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GRBs as a Probe of JWST Excess in High-z Universe

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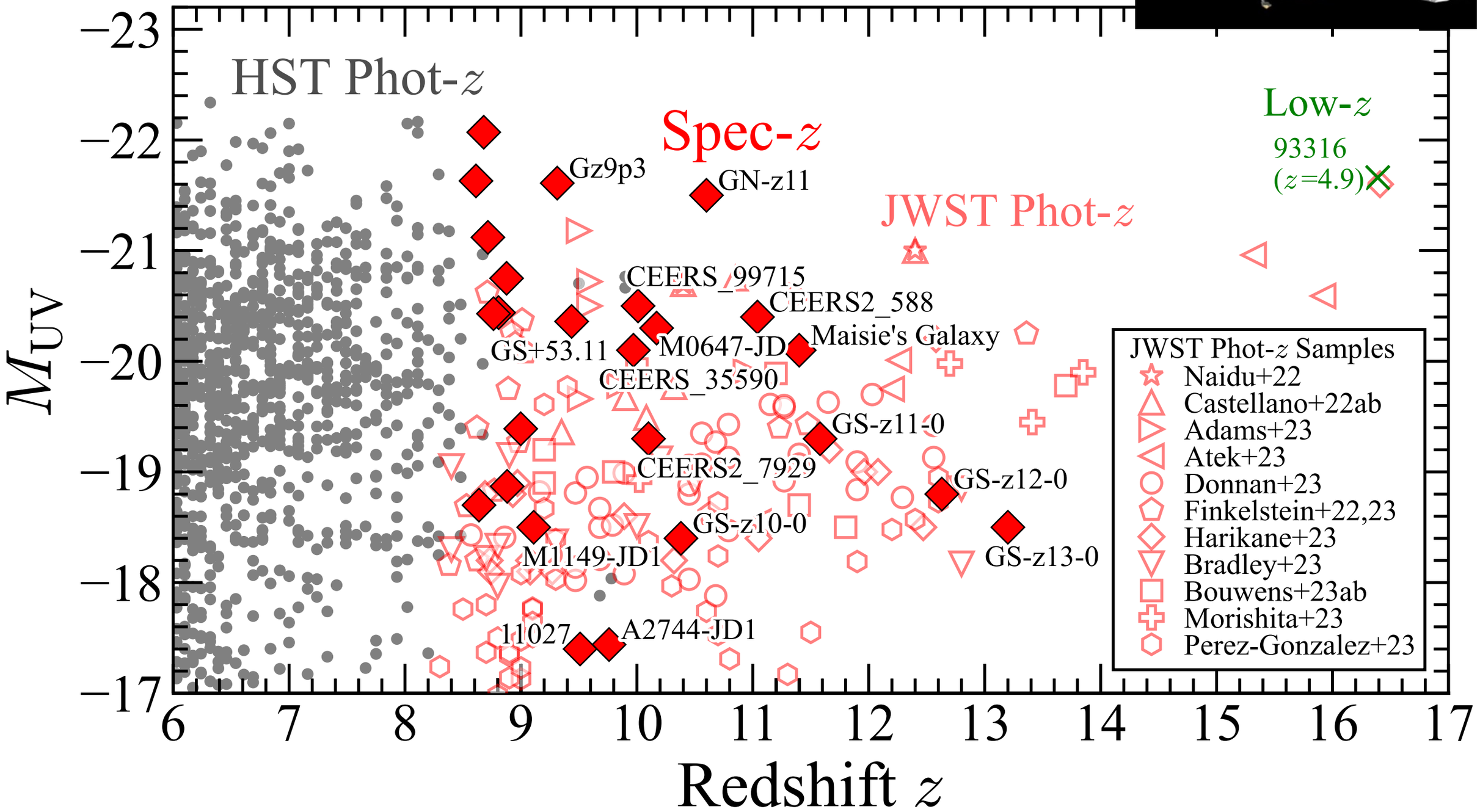
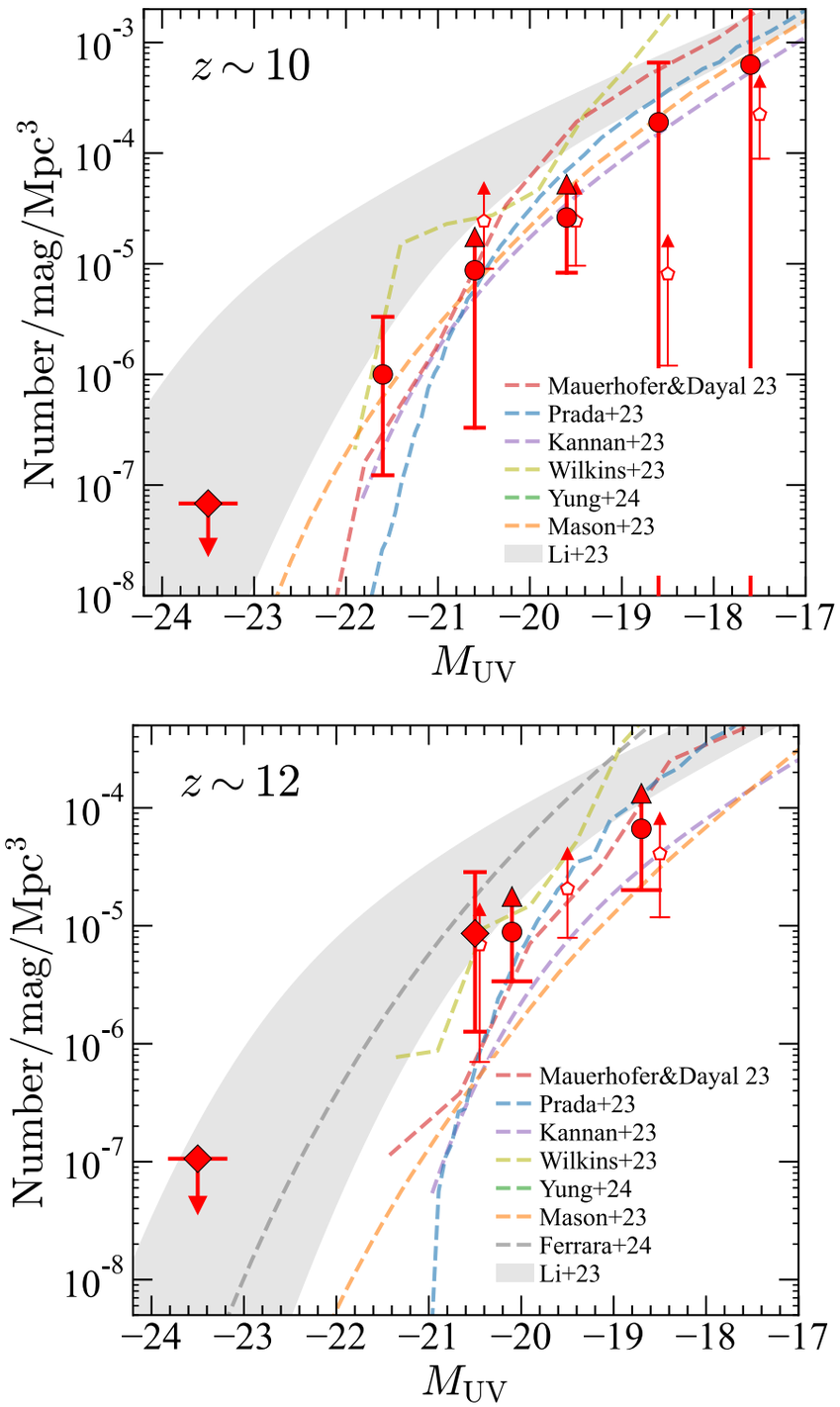
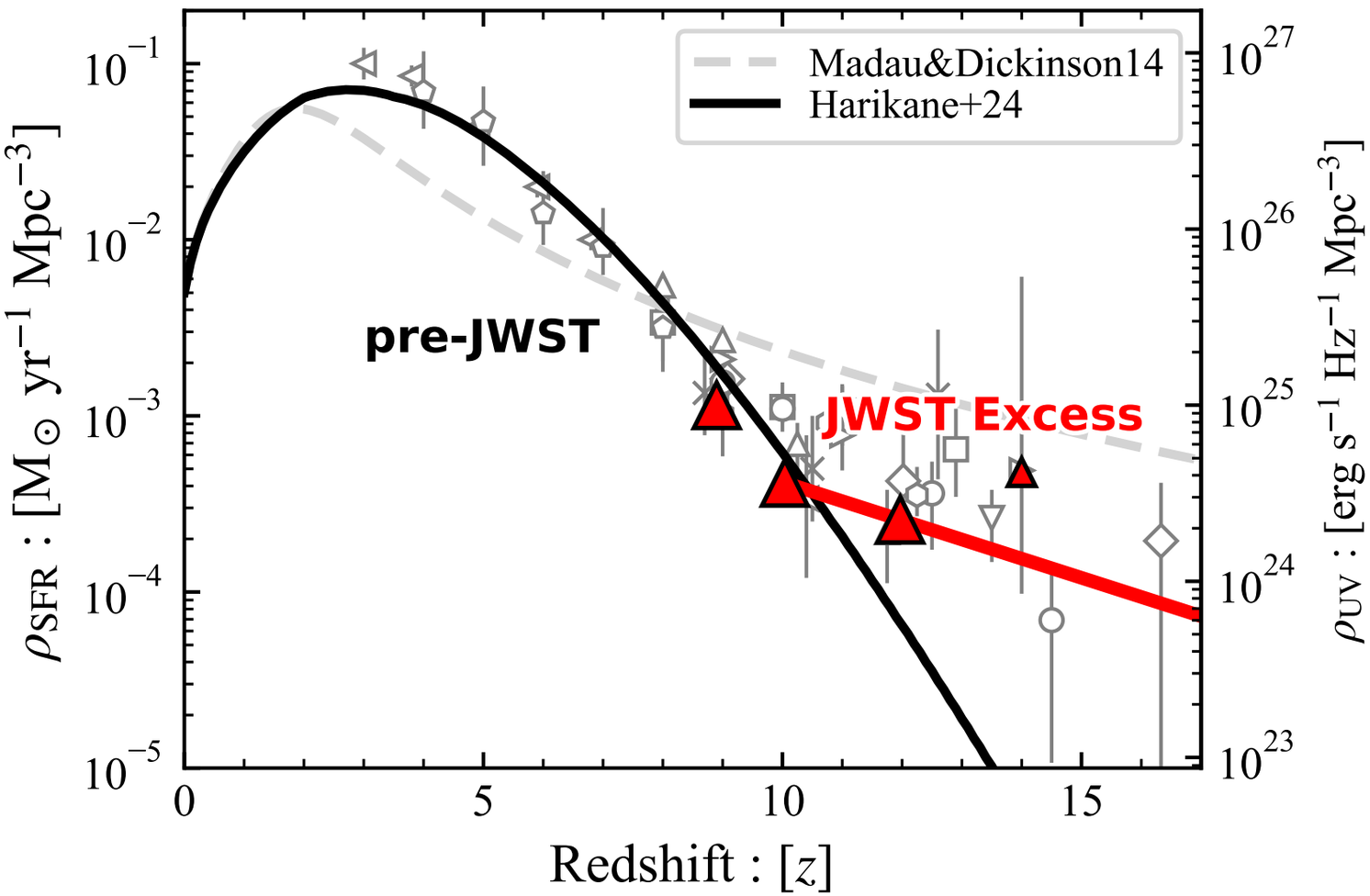
JWST Revolution



Excess in UV Luminosity Function

“JWST excess”





LF => Star Formation Rate (SFR)

$$L_{\rm UV} = \varepsilon_{\rm rad}\, c^2\, {\rm SFR}$$

Salpeter (0.1-100Msun),Zsun, 100Myr

e.g., Madau&Dickinson14

Origins of JWST excess

$$L_{\rm UV} = (\varepsilon_{\rm rad}\, c^2\, {\rm SFR} + L_{\rm AGN}) \exp[-\tau_{\rm UV}]$$

Case A: SFR excess

Dekel+23,Fukushima&Yajima22

Case B: IMF transition

Inayoshi+22,Chon+22,Steinhardt+23

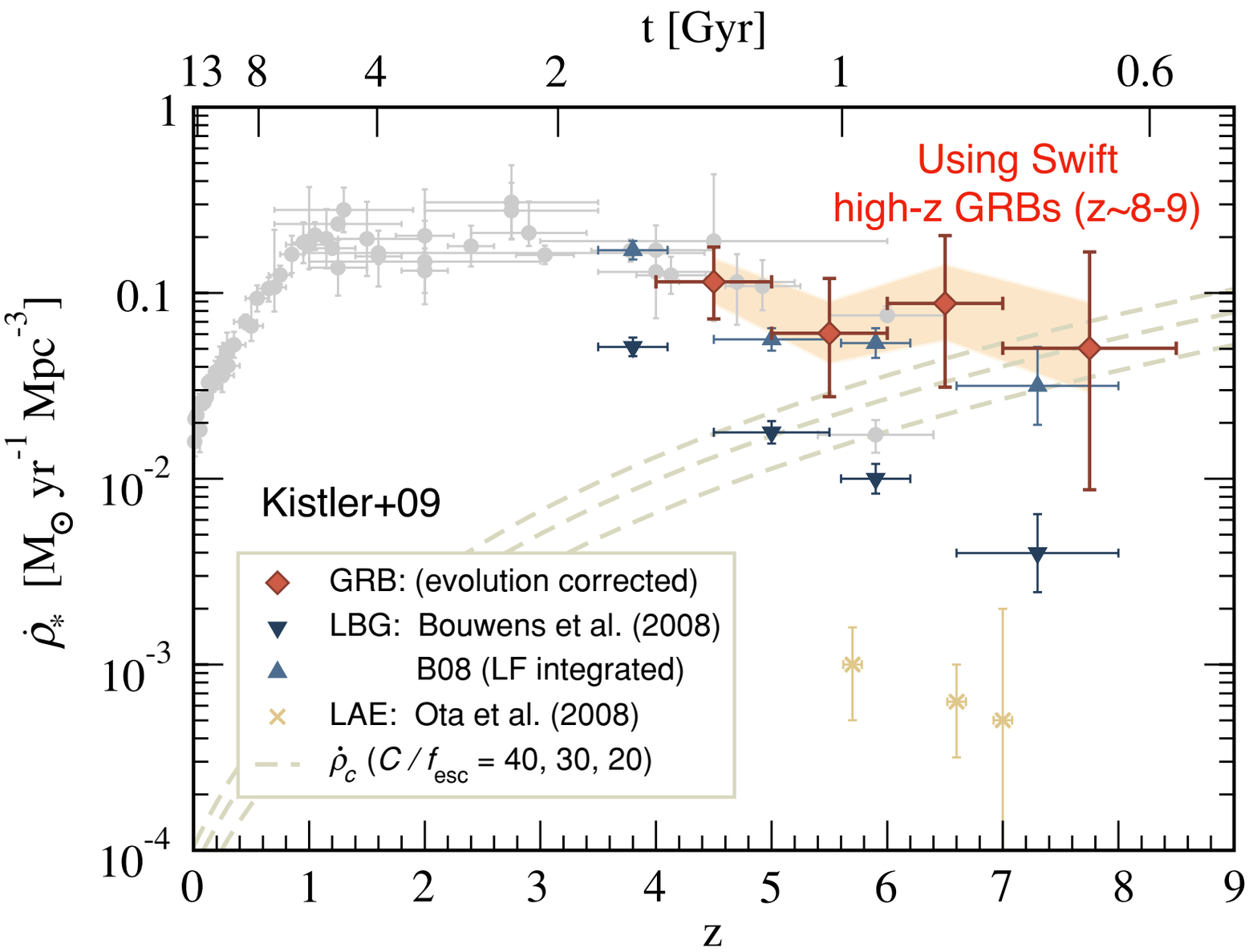
Case C: Small $\tau_{\rm UV}$ / AGN

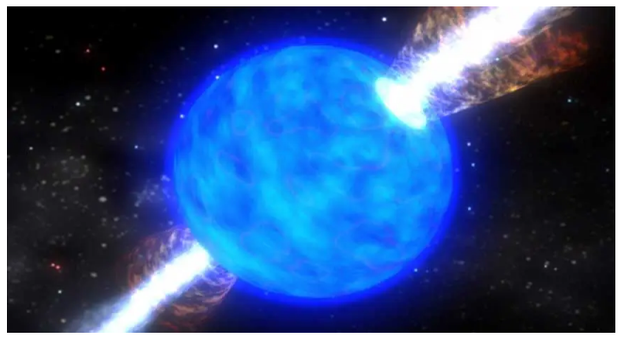
Ferrara24, Harikane+23

Can high-z GRBs discriminate these scenarios?

GRBs as a tracer of SFR

Totani97,Wijers+98,Blain&Natarajan00,Porciani&Madau01, …





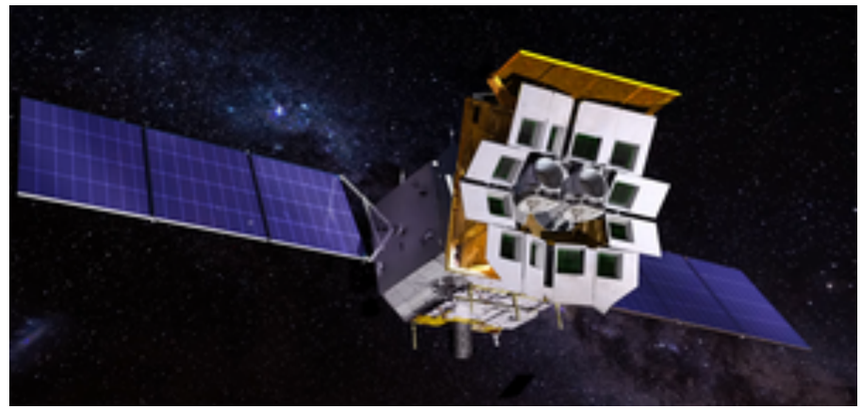
"GRB formation efficiency"
[1/Msun]

$$\Psi_{GRB} = \eta_{GRB}\, \rho_{SFR}$$

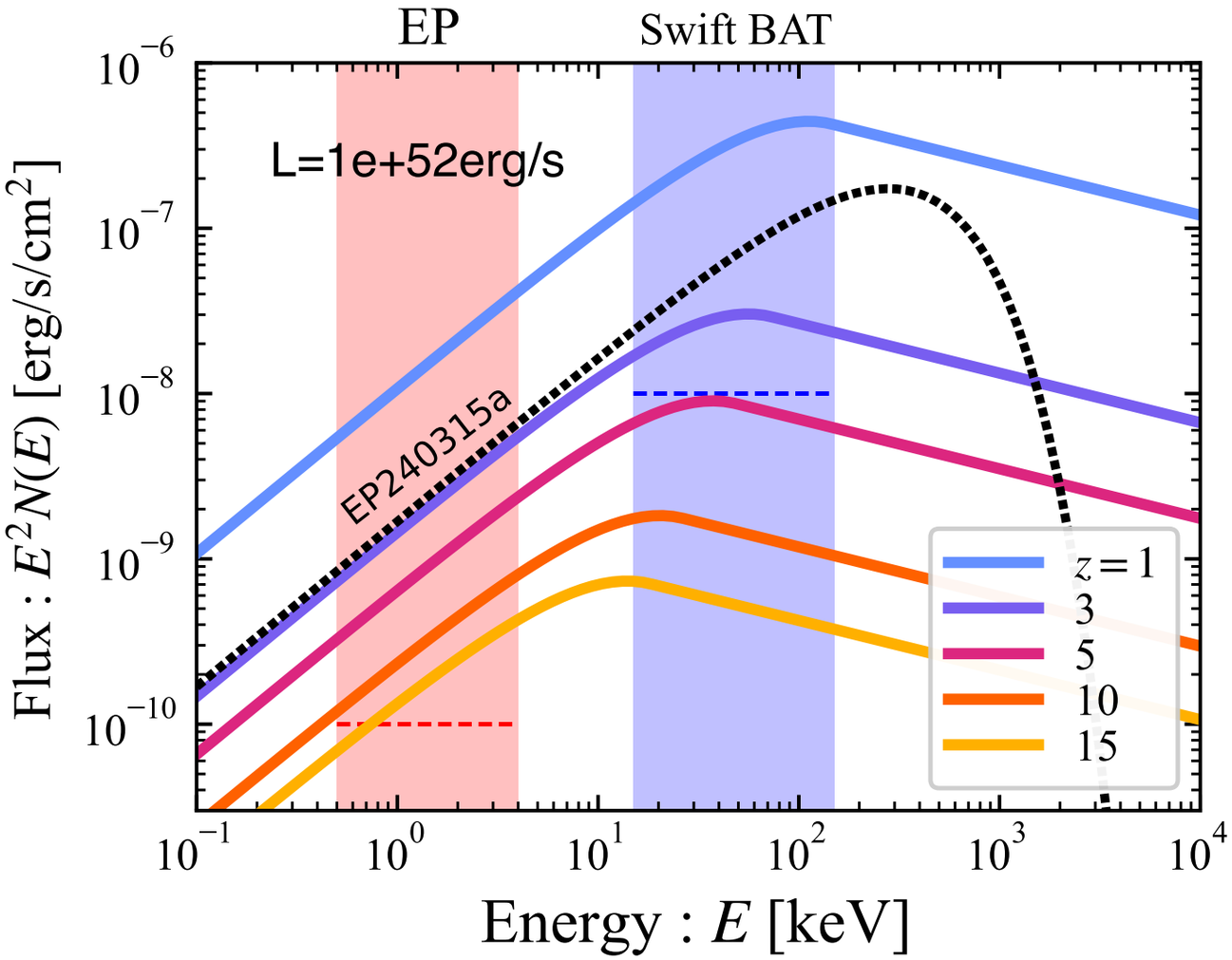
GRB event rate
[/yr/Mpc3]

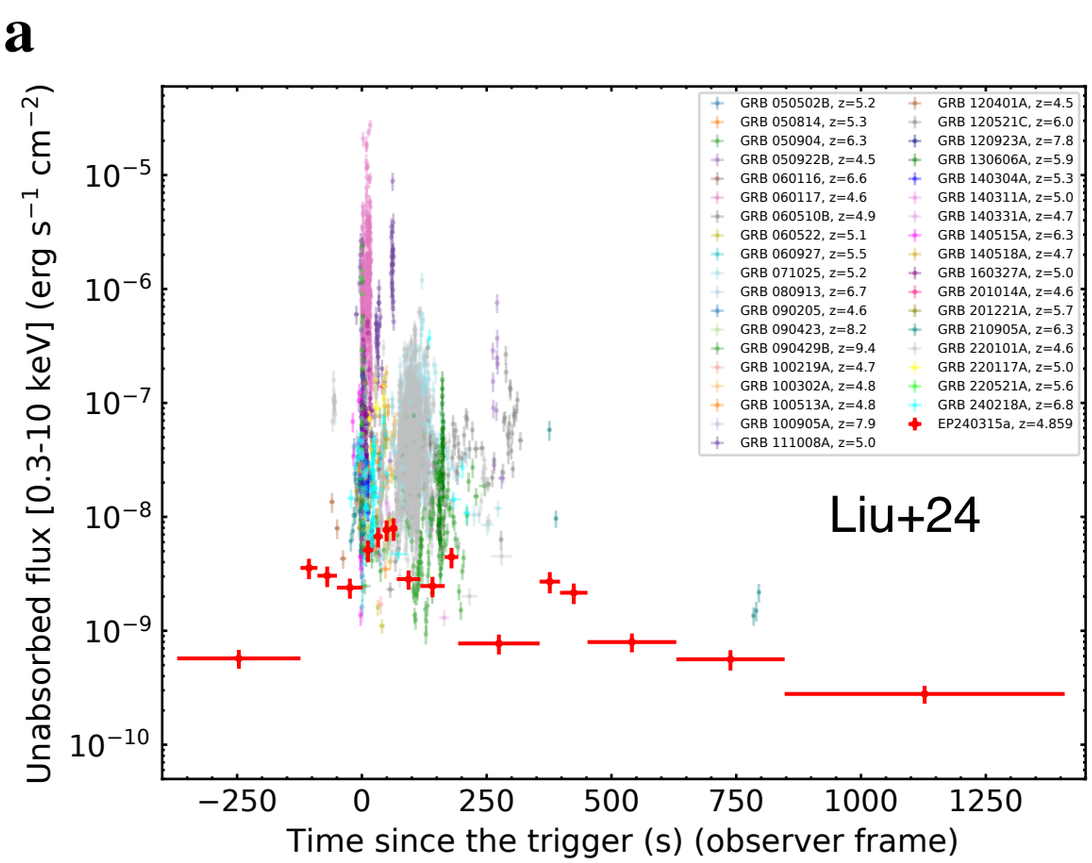
SFR
[Msun/yr/Mpc3]

Einstein Probe



Launched Jan. 2024
05-4 keV, 1.e-10 erg/s/cm2 (for 100s)





EP240315a @z=4.9

Estimate of high-z GRB event rate

$$\frac{dN_{\rm GRB}}{dz} = \Psi^{\rm obs}_{\rm GRB} \frac{\Delta t_{\rm obs}}{1+z} \frac{dV}{dz}$$

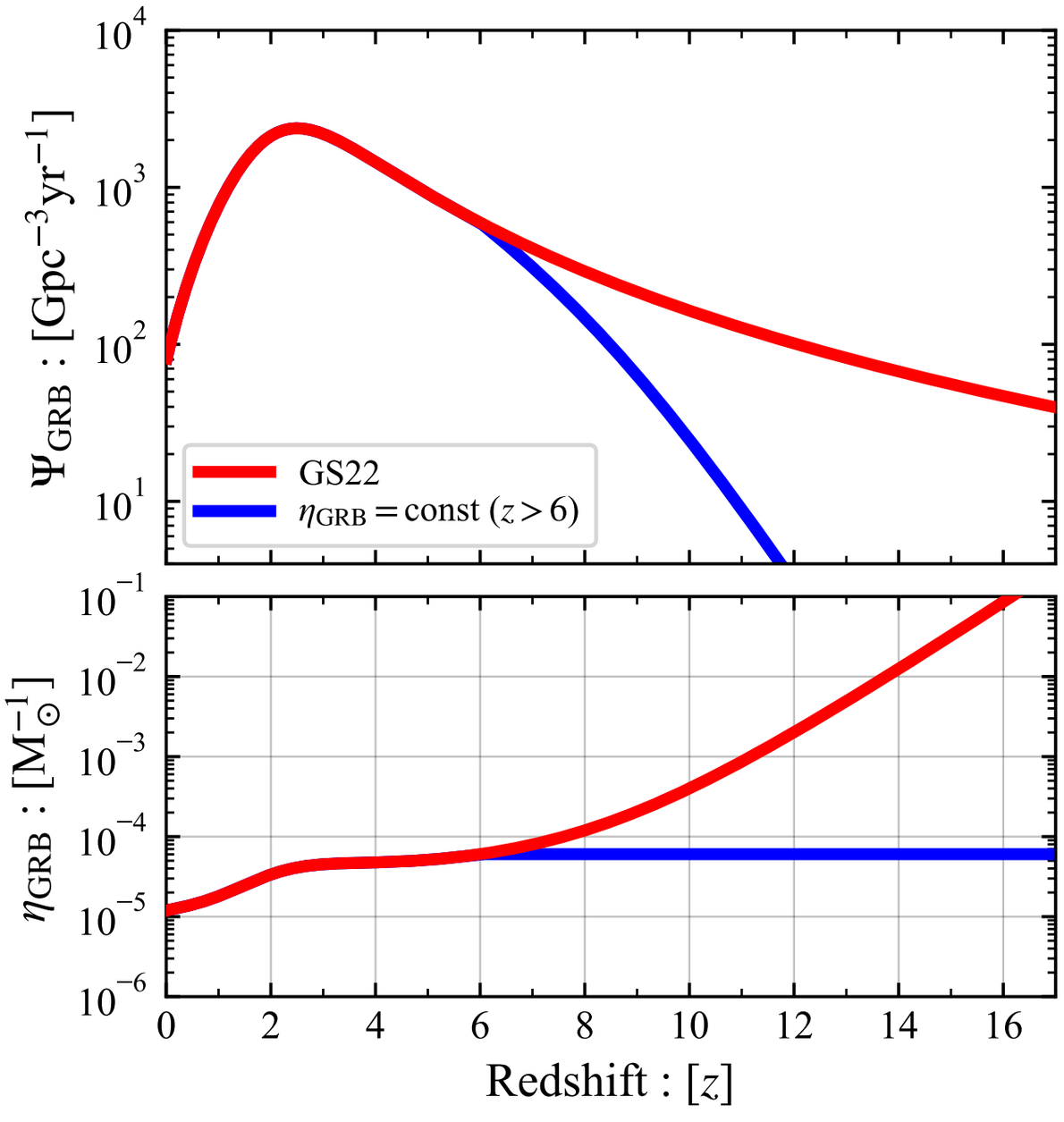
$$\Psi^{\rm obs}_{\rm GRB}(z) = \frac{\Omega}{4\pi} \eta_{\rm beam} \Psi_{\rm GRB}(z) \int_{L_{\rm min}(z)}^{\infty} \frac{dn}{dL} dL$$

GRB event rate (=>)

& **LF** (Broken PL)

taken from recent studies

(Ghirlanda&Salvaterra22)



Estimate of high-z GRB event rate

$$\boldsymbol{\Psi_{\rm GRB} = \eta_{\rm GRB}\, \rho_{\rm SFR}}$$

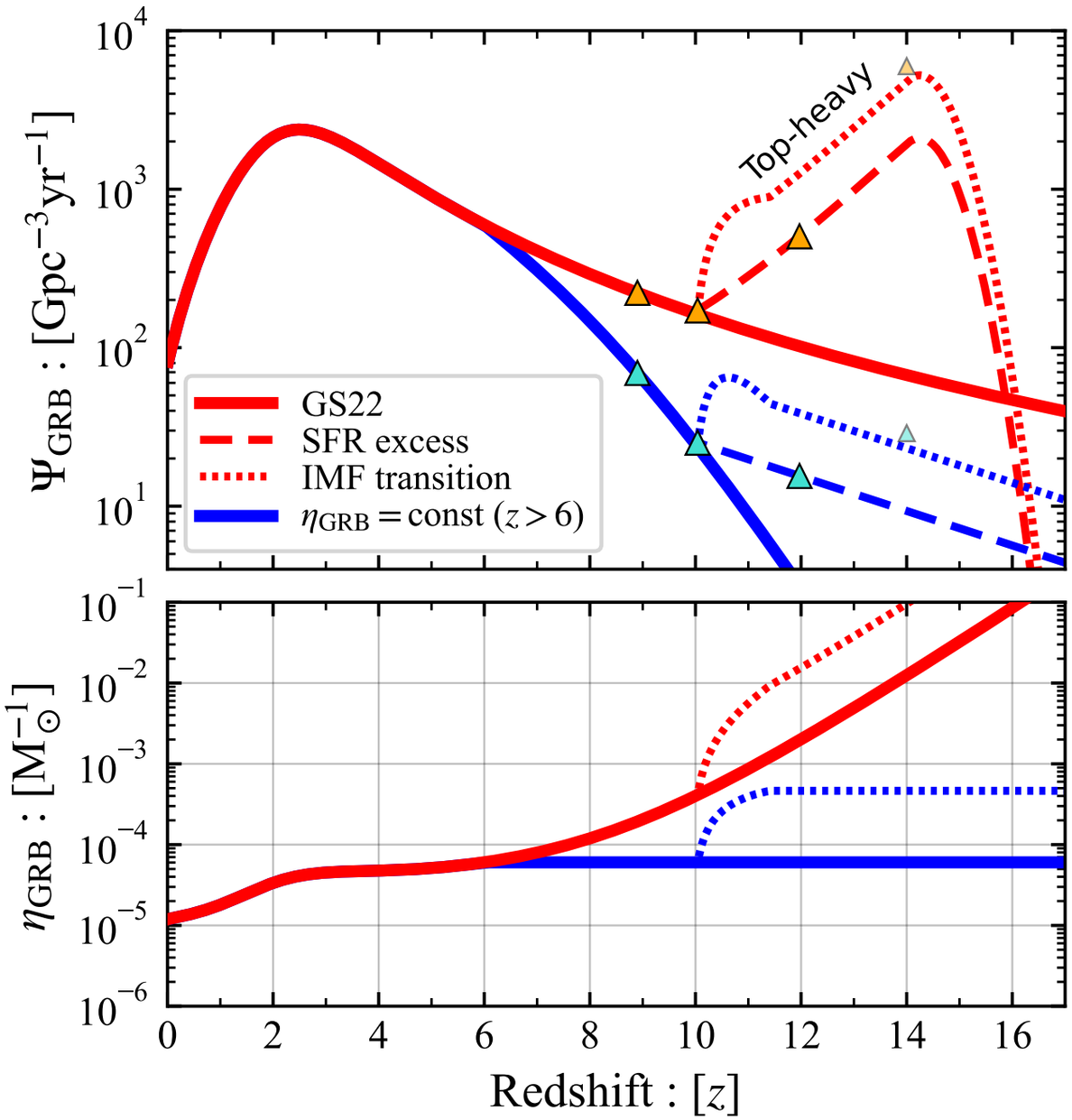
Case A: SFR excess

Case B: IMF transition

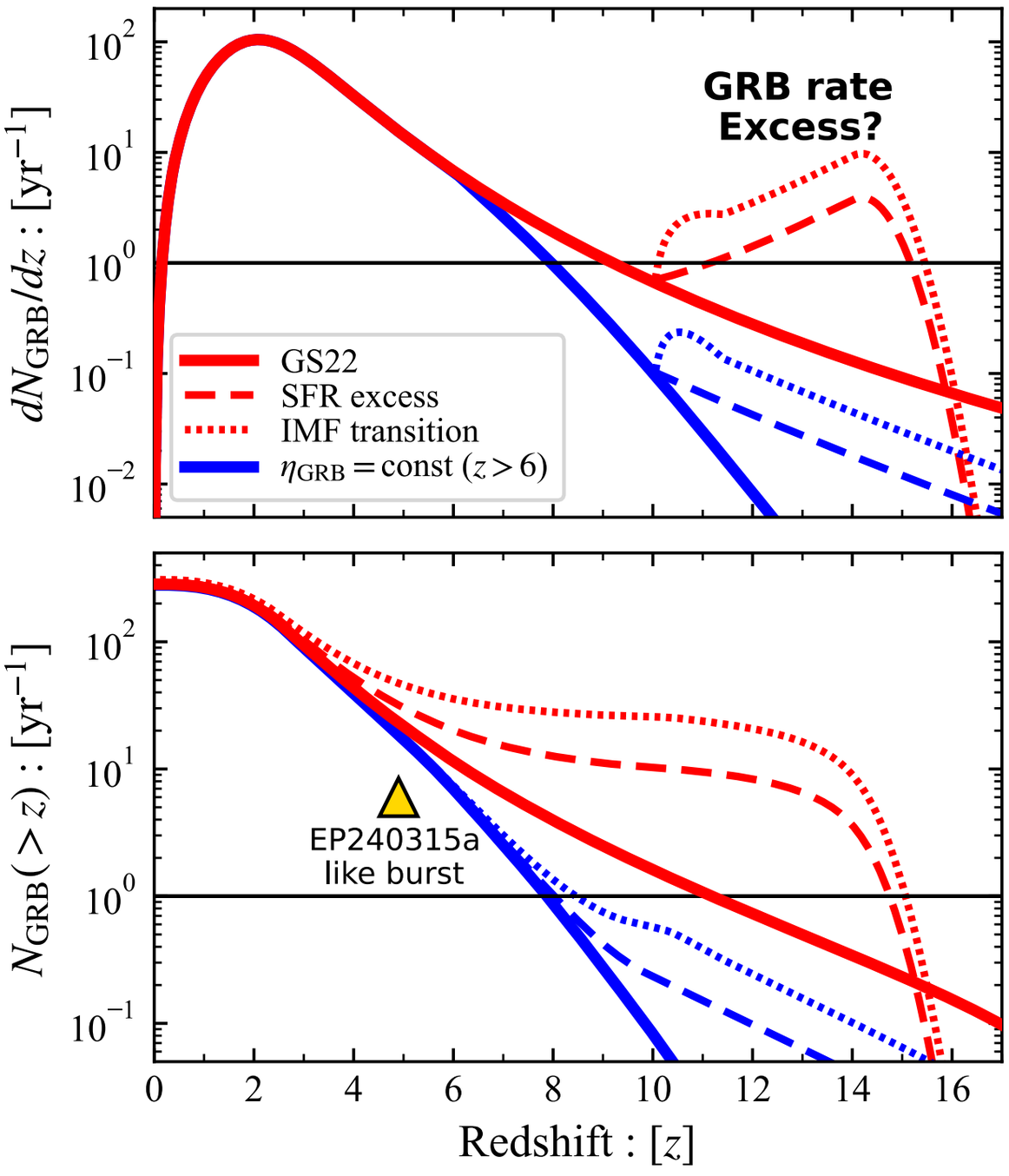
$$\eta_{\rm GRB} \propto \frac{\int_{m_{\rm GRB}}^{m_{\rm up}} \phi(m) dm}{\int_{m_{\rm low}}^{m_{\rm up}} m\phi(m) dm}$$

(1) IMF	(2) Z	(4) $\epsilon_{\star,\rm UV}$	$\frac{\int_{m_{\rm GRB}}^{m_{\rm up}} \phi(m) dm}{\int_{m_{\rm low}}^{m_{\rm up}} m\phi(m) dm}$
Salpeter [0.1, 100]	0.02	2.79×10^{-4}	1.4×10^{-3}
Salpeter [0.1, 100]	0.0004	3.28×10^{-4}	
Salpeter [50, 500]	0	1.26×10^{-3}	
log-normal[a] [1,500]	0	9.42×10^{-4}	1.1×10^{-2}

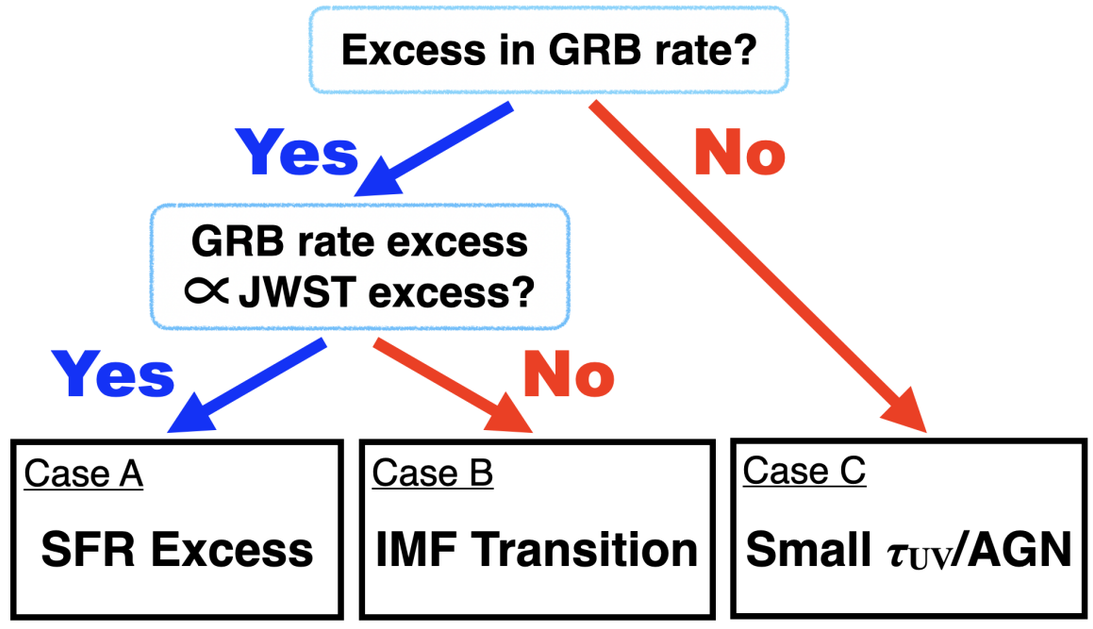
Case C: Small $\tau_{\rm UV}$ / AGN



Estimate of high-z GRB event rate



Origin of the JWST excess probed by high-z GRBs



Summary

- JWST discovered excess in $L_{\rm UV}$ (or SFR)
- Origin of excess? $L_{\rm UV} = (\varepsilon_{\rm rad}\, c^2\, {\rm SFR} + L_{\rm AGN}) \exp[-\tau_{\rm UV}]$
- GRB is a tracer of SFR
- Einstein Probe may detect high-z GRBs