# Cosmological Simulations of Pop III Star formation

Brian O'Shea
Theoretical Astrophysics Group, LANL

Collaborators: Michael Norman (UCSD)
Matt Turk (Stanford/LANL)
Tom Abel (Stanford)

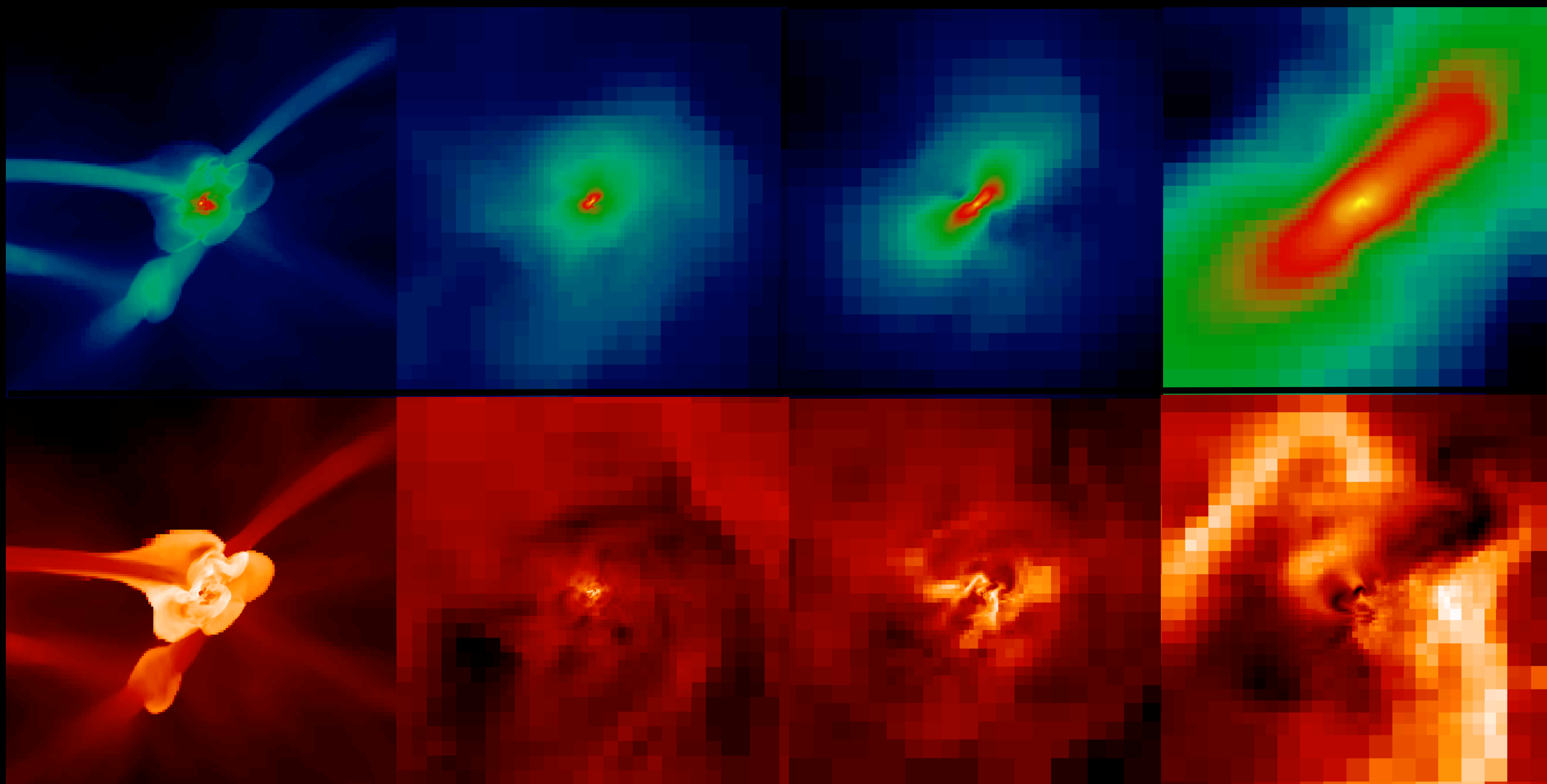
# Pop III star formation: A well-posed problem

- Initial conditions taken from cosmological observations (CMB/LSS)
- Physics straightforward at large (>> au) scales: gravity, hydro, primordial chemistry, optically thin radiative cooling: no metals/ dust, dynamically important B-fields, cosmic rays, etc.
- Complexity is due to large range of scales!

# Components of a Pop III star formation simulation

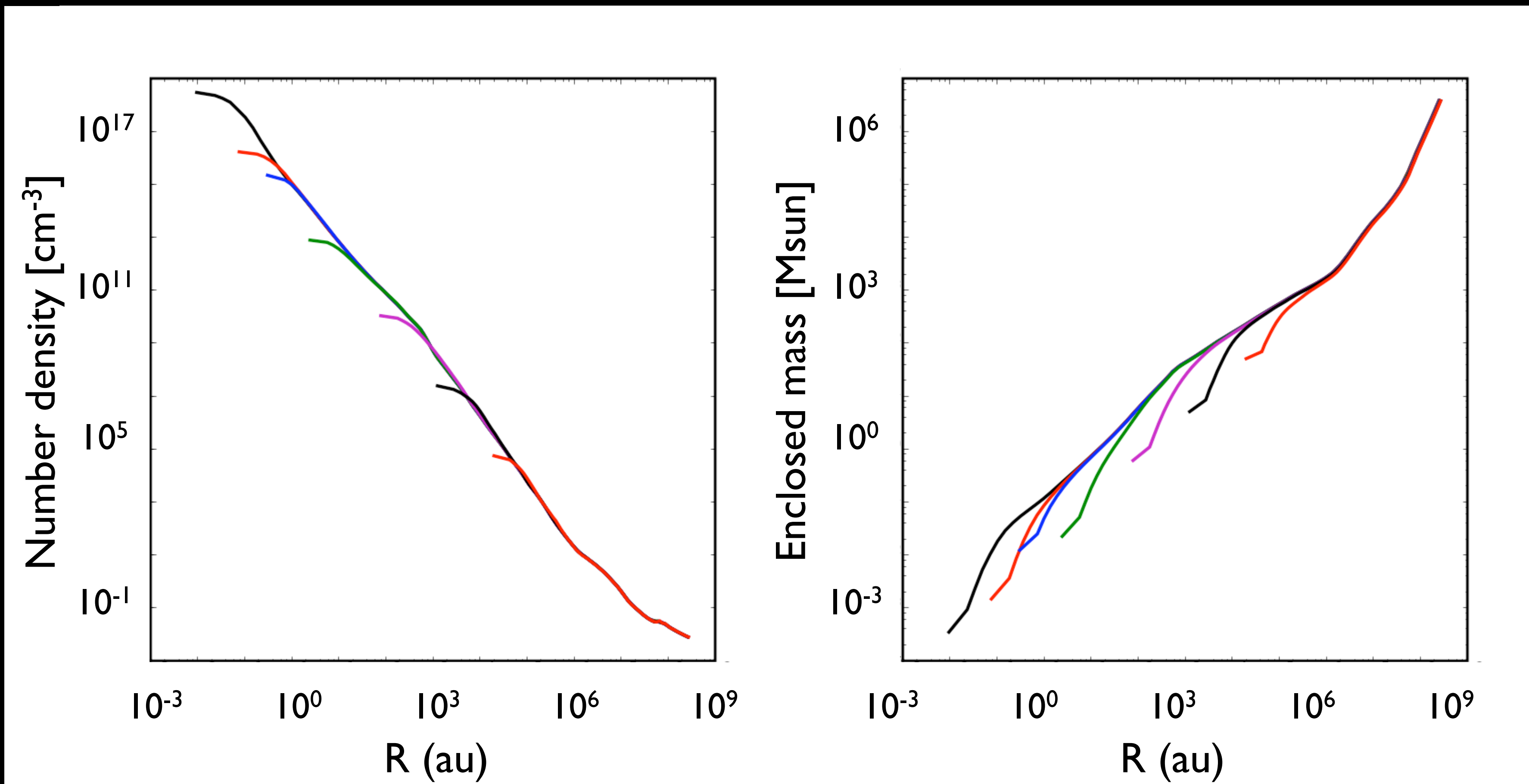
- Cosmological model
- Gravity (dark matter + baryons)
- Hydrodynamics
- Primordial chemistry
- Optically thin radiative cooling (+ extensions for optically thick regime)

# Pop III star formation:  current paradigm



1 kpc    5 pc    0.5 pc    0.05 pc

# Pop III star formation:  current paradigm

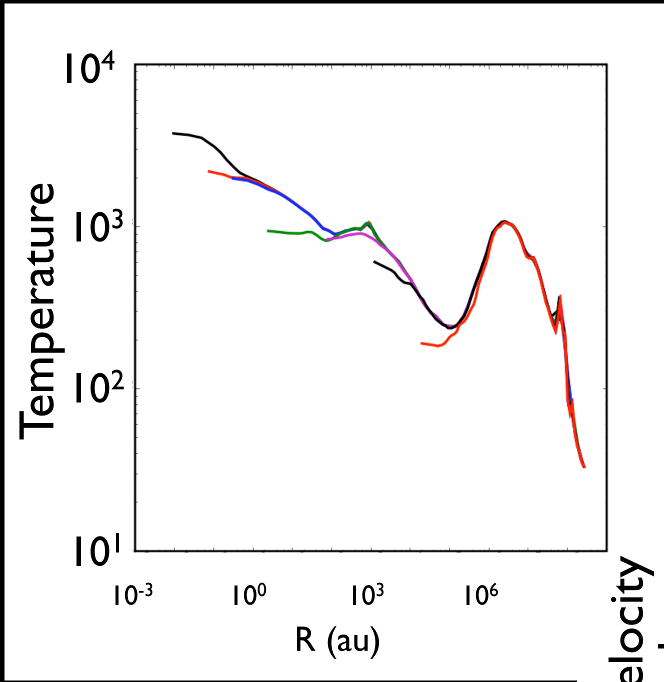


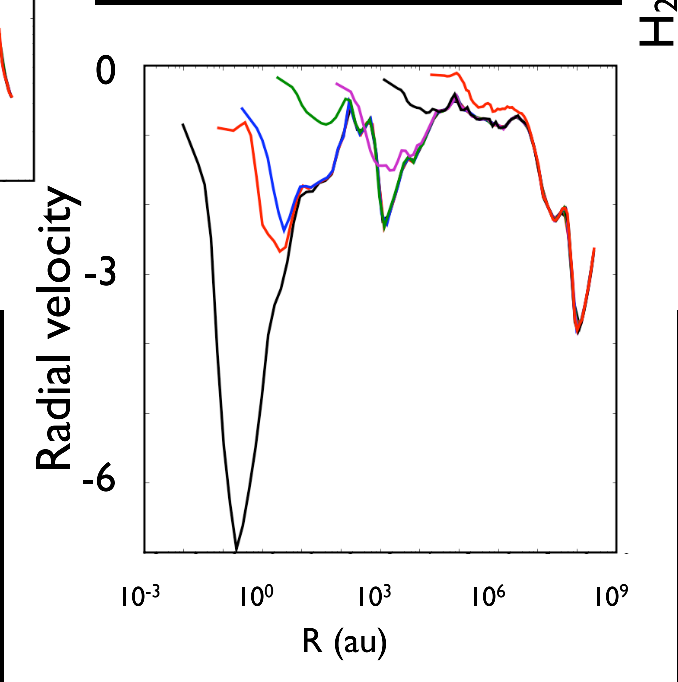

Number density

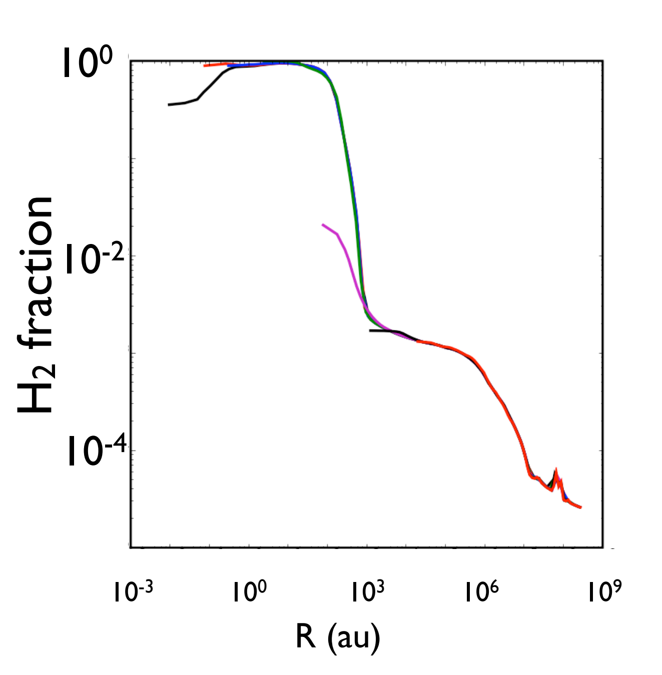
Enclosed mass

Turk, Abel & O'Shea 2007 (in prep)

# Pop III star formation:  current paradigm

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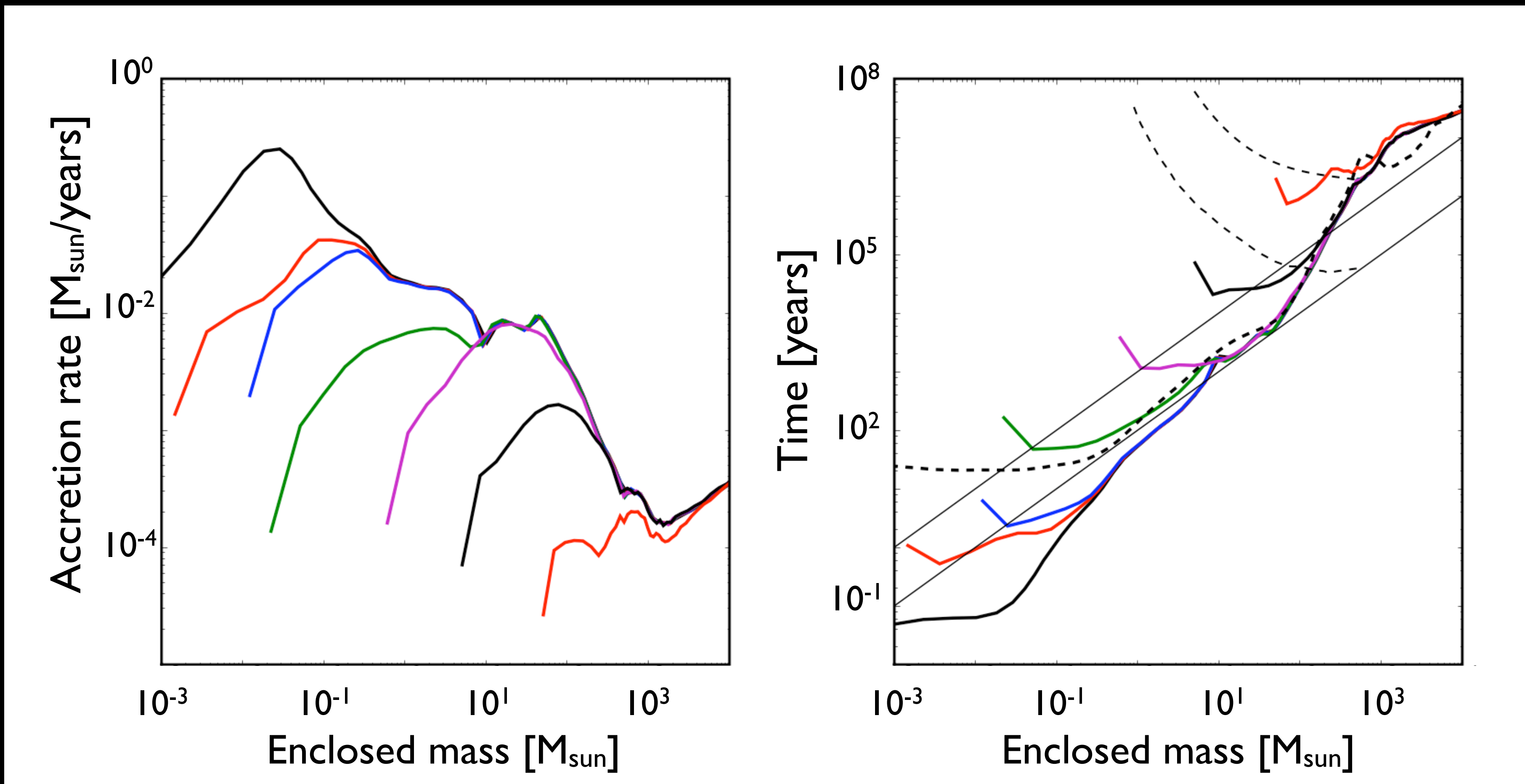


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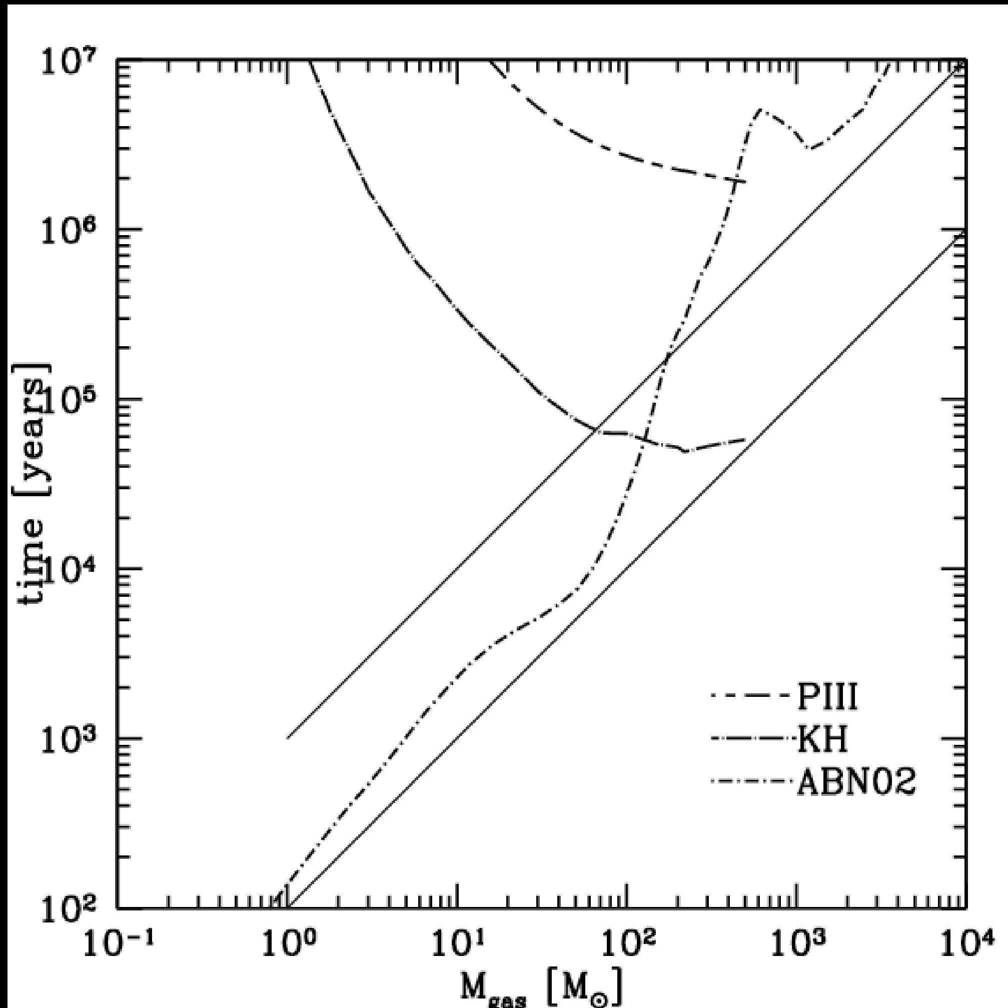
# Variation in accretion rates




O'Shea & Norman 2007, ApJ, 654, 66-92

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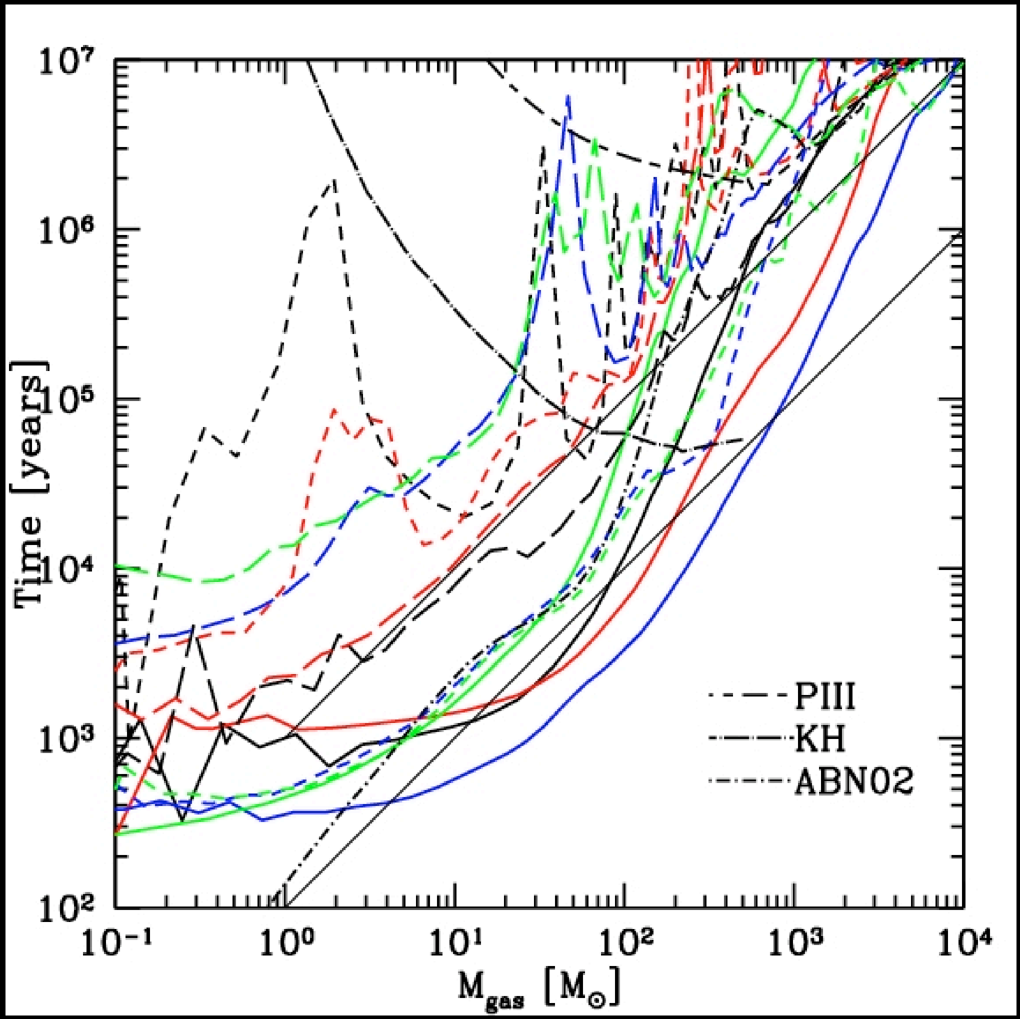


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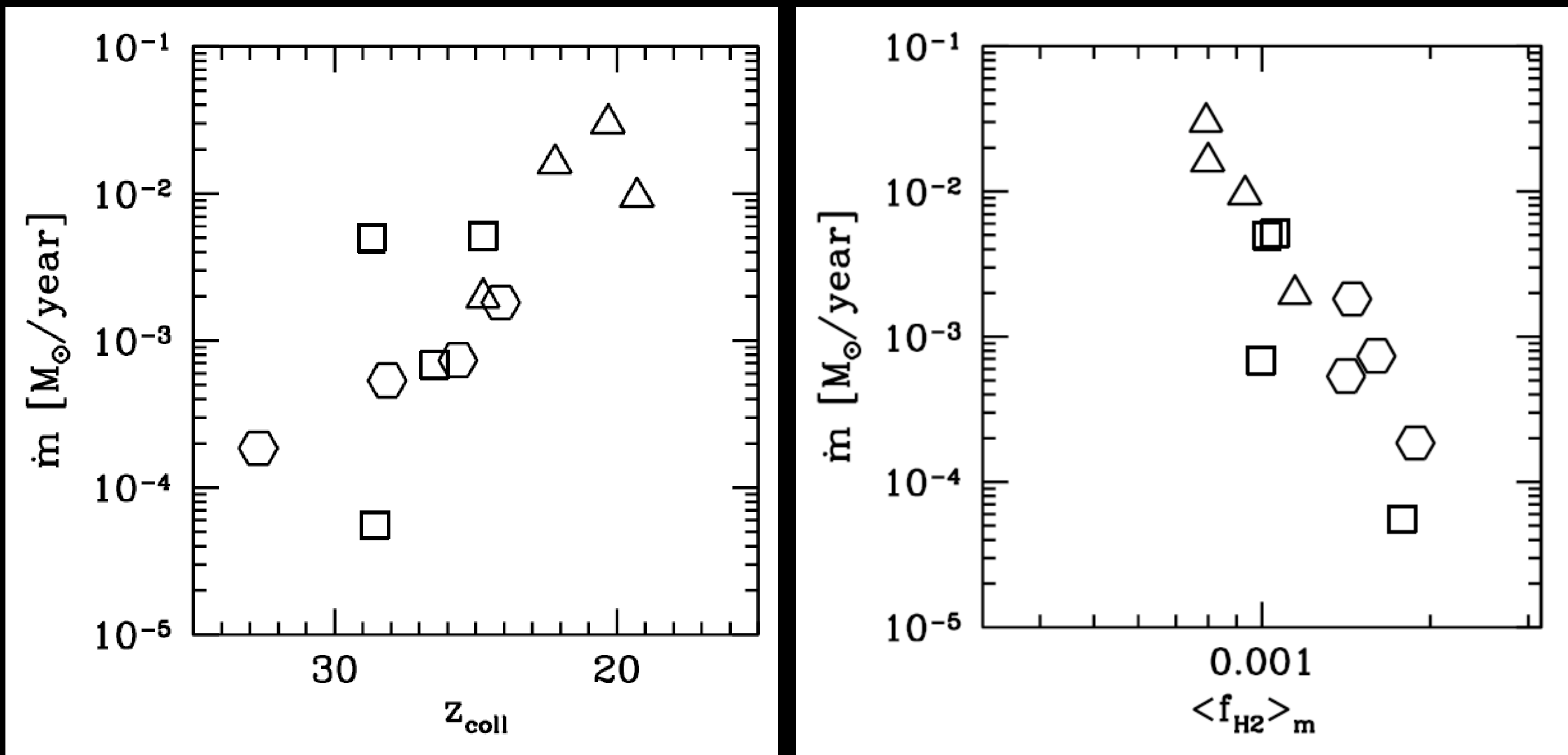


O'Shea & Norman 2007, ApJ, 654, 66-92

# Effect of a soft UV background

- Photodissociation region around a Pop III star is much larger than the HII region (see Whalen et al., astro-ph/0708.1603 [up tomorrow] for more information)
- Takes relatively few stars to build up a far-UV background which suppresses $H_2$ formation
- Most Pop III stars will form in the presence of some sort of radiation background ("Pop III.2 stars")
- How does the destruction of $H_2$ affect properties of primordial stars?
- See O'Shea & Norman 2007, ApJ submitted (astro-ph/0706.4416)

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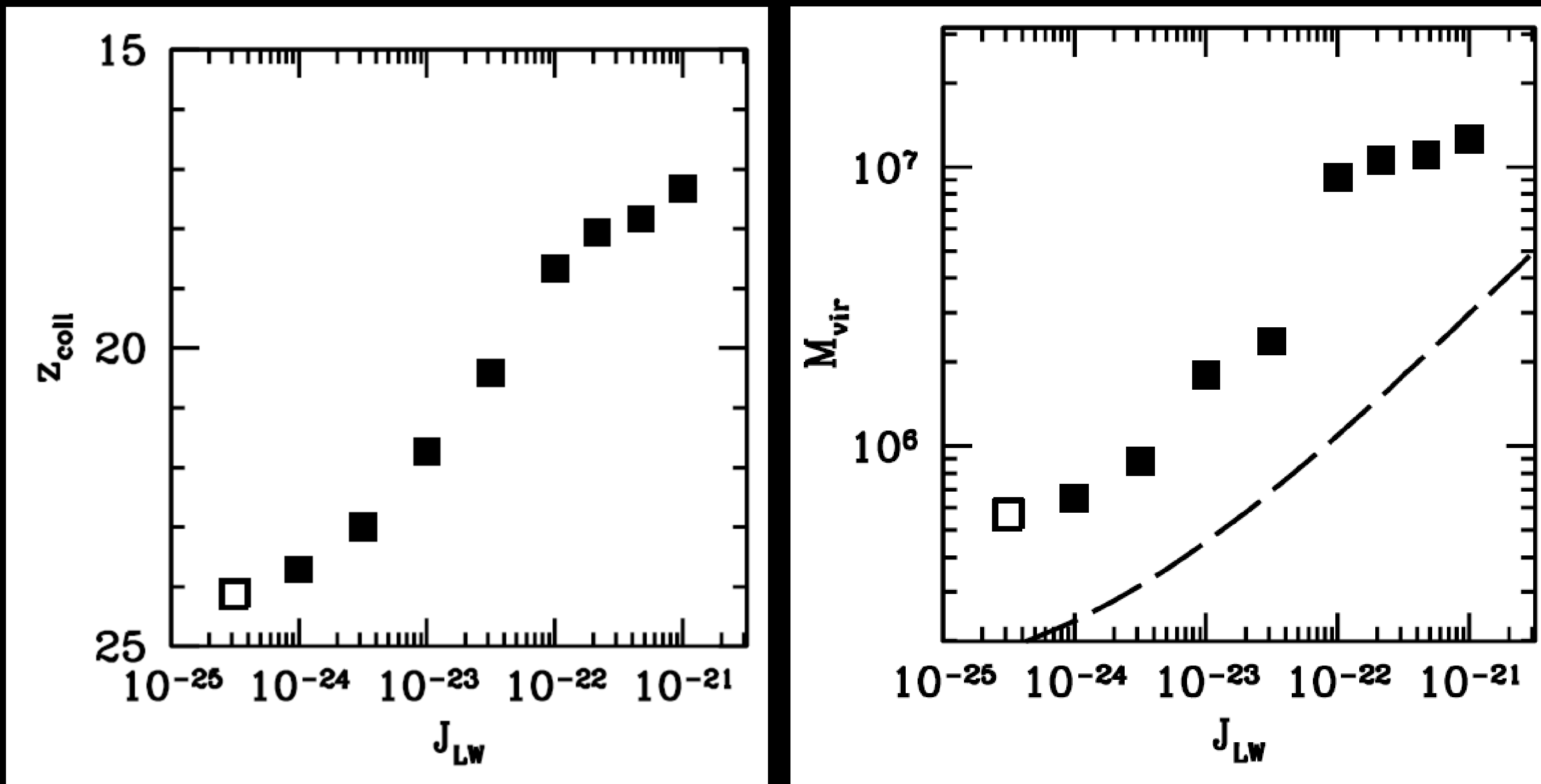


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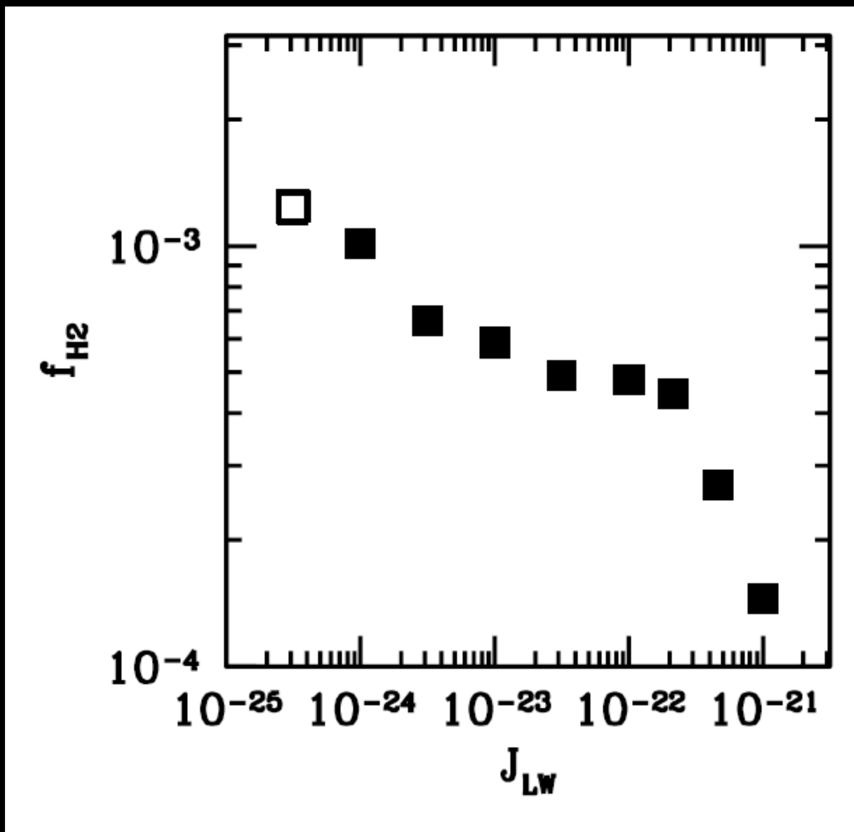
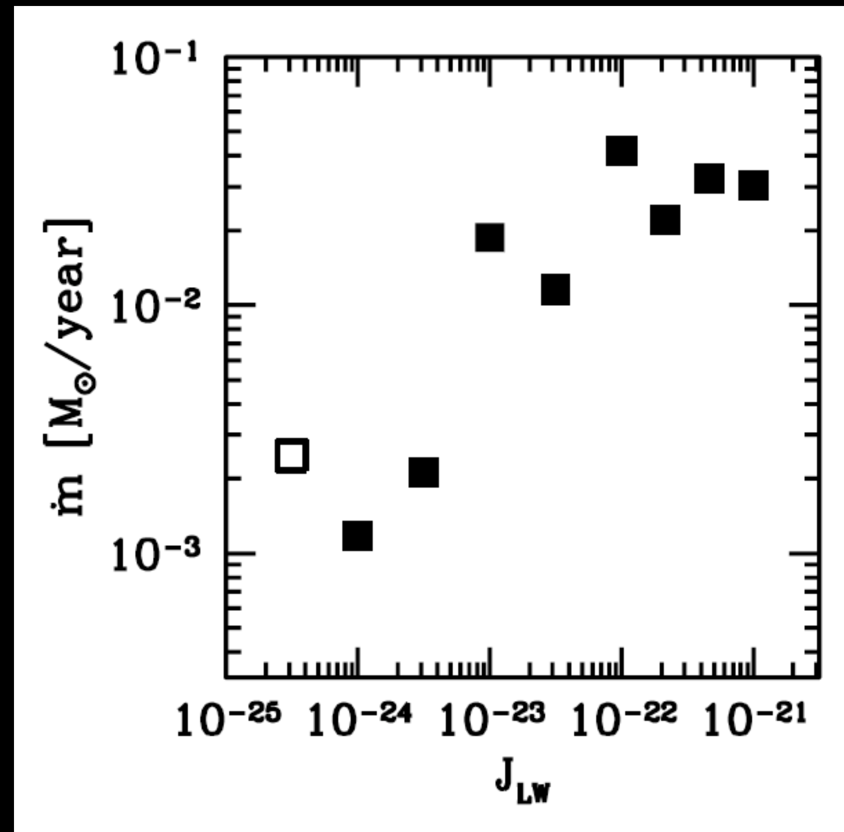
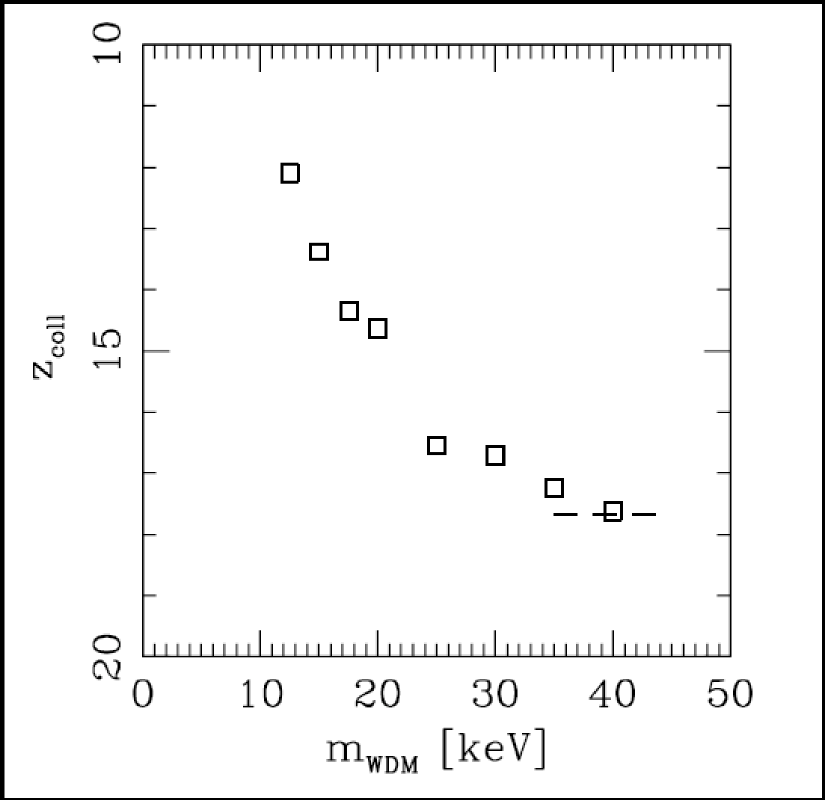
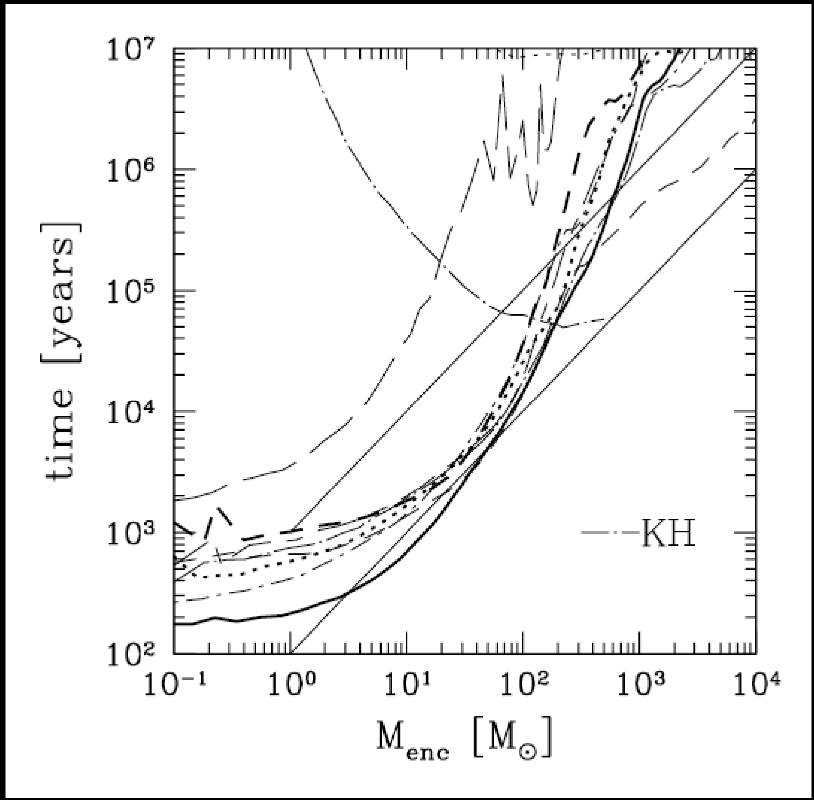



O'Shea & Norman 2007, ApJ submitted (astro-ph/0706.4416)

# A comment on warm dark matter...




O'Shea & Norman 2006, ApJ, <u>648</u>, 31-46

# Q: Where do we go next?

- Cosmological simulations have allowed us to go from Mpc to sub-pc scales (with good agreement between different methods: See O'Shea & Norman 2006, Yoshida et al. 2006, 2007)
- The fundamental problem is *lack of physics* in our simulations, not *lack of resolution*.
- Necessary physics: radiation transport (multigroup/multifrequency?), MHD (non-ideal?), non-ideal EOS, stellar evolution models (see Tan & McKee 2004; McKee & Tan 2007)

# A: Beyond cosmological simulations!

- Lots of baggage associated with cosmological simulations: core of halo (r ~ 1 pc) is effectively decoupled from rest of simulation (and is $10^{-16}$ of the volume)
- It's clear that we'll get a disk at some point: can we reliably do this in our cosmology codes?
- Time to move on abd concentrate on the "inner parsec problem" - more like galactic SF simulations!

# Conclusions

- Cosmological simulations using both AMR & SPH generally converge to similar solutions at large (>> au) scales: this is not so surprising.
- A variety of accretion rates onto Pop III protostars are inferred: all indicate massive stars. But, how massive? Details are unclear.
- We are now at the point where we need to focus on the "last parsec" using codes with more advanced physics - it is time to move past n-body + hydro cosmology codes!