The influence of the cloud virial parameter on the initial mass function

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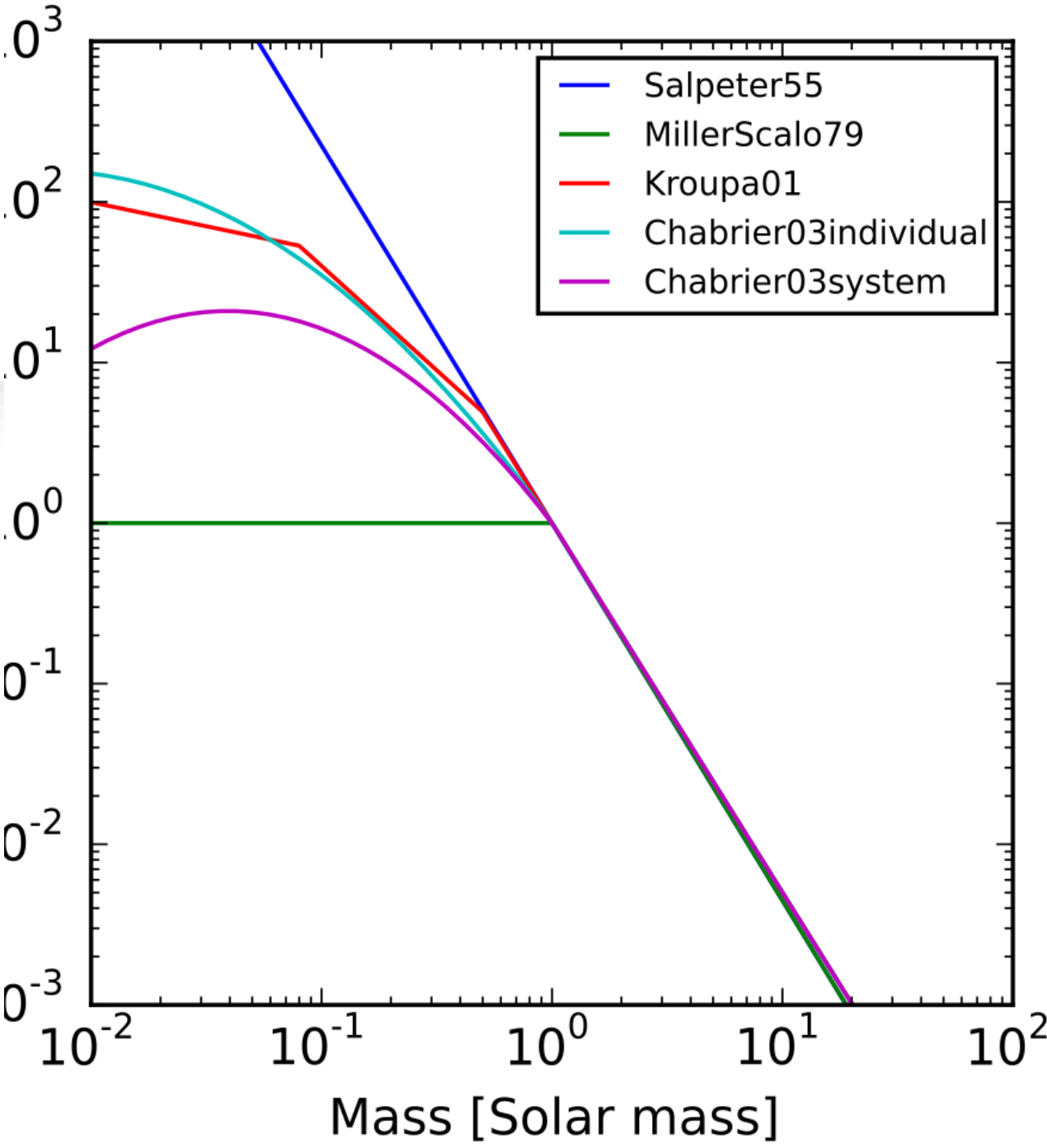
Initial Mass Function

- The distribution of masses of stars formed during a star formation event
- Multiple mechanisms that influence IMF
- Observational studies suggest a near-universal IMF with a peak around 0.3 solar masses and a high-mass tail following a power-law distribution.
- Some observational challenges to that notion, such as top-heavy IMF's near Galactic center
- No clear origin of IMF
- One key mechanism is cloud virial parameter



Virial Parameter

- A measure of the gravitational boundness of an object
- Measures kinetic vs gravitational energy
- Key quantity that measures turbulence vs gravity
- In individual clouds, differences can be up to an order of magnitude
- Strong dependence of IMF on this could challenge IMF universality

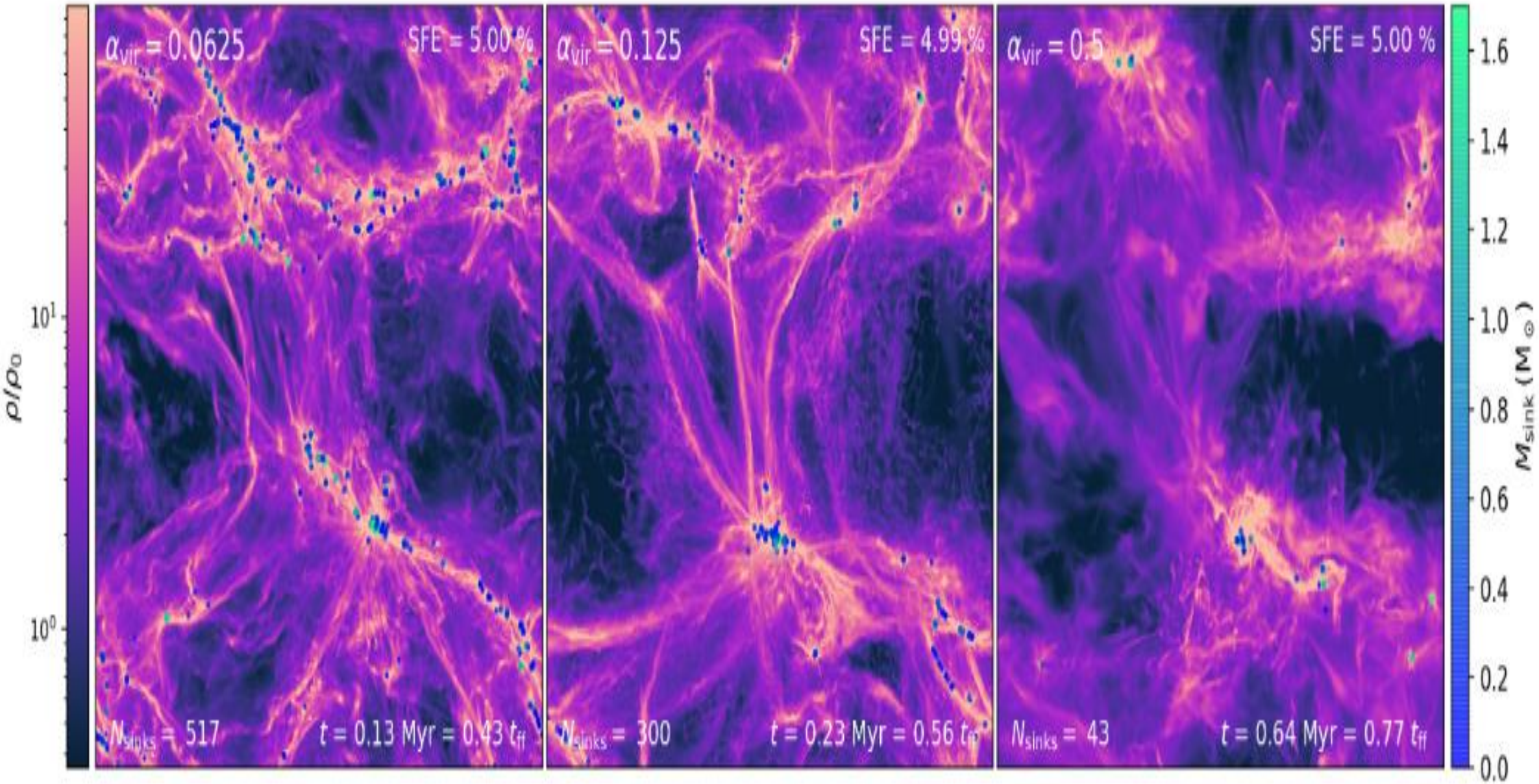
Methods

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho v) = 0,$$

$$\rho \left(\frac{\partial}{\partial t} + v \cdot \nabla \right) v = \frac{(B \cdot \nabla) B}{4\pi} - \nabla P_{\text{tot}} + \rho (g + F_{\text{stir}}),$$

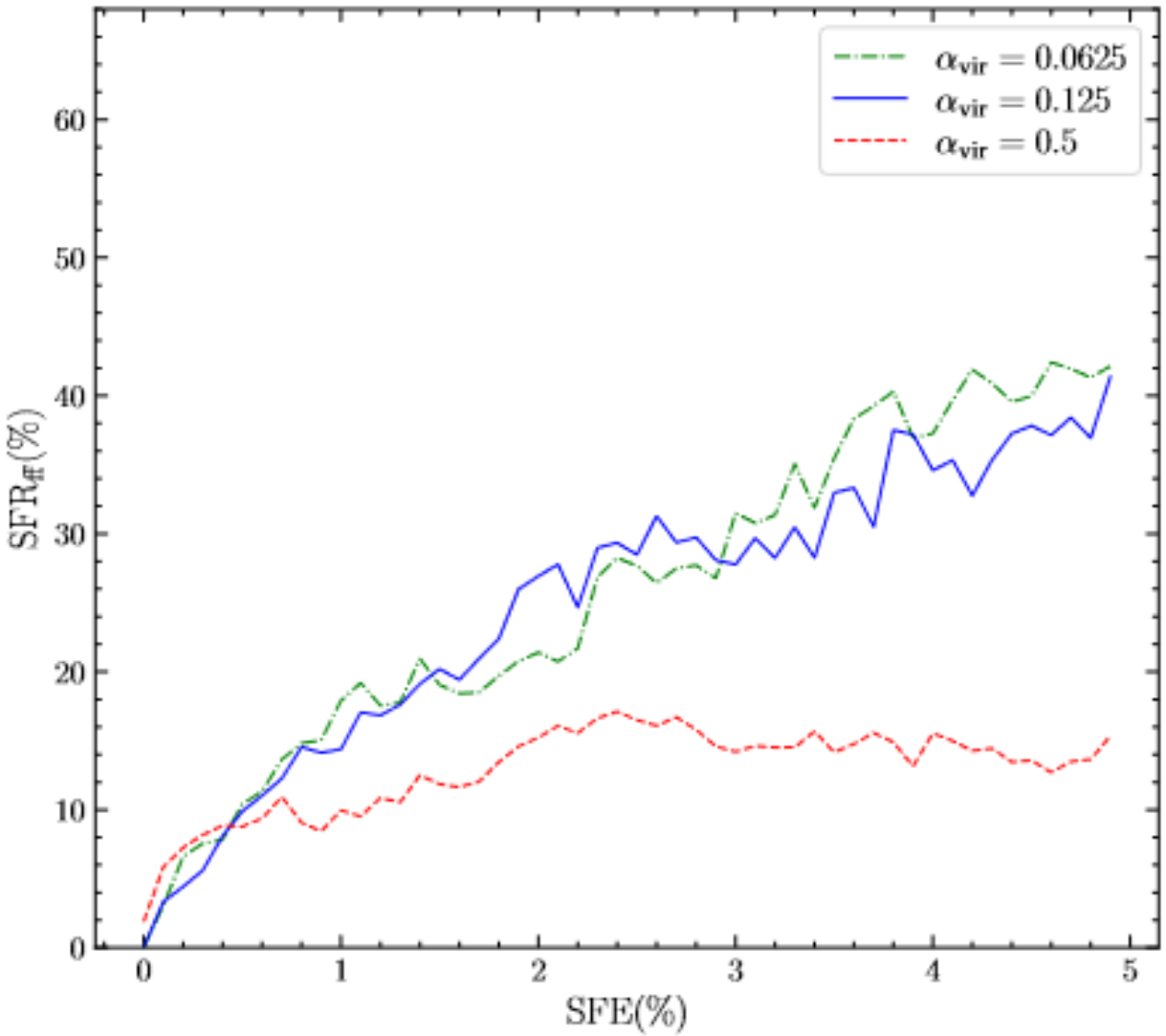
$$\frac{\partial B}{\partial t} = \nabla \times (v \times B), \quad \nabla \cdot B = 0,$$

- magnetohydrodynamic simulations to model star formation
- Initial conditions of uniform gas density, magnetic field along the z-axis, and an isothermal temperature of 10 K.
- Three virial parameter values tested(α_{tir} = 0.0625, 0.125, and 0.5)
- Once turbulence reaches a steady state, gravity is activated (t = 0). The simulations continue until 5% of the total cloud mass is converted into stars


$\alpha_{vir} = 0.0625$
SFE = 5.00 %
N_{sinks} = 517
t = 0.13 Myr = 0.43 t_{ff}
$\alpha_{vir} = 0.125$
SFE = 4.99 %
N_{sinks} = 300
t = 0.23 Myr = 0.56 t_{ff}
$\alpha_{vir} = 0.5$
SFE = 5.00 %
N_{sinks} = 43
t = 0.64 Myr = 0.77 t_{ff}
ρ/ρ_0
10^1
10^0
M_{sink} ($M_\odot$)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0

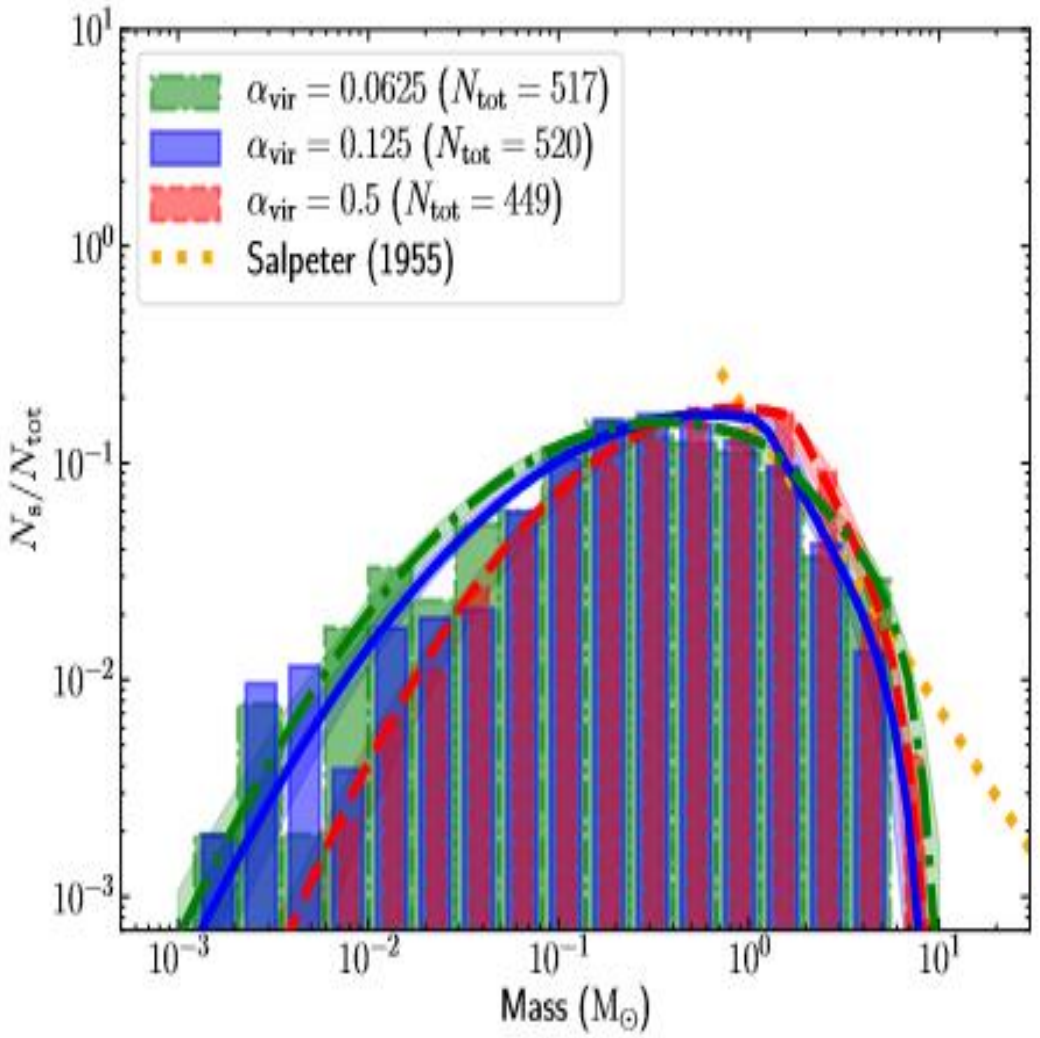
Star Formation Rate

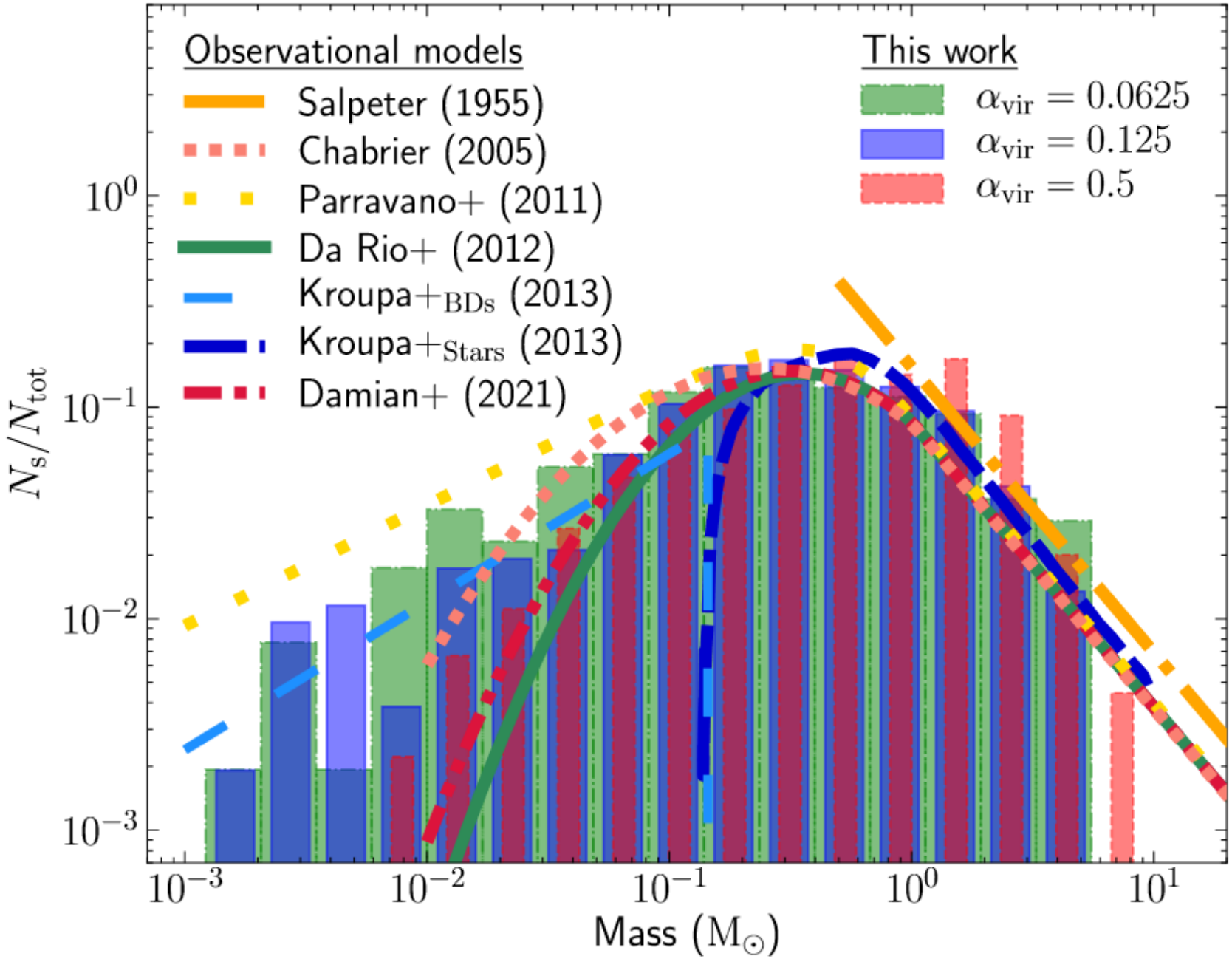
- In low-α_vir clouds, gravitational forces dominate and accelerate SFR over time, while turbulence plays a more significant role in slowing star formation in high-α_vir models



IMF Results

- Models with αvir= 0.0625 and 0.125 produce similar mass distributions, showing that the IMF becomes relatively insensitive to αvir when gravitational forces dominate. Higher fraction of low mass stars
- In contrast, the αvir = 0.5 model forms fewer stars overall, with a noticeable difference in the IMF tail, reflecting the impact of turbulence. More massive stars
- the IMF has a relatively weak, but systematic dependence on the cloud virial parameter

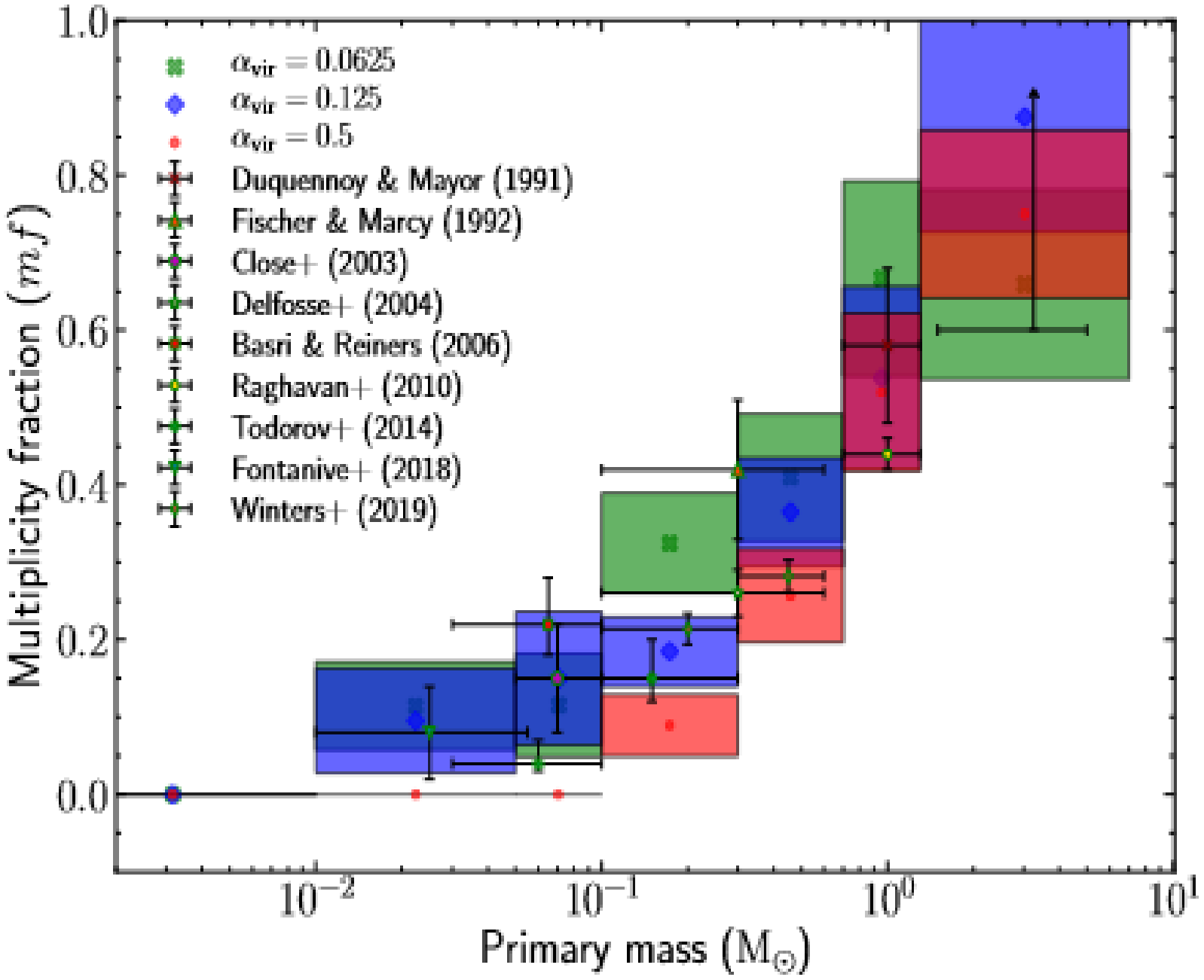



Observational models
Salpeter (1955)
Chabrier (2005)
Parravano+ (2011)
Da Rio+ (2012)
Kroupa+BDs (2013)
Kroupa+Stars (2013)
Damian+ (2021)
This work
$\alpha_{\rm vir} = 0.0625$
$\alpha_{\rm vir} = 0.125$
$\alpha_{\rm vir} = 0.5$
$N_{\rm s}/N_{\rm tot}$
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-3}
10^{-2}
10^{-1}
10^{0}
10^{1}
Mass ($M_\odot$)

Multiplicity fraction

- The fraction of a set of star systems that have multiple stars.
- Singles, binaries, triples, quadruples

$$mf = \frac{B + T + Q}{S + B + T + Q},$$



$m\,f$ increases with primary mass, which is consistent with the established understanding

At sub solar mass, virial parameters are influential, but not at super solar masses

Conclusions

- Lower α_vir values lead to higher star formation rates but has a non-linear effect.
- The IMF shows a weak dependence on α_vir. Lowering α_vir shifts the peak and median mass of the IMF to smaller values by a factor of ~2
- mf is higher for lower α_vir values, particularly for stars with sub-solar masses, where it increases by a factor of ~2 compared to the αvir = 0.5 case.
- Non-linear dependence of SFR and IFM on α_vir suggests broader ranges of αvir values need to be considered.