近傍大質量星からの紫外線照射による分子雲コアの光蒸発：コア寿命の金属量依存性

仲谷崚平　（東京大学D3）

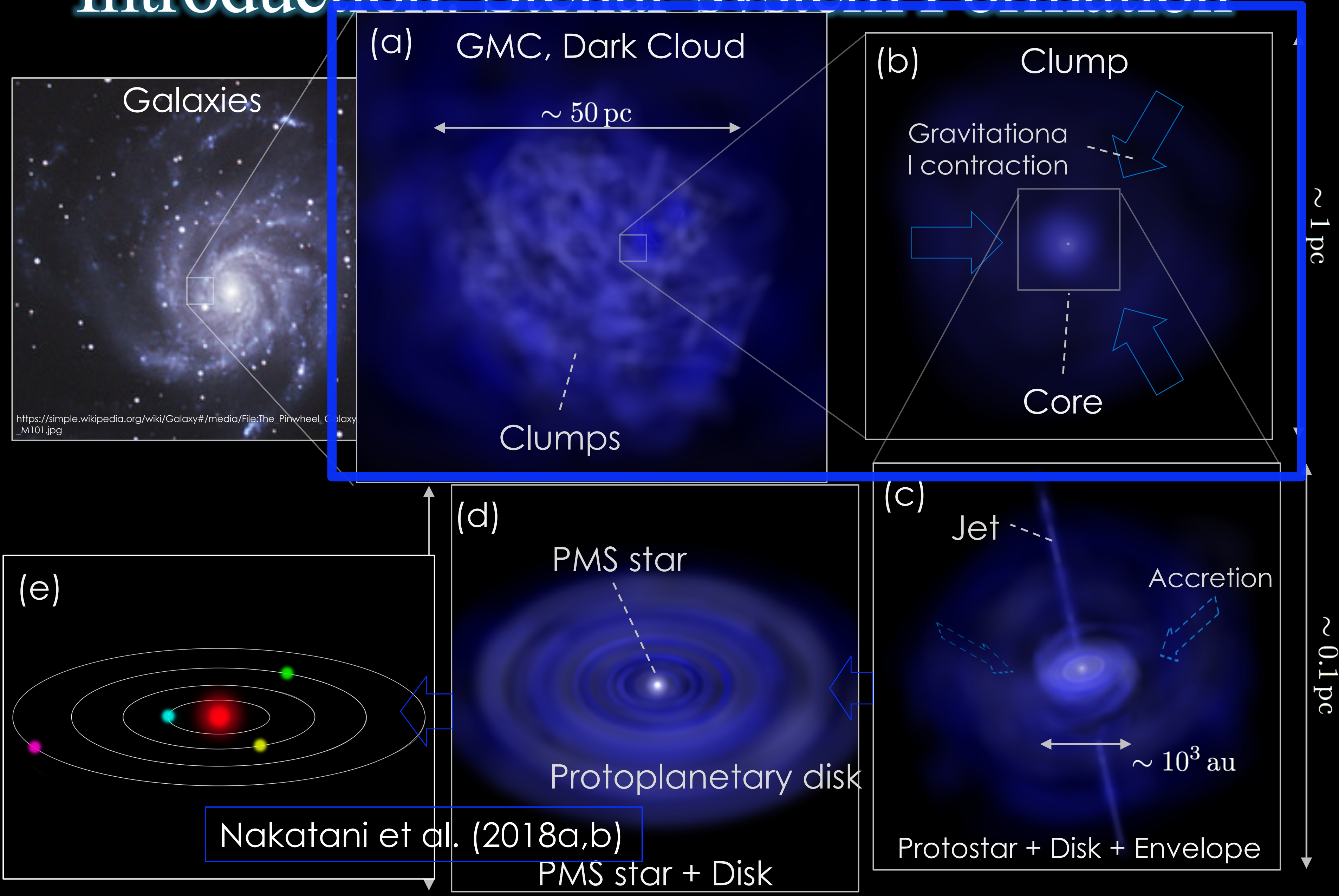
This talk is based on

- **Nakatani & Yoshida (arXiv:1811.00297; Submitted to ApJ)**

(and Nakatani et al. (ApJ, 857, 57, 2018); Nakatani et al. (ApJ, 865, 75, 2018))

第31回理論懇シンポジウム@京都大学基礎物理学研究所パナソニックホール, 12/20/2018

Introduction: Stellar-system Formation



Galaxies

https://simple.wikipedia.org/wiki/Galaxy#/media/File:The_Pinwheel_Galaxy_M101.jpg

(a) GMC, Dark Cloud

~ 50 pc

Clumps

(b) Clump

Gravitational contraction

Core

~ 1 pc

(c)

Jet

Accretion

$\sim 10^3$ au

Protostar + Disk + Envelope

~ 0.1 pc

(d)

PMS star

Protoplanetary disk

PMS star + Disk

(e)

Nakatani et al. (2018a,b)

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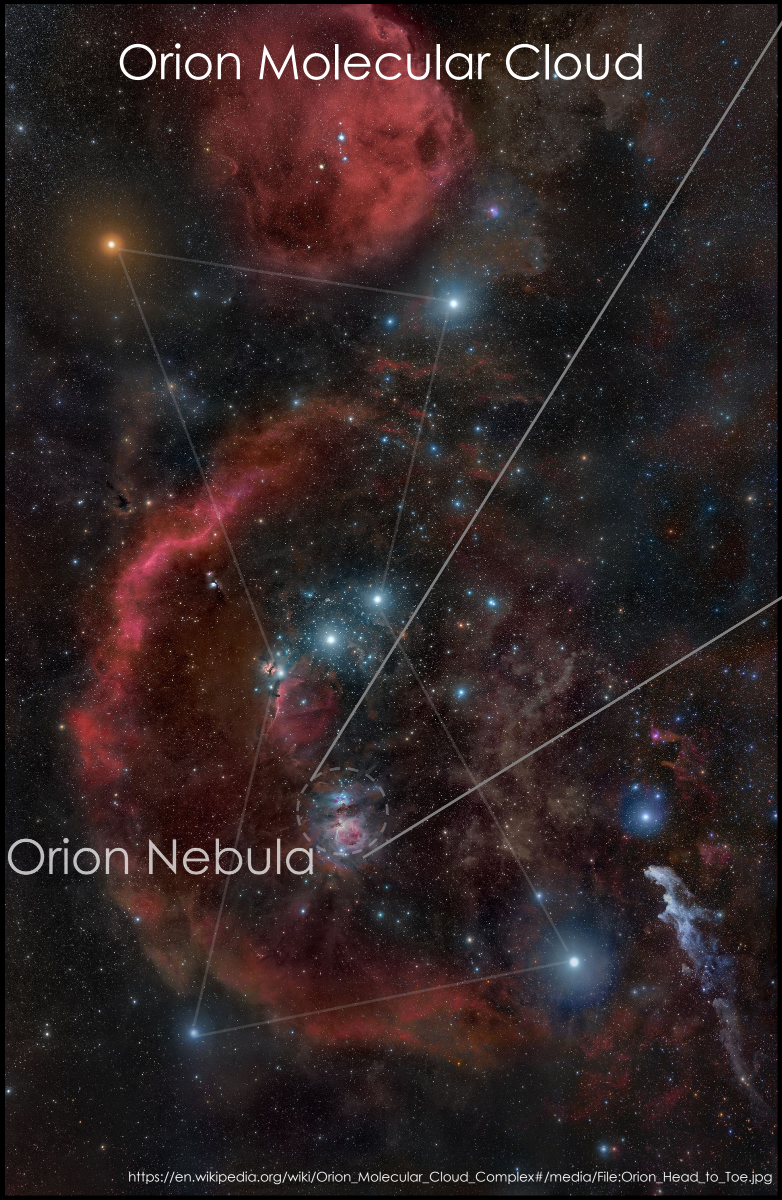
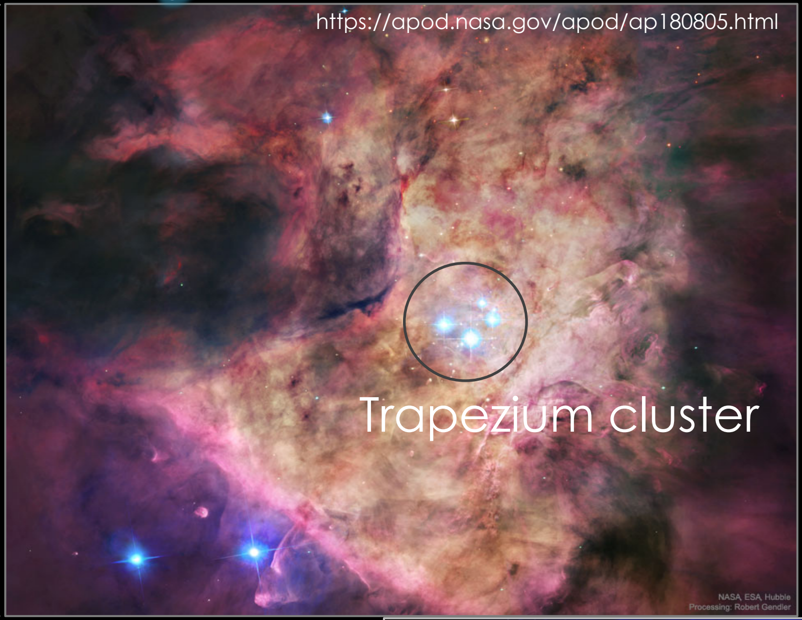
Cloud Destruction by Massive Stars

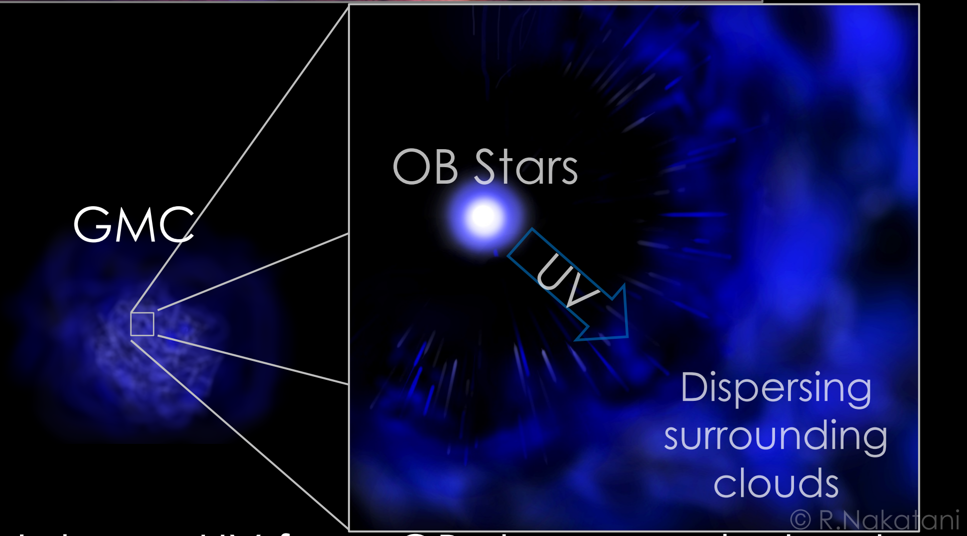


https://en.wikipedia.org/wiki/Orion_Molecular_Cloud_Complex#/media/File:Orion_Head_to_Toe.jpg



https://apod.nasa.gov/apod/ap180805.html

NASA, ESA, Hubble
Processing: Robert Gendler



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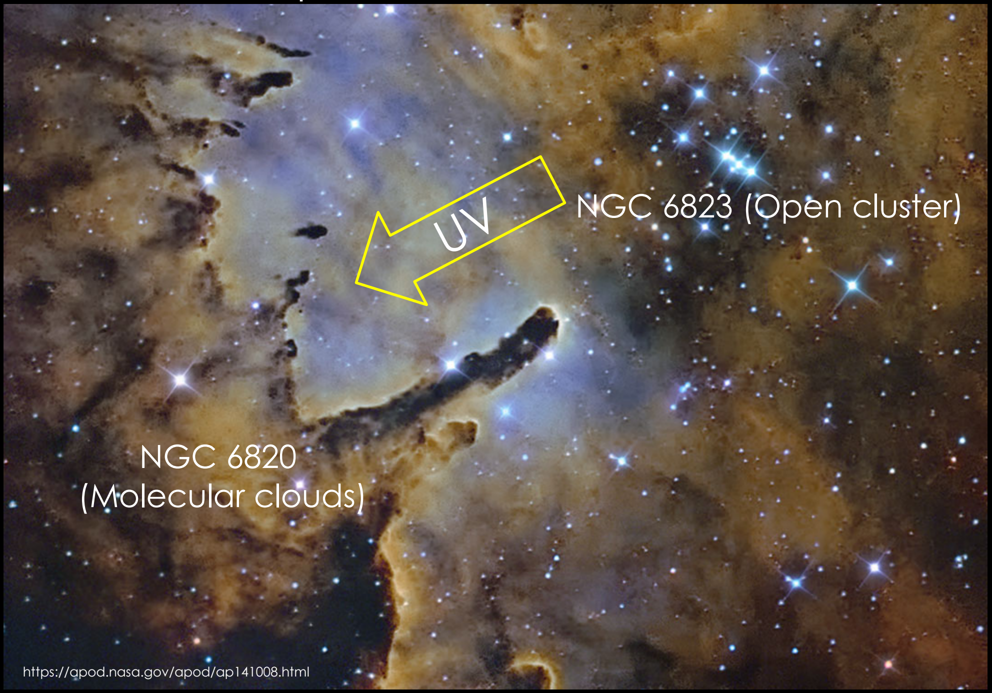
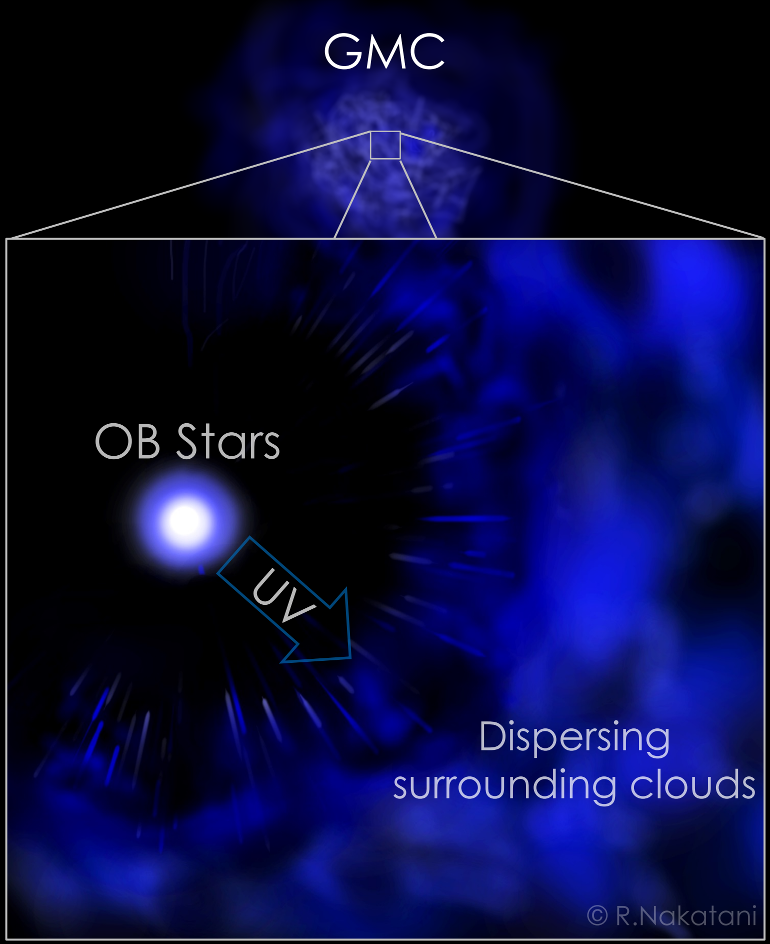
Intense UV from OB stars can destruct ambient cores/clumps.

Cloud Destruction by Massive Stars

Vulpecula OB1 association



https://apod.nasa.gov/apod/ap141008.html



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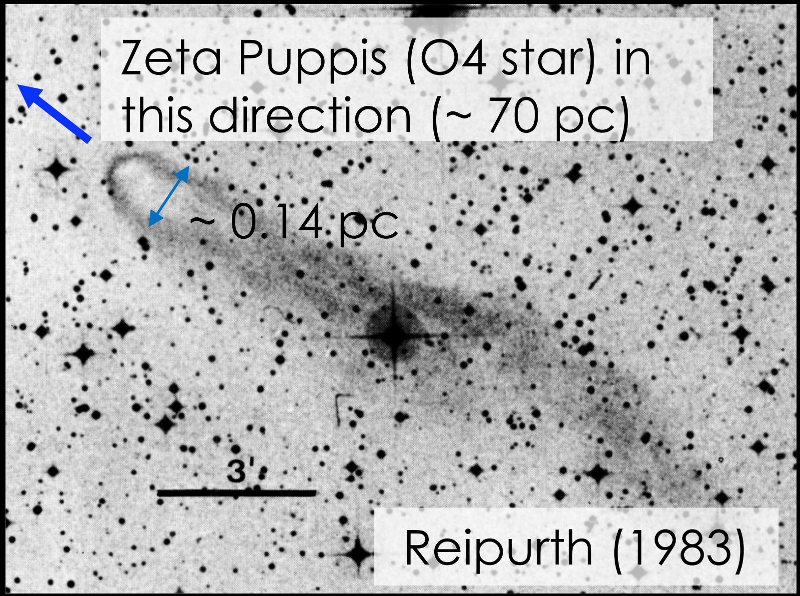
This situation is observed in many other GMCs.

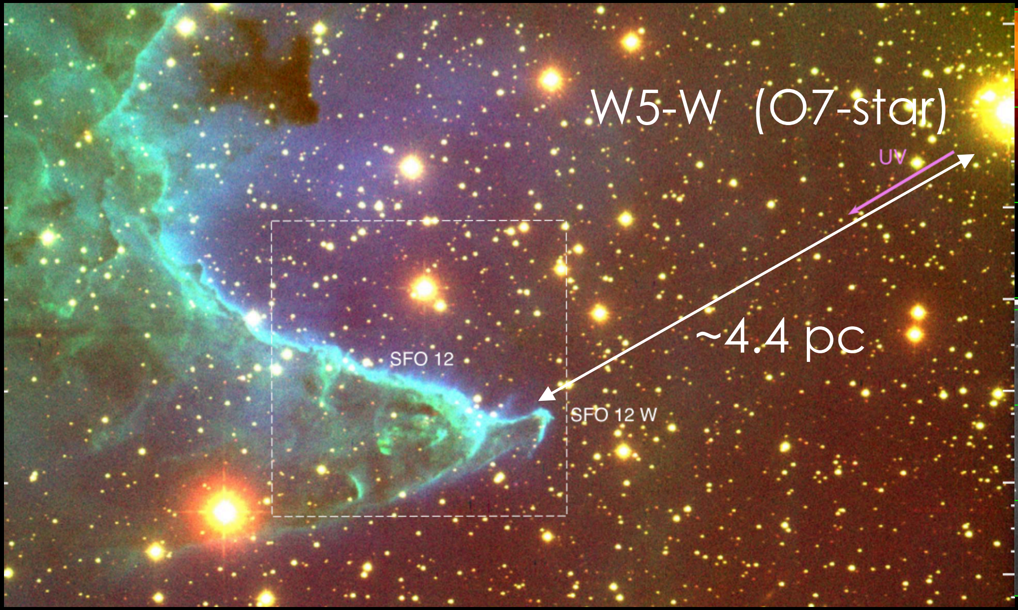
Radiation Impacts on Clouds

- Erode clouds through *photoevaporation*
- Cometary structure
- Radiation-driven **compression**

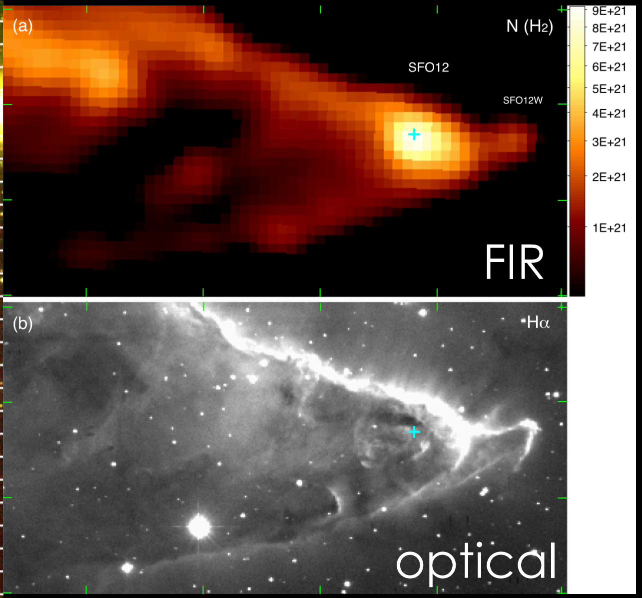


Zeta Puppis (O4 star) in this direction (~ 70 pc)

Reipurth (1983)



W5-W (O7-star)



FIR

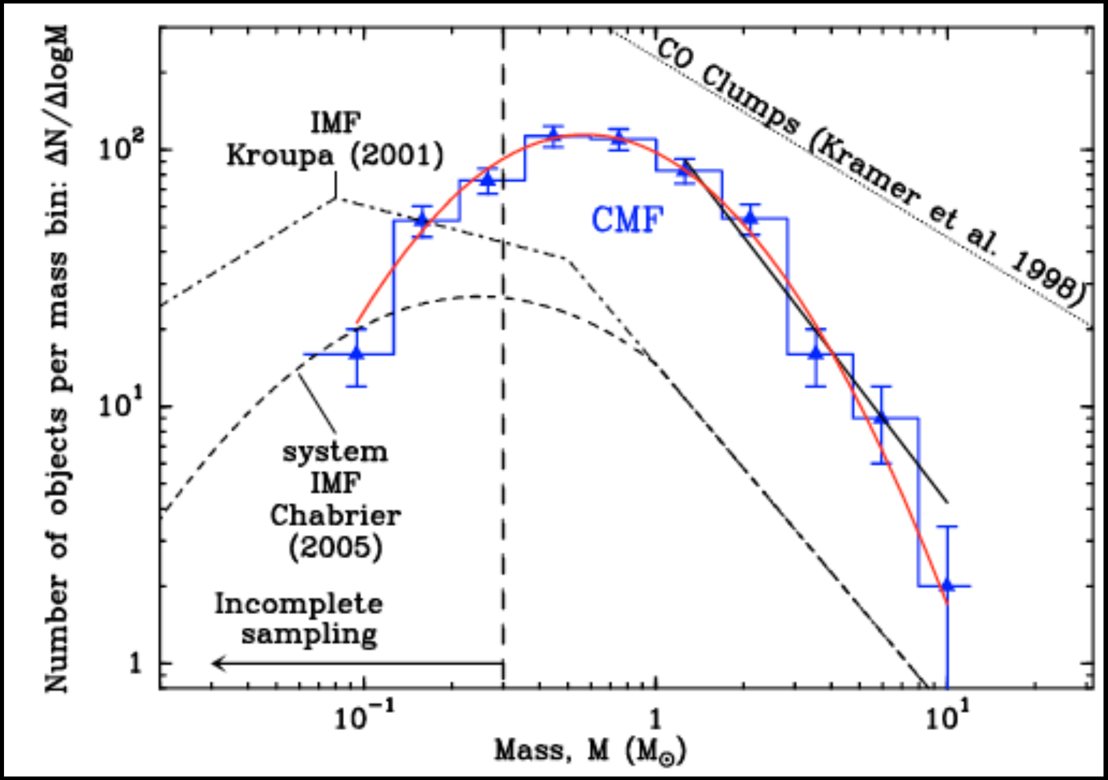
optical

Imai et al. (2017)

Mass functions of cores, clumps, and stars can be s affected

Influences of Massive Stars on Star Formation

André et al. 2010

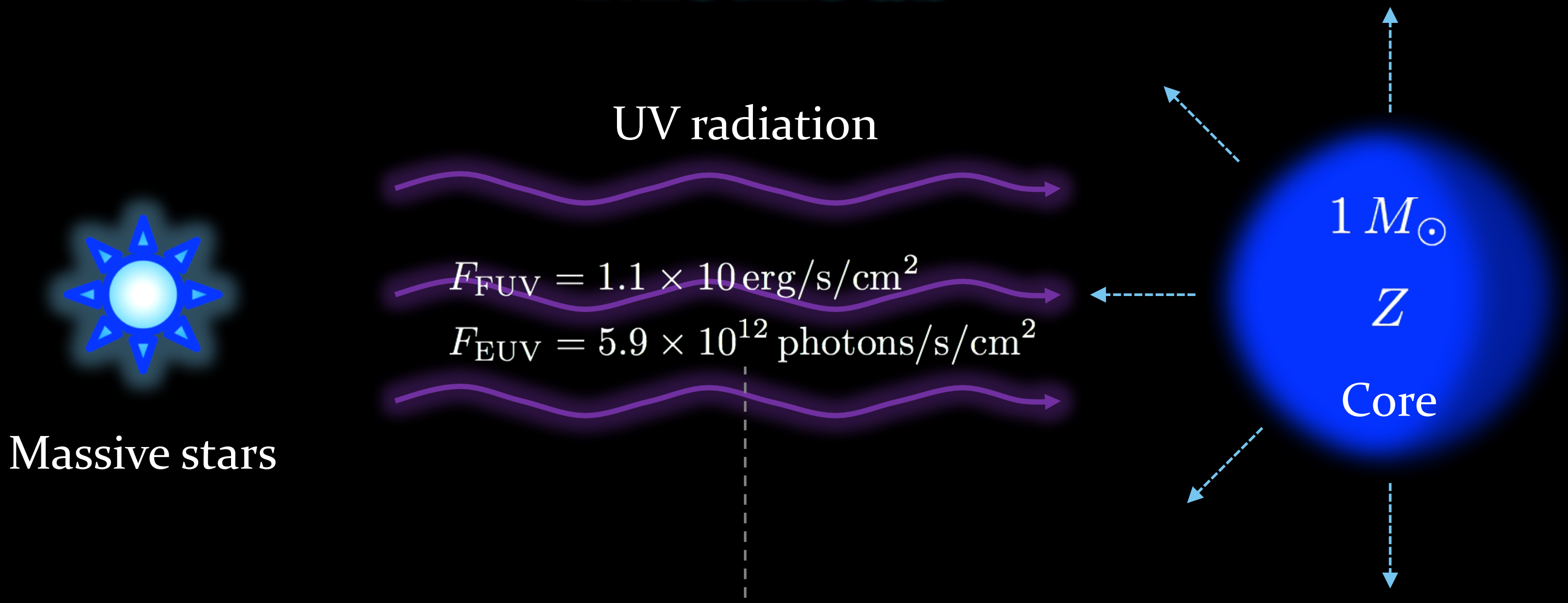


Core mass function (CMF) resembles stellar IMF in GMCs

Massive star radiation may affect to some extent

- ➢ LMC (lower metallicity; strong UV field) has similar Clump MF (e.g., Brunetti & Wilson 2018) → Is there any metallicity effects ?
- ➢ What about **other low-metallicity environment** ? (protogalaxies, high-z galaxies, outer Galaxy.)

Methods



UV radiation

$F_{\mathrm{FUV}} = 1.1 \times 10\,\mathrm{erg/s/cm^2}$

$F_{\mathrm{EUV}} = 5.9 \times 10^{12}\,\mathrm{photons/s/cm^2}$

Massive stars

$1\,M_\odot$

Z

Core

Corresponding distance: O-type star at 0.1 pc.

- 3D Hydrodynamics + Radiation transfer (ray-tracing) + Chemistry
    - Metallicity is varied over a range of $10^{-3} < Z/Z_{\rm sun} < 1$

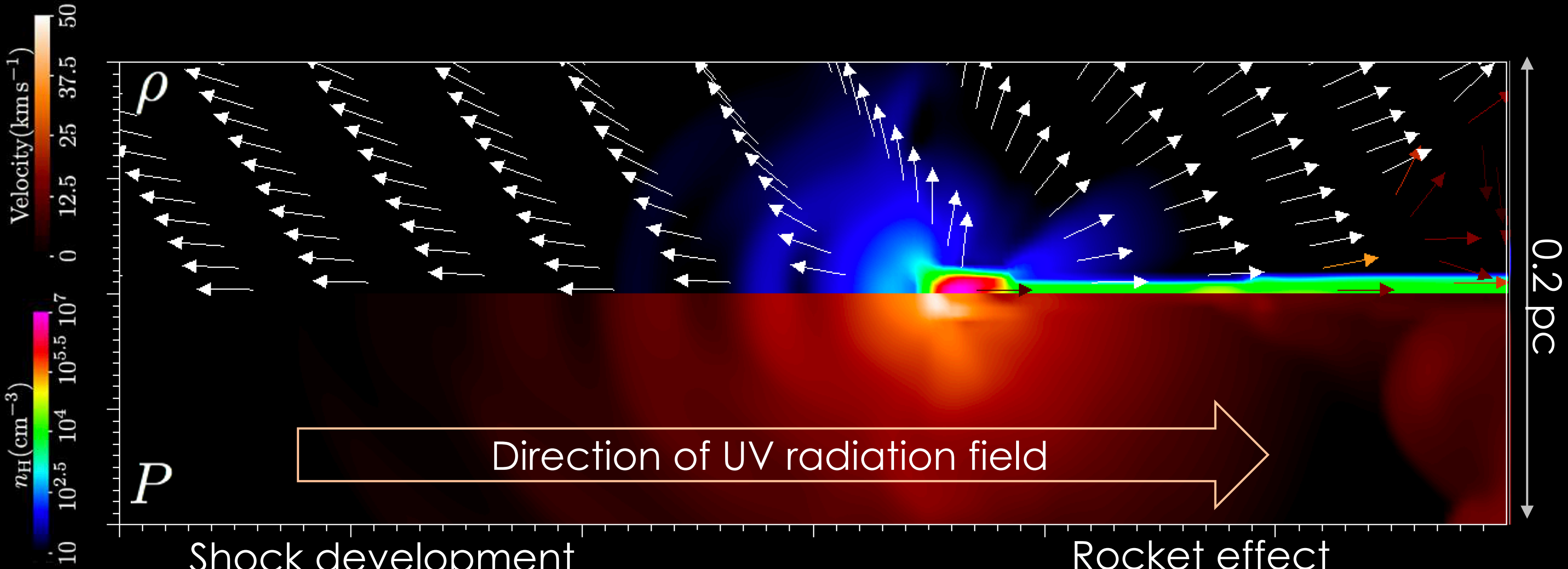
Solar-Metallicity Core

Initial Condition

$t = 0\,\mathrm{yr}$

Cometary structure formation

$t \simeq 5000\,\mathrm{yr}$



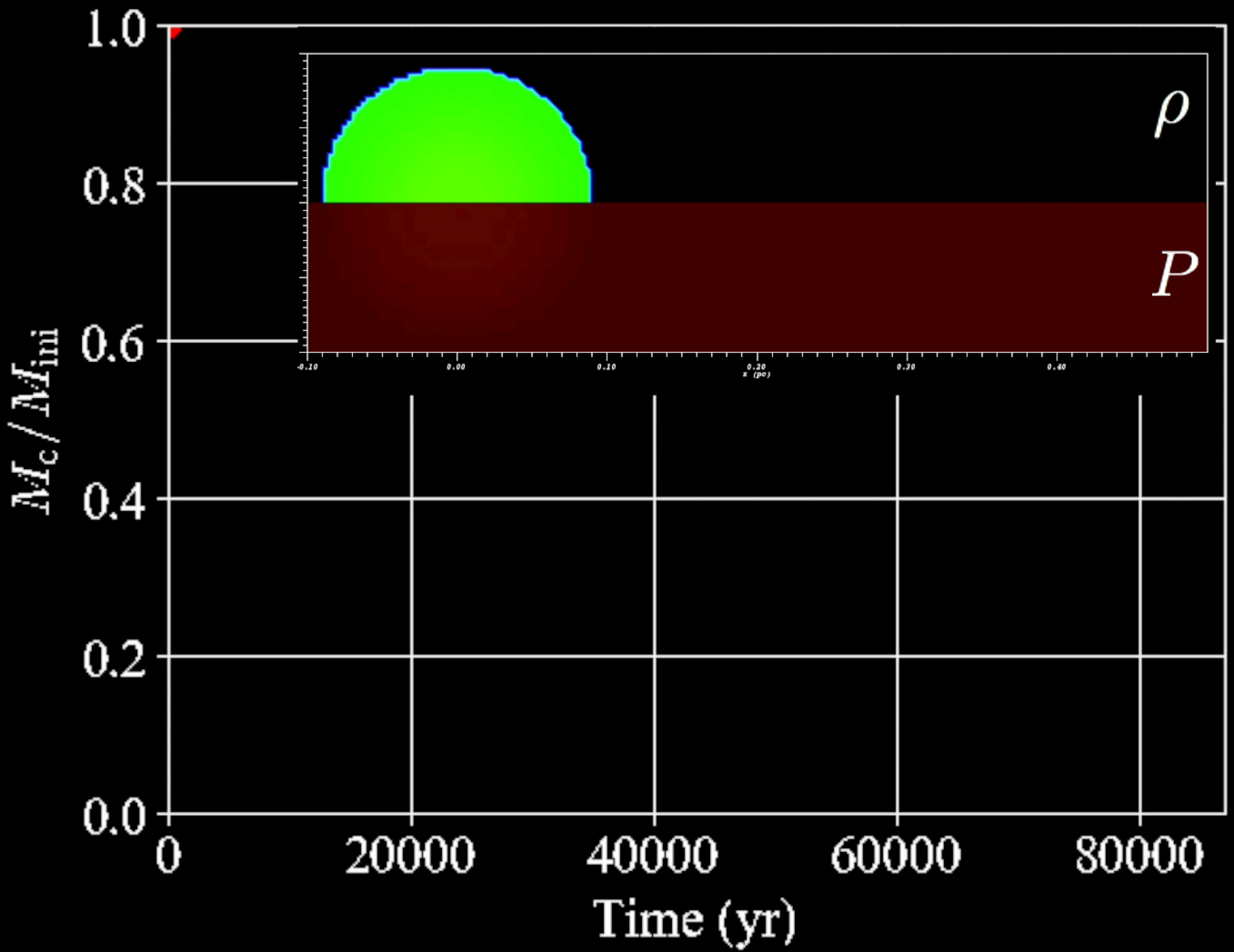
Shock development

$t \simeq 3000\,\mathrm{yr}$

Rocket effect

$t \simeq 30000\,\mathrm{yr}$

Solar-Metallicity Core



- Mass loss is higher with high cross-section, inefficient in the cometary phase
  - Lifetime is 10^5 years for $Z_\odot$ core

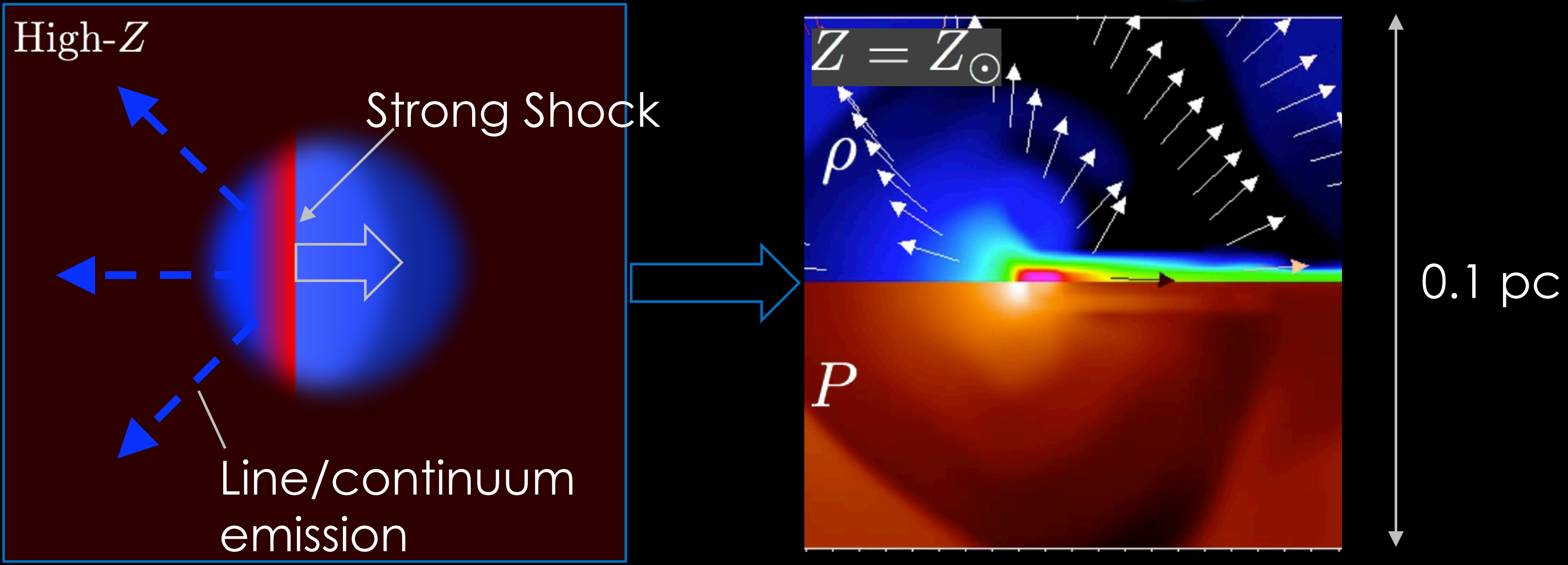
Comparison with Other Z

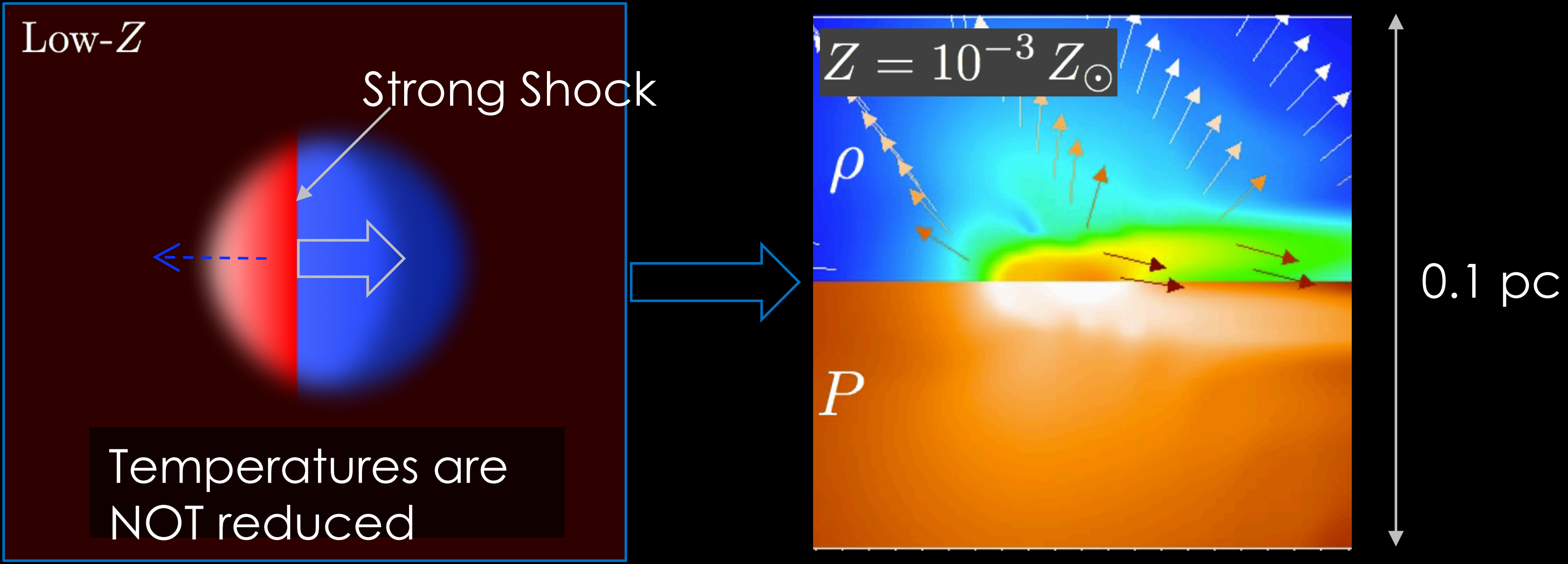
↑ Forms cometary structure

↑ Disappears very soon

- Faster disapperance for lower-Z cores

Effects of Metal Cooling

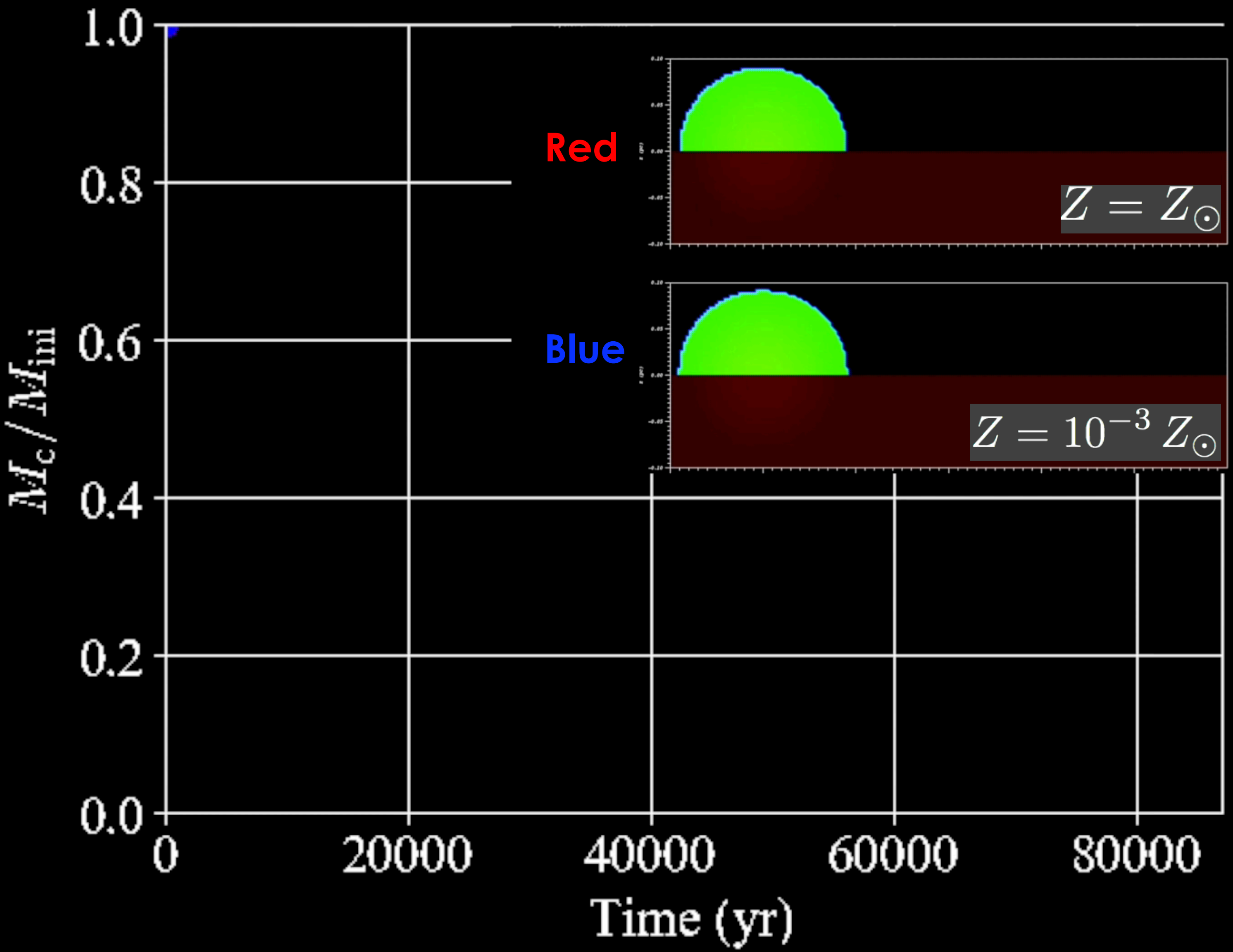




Temperatures are NOT reduced

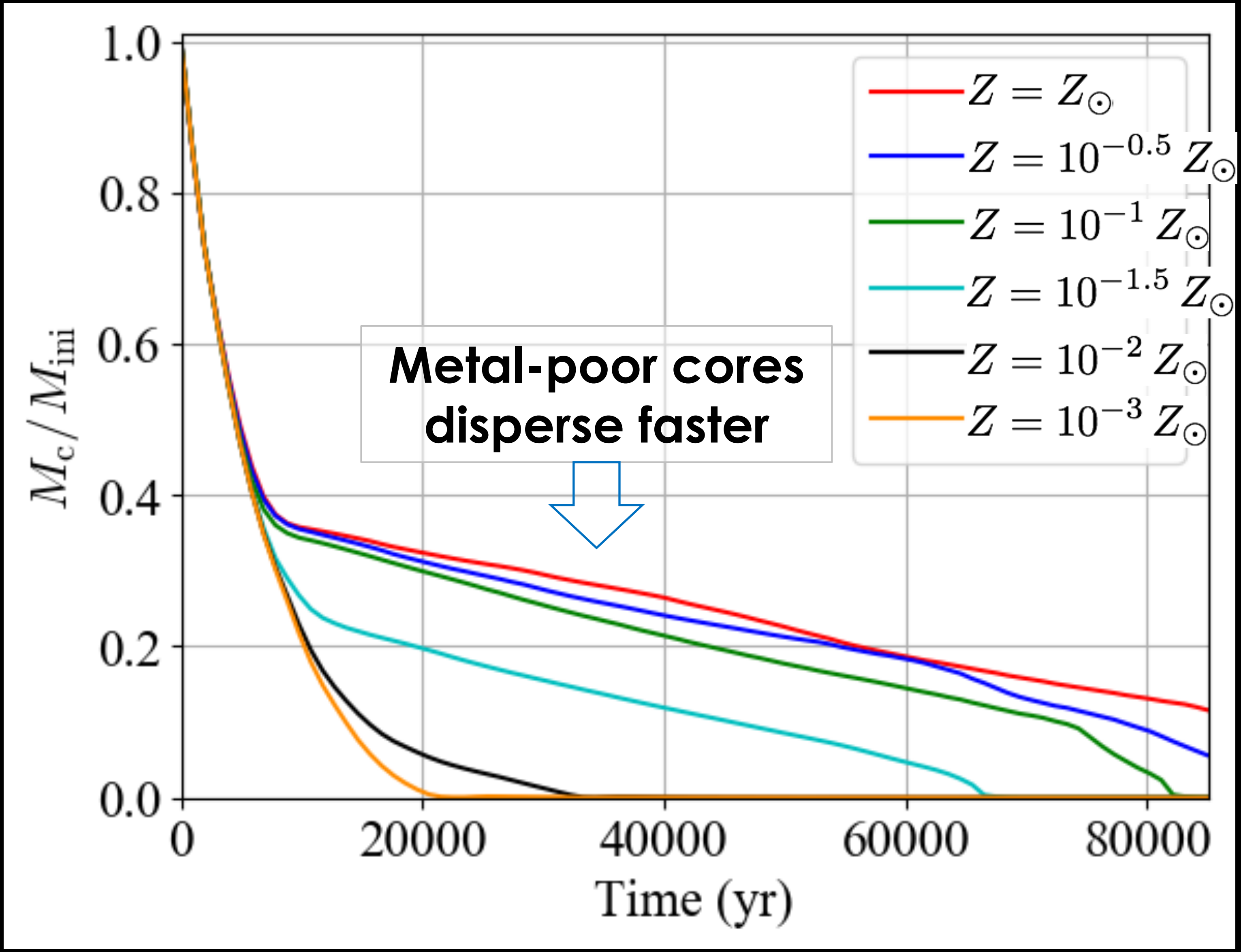
Lower metallicity clumps remain larger in launch surface

Mass Evolution with Various Z



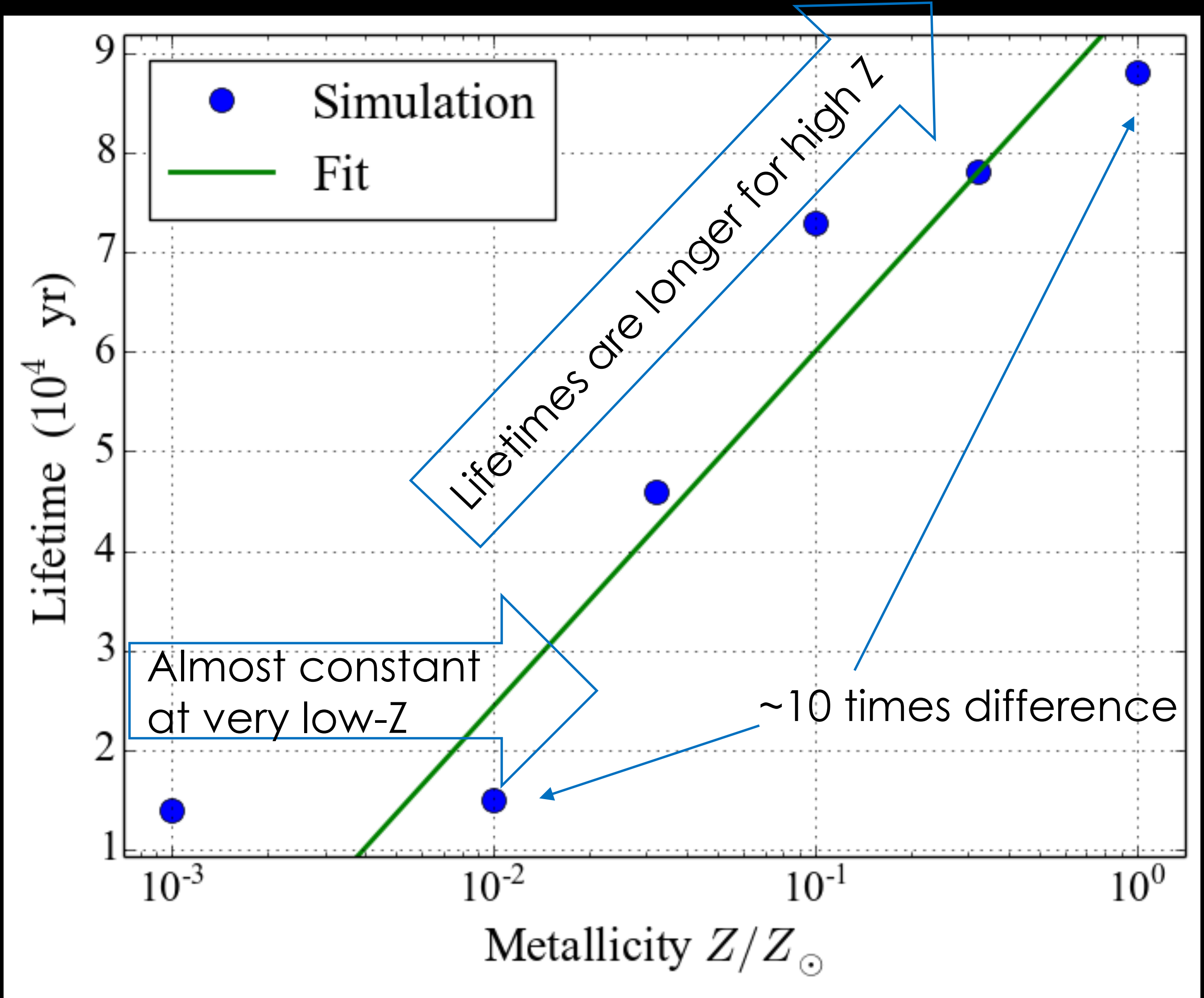
- Lifetime is ~10^4 years for $Z = 10^{-3} Z_\odot$

Core Mass Evolution



Metal-poor cores disperse faster

Lifetime VS Metallicity



Lifetimes are longer for high Z

Almost constant at very low-Z

~10 times difference

Implication to Star Formation

$t_{\mathrm{ff}} < t_{\mathrm{life}}$ Would be necessary to gravitationally collapse.

$Z = Z_{\odot}$	○	Compression shortens the free fall time
$Z = 10^{-0.5}\, Z_{\odot}$	○	
$Z = 10^{-1}\, Z_{\odot}$	○	
$Z = 10^{-1.5}\, Z_{\odot}$	△	Marginal
$Z = 10^{-2}\, Z_{\odot}$	×	Photoevaporation is very efficient
$Z = 10^{-3}\, Z_{\odot}$	×	

Massive stars have potential to significantly suppress star formation in nearby cores with low metallicities.

Summary

- Aims:
  Metallicity dependence of the lifetimes of cores illuminated by external massive stars.

- Results:
  The lifetime is 100,000 years for solar-metallicity cores, and is shorter with metal-poor cores.
  The lifetime is 10,000 years for very low-metallicity cores.

- Conclusion:
  - the gas metallicity strongly affects the core lifetime and thus determines the strength of feedback from massive stars in star-forming regions.
  - star formation could be significantly suppressed in low-metallicity environments.

- Future prospects:
  - Parameter study (metallicity, flux, core density, size)
  - Postprocess study in the context of galaxy evolution

Appendices