Mass Functions from the Fragmentation of Expanding Shells

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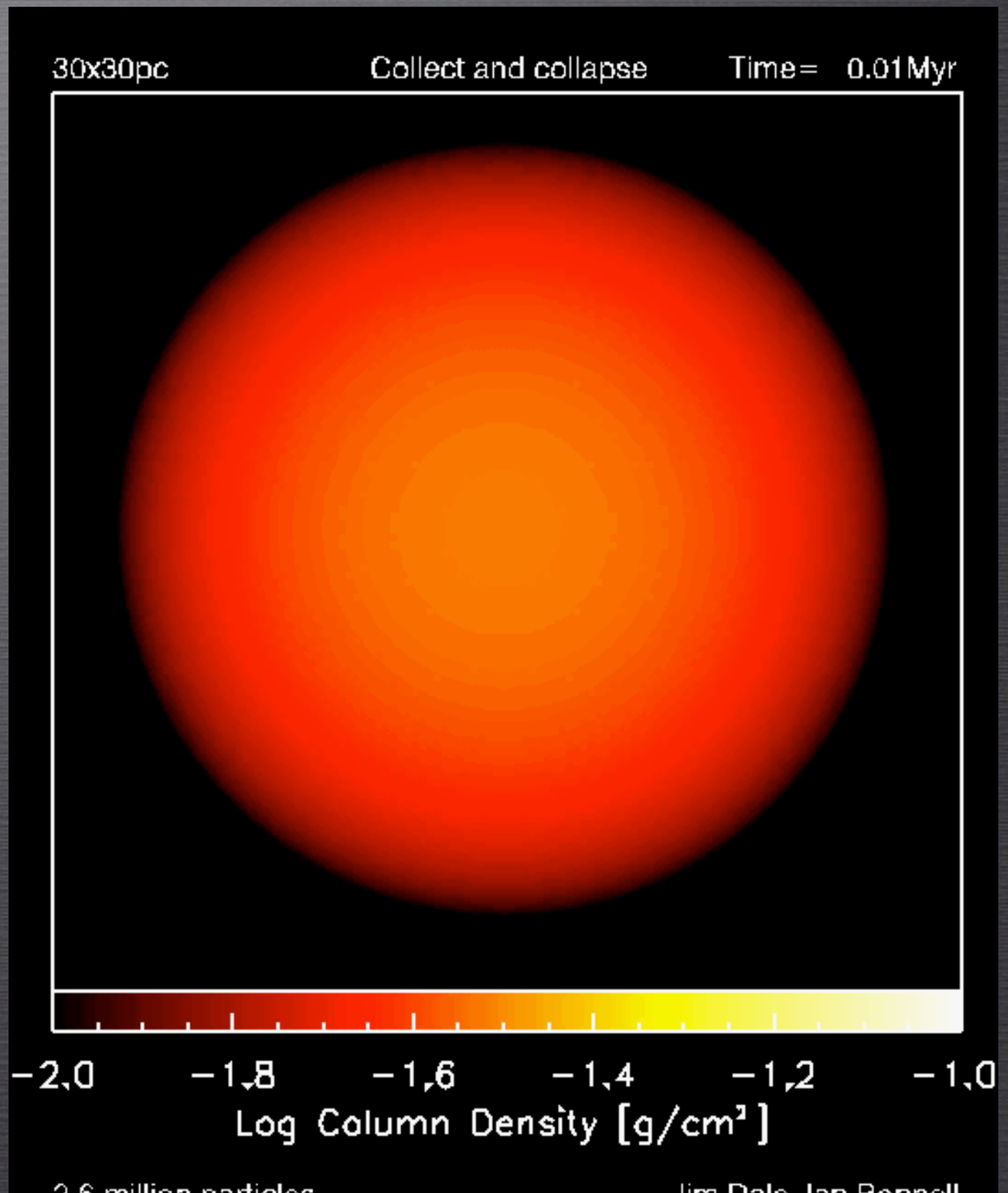
Bubbles and Shells

Triggered star formation

-SPH simulation of collect and collapse process

-clearly works - can make stars out of previously-uniform gas (if you can make an O-star

-but can the process self-propagate - can it make more O-stars?



Need to know the mass function

-Consider thin shell of gas swept up by expanding bubble

-treat fragmentation as two-dimensional

-look at stability of perturbations of size λ, angular wavenumber l

$$l = \frac{2\pi R}{\lambda}$$

-dispersion relation:

$$\omega(l) = -\frac{AV}{R} + \sqrt{\frac{BV^2}{R^2} - \frac{c_s^2 l^2}{R^2} + \frac{2\pi G\Sigma l}{R}}$$

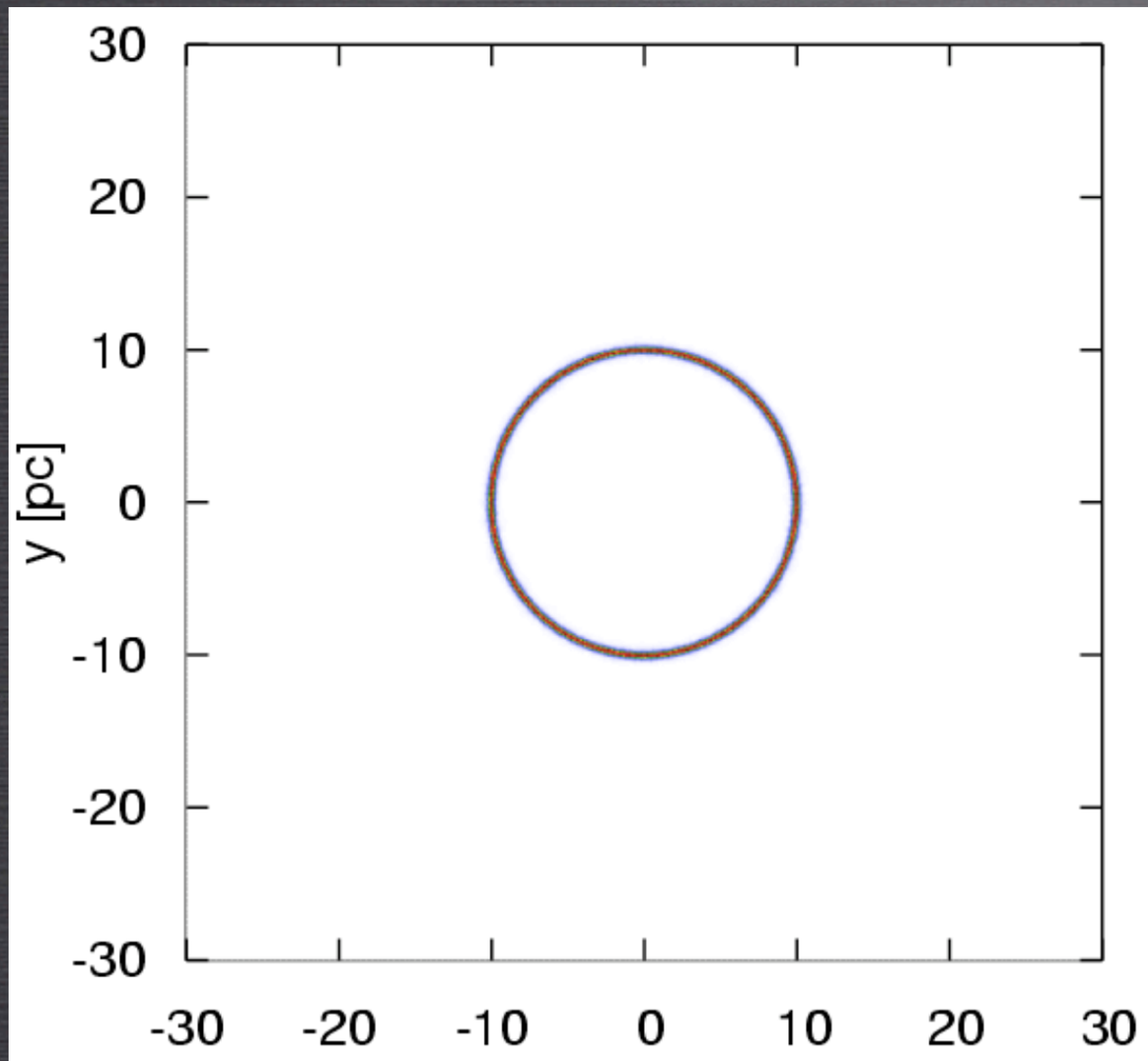
(e.g. elmegreen 1994)

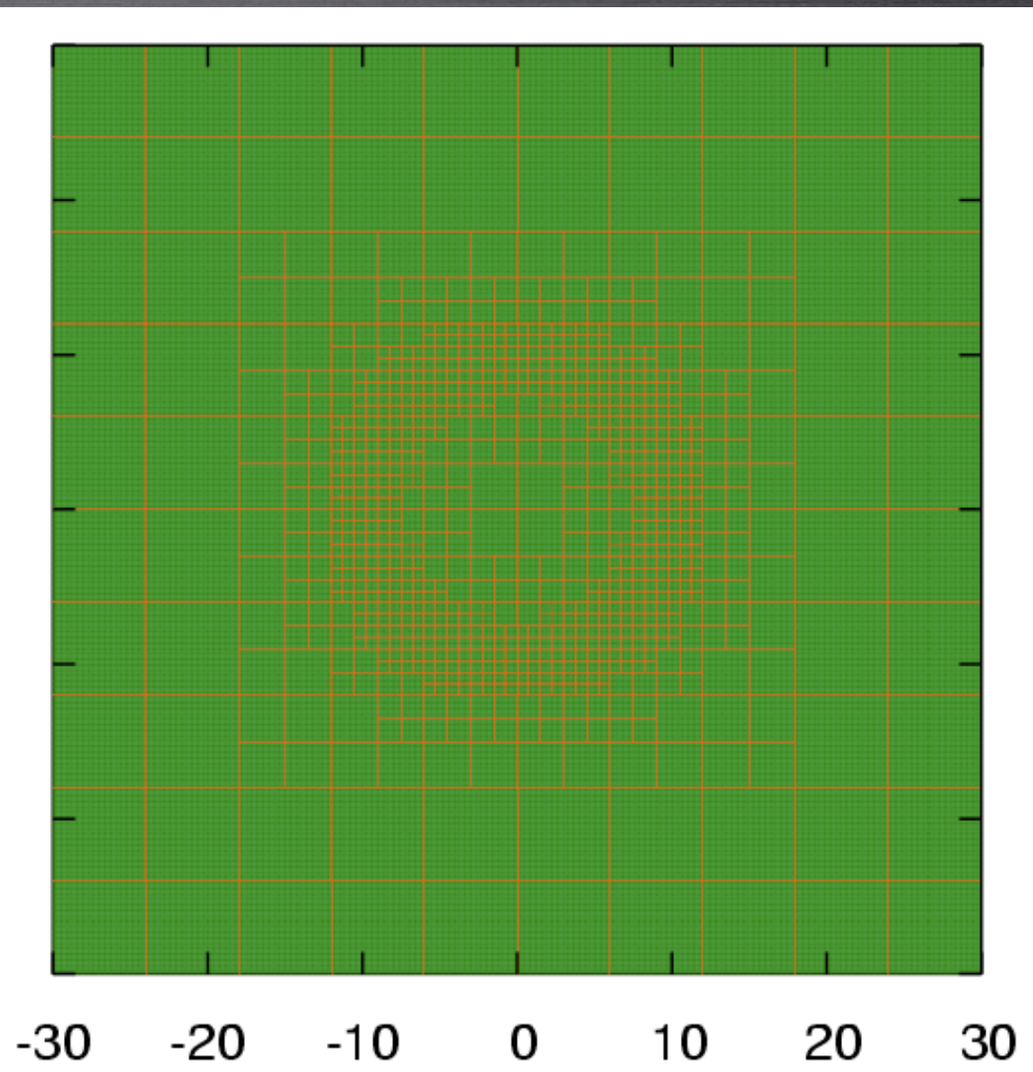
SIMULATIONS

-IDEAL TESTBED FOR COMPARING AMR AND SPH SIMULATIONS

-MUST AVOID OTHER INSTABILITIES

-PURE GRAVITATIONAL FRAGMENTATION





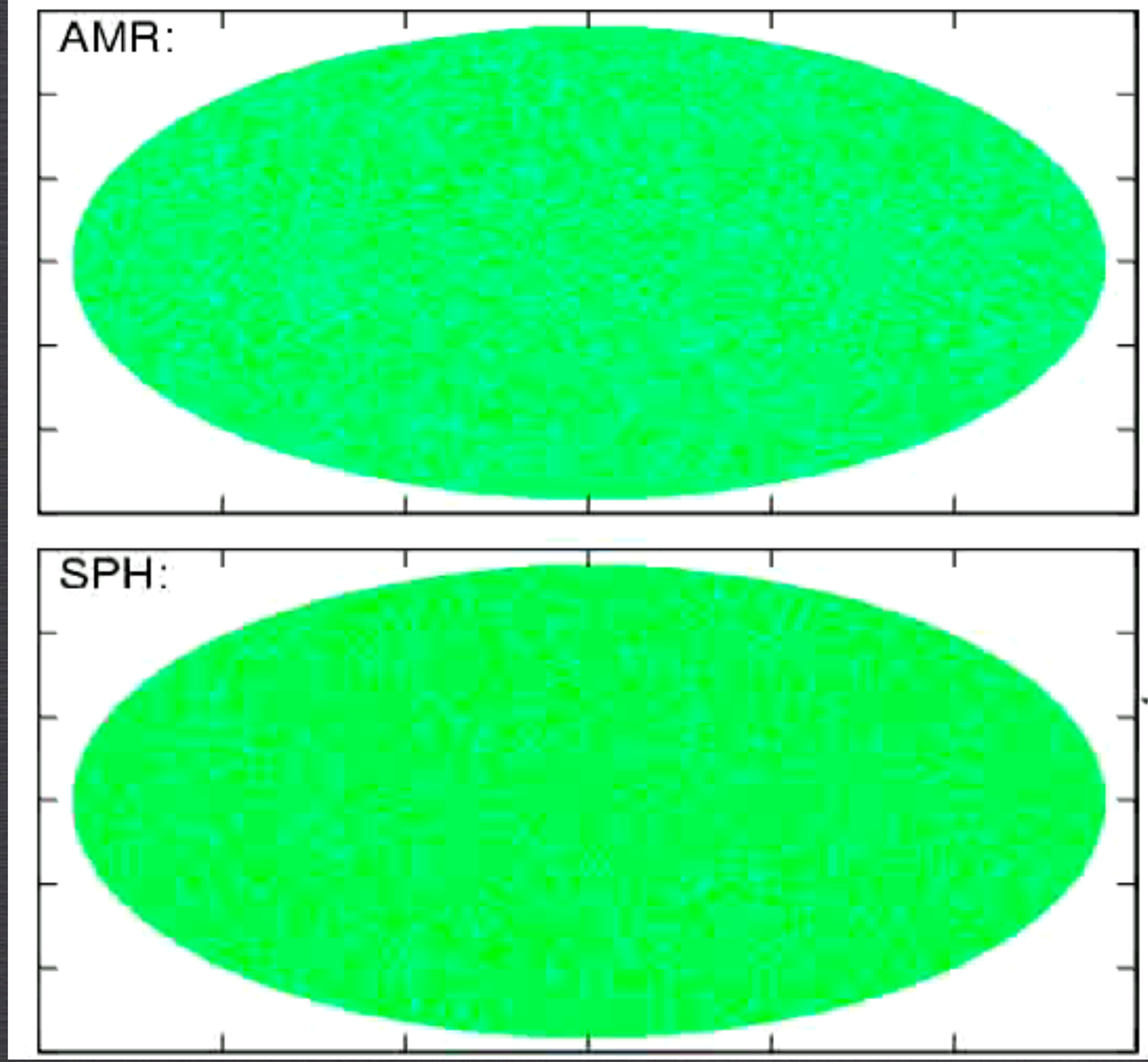
ANALYSIS

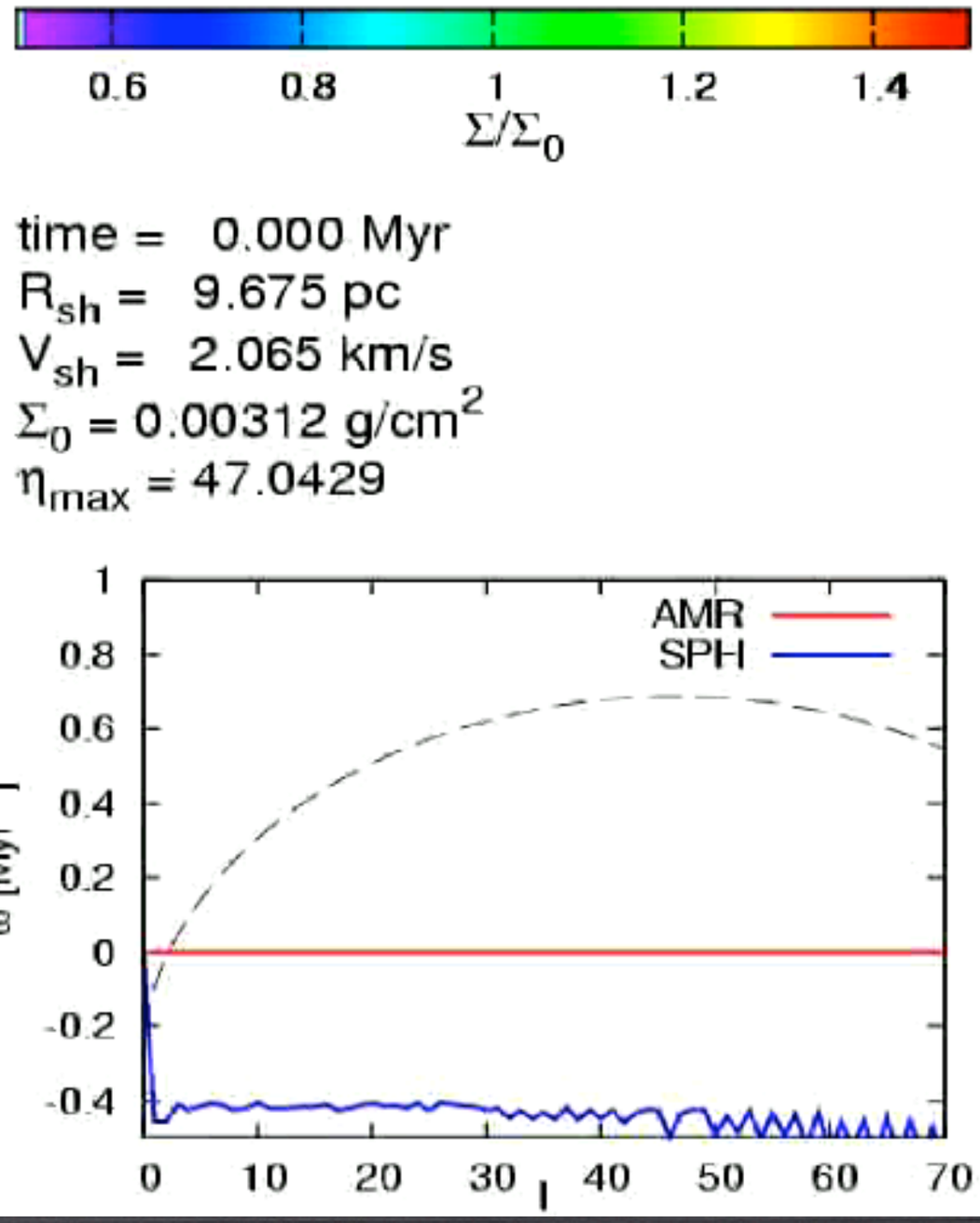
-Make surface-density maps at regular time intervals

-decompose into spherical harmonics (2-d Fourier transform)

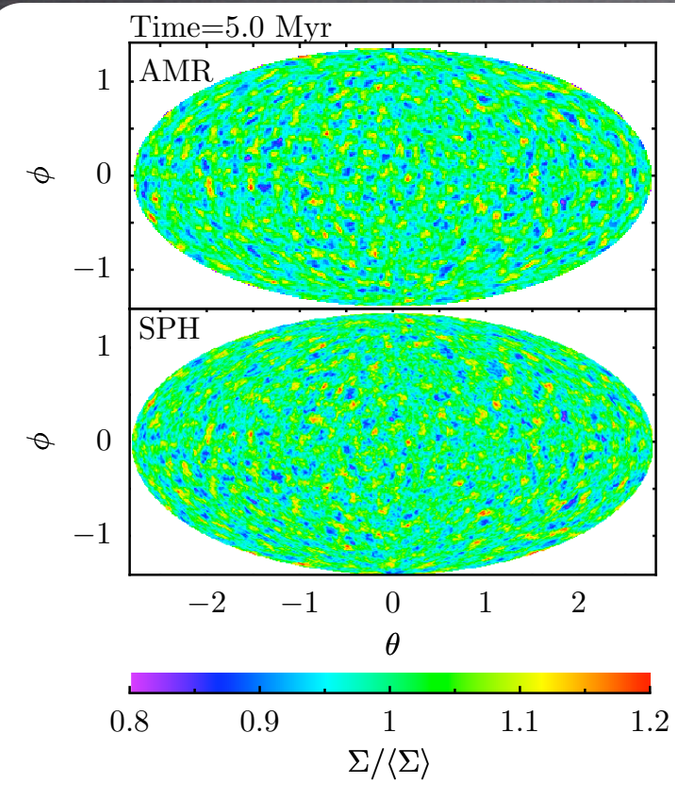
-NUMERICALLY DIFFERENTIATE BETWEEN SNAPSHOTS

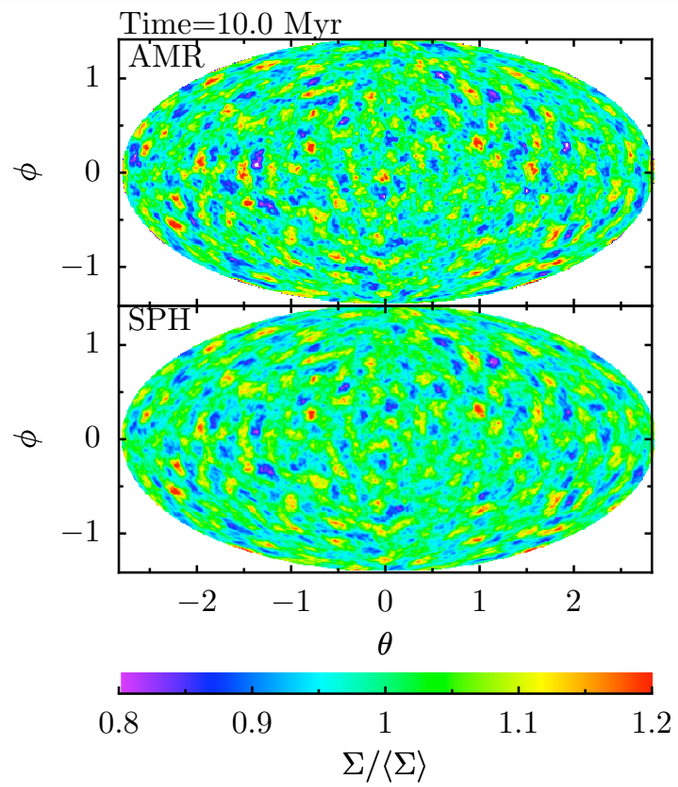
CODE COMPARISON

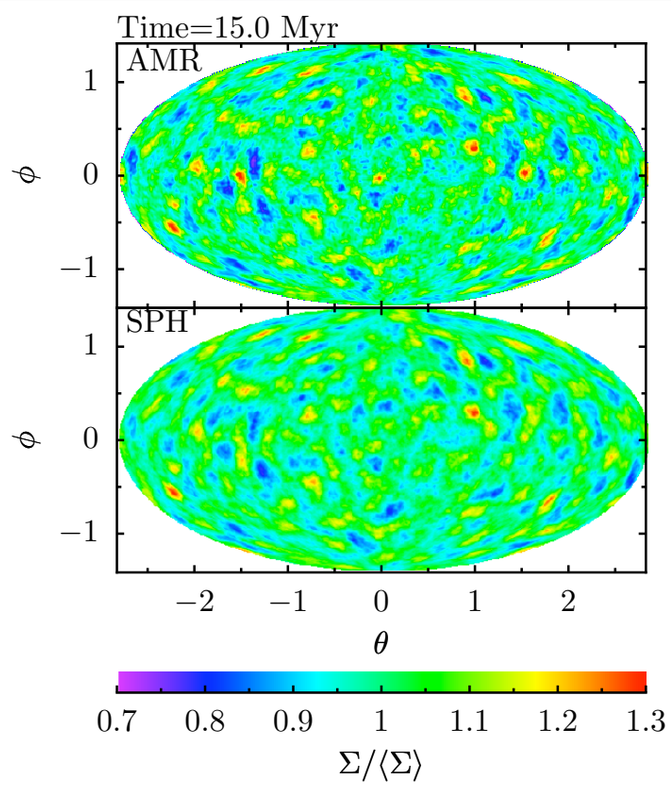


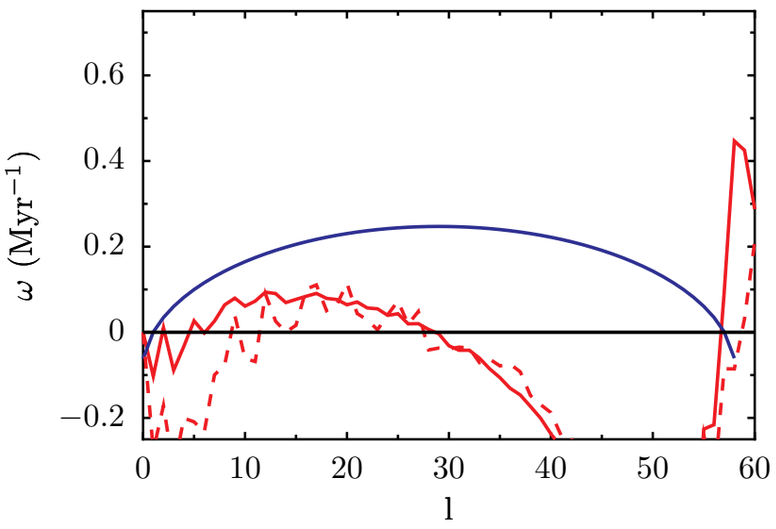


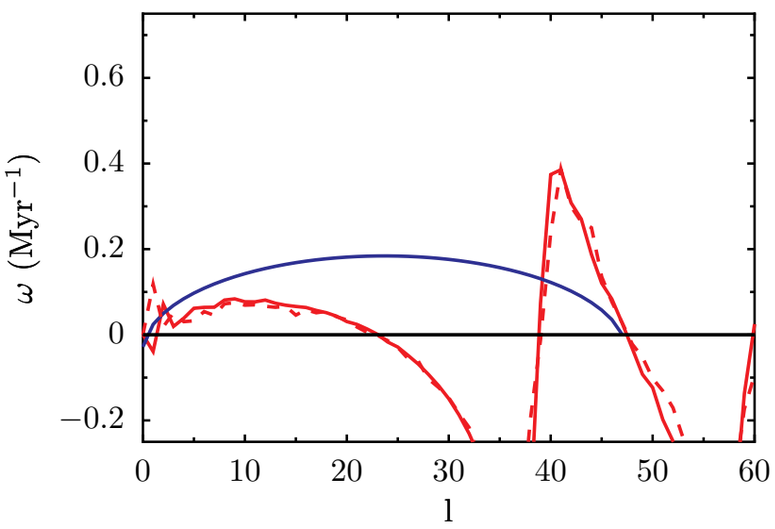
COMPARISON WITH THEORY

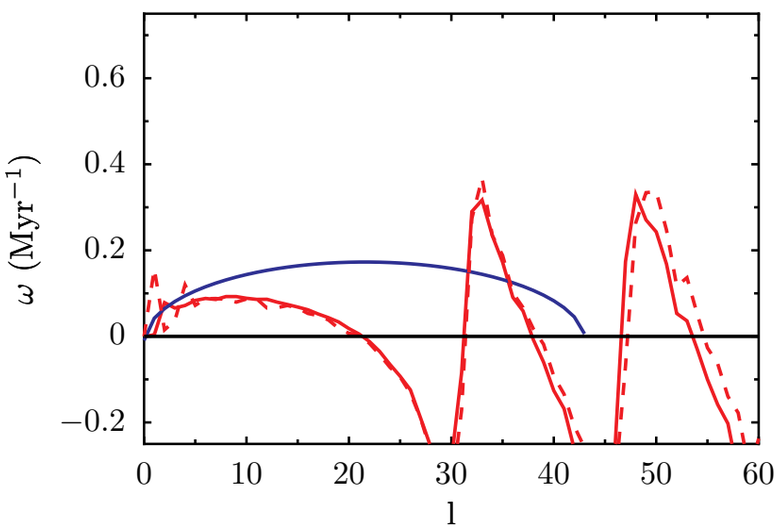




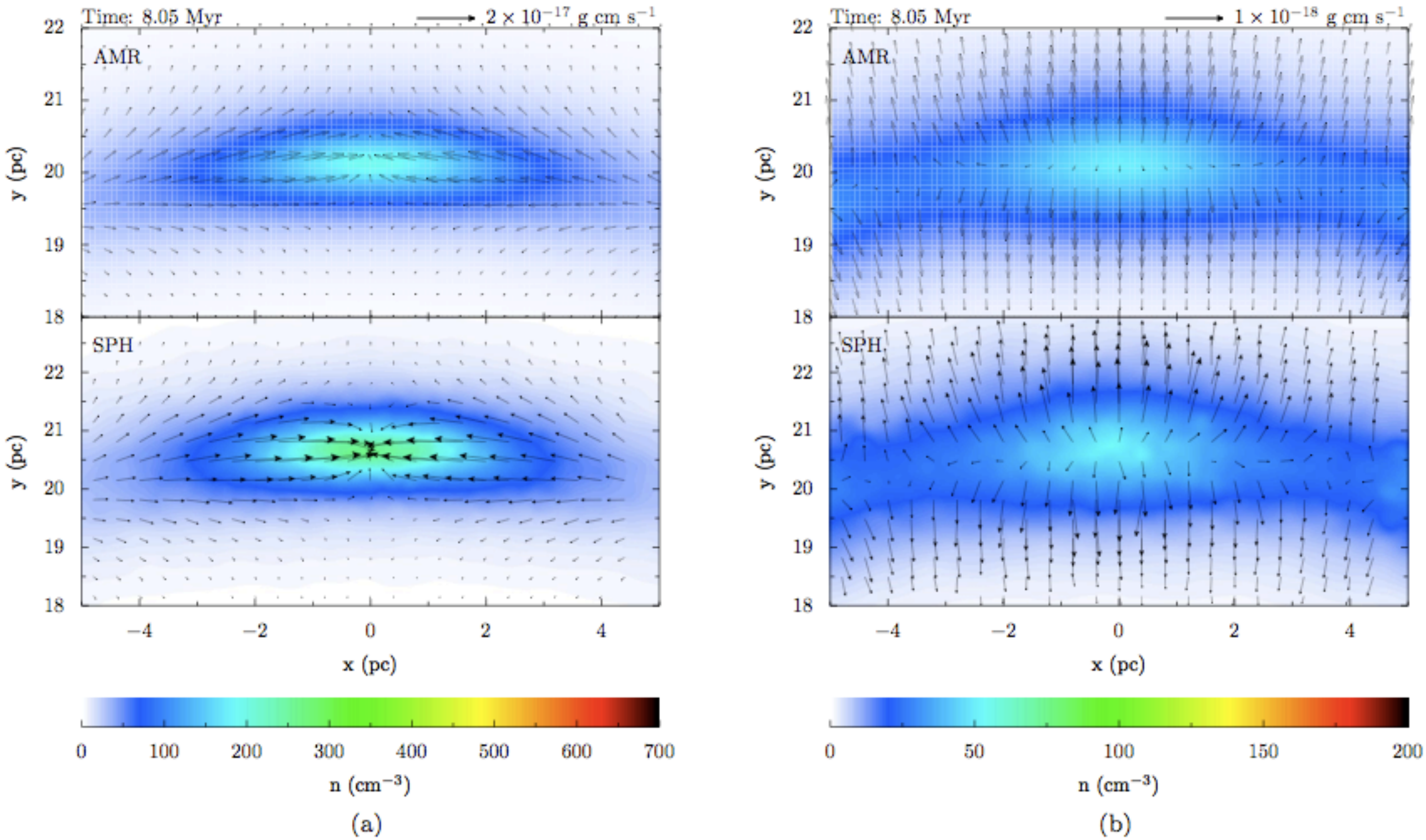




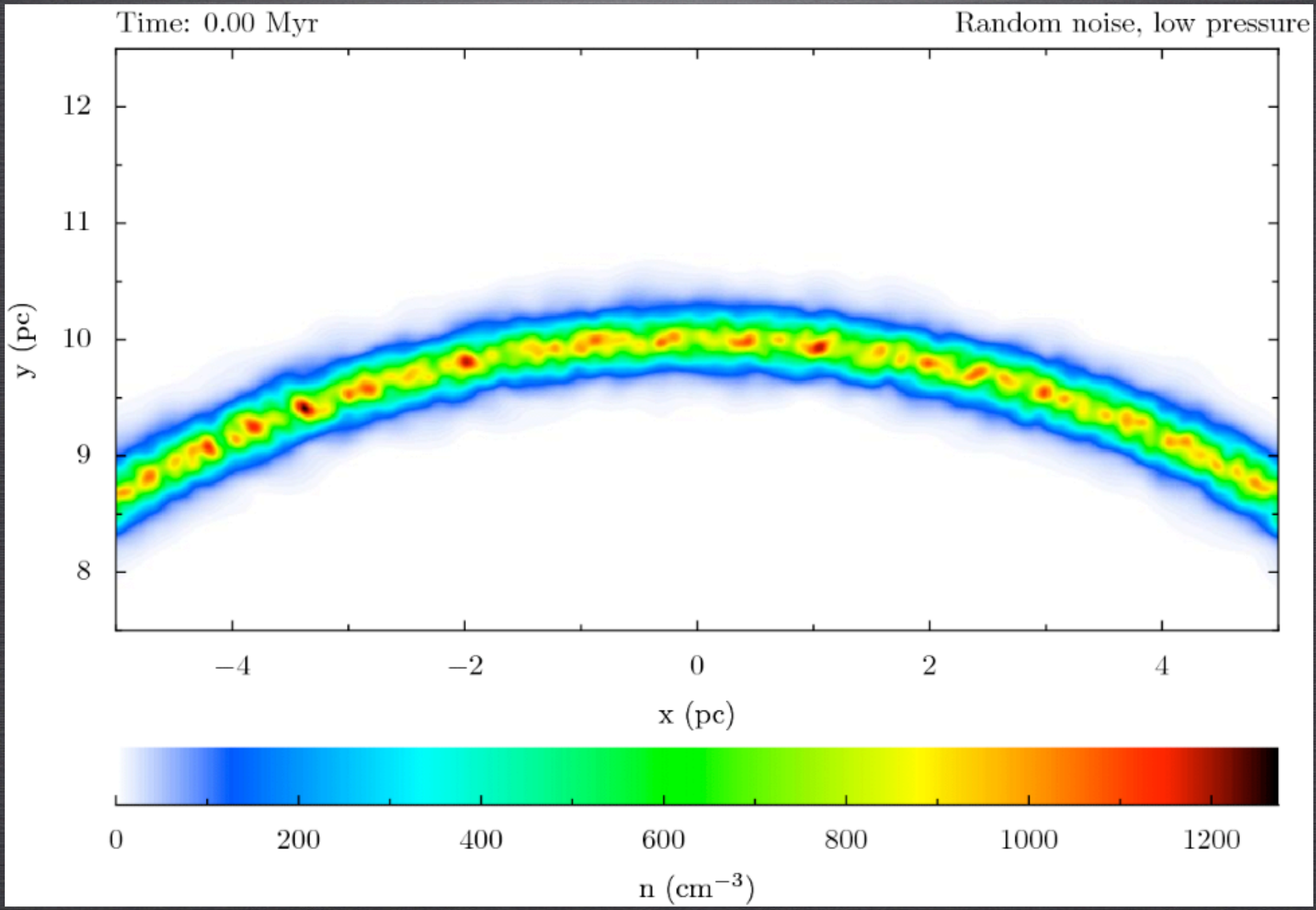




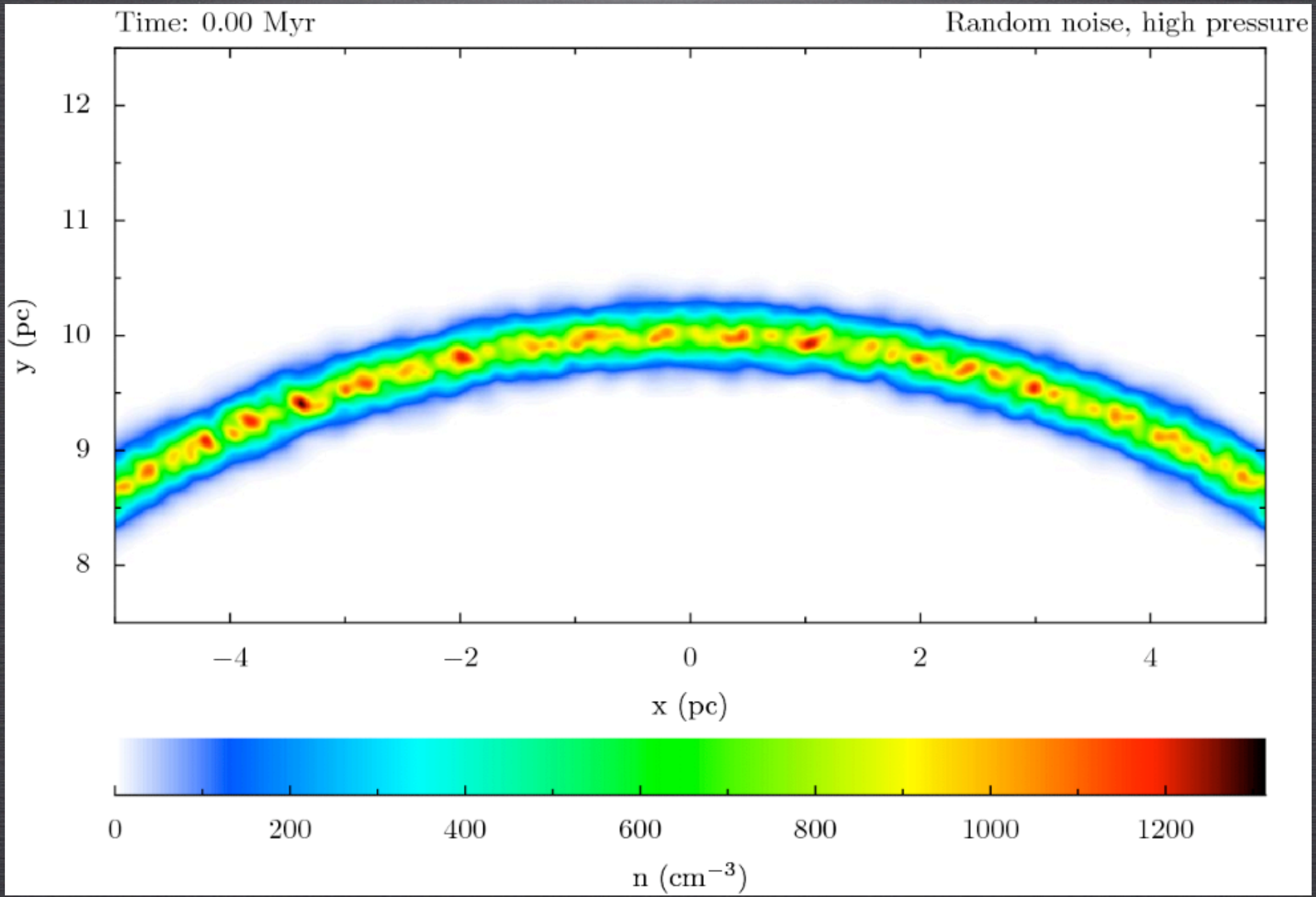
SUPPRESION OF SHORT WAVELENGTH MODES



LOW PRESSURE

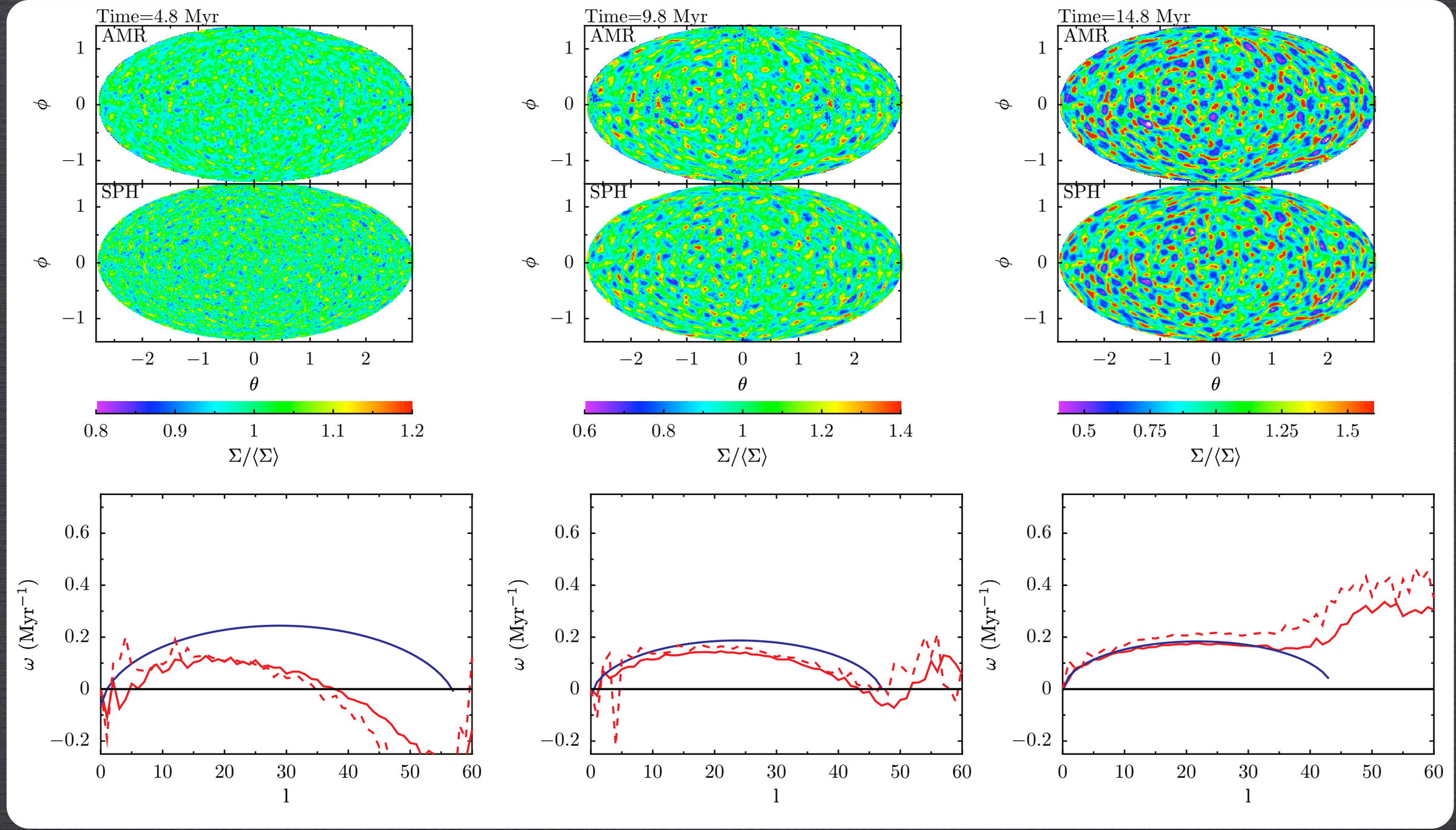


HIGH PRESSURE



PRESSURE CONFINEMENT

(DALE ET AL, 2009)



MASS FUNCTIONS

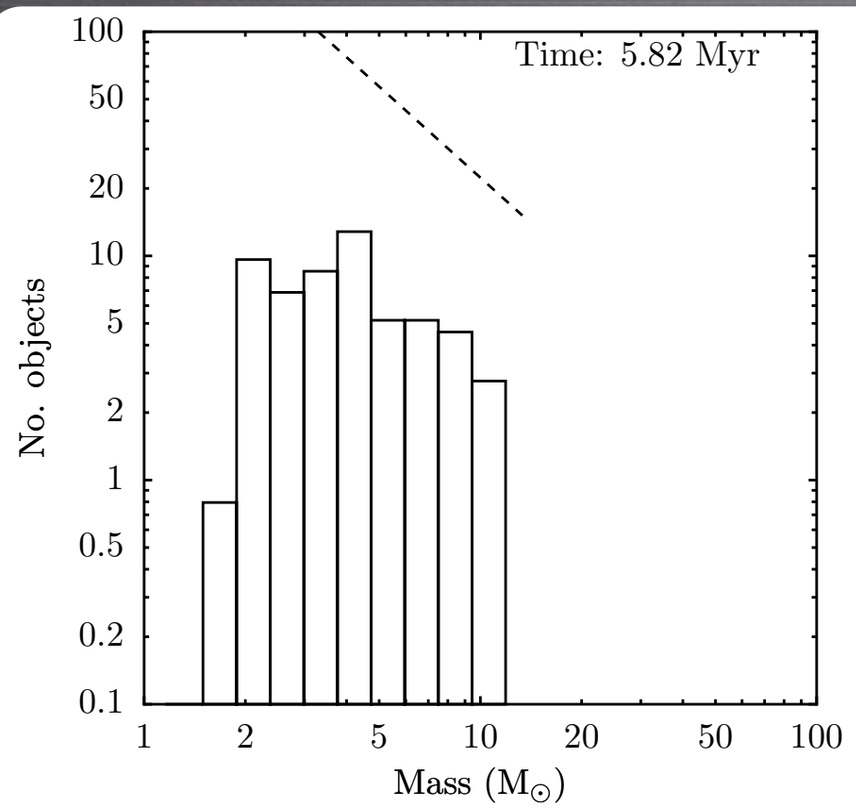
-CAN INTEGRATE THE DISPERSION RELATION W.R.T. TIME AND DERIVE MASS FUNCTIONS (WUNSCH AND PALOUS, 2001)

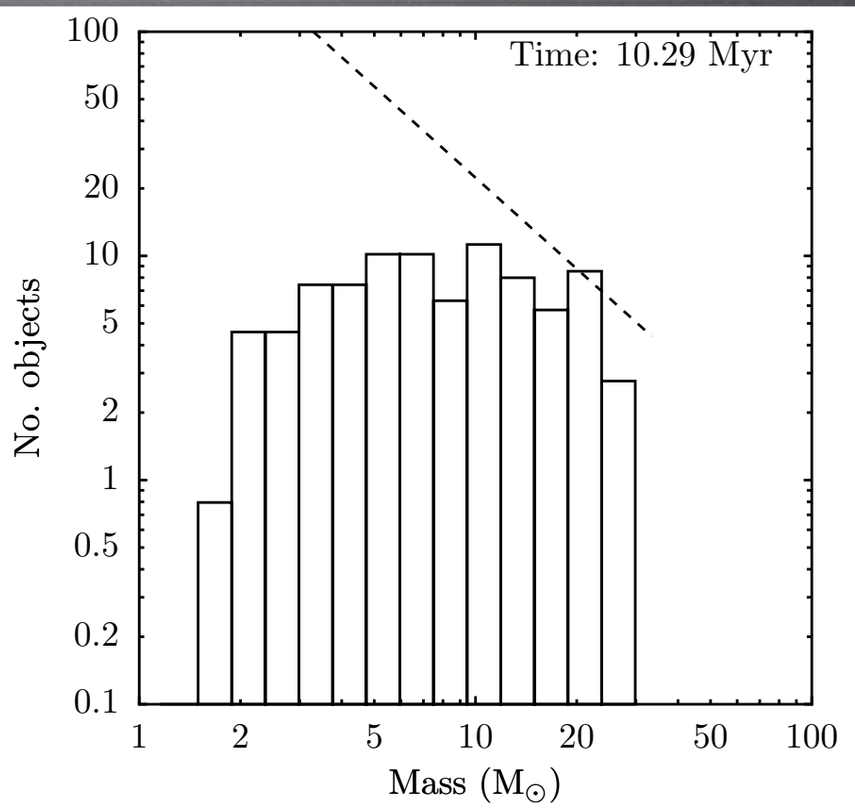
-RESULTS IN A SALPETER-LIKE POWER LAW

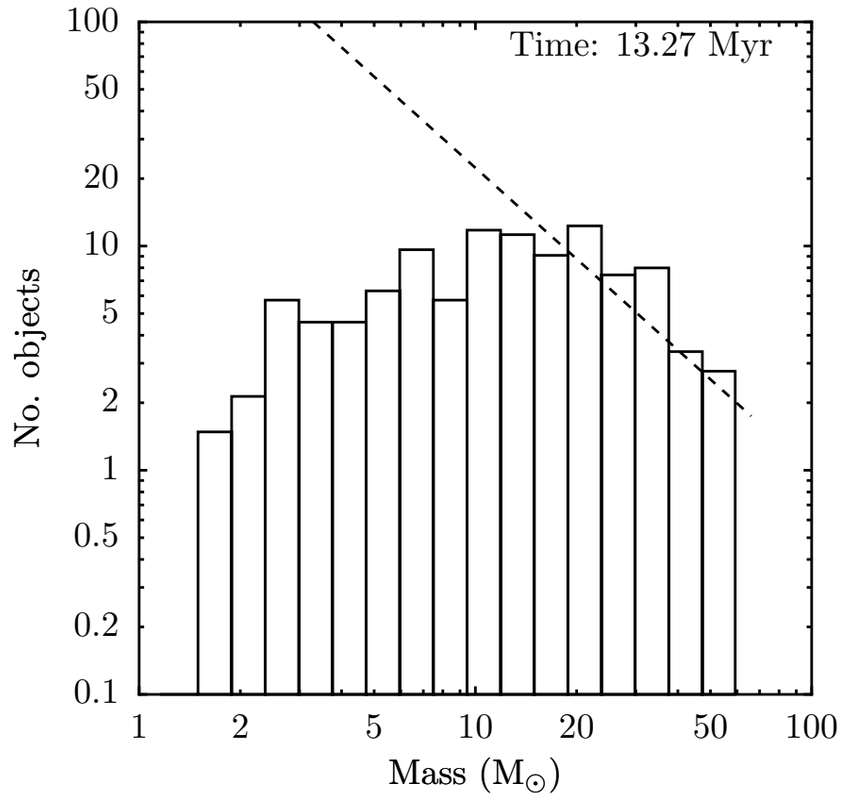
-WE OBTAIN FRAGMENT MASS FUNCTIONS IN OUR EXPANDING SHELLS USING THE POTENTIAL-BASED CLUMP-FINDING METHOD FROM SMITH ET AL, 2009 (ALLOWS US TO IDENTIFY OBJECTS BEFORE THEY BECOME GRAVITATIONALLY-BOUND)

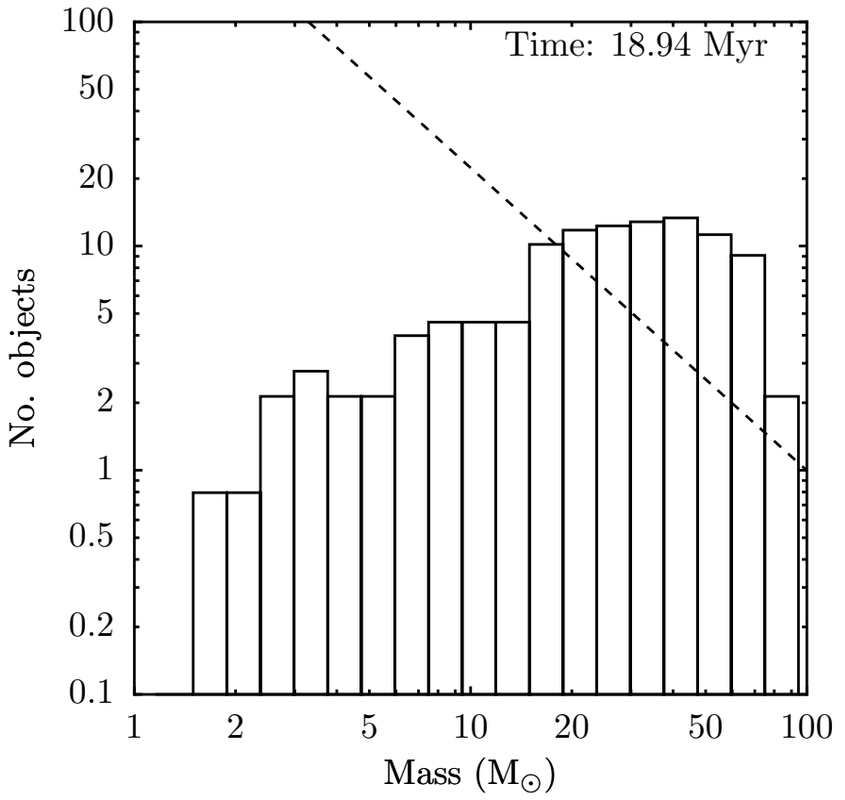
-WE ALSO USE SPH SINK-PARTICLES TO FOLLOW THE ACCRETION OF MATERIAL ONTO BOUND OBJECTS

UNBOUND CLUMPS









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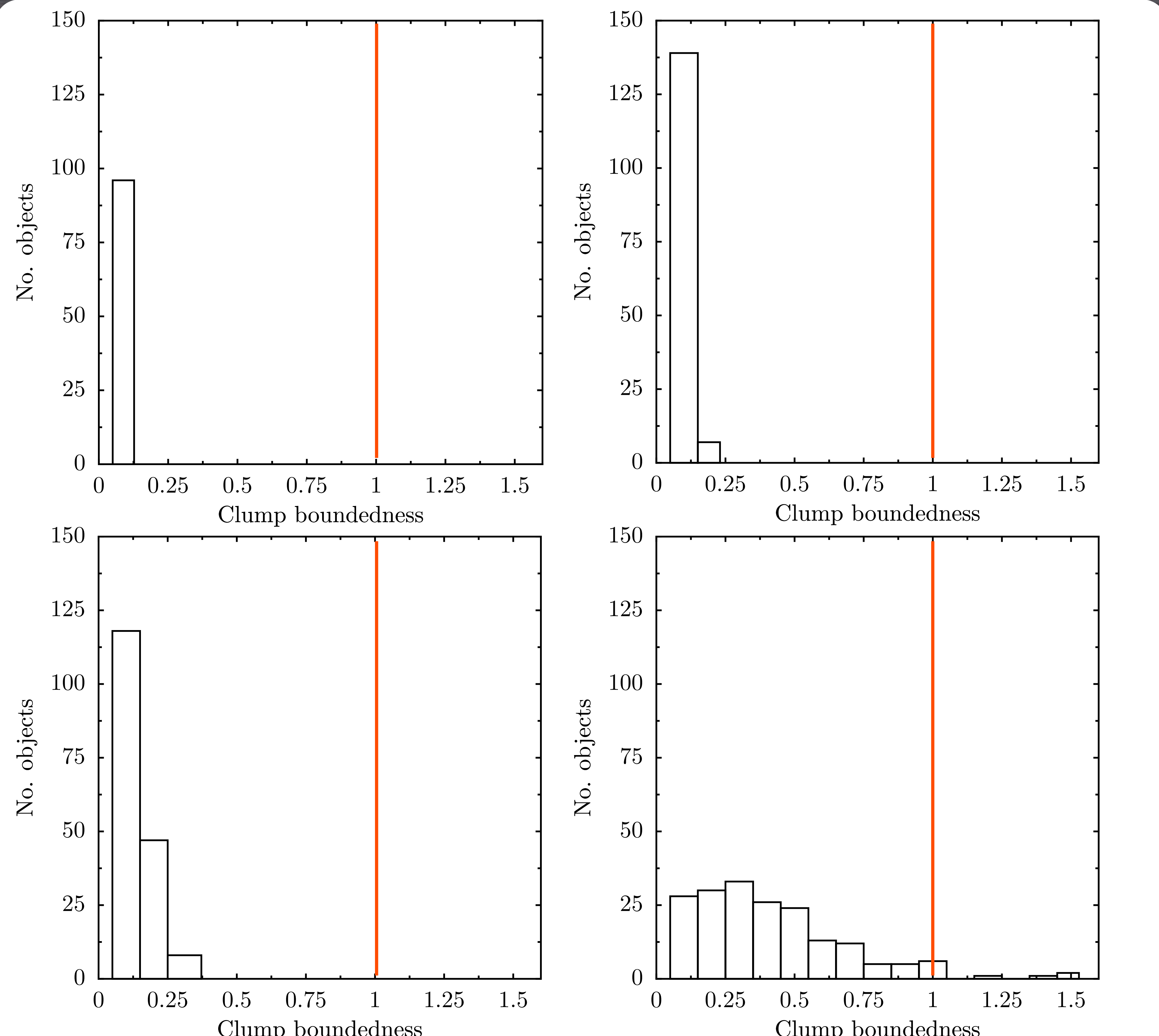
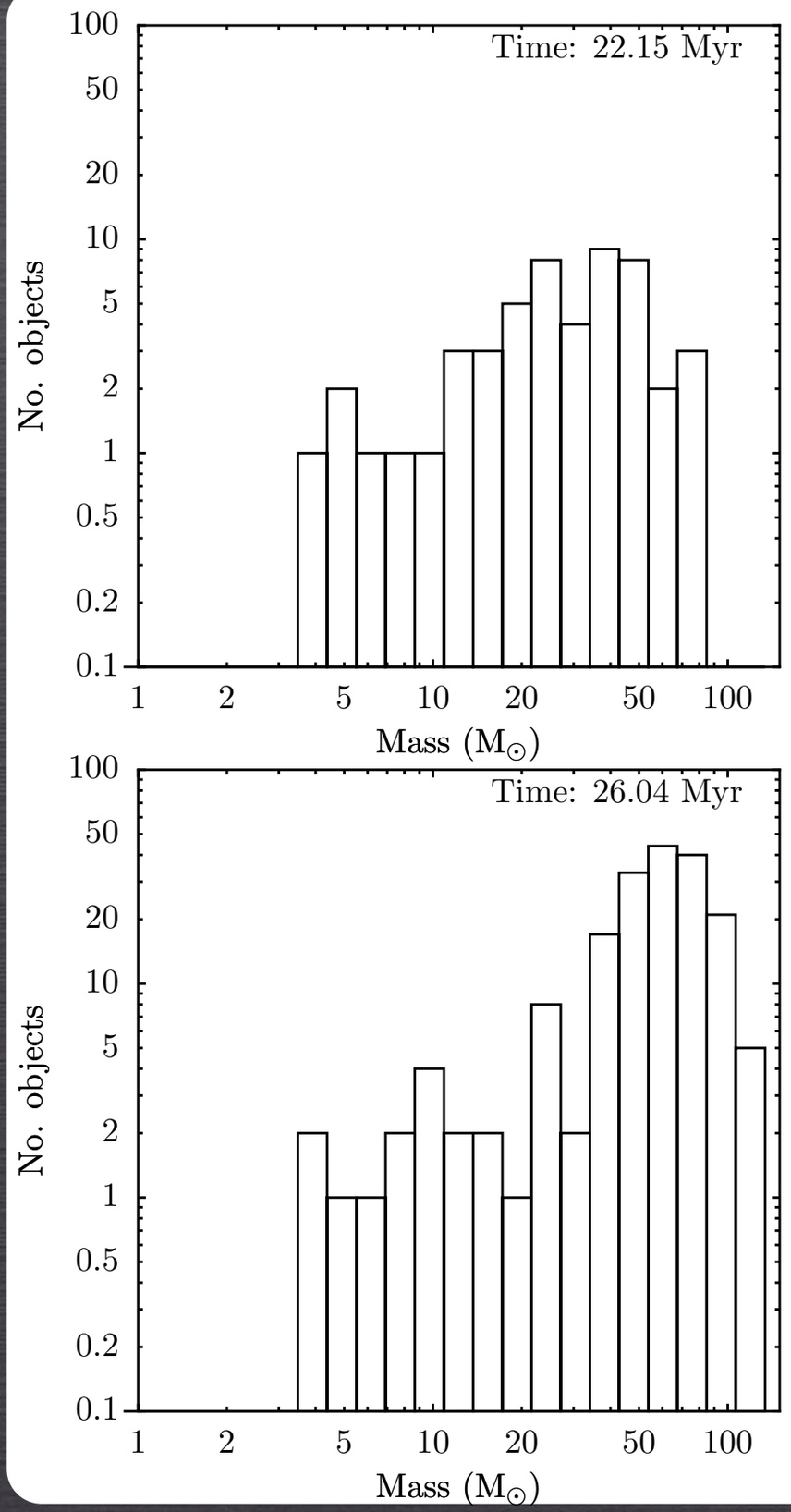
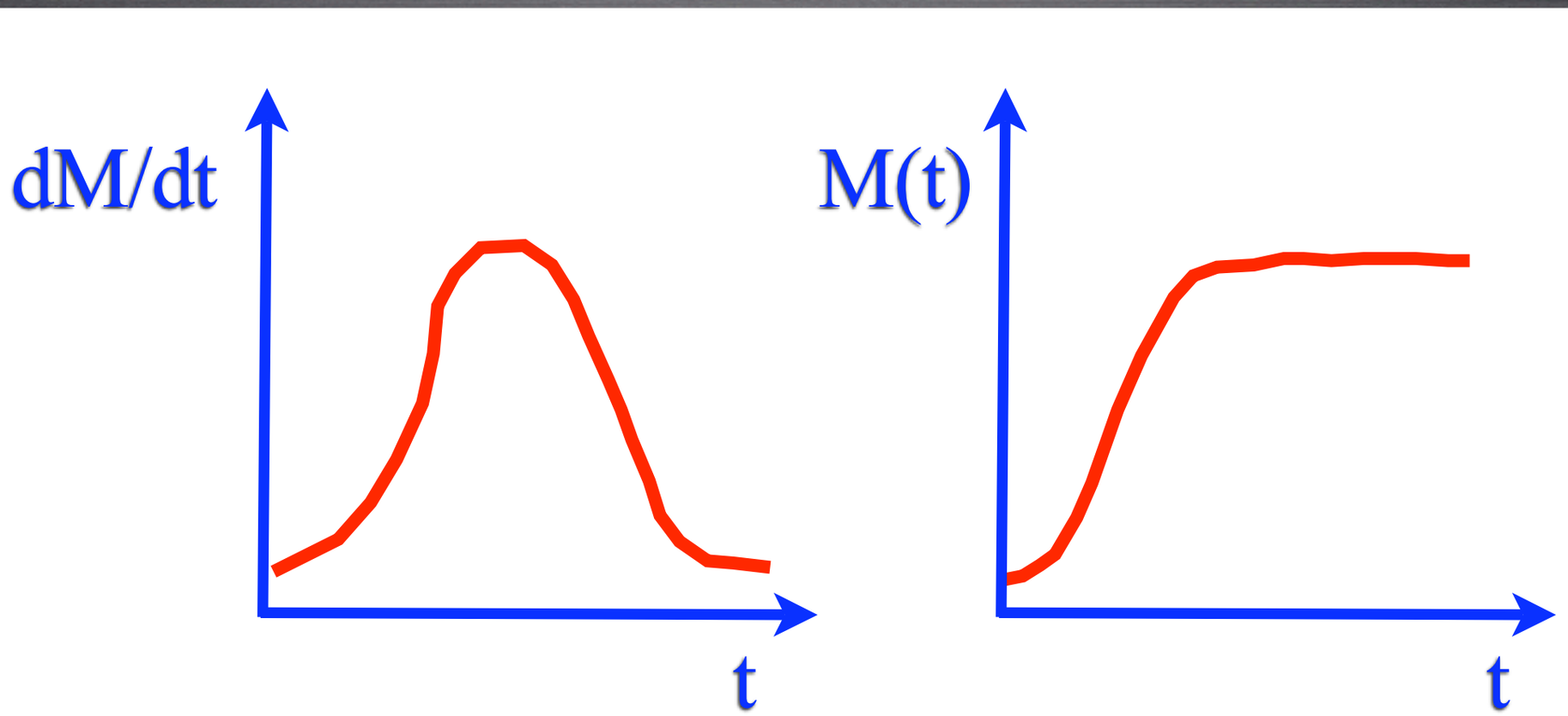


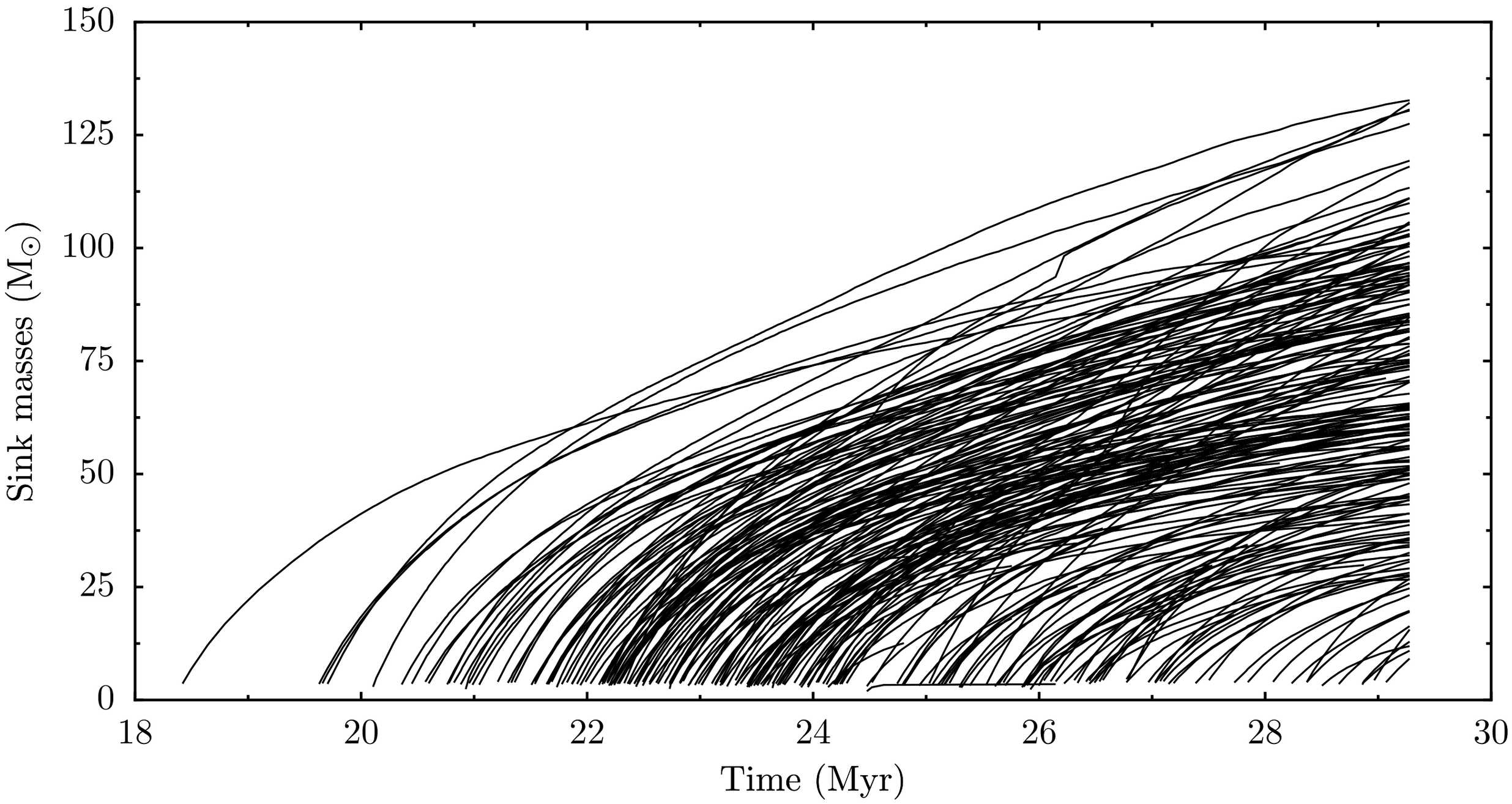
BOUND OBJECTS - SINKS



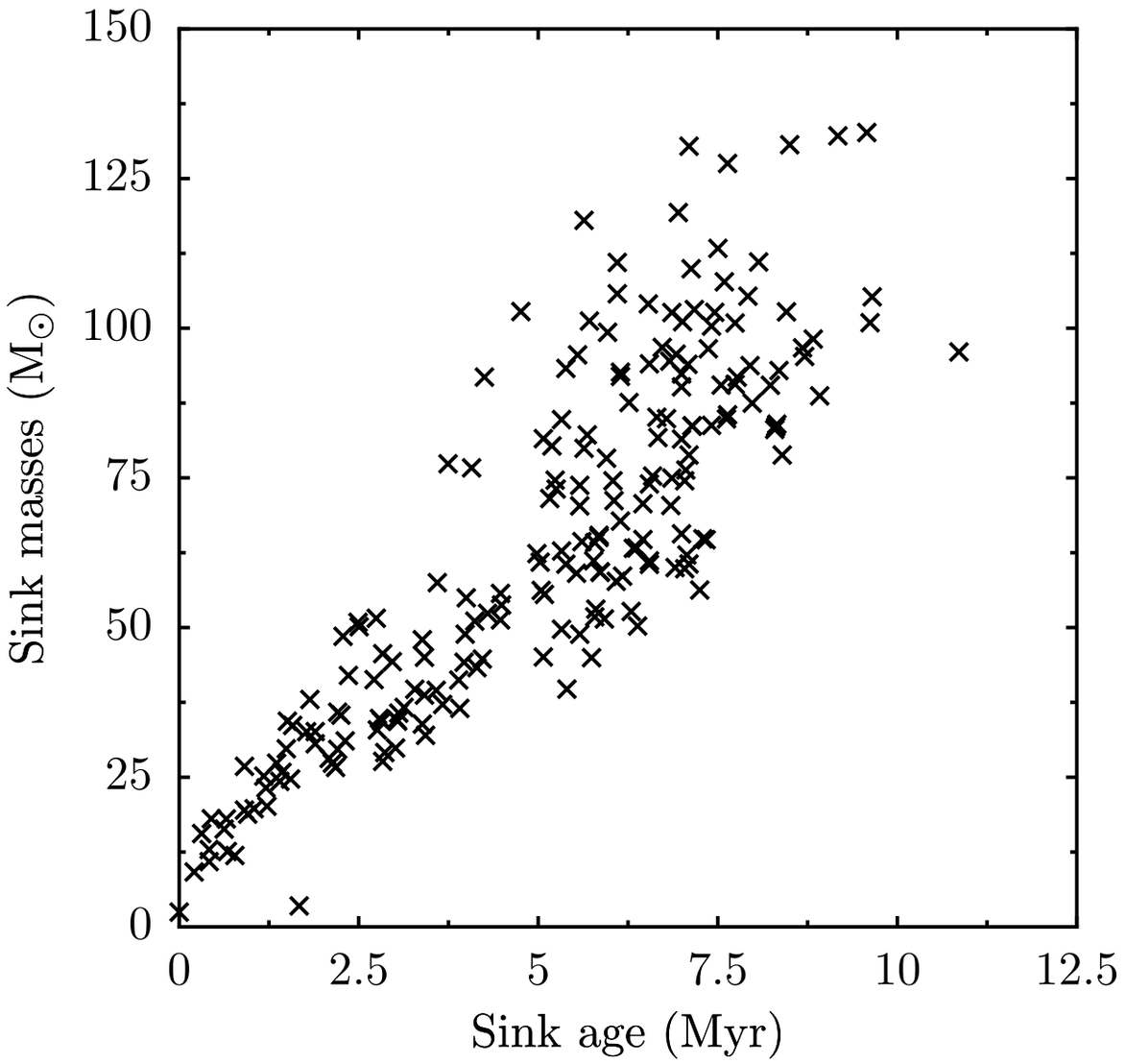
STAR FORMATION IN THEORY...

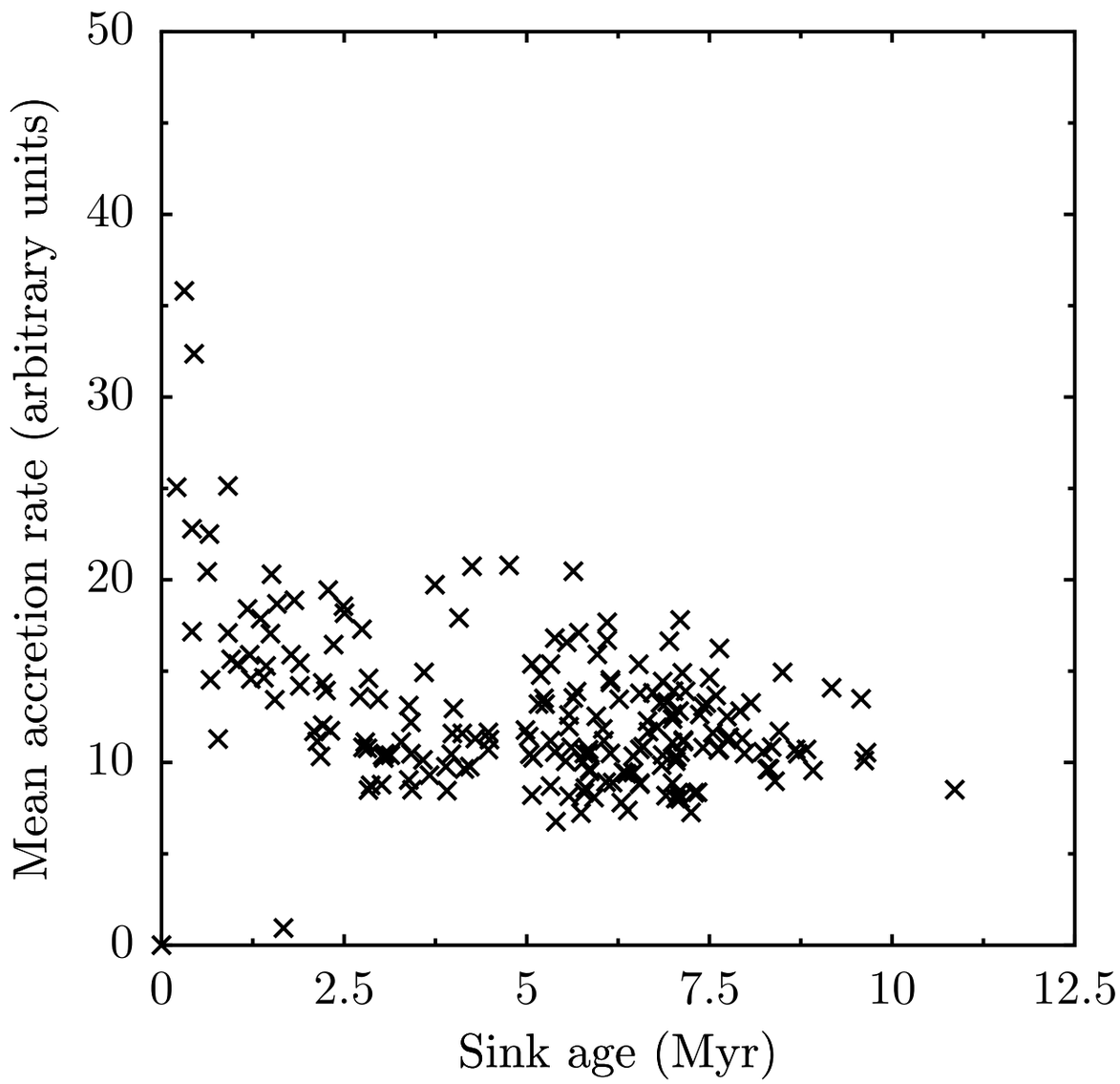


...AND IN PRACTICE



COMPETITIVE ACCRETION, OF A SORT





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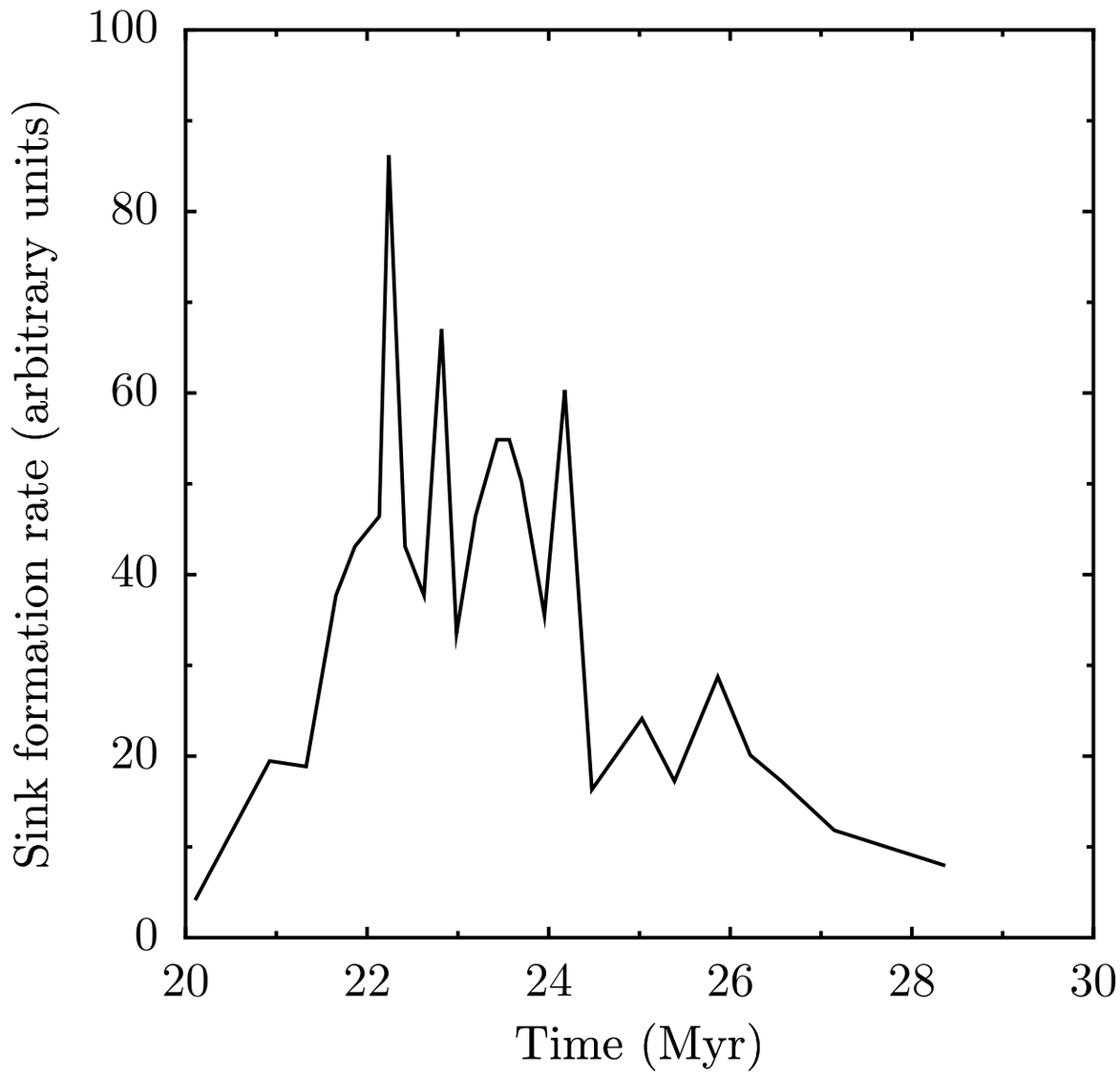

COMPETITIVE ACCRETION, OF A SORT

-ACCRETION PROCEEDS IN A 'FIRST-PAST-THE-POST' FASHION - THE OBJECTS THAT COLLAPSE FIRST WIN MOST OF THE MASS

-THEY DO THIS IN AT LEAST TWO WAYS: (I) THEY STARVE OTHER OBJECTS OF GAS (II) THEY SUPPRESS FORMATION OF LATER OBJECTS

-THESE TECHNIQUES PROBABLY ONLY WORK BECAUSE THE SHELL MASS IS FIXED

UNANSWERED QUESTIONS...

-DO THE FRAGMENTS INTERACT WITH EACH OTHER? DO THEY MERGE? DO THE BIG ONES CANNIBALISE THE SMALL ONES?

-IF THE SHELL WERE CONTINUOUSLY REPLENISHED WITH SWEPT-UP MATERIAL, WOULD THIS ALLOW SMALLER FRAGMENTS TO GROW AND PRODUCE A MORE NORMAL-LOOKING MASS FUNCTION?

CONCLUSIONS

-AMR AND SPH AGREE BEAUTIFULLY ON THE EVOLUTION OF THE GRAVITATIONAL INSTABILITY IN EXPANDING SHELLS

-IN THE CASE WHERE THE SHELL IS PRESSURE-CONFINED SO THAT ITS THICKNESS IS ~CONSTANT, THE THIN SHELL MODEL FAITHFULLY DESCRIBES THE FRAGMENTATION IN THE LINEAR REGIME

-ONCE THE EVOLUTION BECOMES NON-LINEAR, ACCRETION BECOMES THE DOMINANT PROCESS IN DECIDING FRAGMENT MASSES

-IN A SHELL OF FIXED MASS, OBJECTS THAT COLLAPSE FIRST WIN MORE THAN THEIR SHARE OF THE MATERIAL, LEADING TO A TOP-HEAVY MASS FUNCTION