Episodic Accretion in Low Metallicity Environments

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Accretion and Luminosity Bursts Across the Stellar Mass Spectrum

Structure of the Talk

- Metallicity and physical processes
- Modelling low metallicity
- Effects of metal poor environment on disk structure & evolution

Why Low Metallicity

1. Outer galaxy

Observed star-forming regions with ~10% $Z_{\odot}$

2. Early universe

Young galaxies undergoing their first major episodes of star formation (~2% $Z_{\odot}$)

- All of the outbursting YSOs are in the immediate solar neighborhood, once the eruption begins the stellar photosphere is not visible

Effects of Metallicity

1. Disk opacity:

   Dust dominates the opacity of a disk, controls its cooling properties and thermal equilibrium[1]

2. Thickness of the active layer:

   Reduces the recombination rate on the dust grain surfaces and thus controls the MRI-active column density[2]

3. Temperature of the cloud core:

   At low densities, dust continuum emission leads to cooling and lower gas temperature[3]

[1]Lodato (2008), [2]Hartmenn et al. (2006), [3]Vorobyov et al. (2020)

Modelling Low Metallicity Disks

1. Opacity: lower dust-to-gas ratio, scaling down the gas and dust opacities in proportion

2. Active layer thickness: $\Sigma_a = 100 \rightarrow 200\text{g cm}^{-2}$

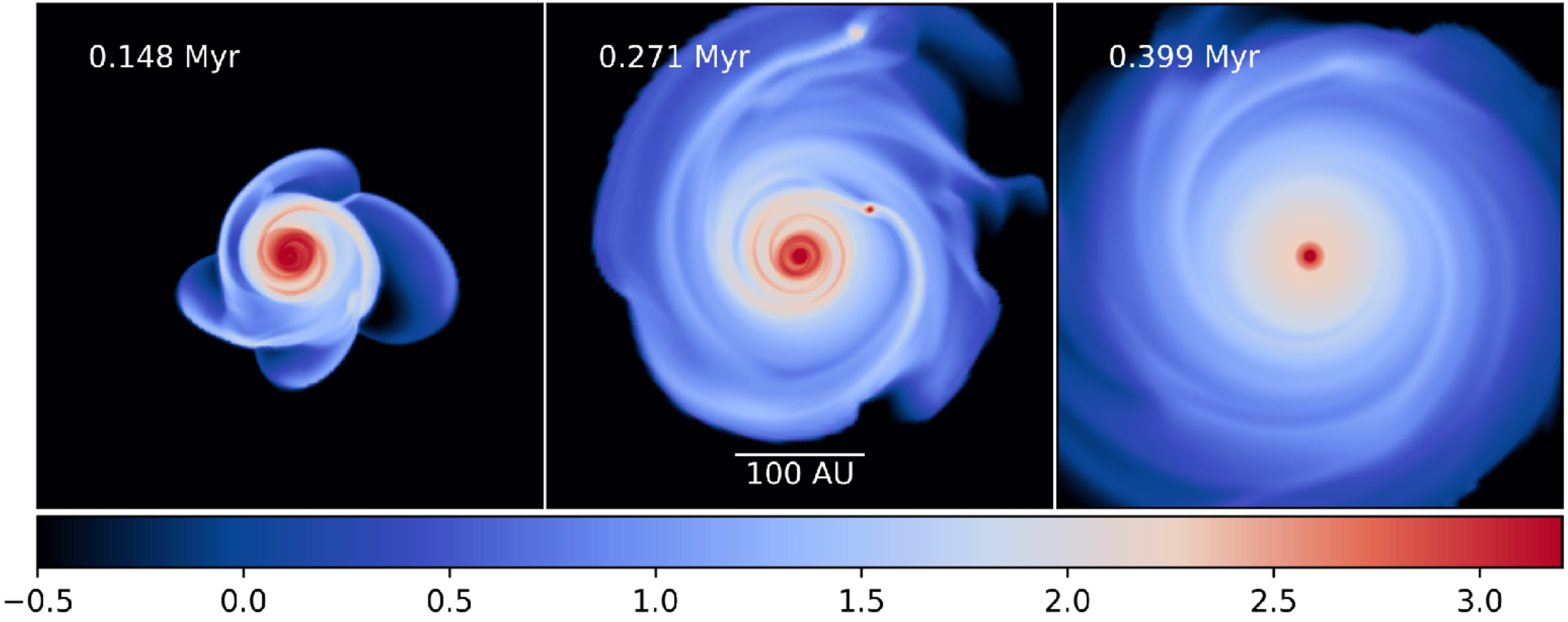
$$\alpha_{\text{eff}} = \frac{\Sigma_a \alpha_a + \Sigma_d \alpha_d}{\Sigma_a + \Sigma_d}$$

3. Cloud core temperature: $T_c = 15 \rightarrow 25\text{K}$

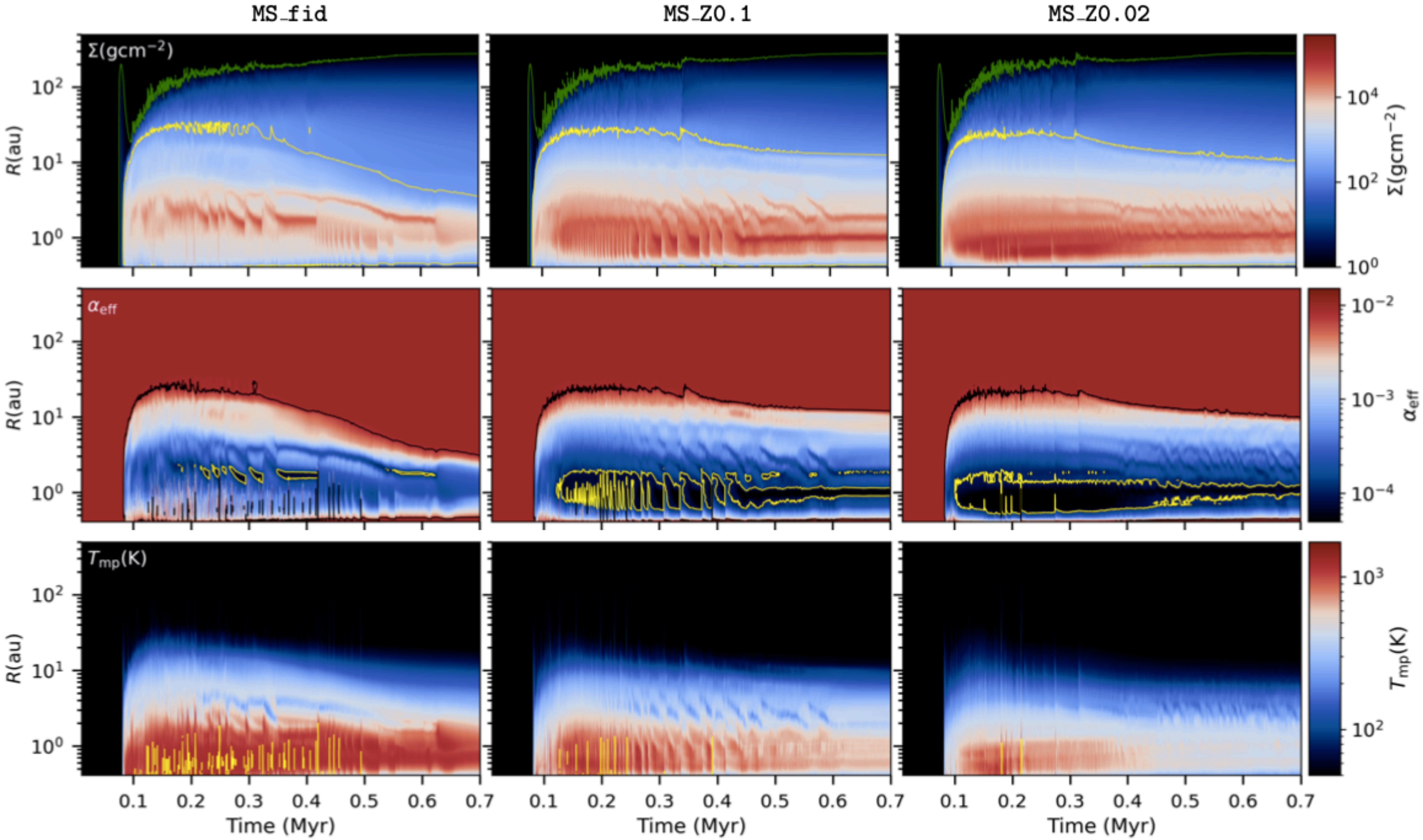
Hydrodynamic model

- Global hydrodynamic simulations
- Start with the gravitational collapse phase of a starless cloud core
- Solved equations of mass, momentum, and energy transport in thin disk limit
- Self-gravity of the disk
- Stellar and background irradiation of the disk, viscous & shock heating, radiative cooling
- Semenov (2013) opacities
- Coupled stellar evolution with pre-main-sequence tracks of D’Antona & Mazzitelli (1997).

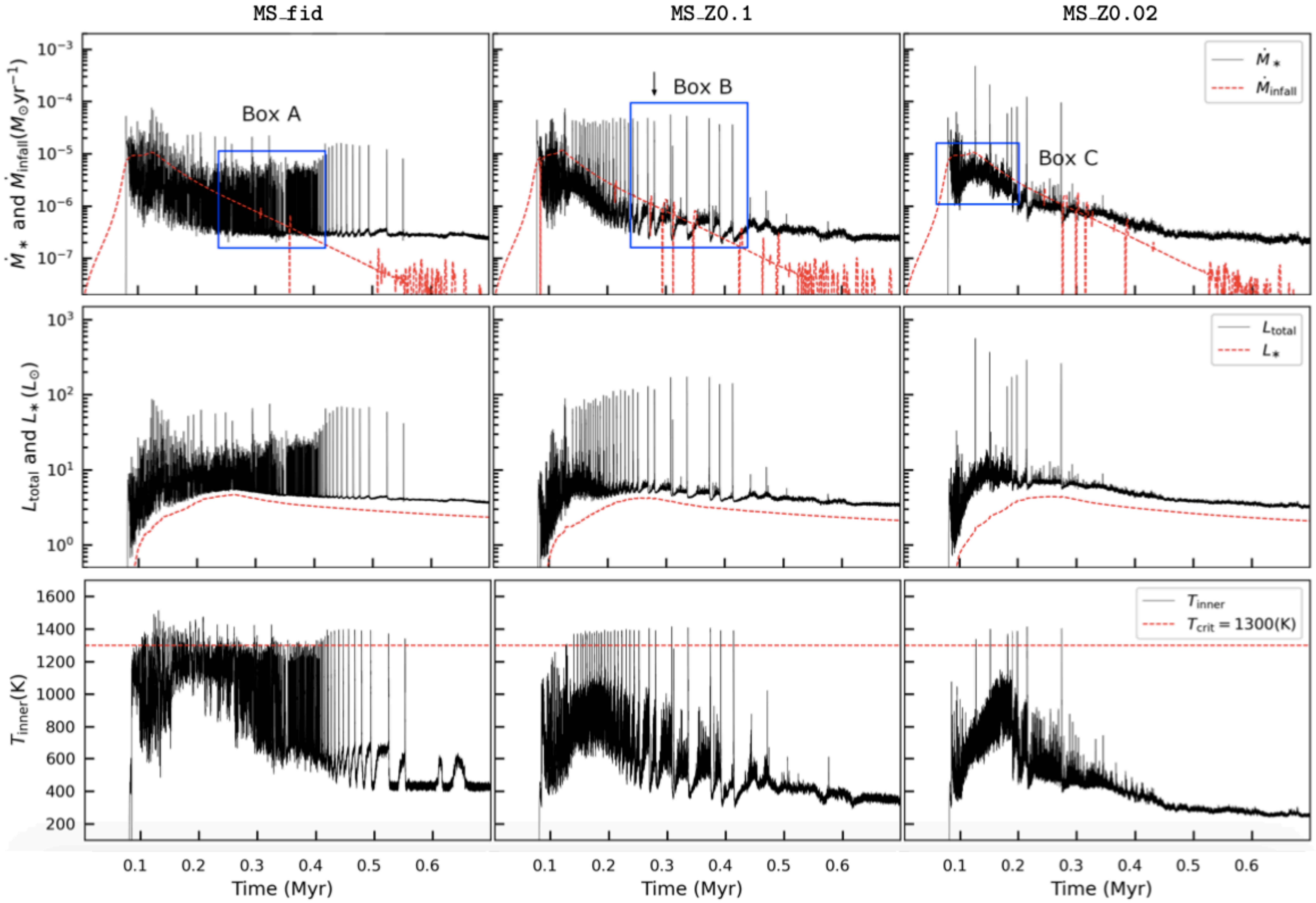
Global Disk Evolution



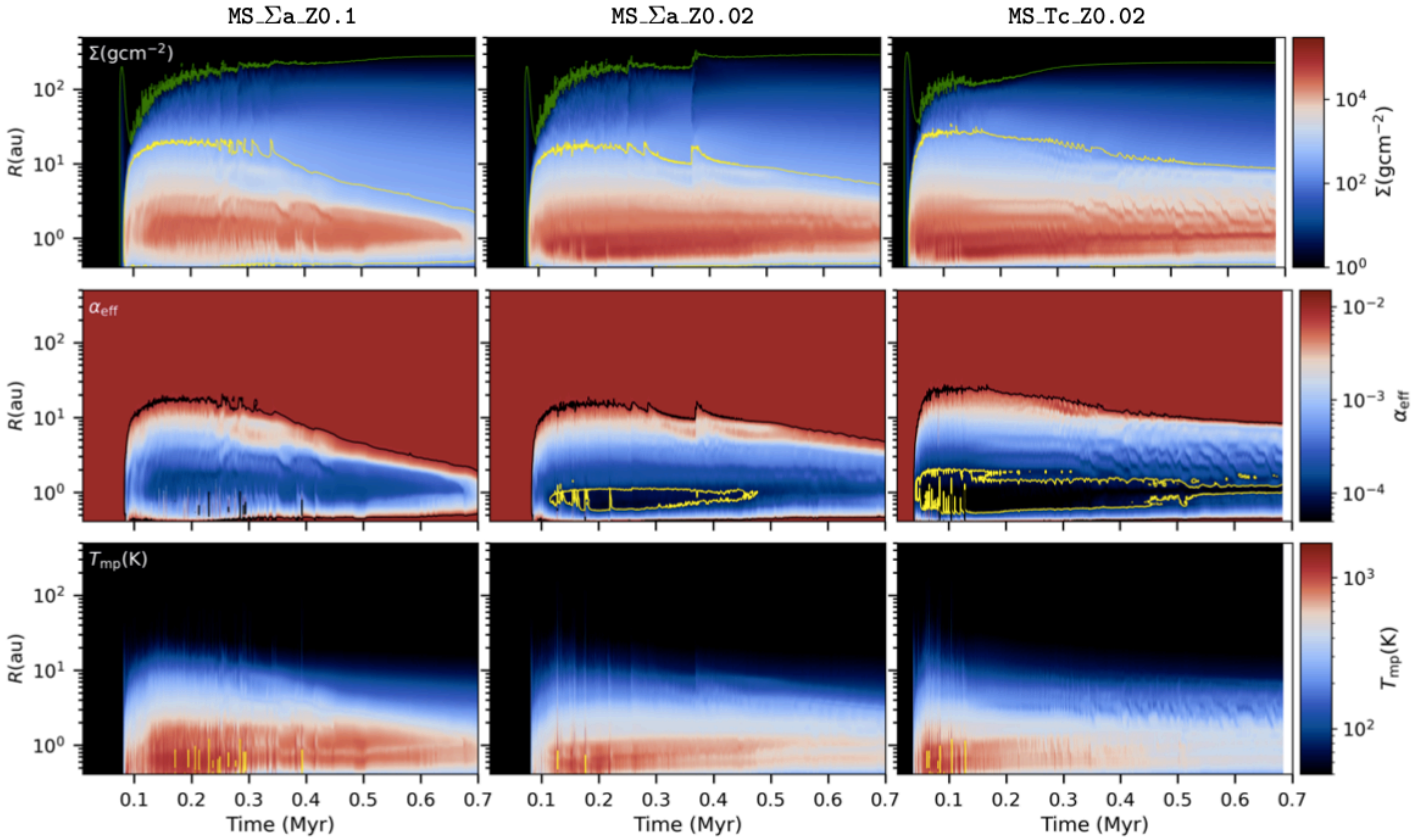
Inner Disk Structure (1.2 $M_\odot$, Opacity effects)



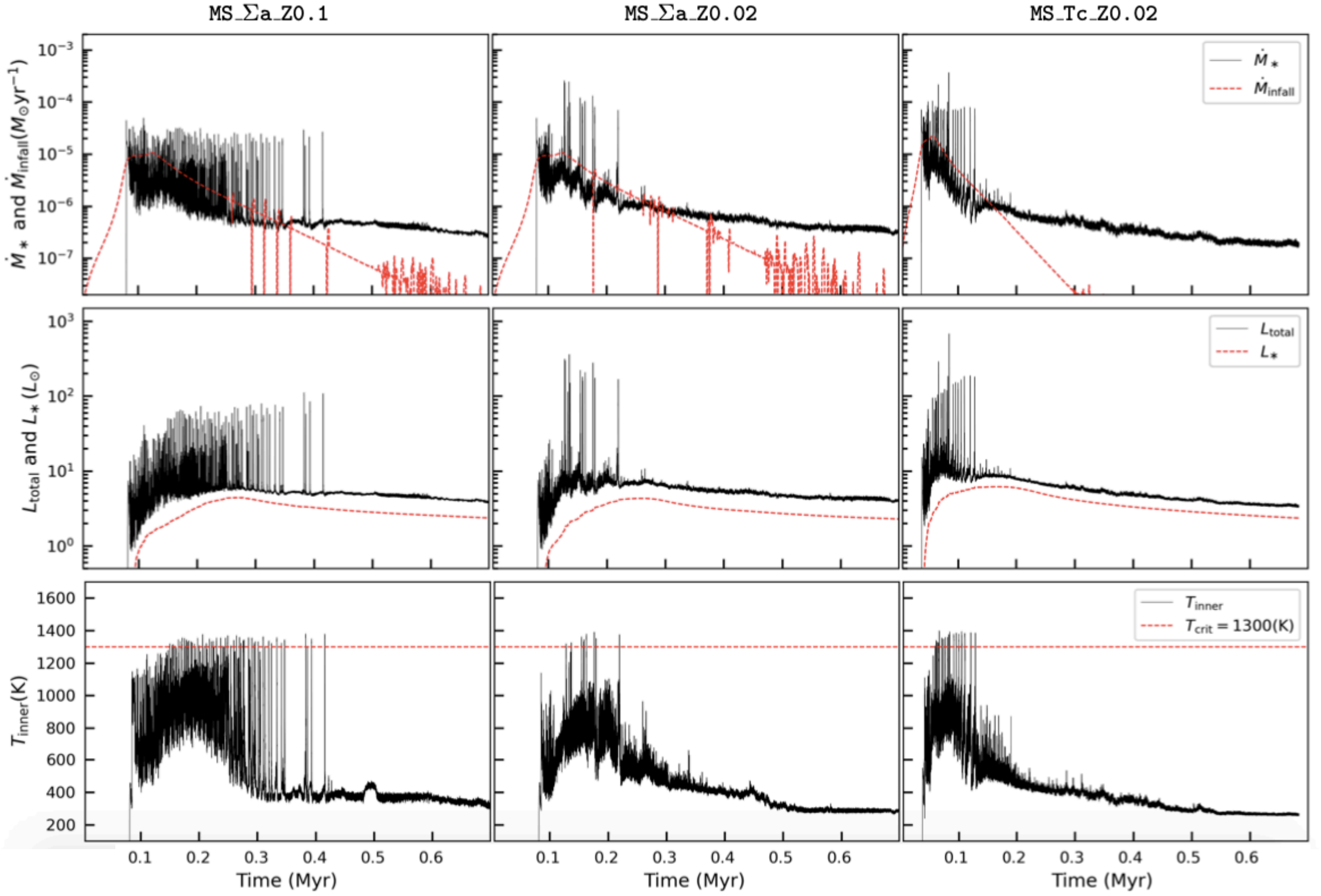
Episodic Accretion (1.2 $M_\odot$, Opacity effects)



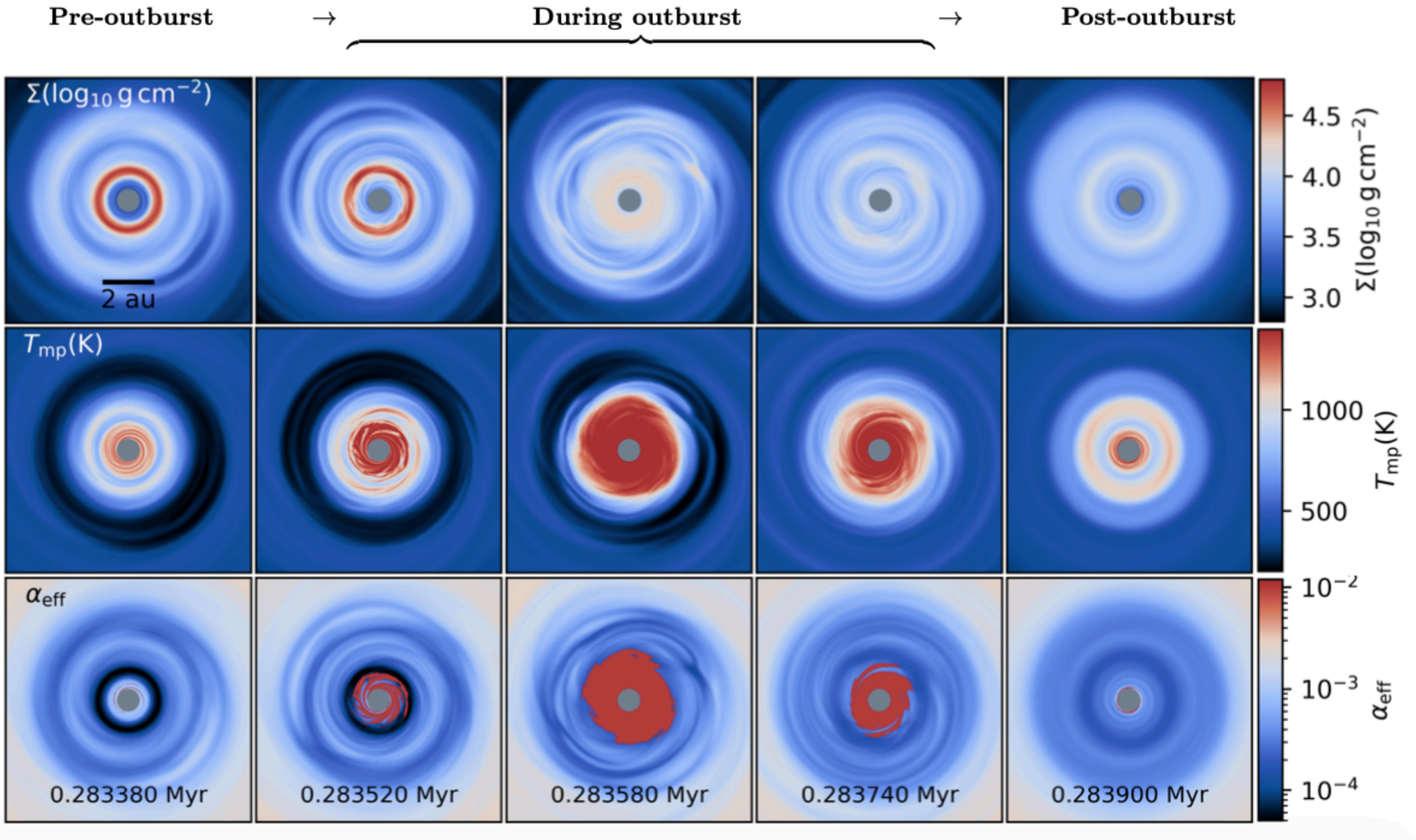
Inner Disk Structure (1.2 $M_\odot$, Σ_a, T_c)



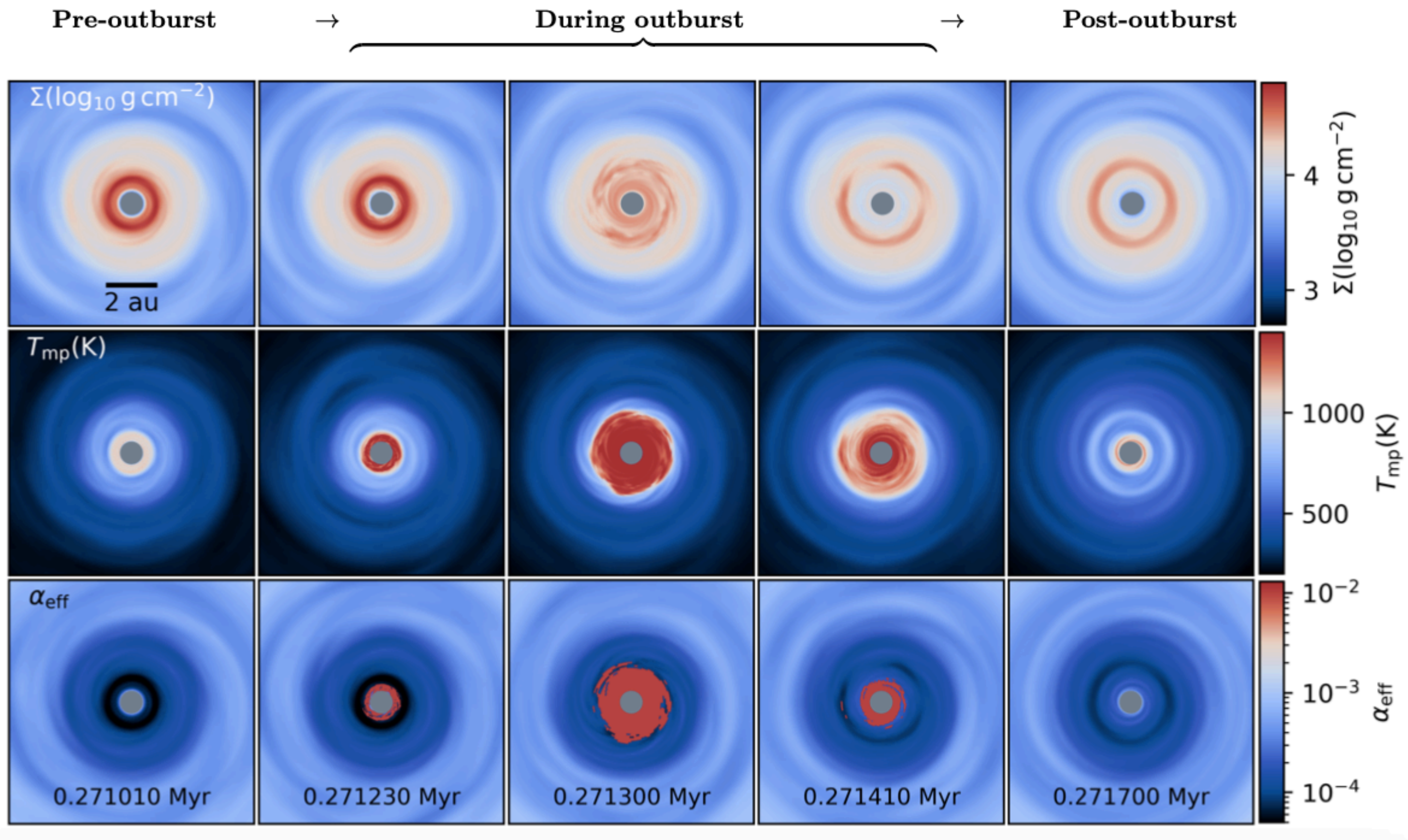
Episodic Accretion (1.2 $M_\odot$, Σ_a, T_c)



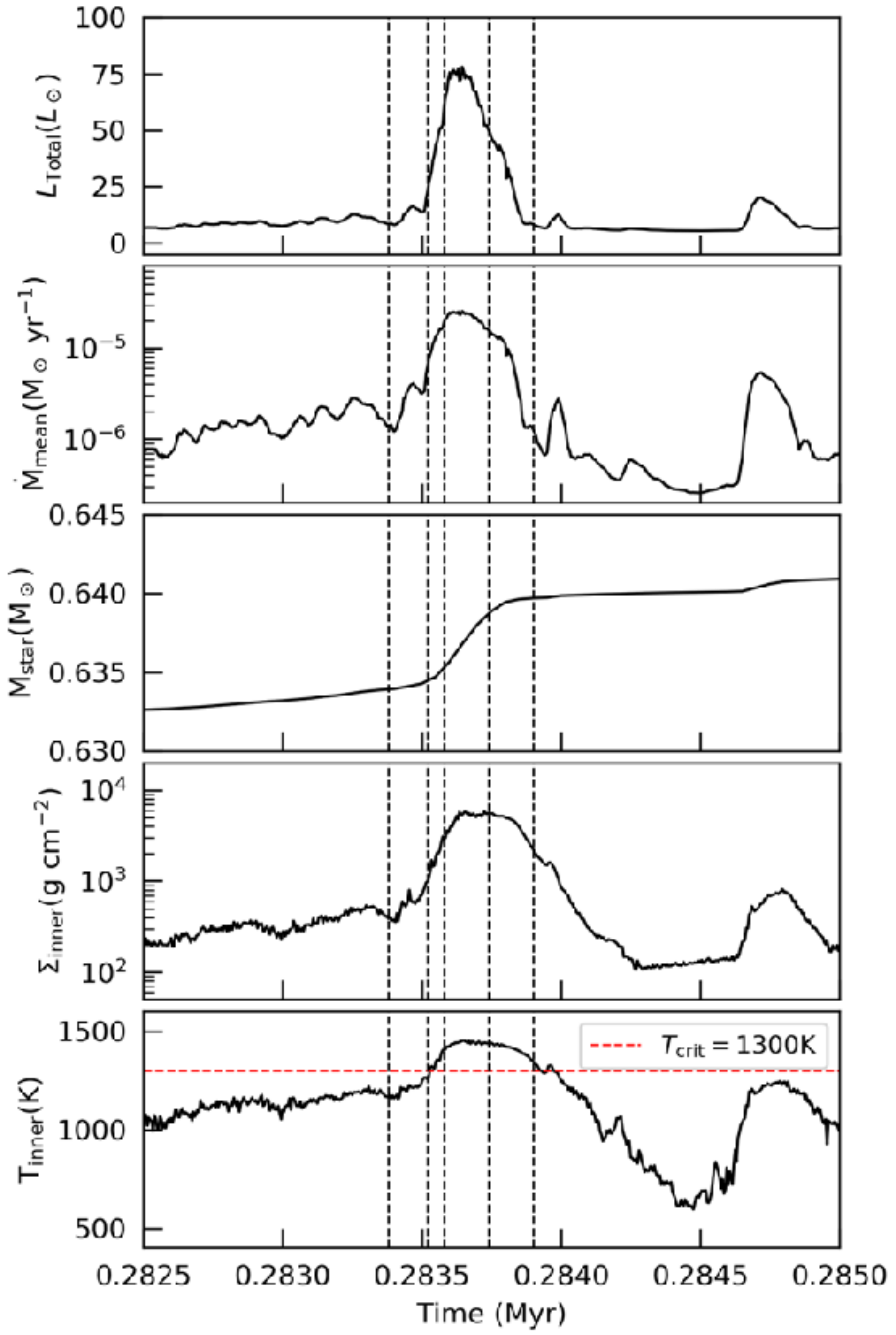
Outburst Progression (Solar metallicity)

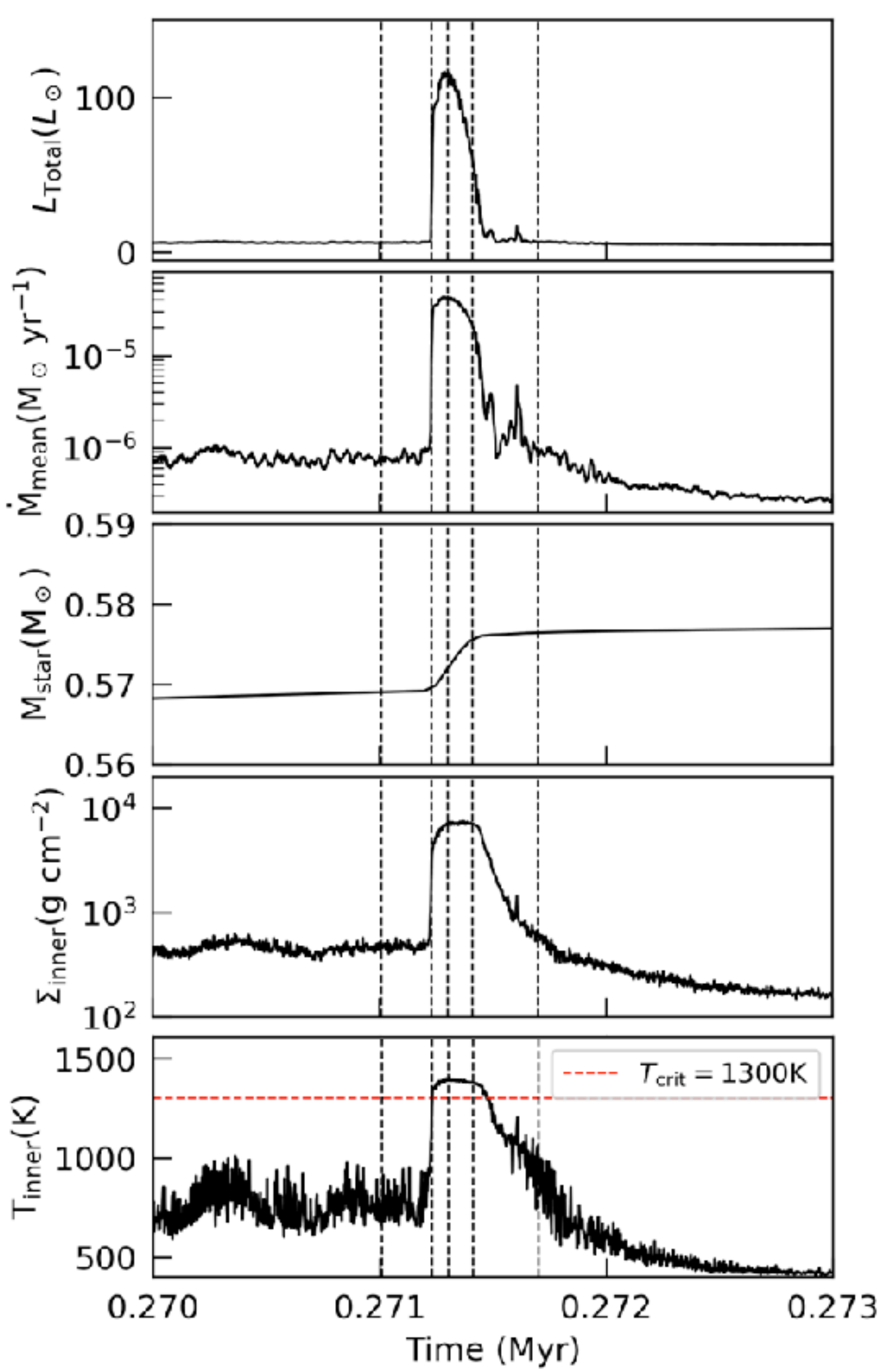


Outburst Progression (Low metallicity)

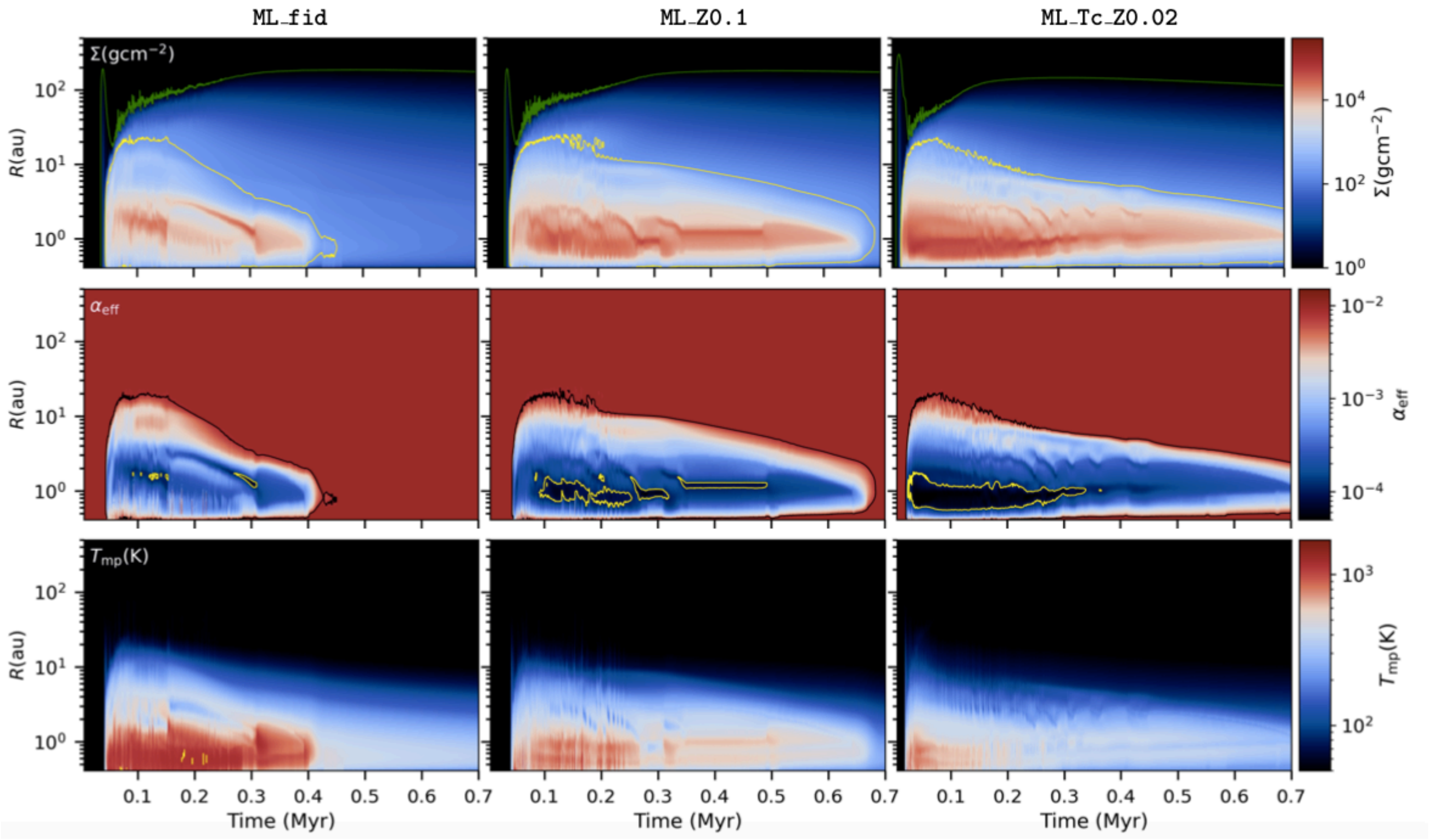


Individual Outburst (Solar vs low metallicity)

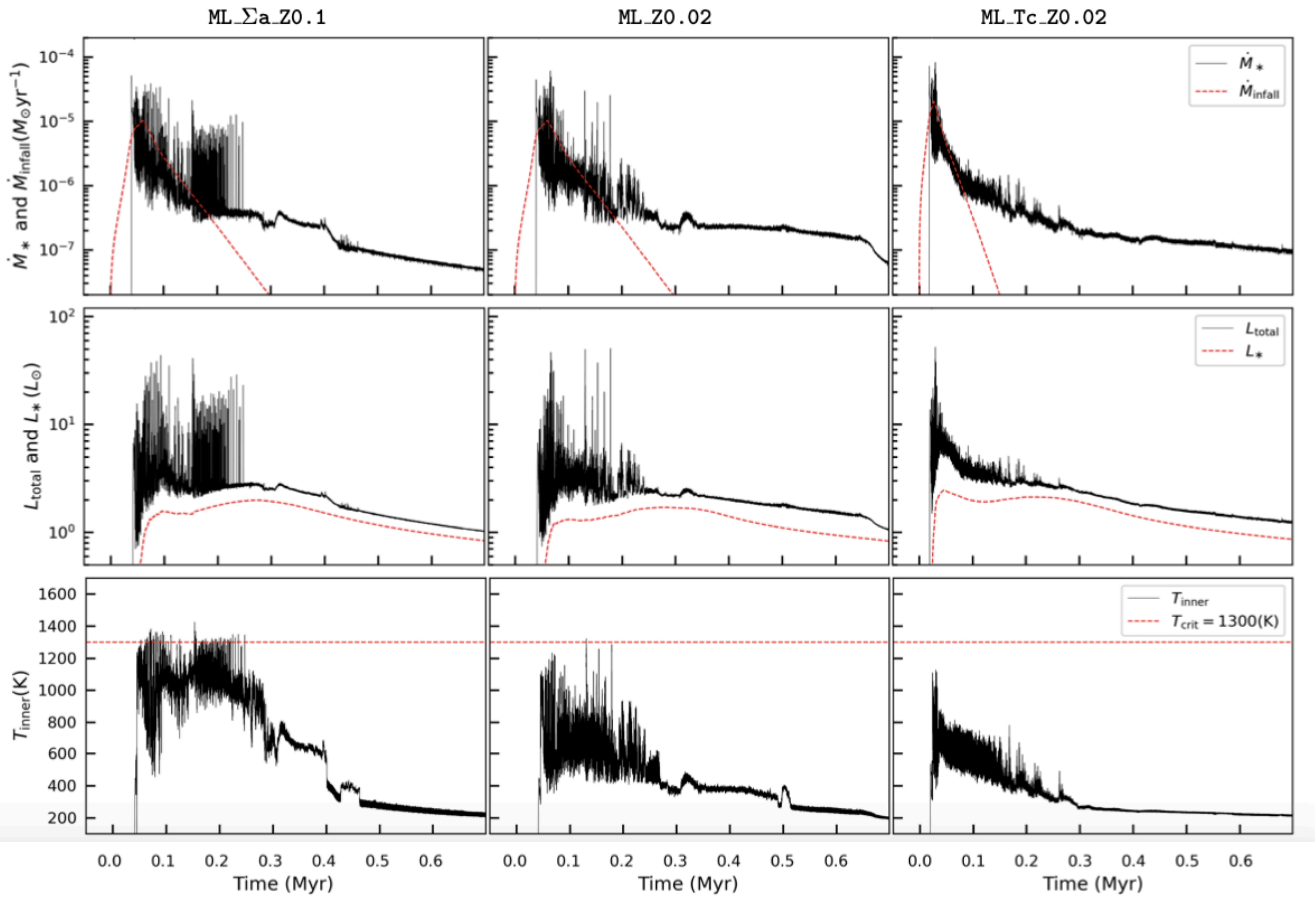




Inner Disk Structure (Low Mass, 0.58 $M_\odot$)



Episodic Accretion (Low Mass, 0.58 $M_\odot$)



Conclusions

With decreasing metallicity..

- Density rings were more robust, larger mass in the inner disk
- Can explain observed trends-

> higher mass accretion rates in low metallicity disks (Spezzi et al. 2012)

> insensitivity of high mass super-Earths to metallicity (Petigura et al. 2018)

- Burst phase became shorter
- MRI-outbursts were rare for a lower mass star, more so for low metallicity
- Individual luminosity curve was more luminous, steep rising and shorter