Feedback & Fragmentation: Key processes in high-mass star formation

Takashi Hosokawa (Kyoto U.)

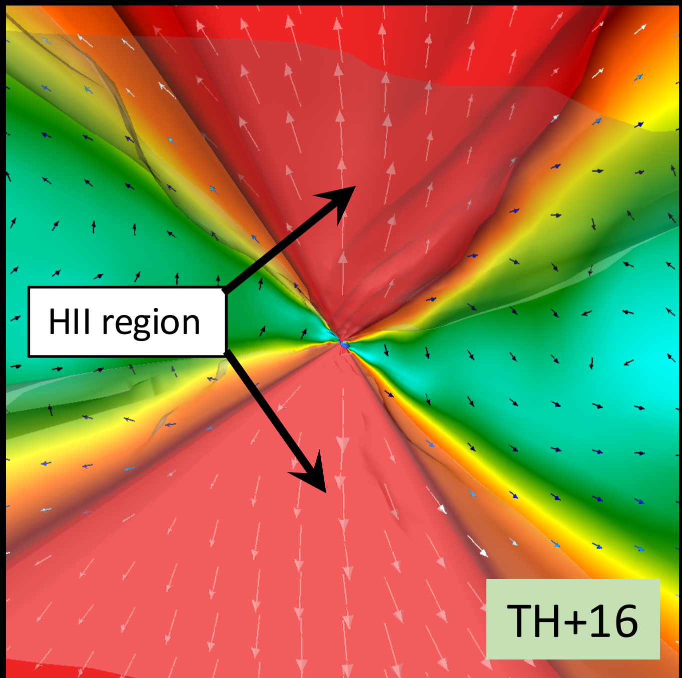
Kuiper & HH (2018) A&A
Chon & TH in prep.

3.Dec.2018 Tokyo Time Machine @IPMU

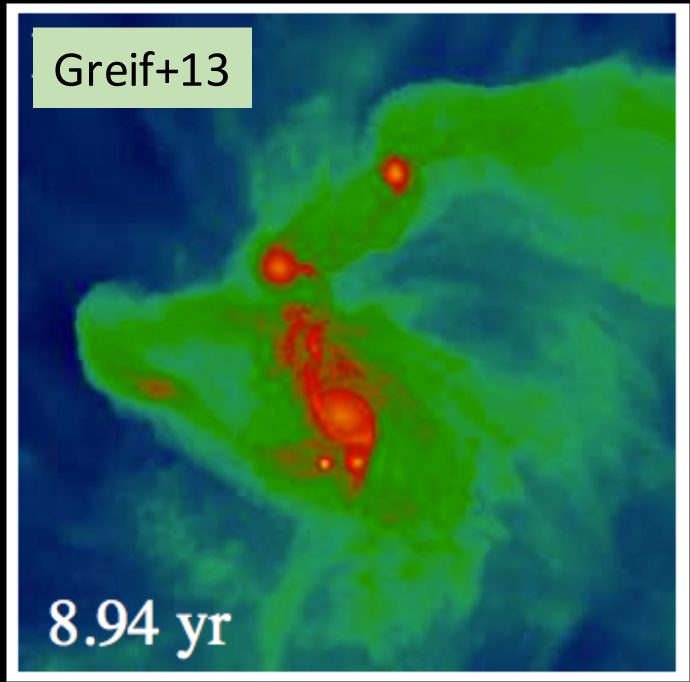
Two Key Processes

in Pop III star formation

Radiative Feedback



Disk Fragmentation



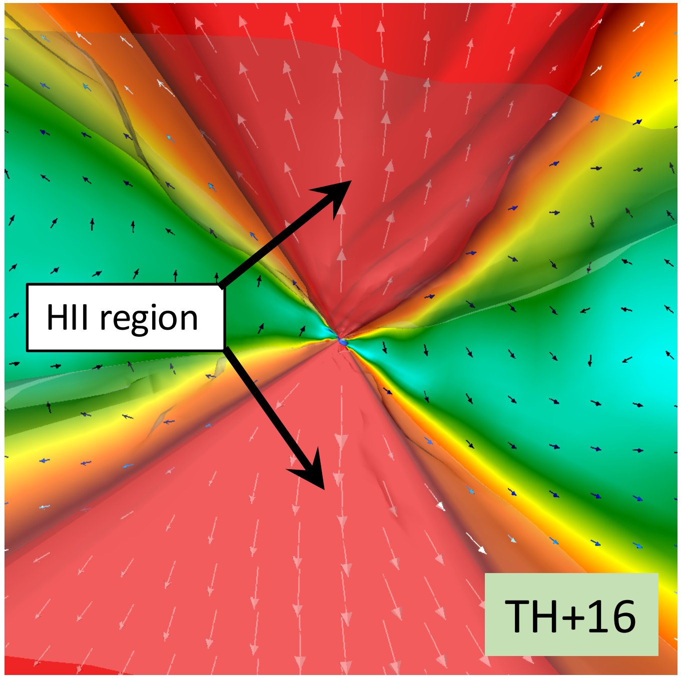
How massive stars form with these processes?

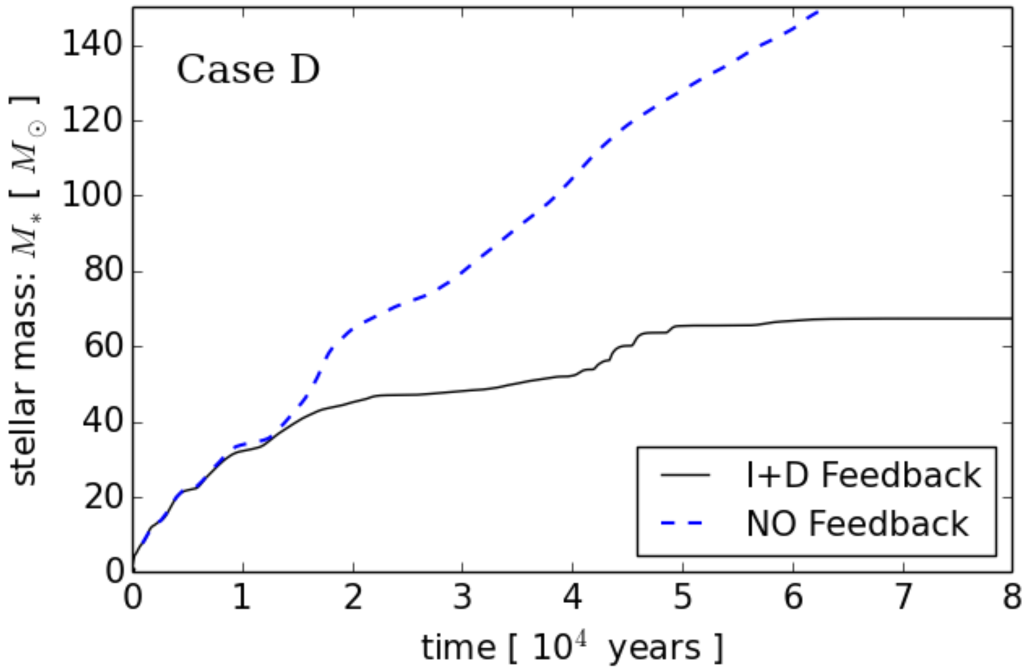
How many low-mass stars form together with the high-mass stars?

Any metallicity dependences?

Pop III UV feedback

(TH+16, 11; Stacy+16, 12; Susa+14, 13 etc)



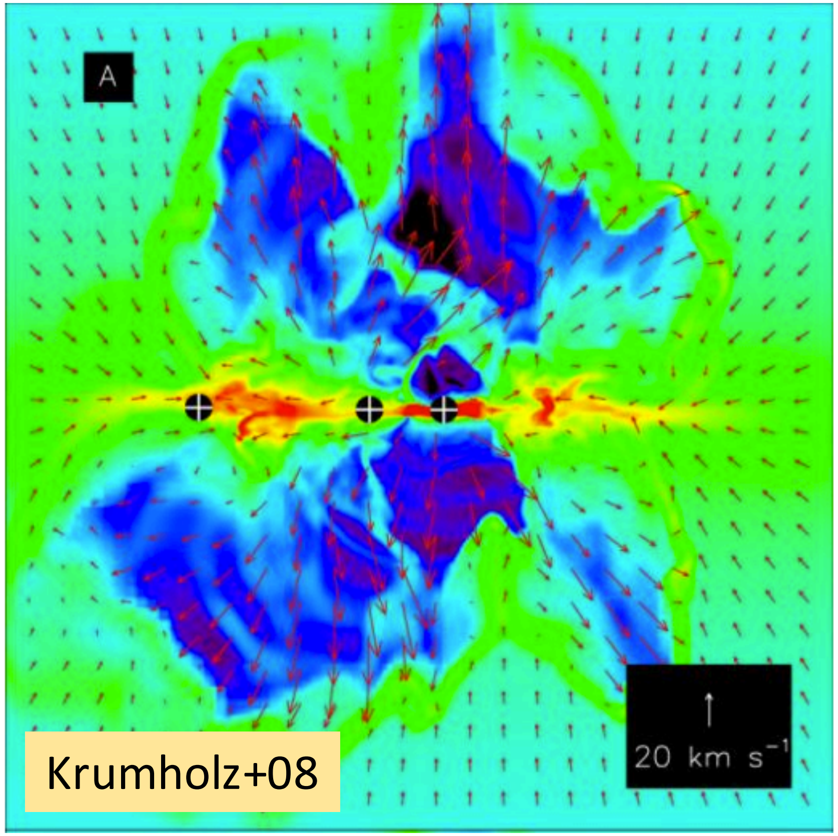


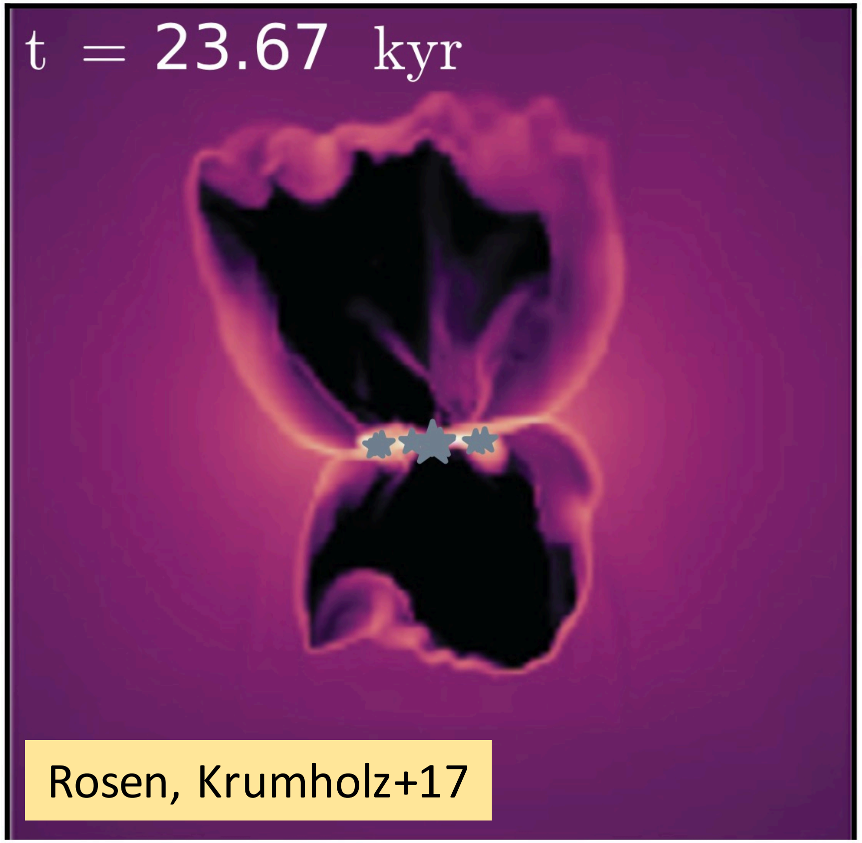
+ The mass accretion onto the star is shut off by the UV feedback at least in some cases.

→ The stellar mass growth is limited, and this effect determines how massive star is finally formed.

※**Gas pressure** effect (UV radiation enhances the gas pressure)

Pop I UV feedback: ignored…



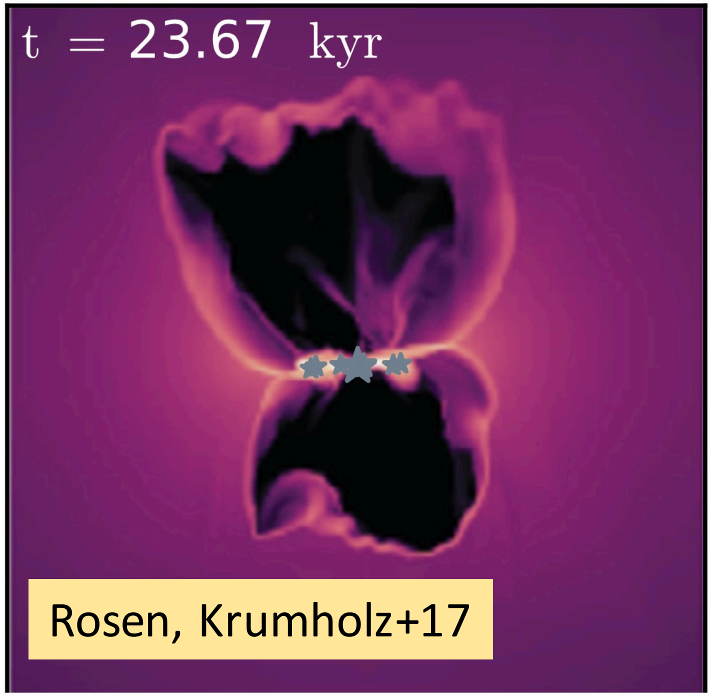


No HII region forming in these RHD simulations (!)

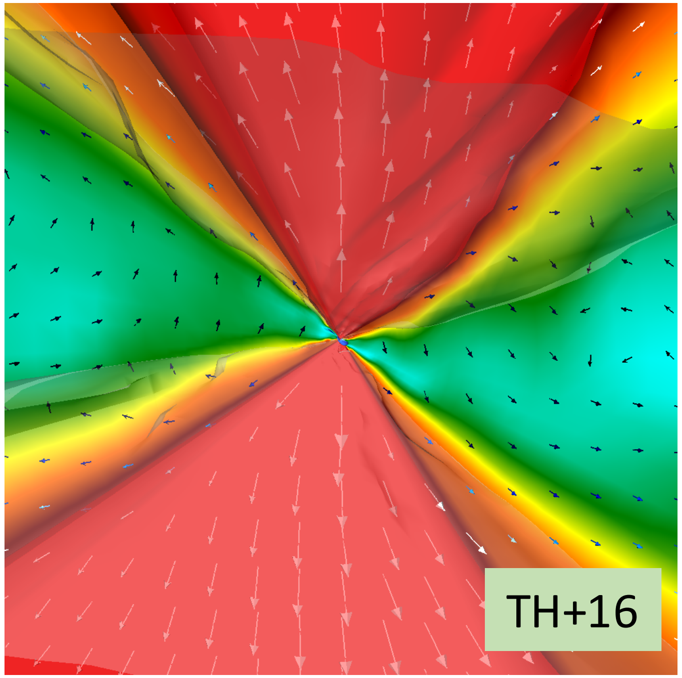
Actually they have studied a qualitatively different effect, radiation force feedback against the dusty accretion flow.

Interplay?

Rad. force *v.s.* Photoionization



Radiation force feedback



Photoionization feedback

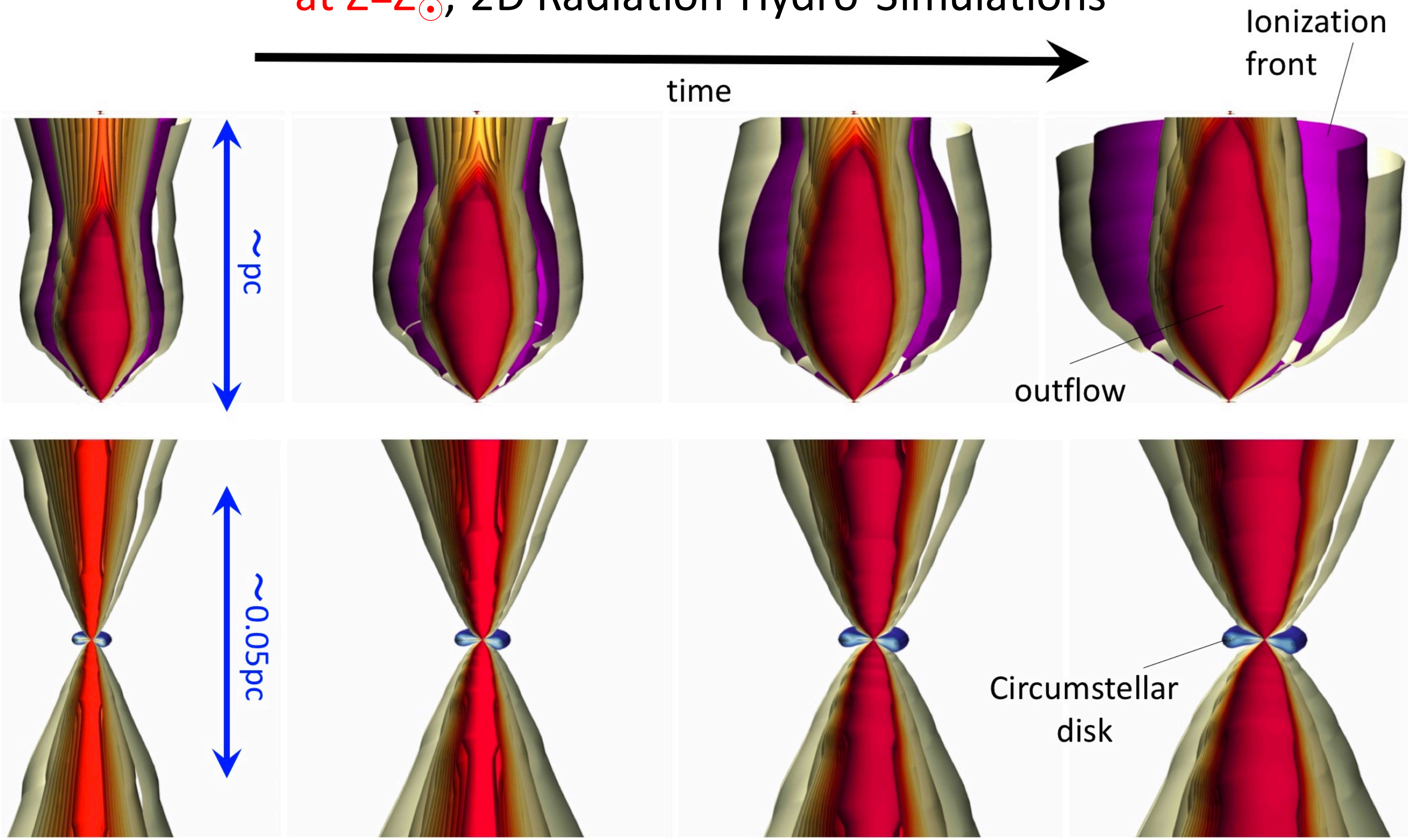
How is the final mass determined under both of these feedback?

First Hydrodynamics Simulations of Radiation Forces and Photoionization Feedback in Massive Star Formation

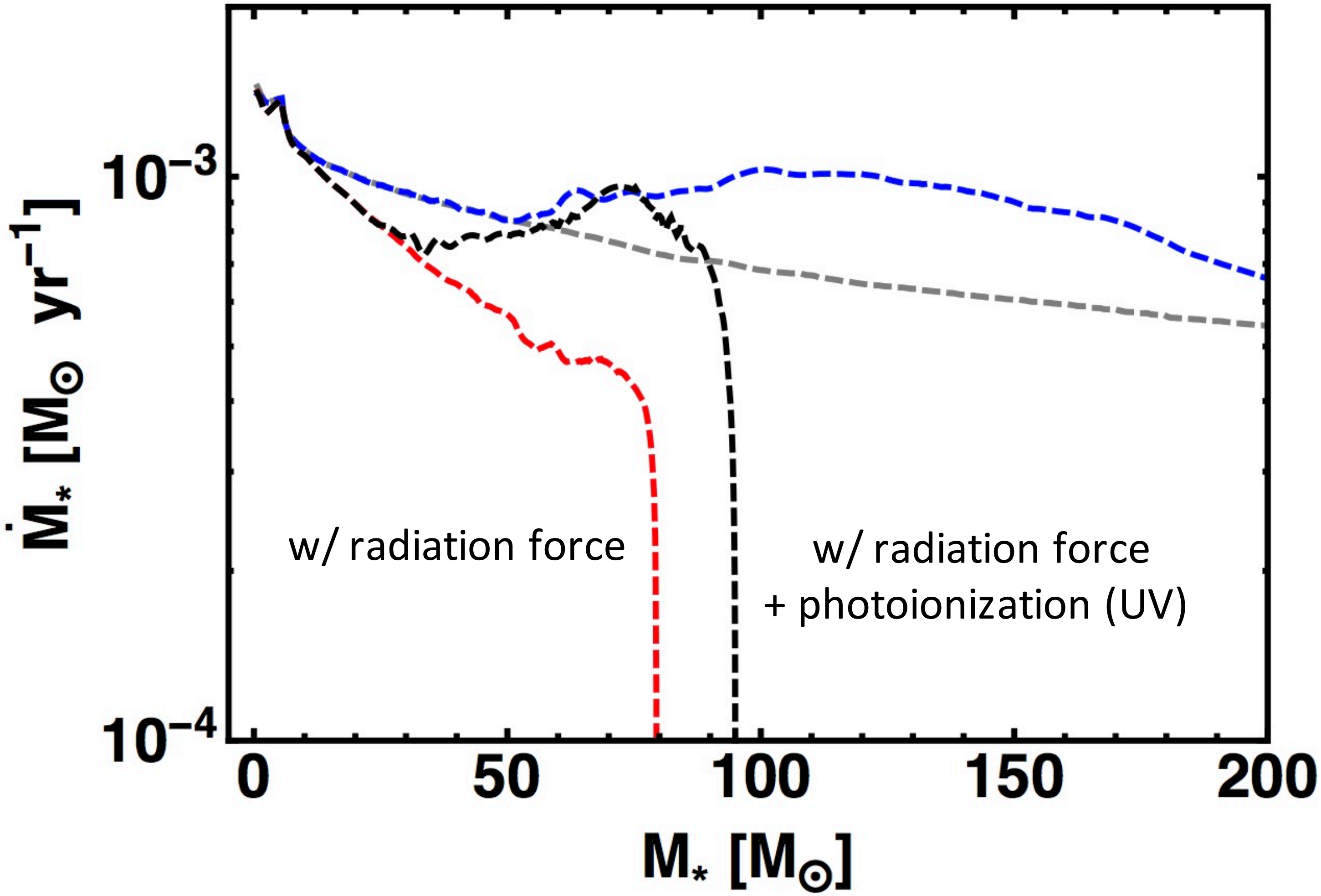
R. Kuiper[1] and T. Hosokawa[2]

(2018) A&A

at $Z=Z_{\odot}$, 2D Radiation-Hydro Simulations



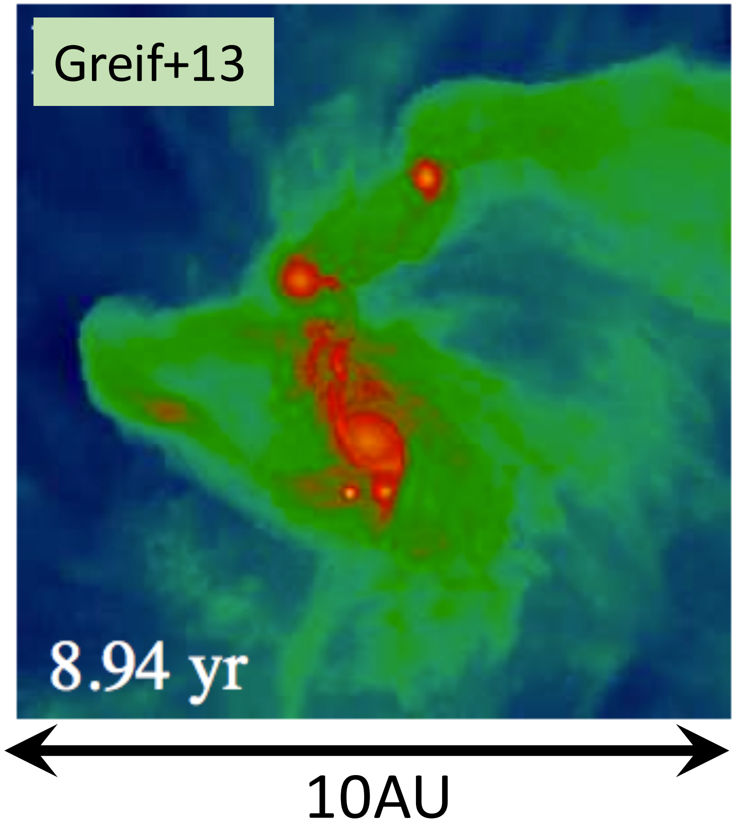
Accretion Histories

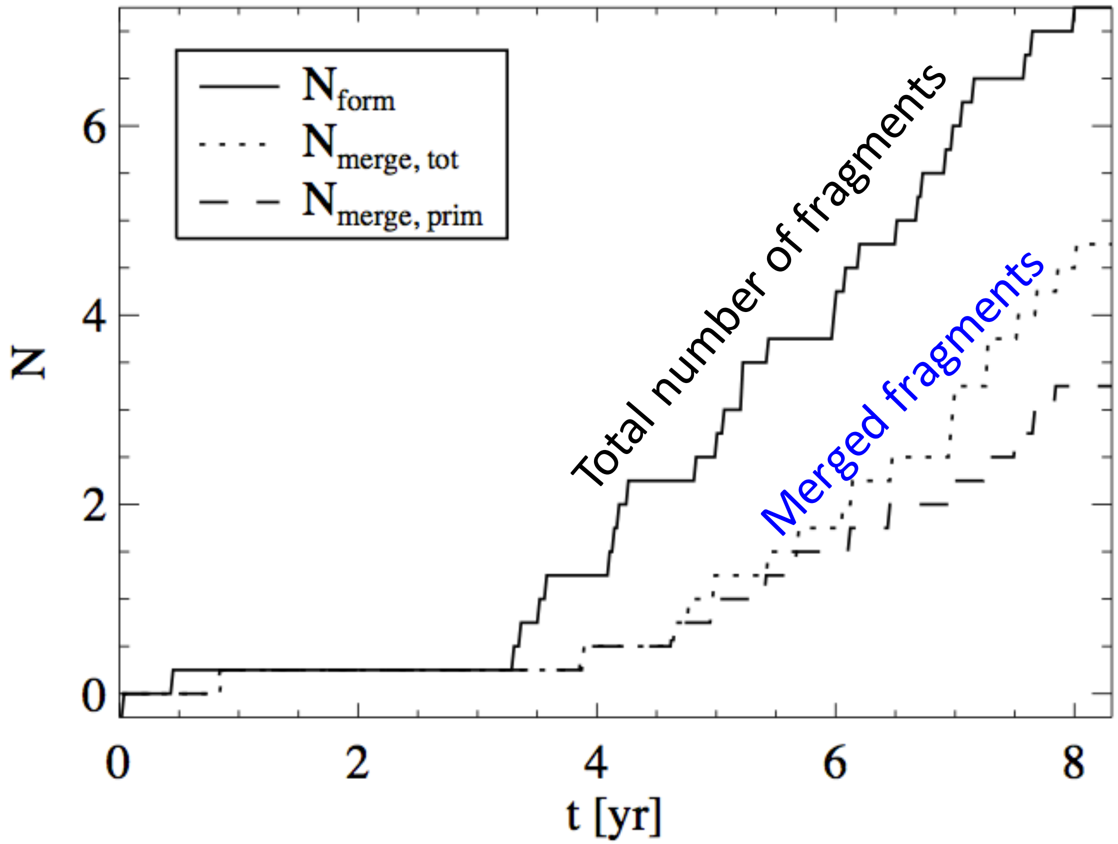


+ UV feedback rather increase the final mass (opposite to Pop III case)

Hajime Fukushima explains why (next talk)

Disk Fragmentation





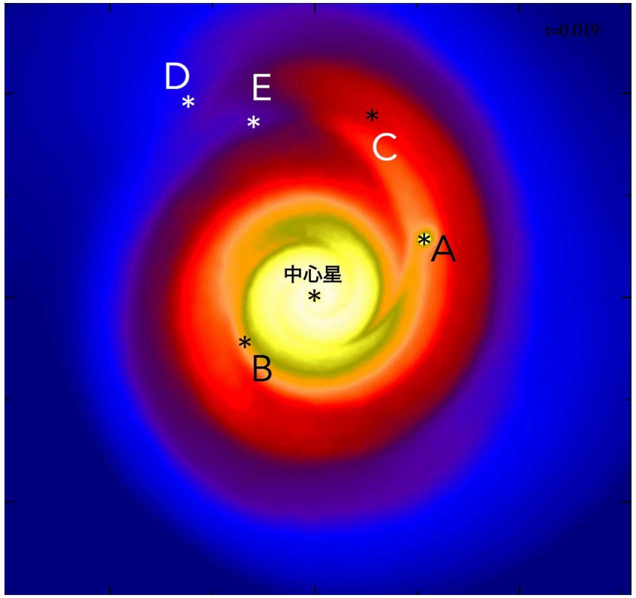
Fragmentation does occur, but merger of the fragments also occurs.

What determines the survival rate of the fragments?
⇒ low-mass Pop III stars?

Binary *v.s.* Merger

What determines such different fates?

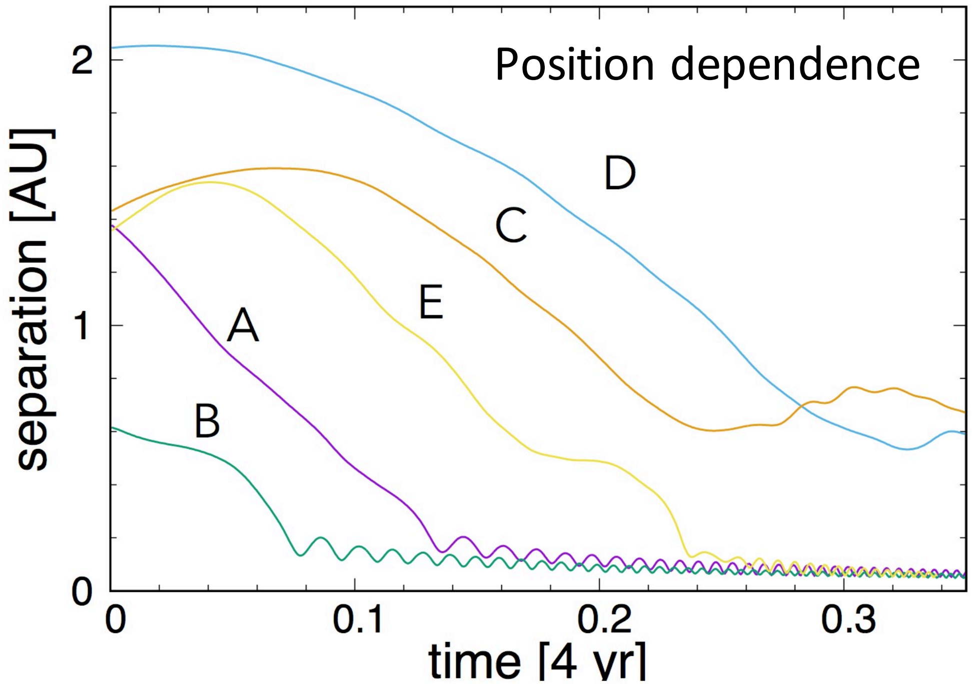
Chon + TH in prep.

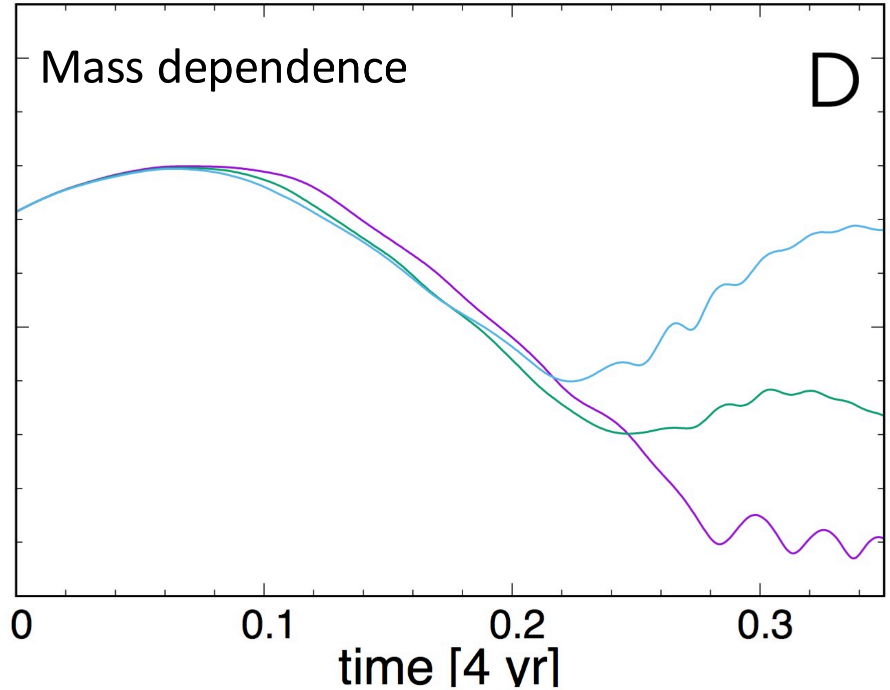


Simple experiments

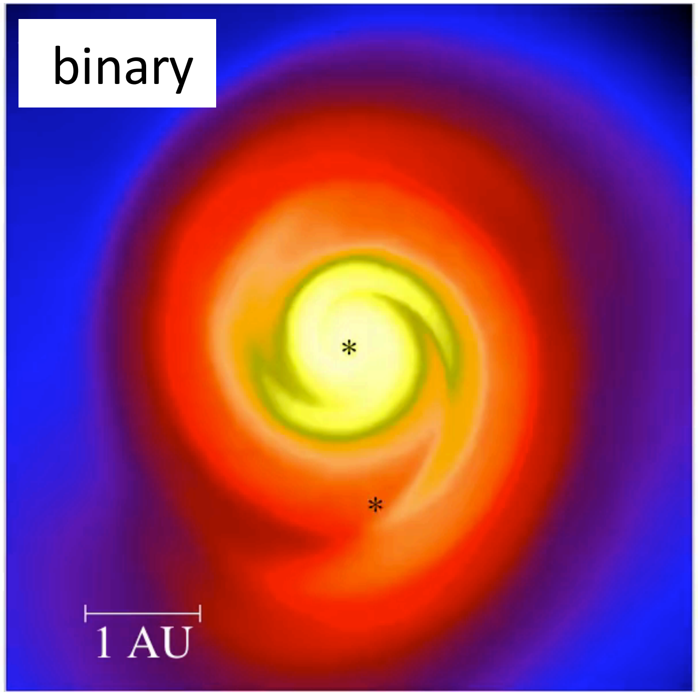
Put a fragment (point particle) in a disk by hand, then follow its orbital evolution

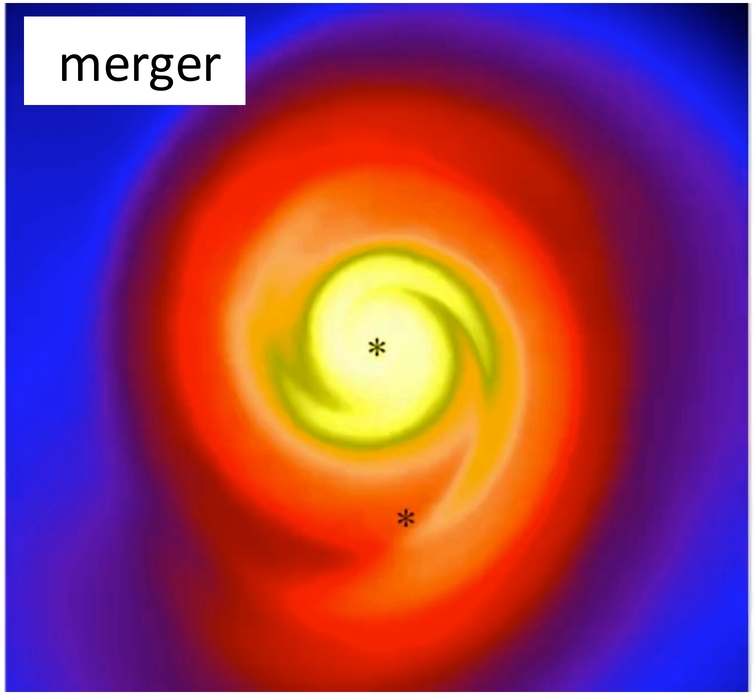
Great diversity, depending on the initial positions, and fragment mass





Underlying Physics





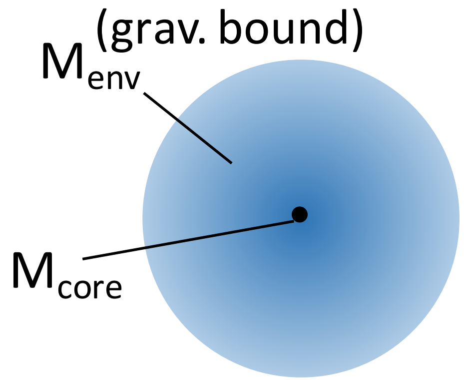
Inward migration stalls when the "gap" is opened up in the disk (III)

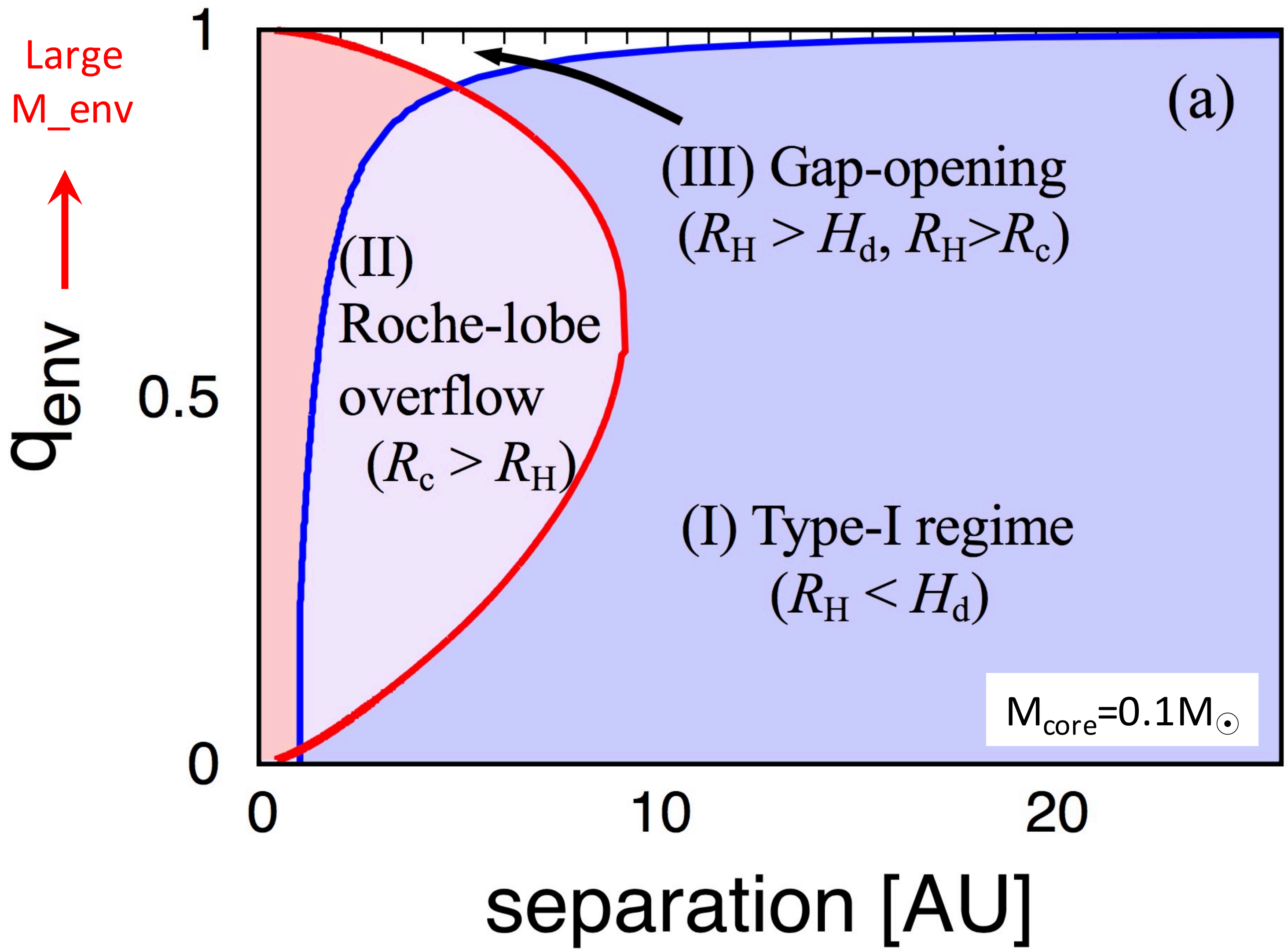
Angular momentum loss via
(I) type-I migration
(II) Roche Lobe Overflow

Simple analytic considerations
$\Rightarrow$ predict under which conditions the above processes operate…

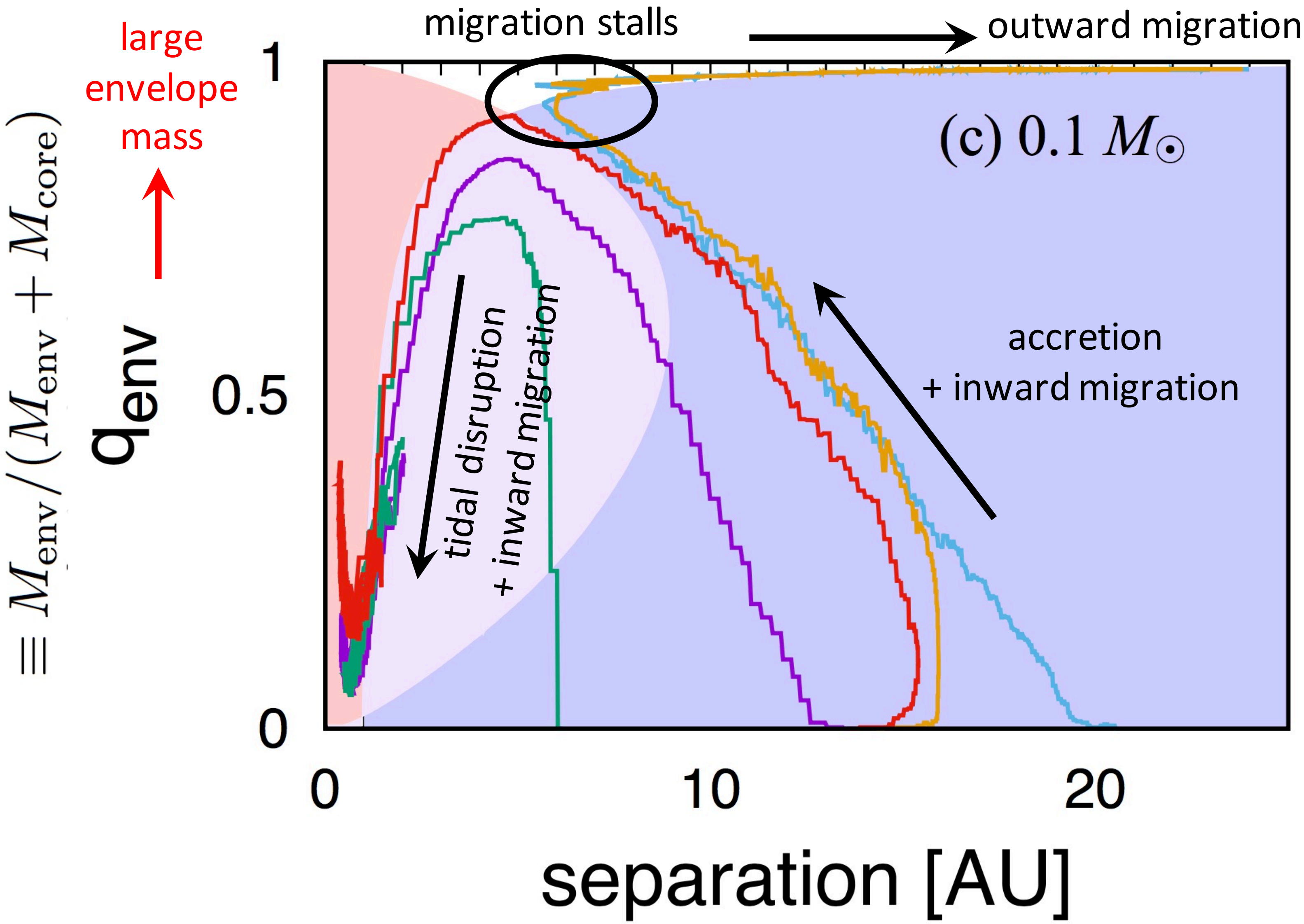
Diagram

$$q_{\rm env} \equiv M_{\rm env}/(M_{\rm env} + M_{\rm core})$$





Putting Numerical Results



Divergent fates are now interpreted well with the diagram.

Summary

Feedback and Fragmentation :
key processes in high-mass star formation

Feedback: UV (Pop III) v.s. Rad. Force (Pop I)
Pop I UV feedback enhances the mass accretion
$\Rightarrow$ metallicity dependence (Hajime Fukushima's talk)

Fragmentation: binary formation v.s. merger
It looks quite complex, but underlying physics can be derived at least with a simplified setting.