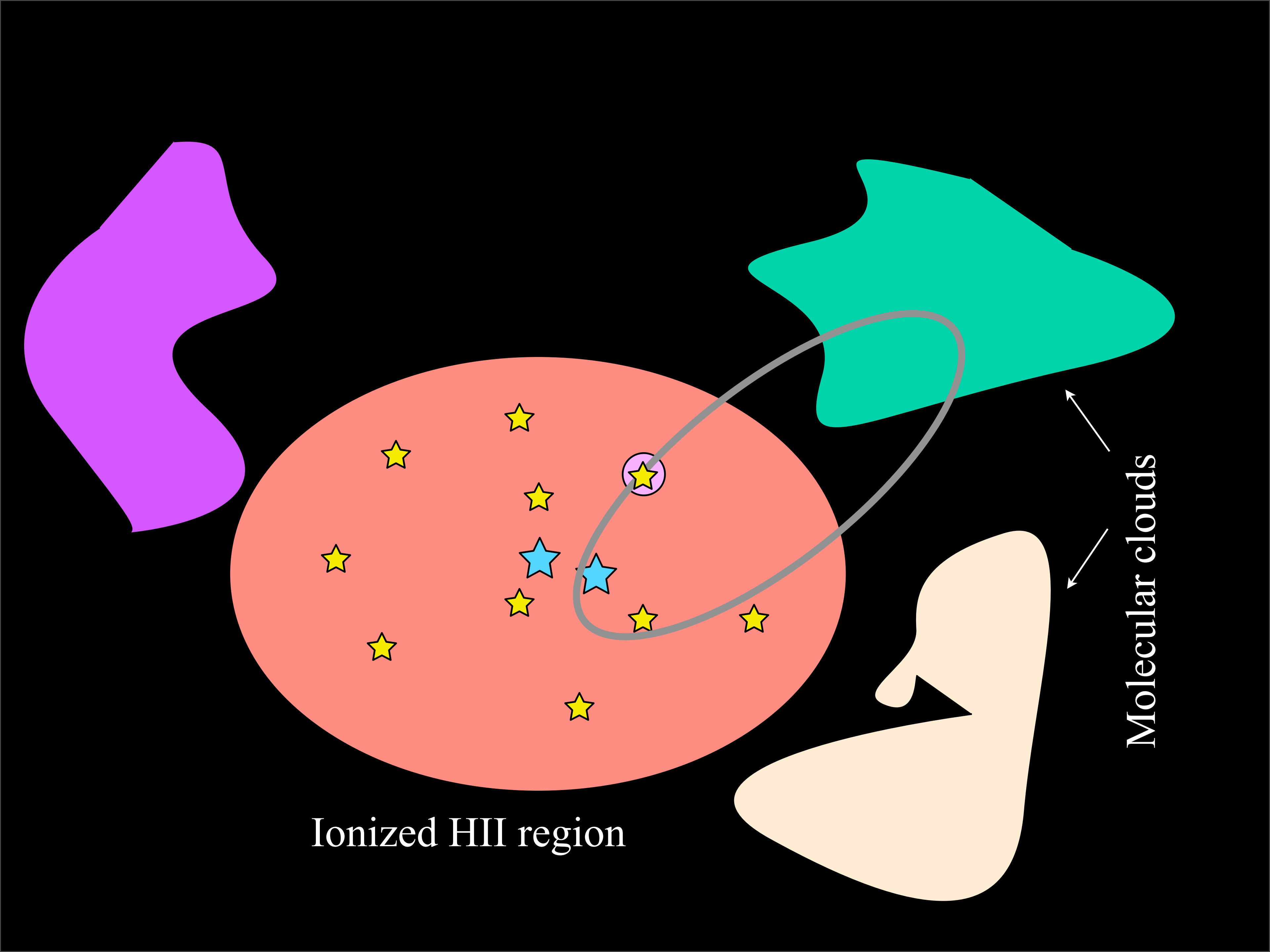
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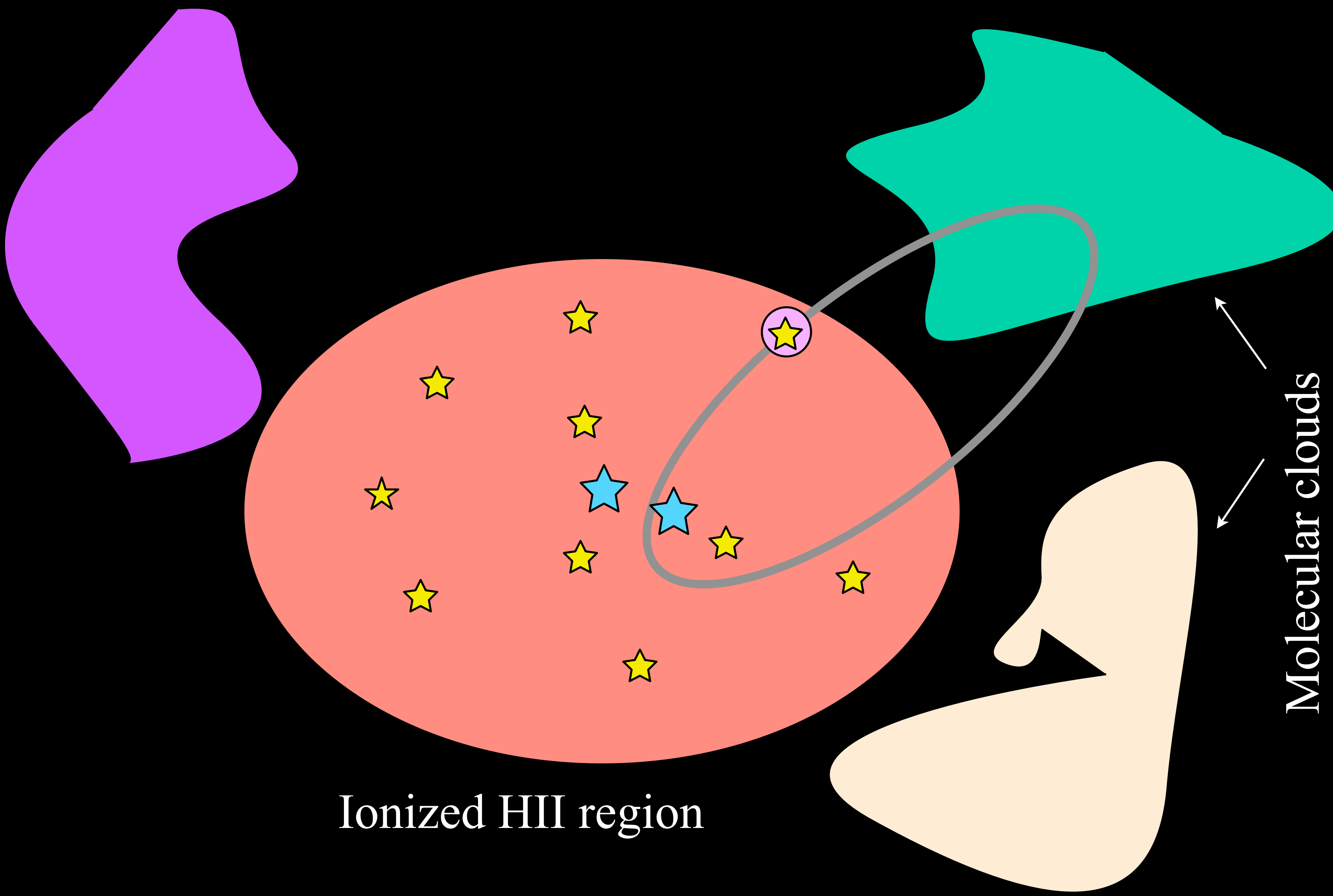

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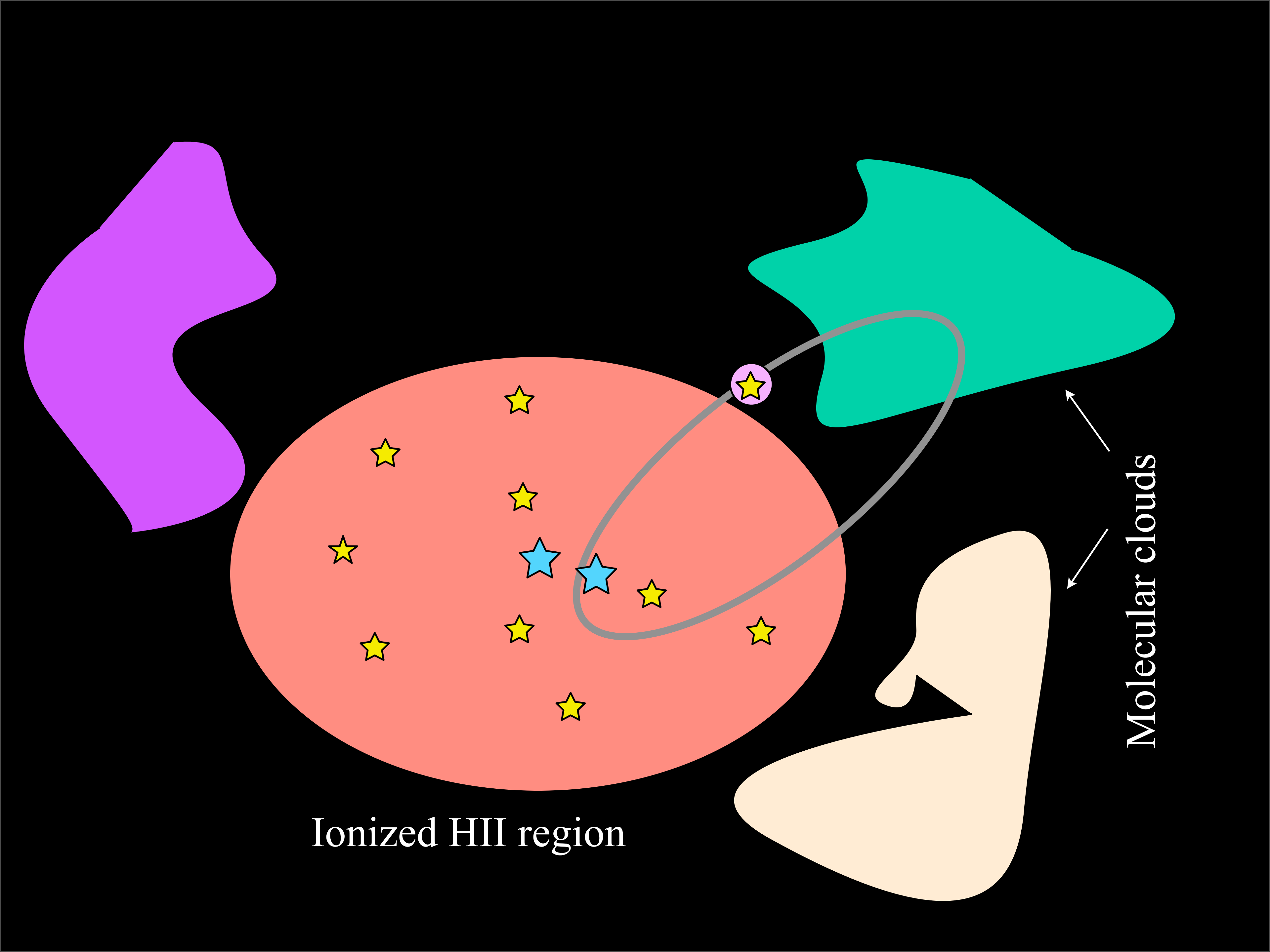
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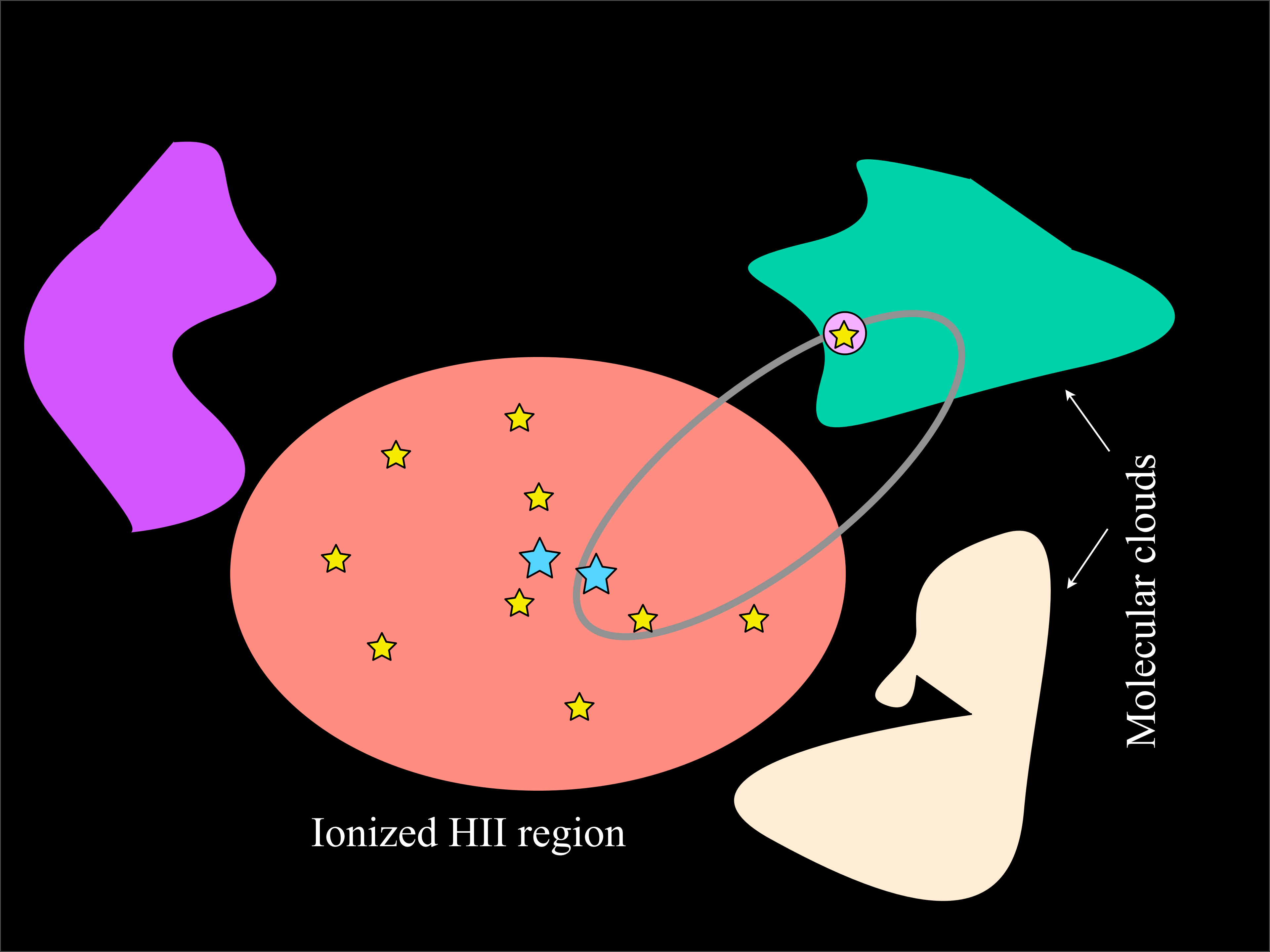
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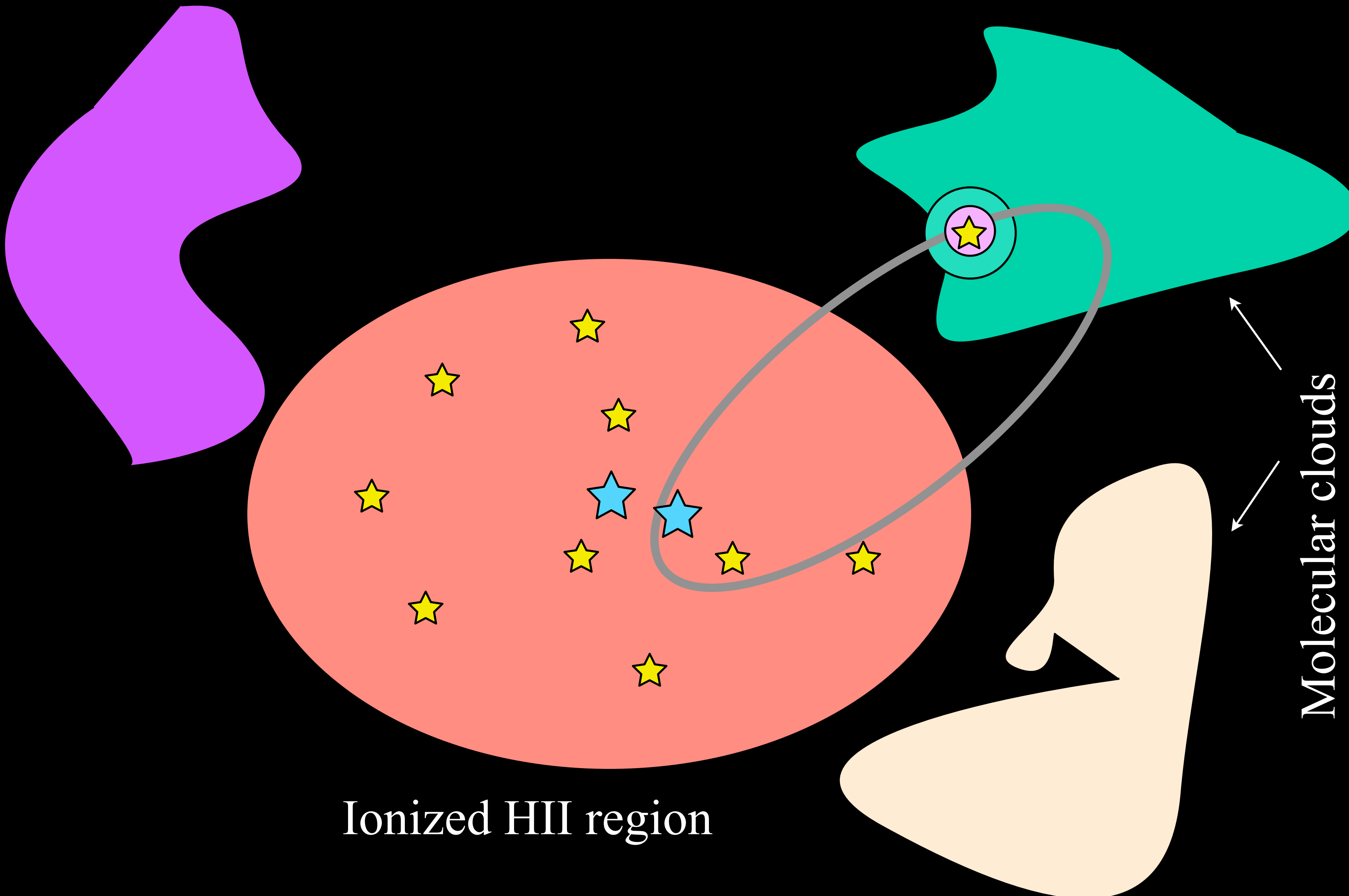
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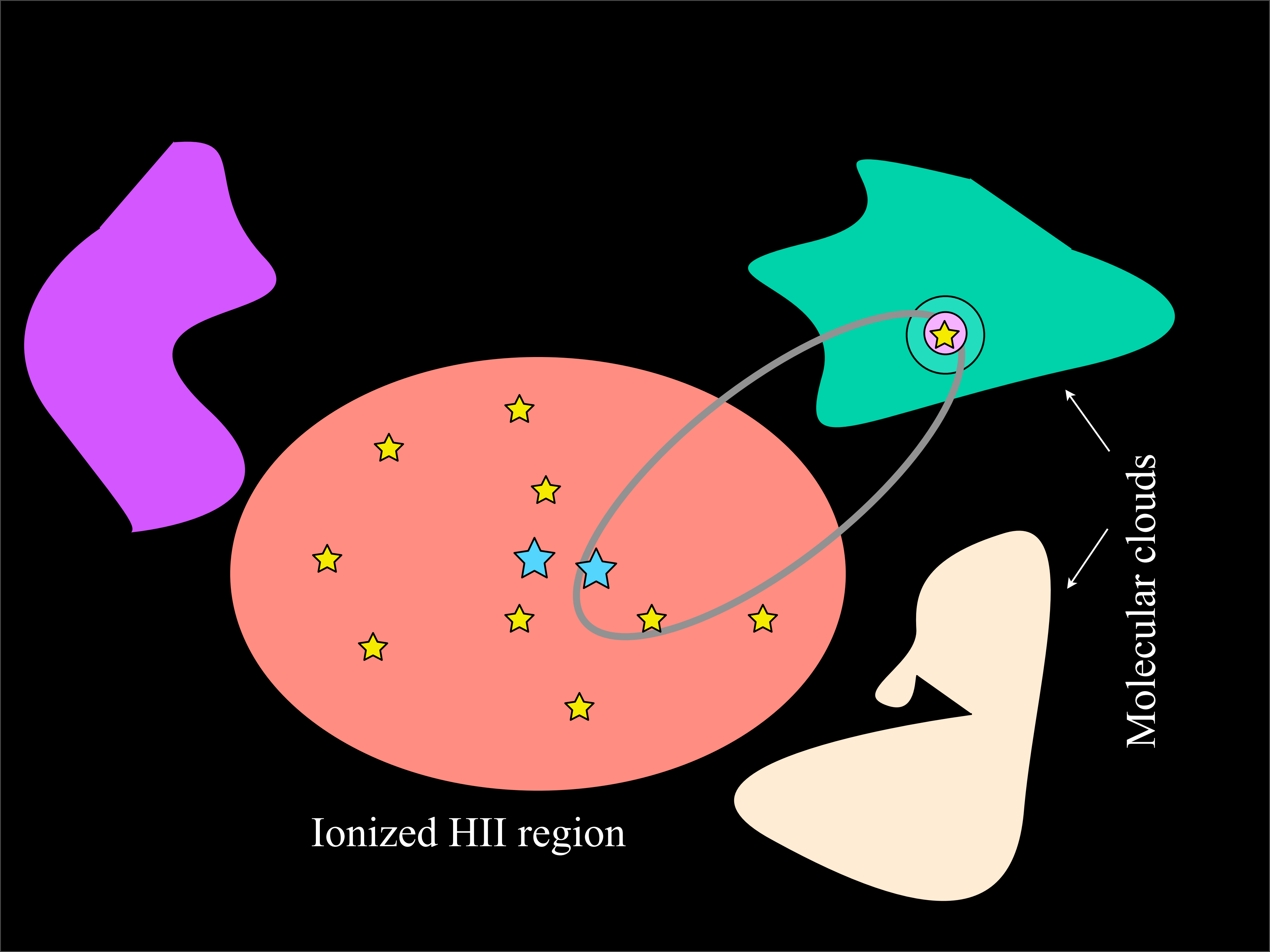
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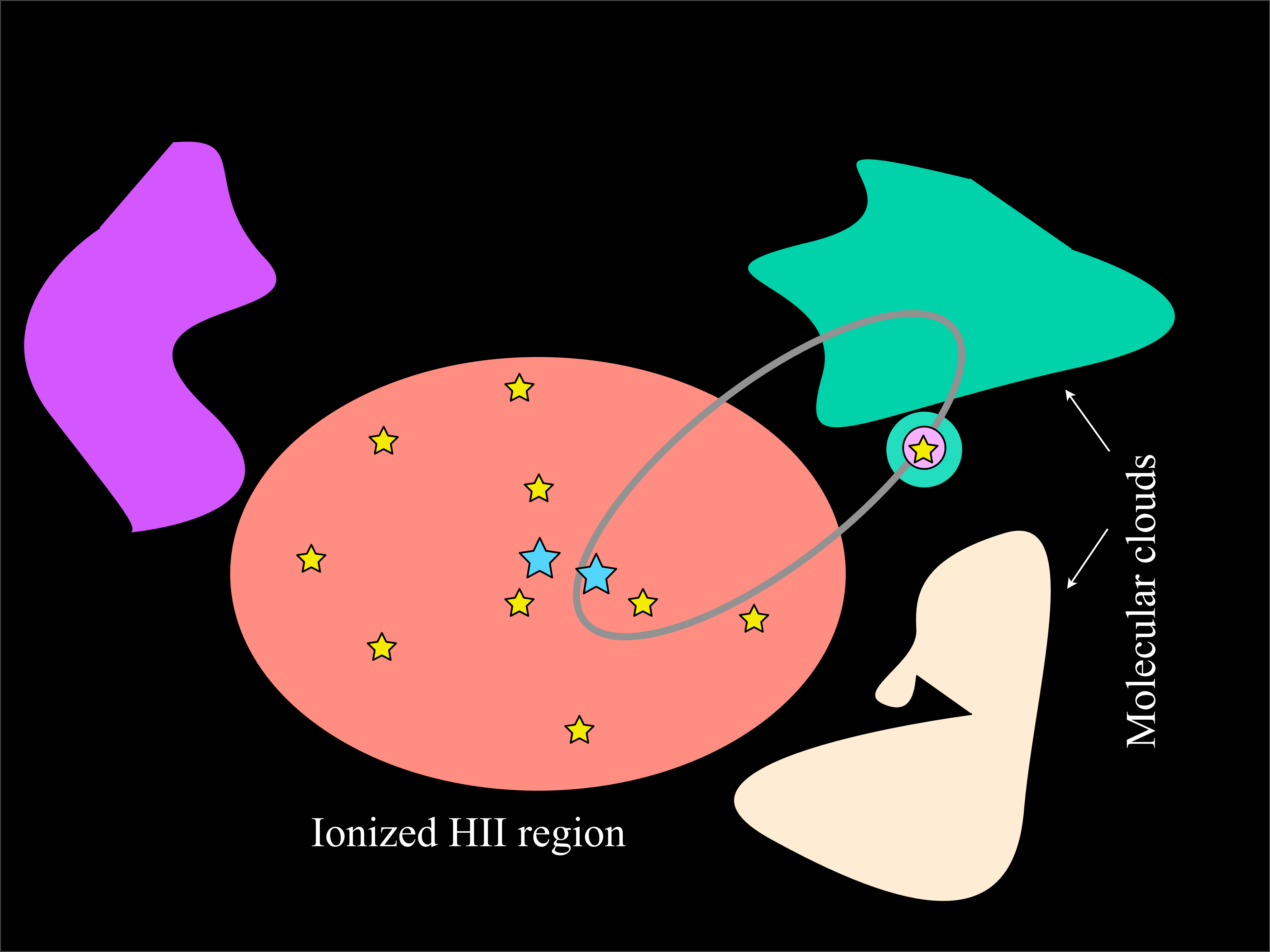

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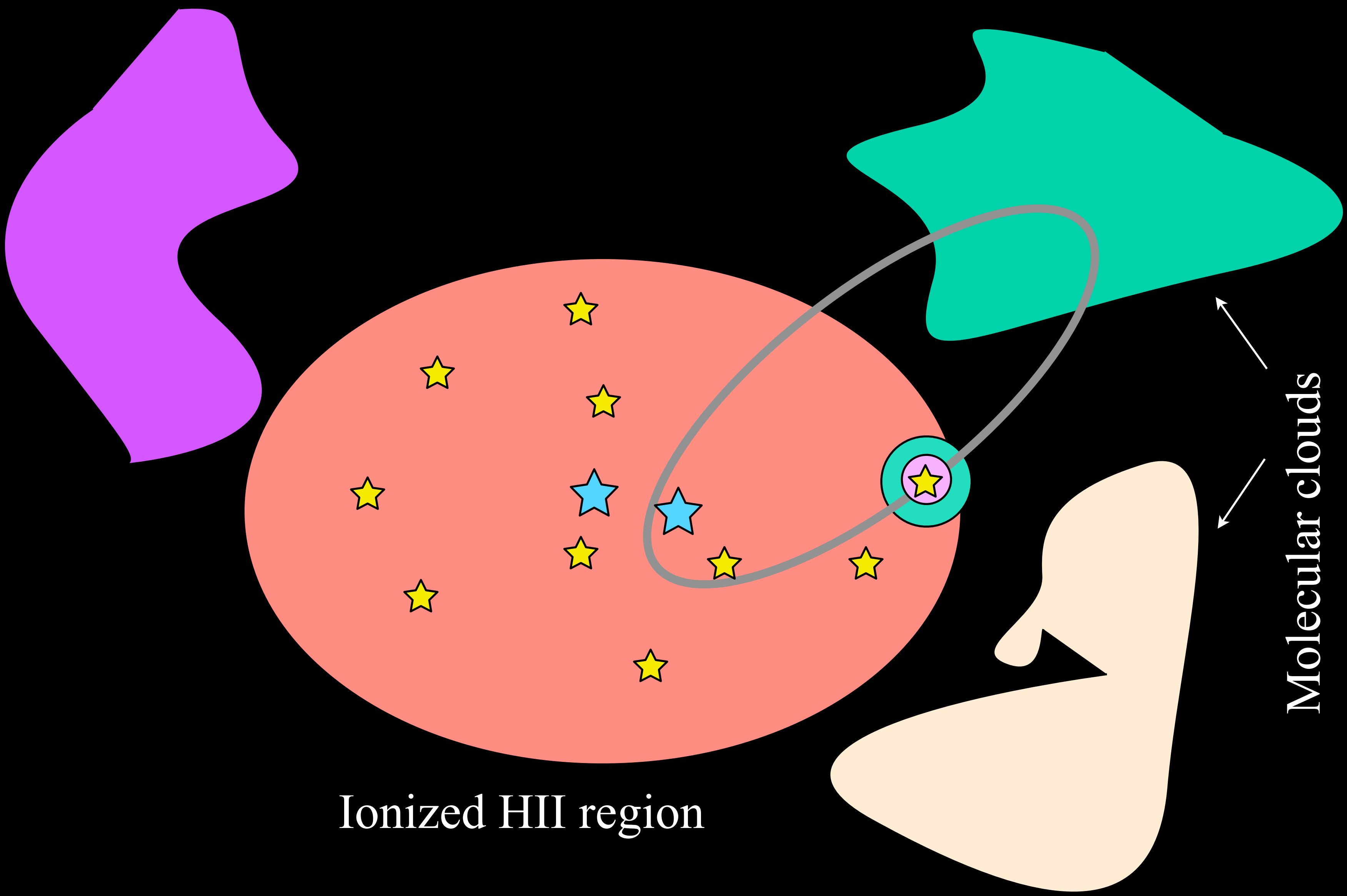
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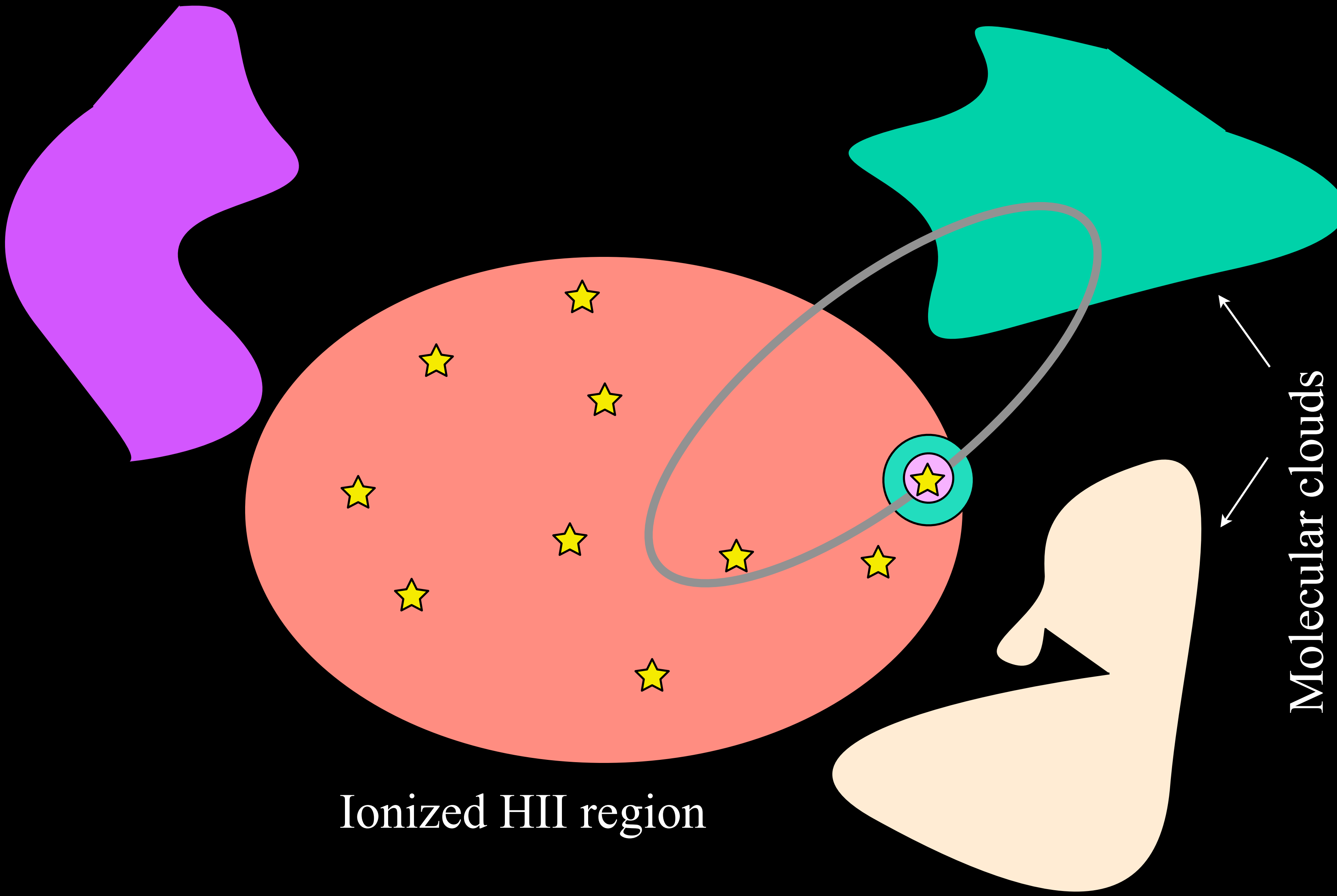
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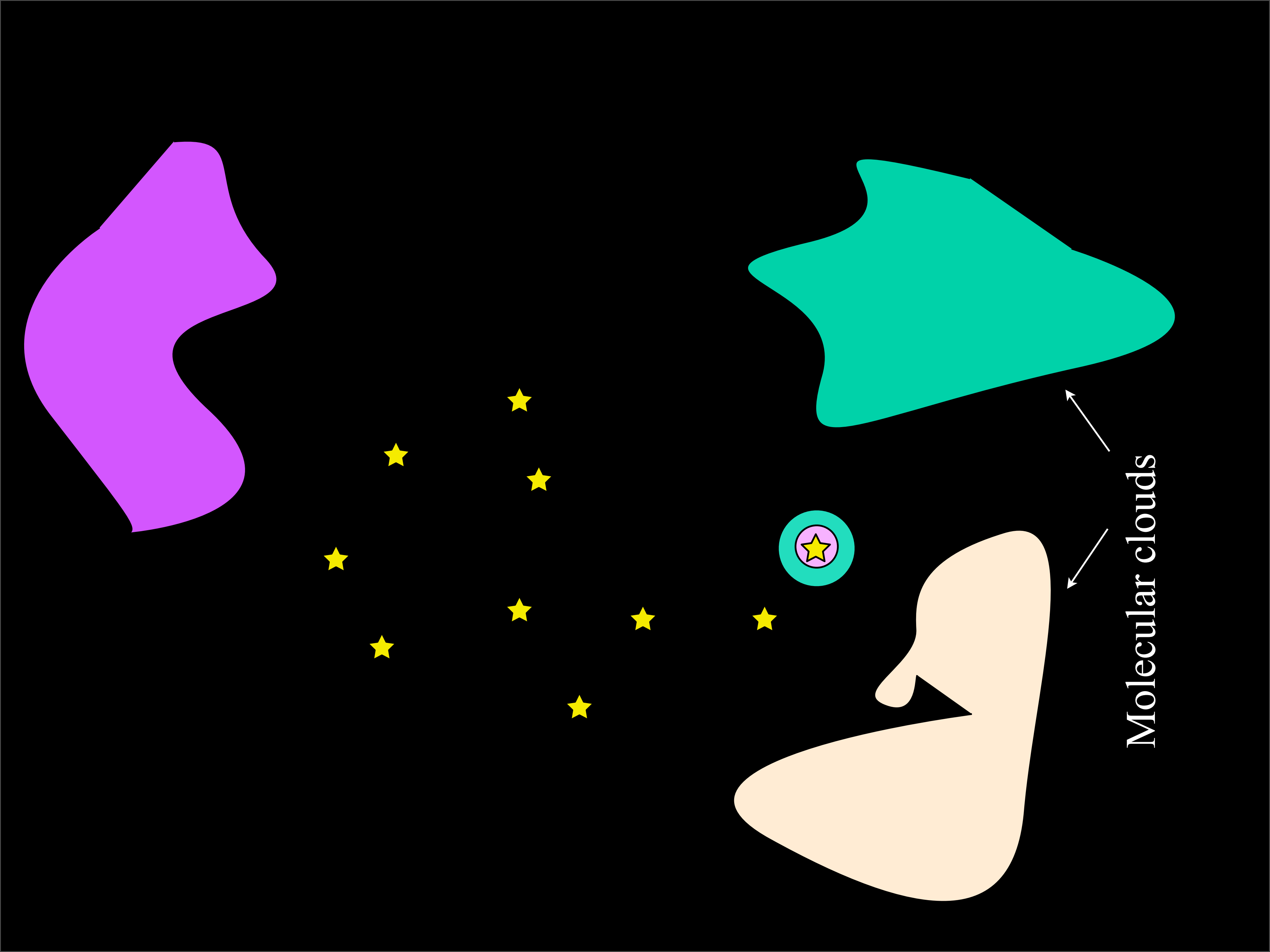
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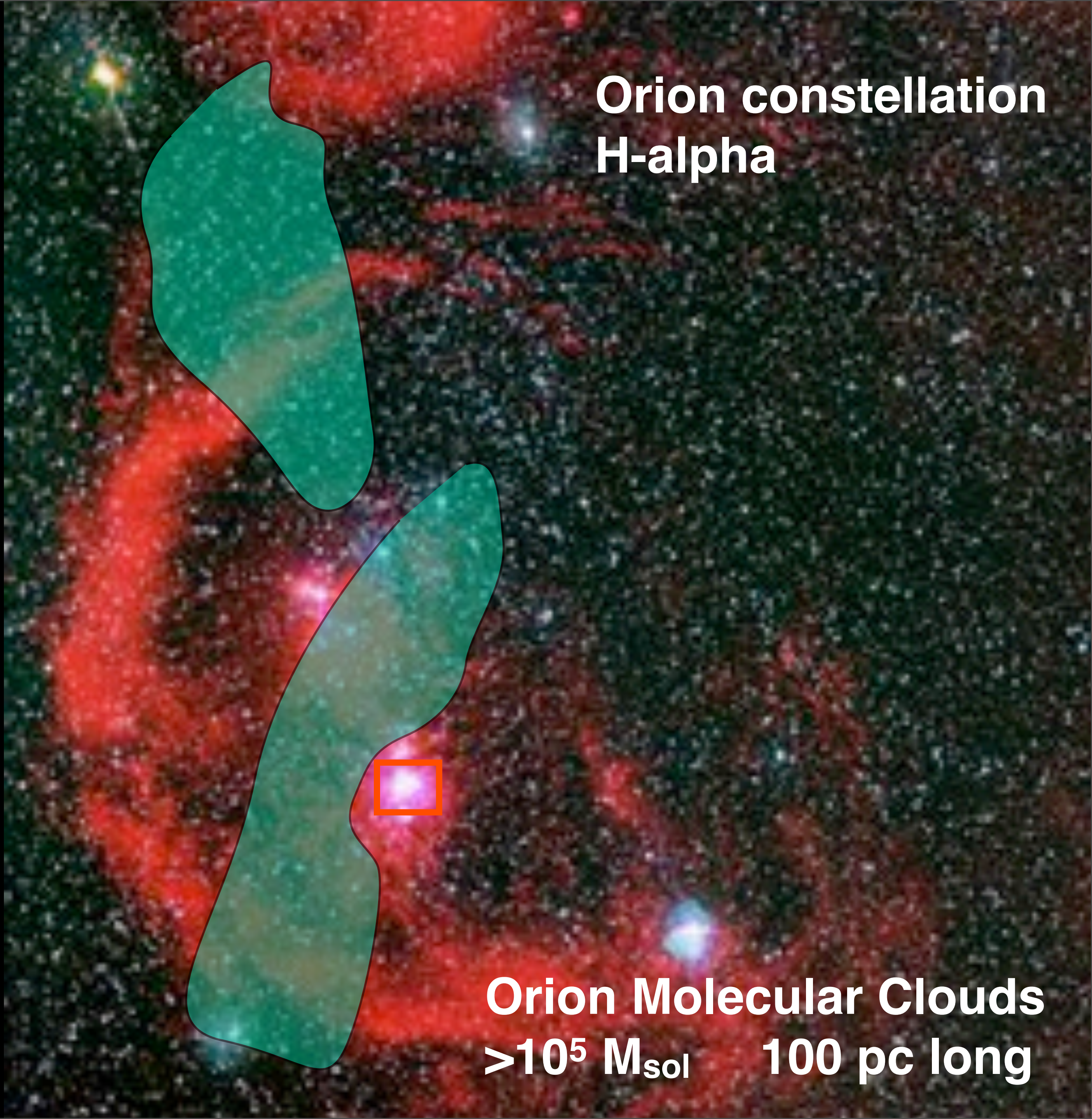
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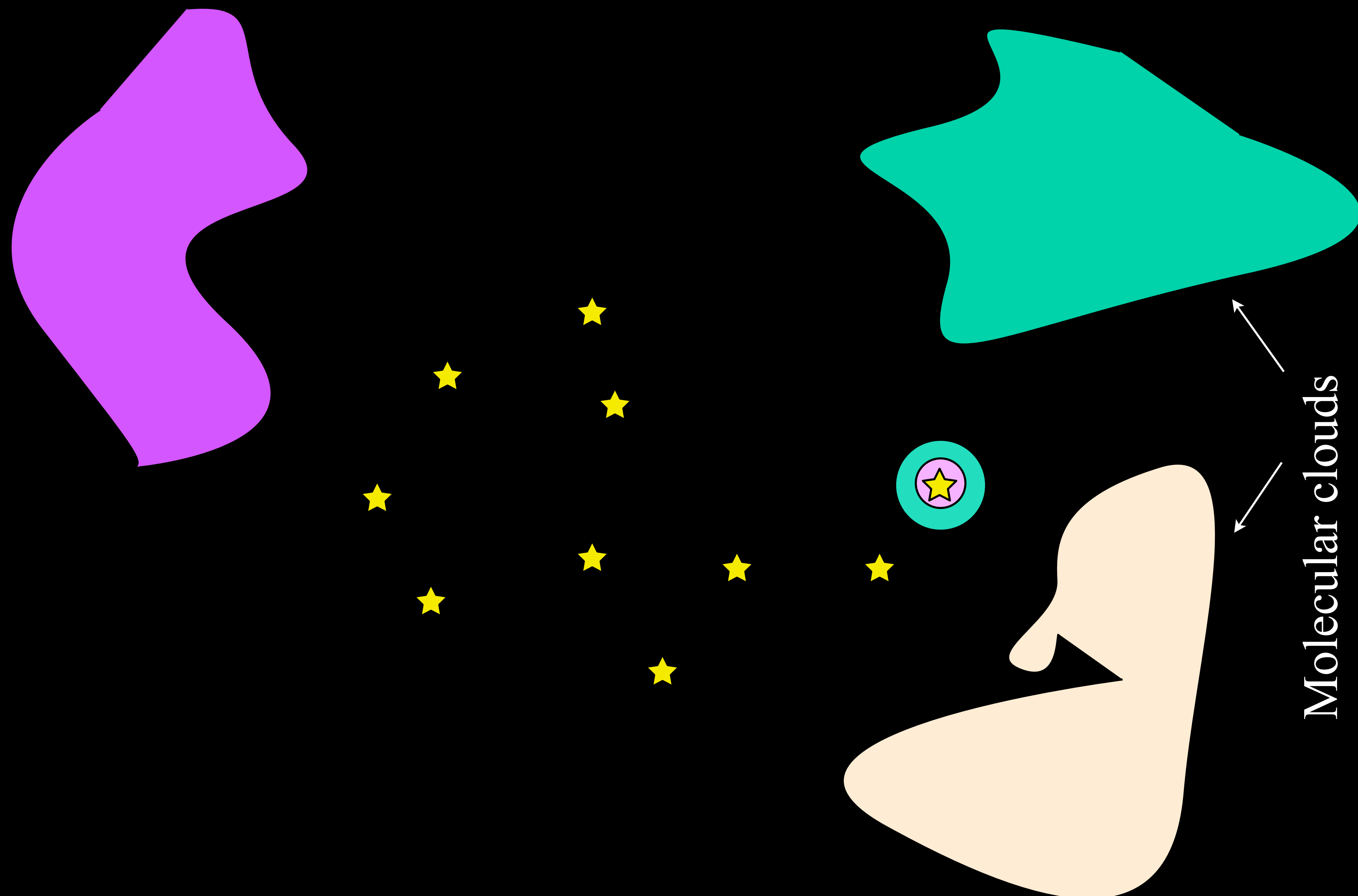
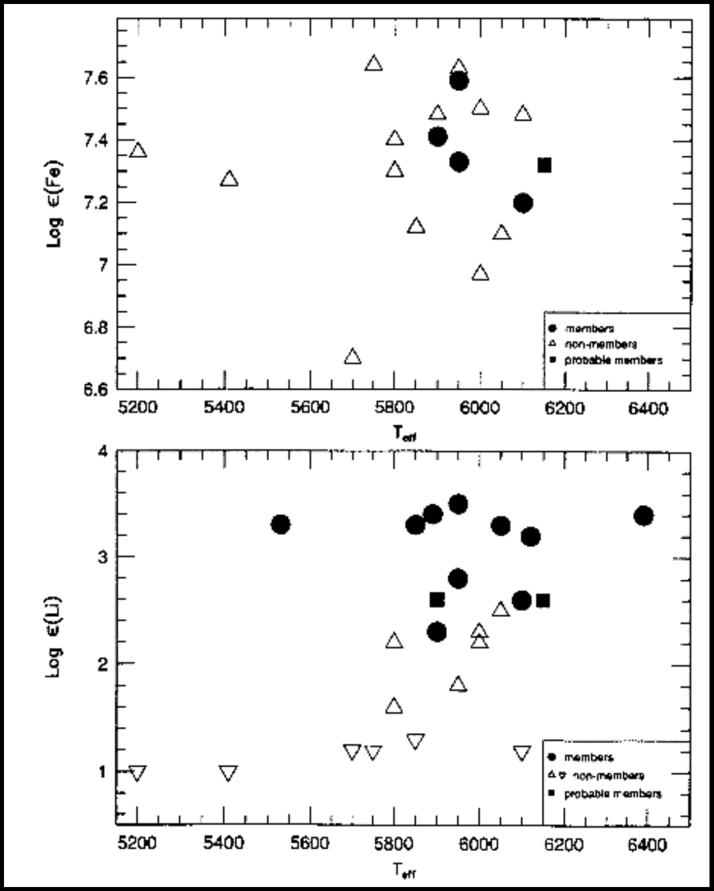

Molecular clouds

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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AJ 135
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'Tail-end' Bondi-Hoyle Accretion in Young Star Clusters: Implications for Disks, Planets, and Stars
Submitted to AJ, 7-Nov-2007
Revised, 29-Feb-2008
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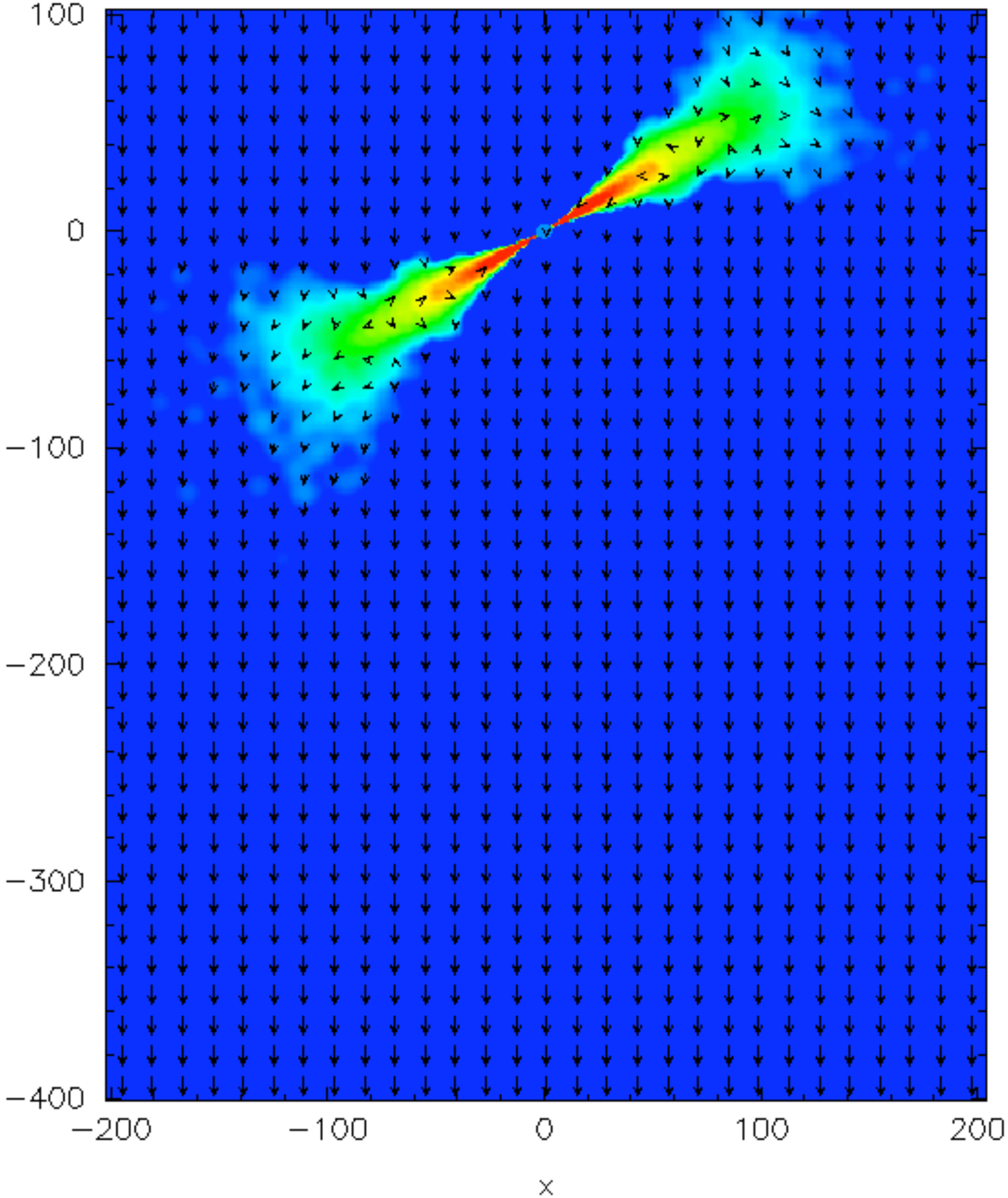
ABSTRACT


The
End



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