An Ultra Metal-poor Star Near the Hydrogen-burning Limit

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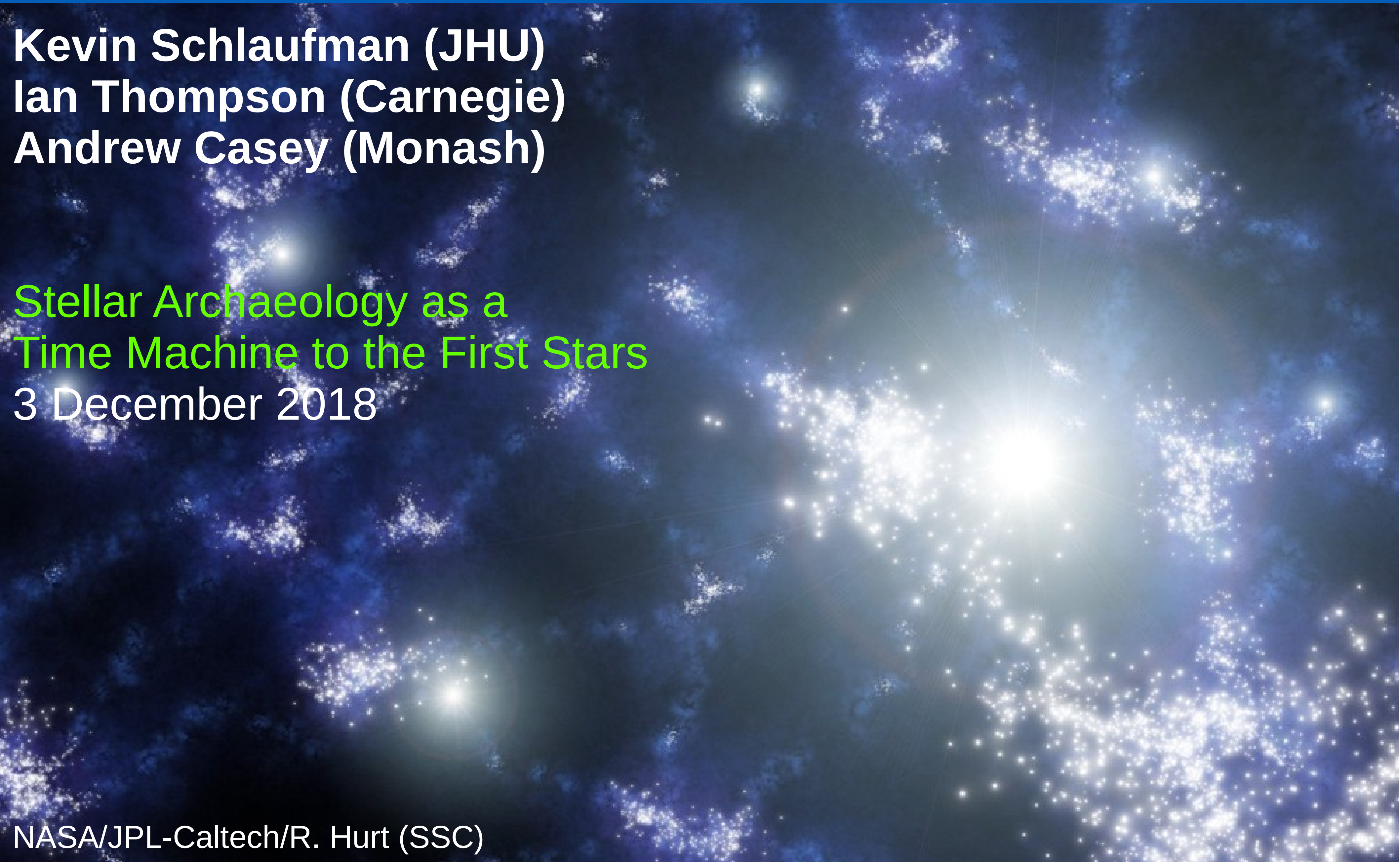
Stellar Archaeology as a
Time Machine to the First Stars
3 December 2018



NASA/JPL-Caltech/R. Hurt (SSC)

What Were Pop III Stars Like?

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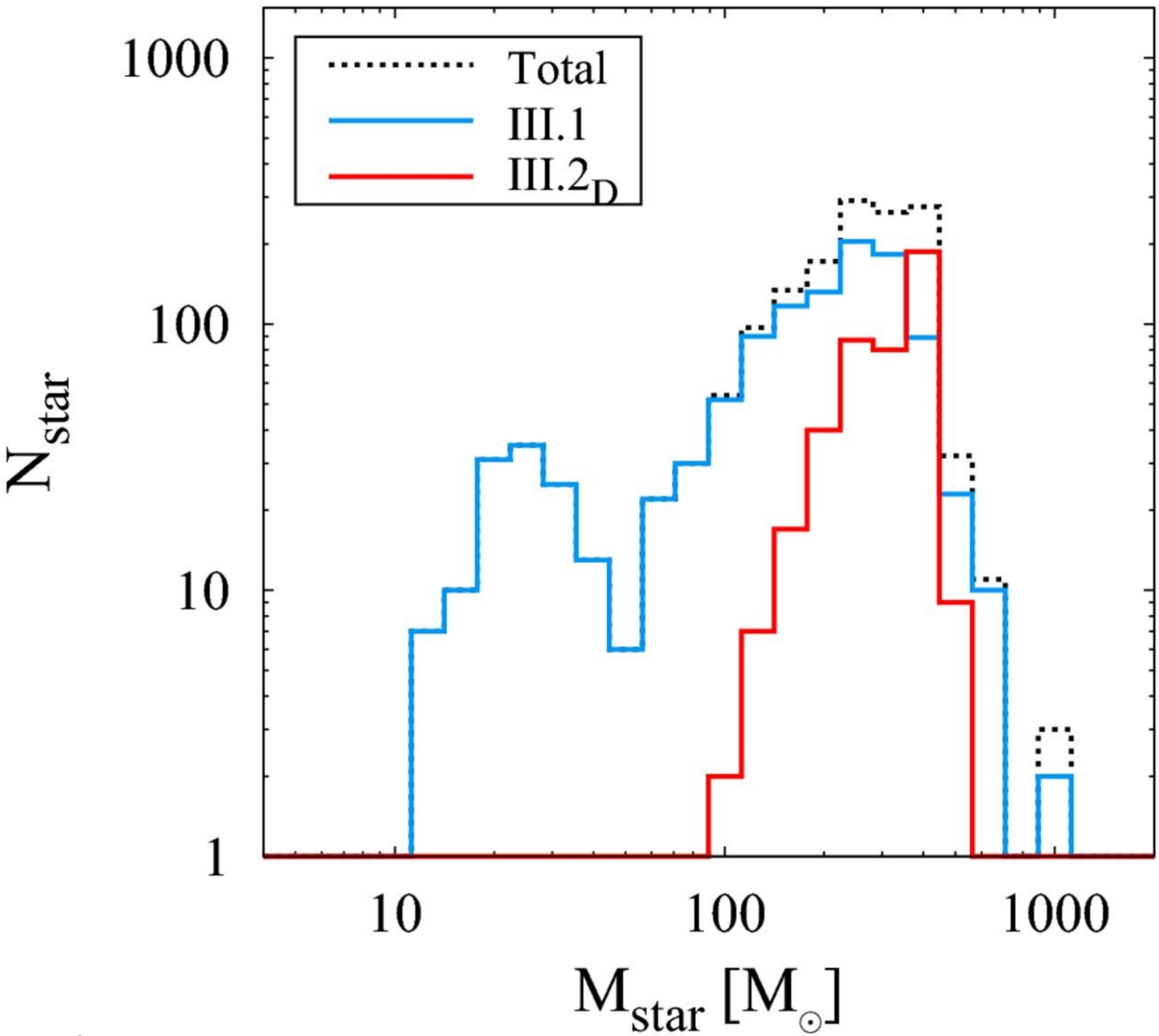
A Possible Theoretical Pop III IMF?



Hirano et al. (2015)

A Possible Empirical Pop III IMF?

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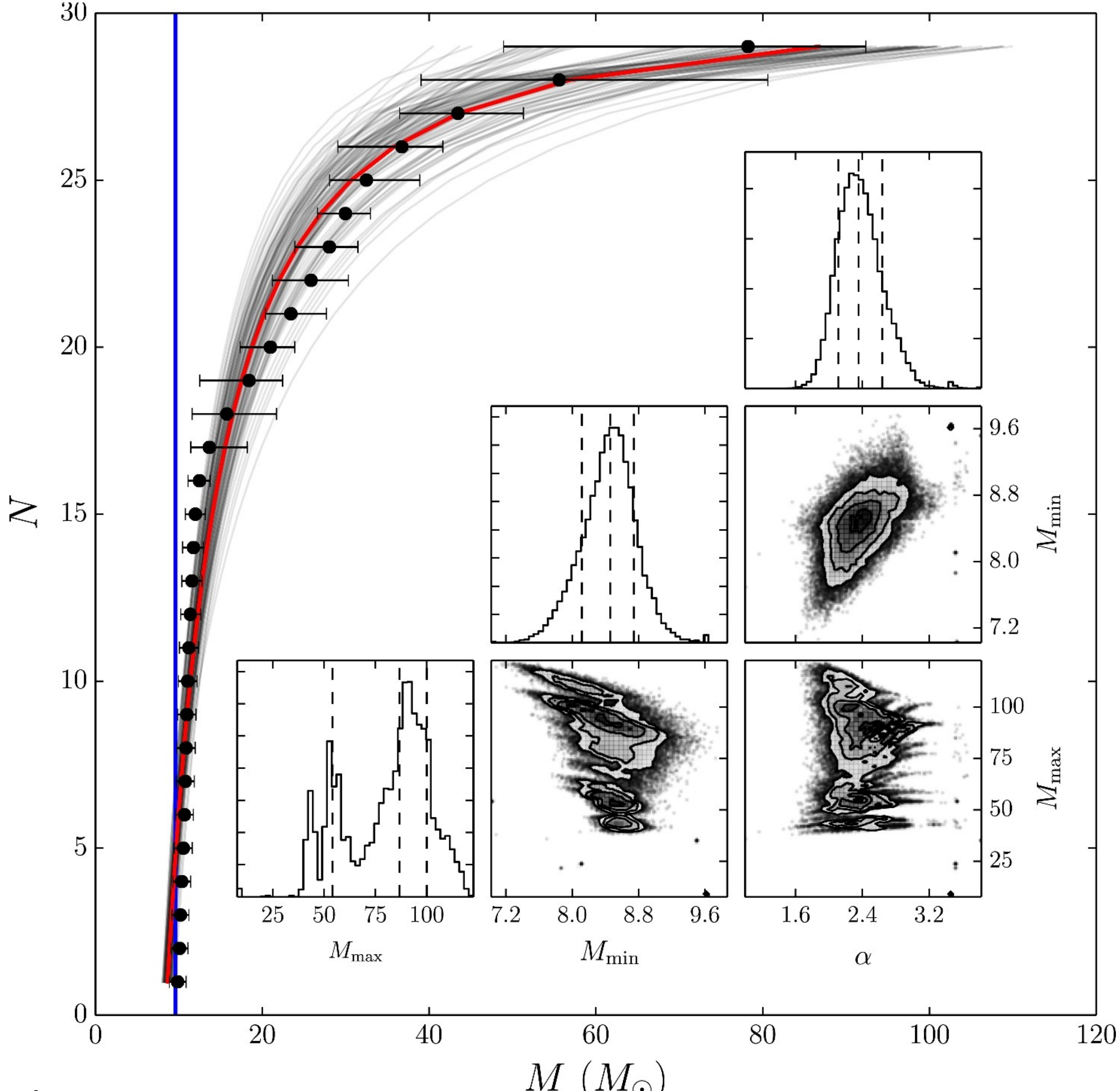

Fraser et al. (2017)

Importance of Disk Fragmentation?

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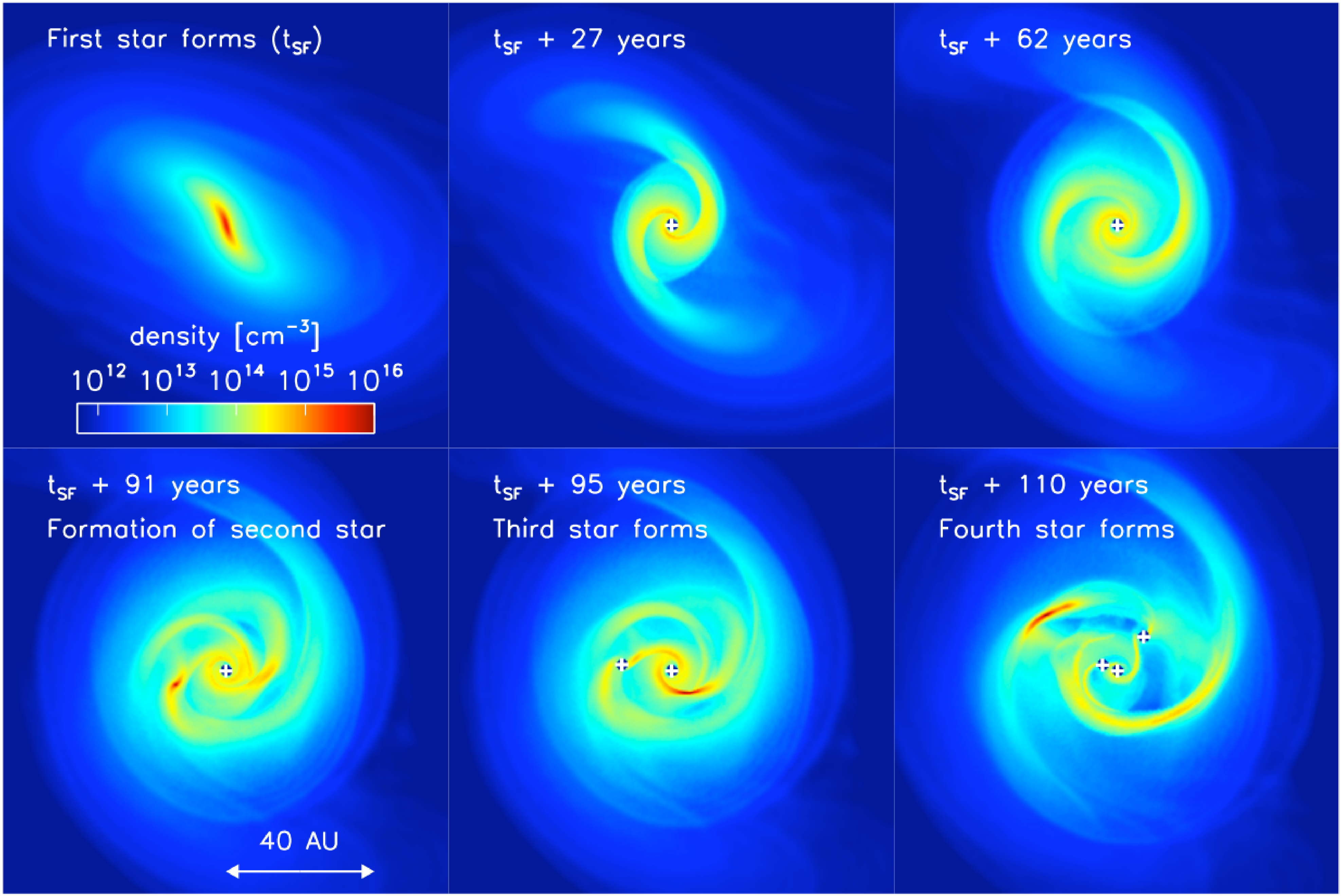

Clark et al. (2011a, 2011b); Grief et al. (2011, 2012); Stacey et al. (2010, 2012, 2016)

Importance of Disk Fragmentation?

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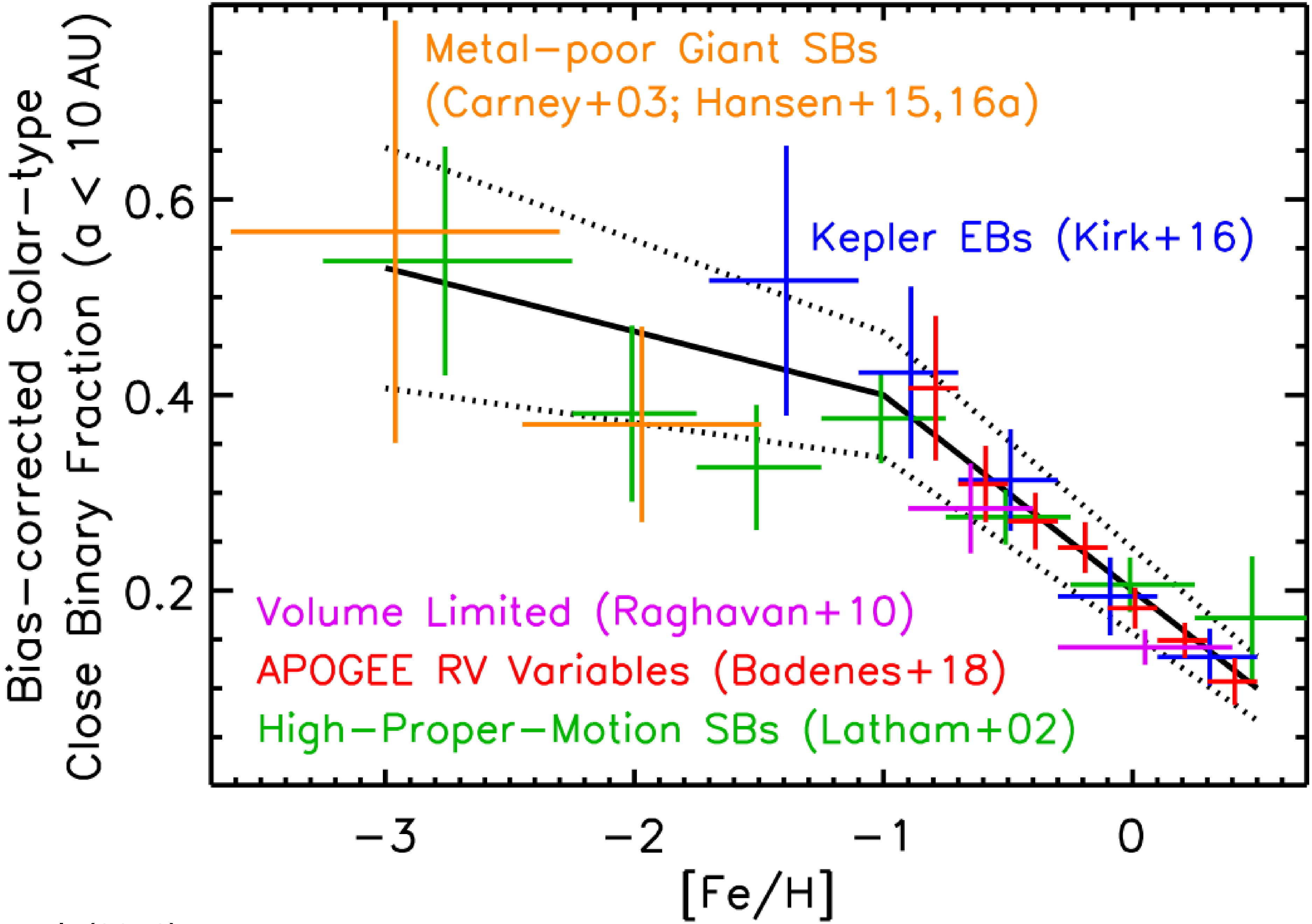
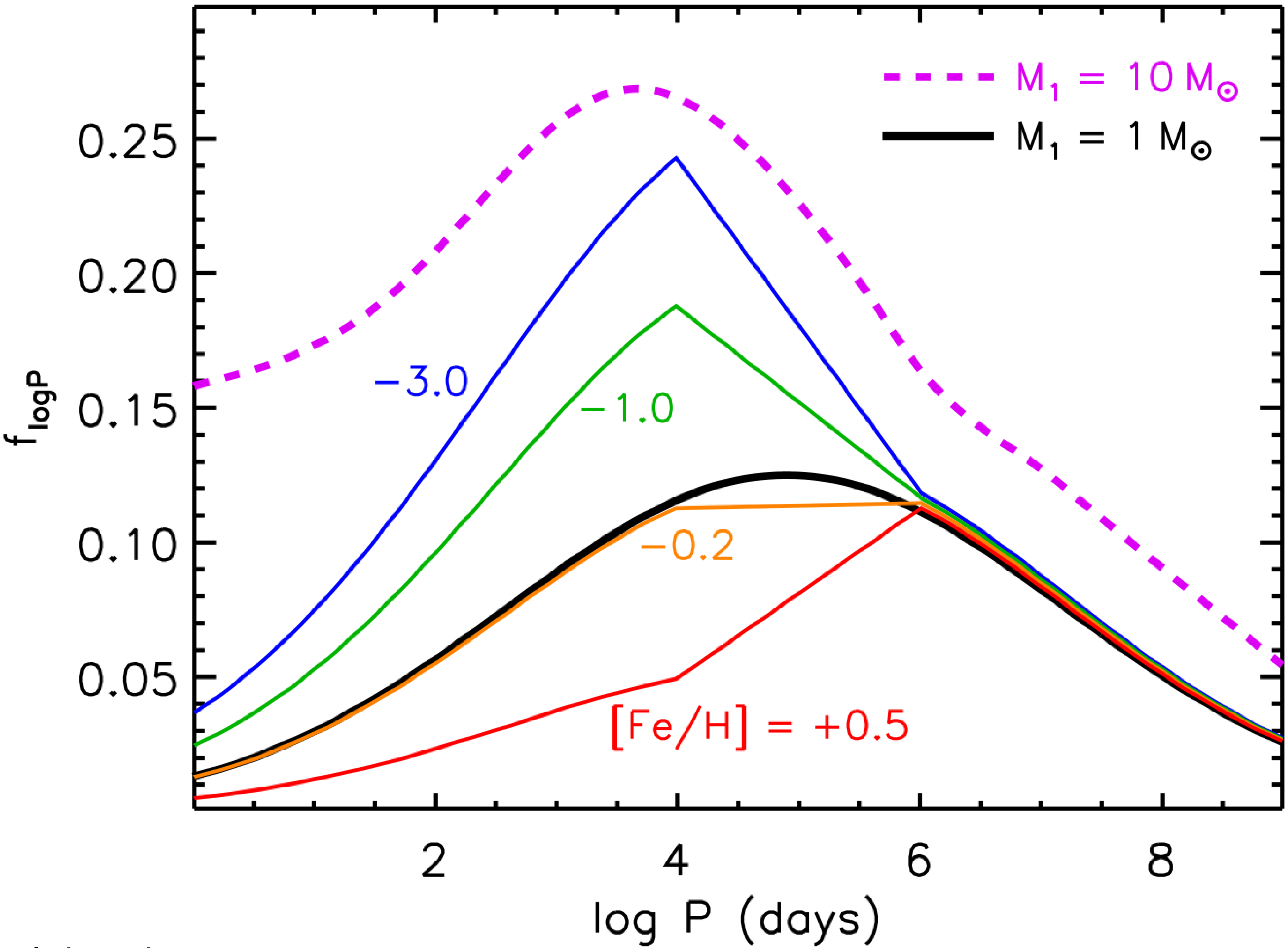


Moe et al. (2018)

Importance of Disk Fragmentation?



Moe et al. (2018)

2MASS J18082002–5104378

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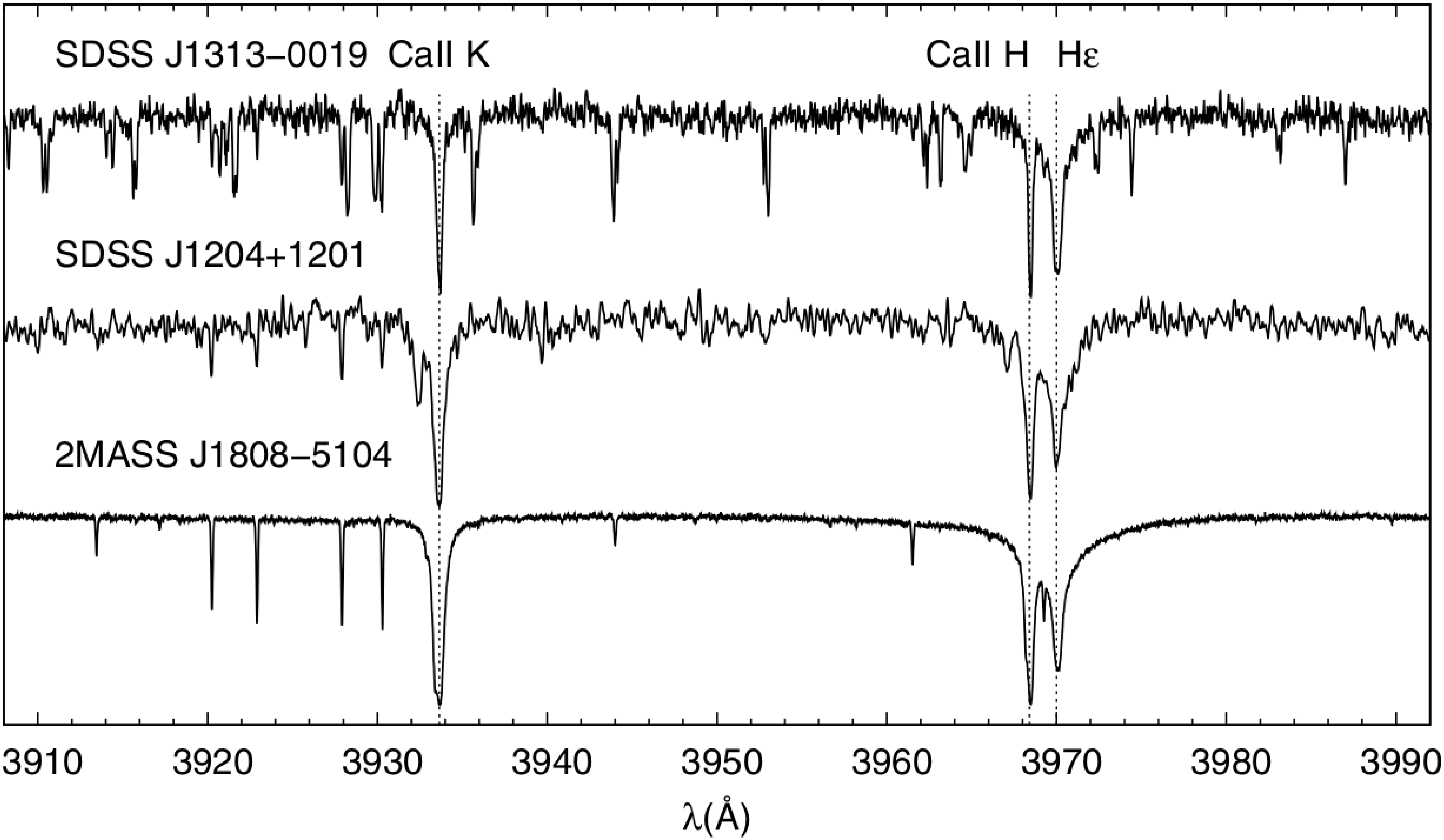
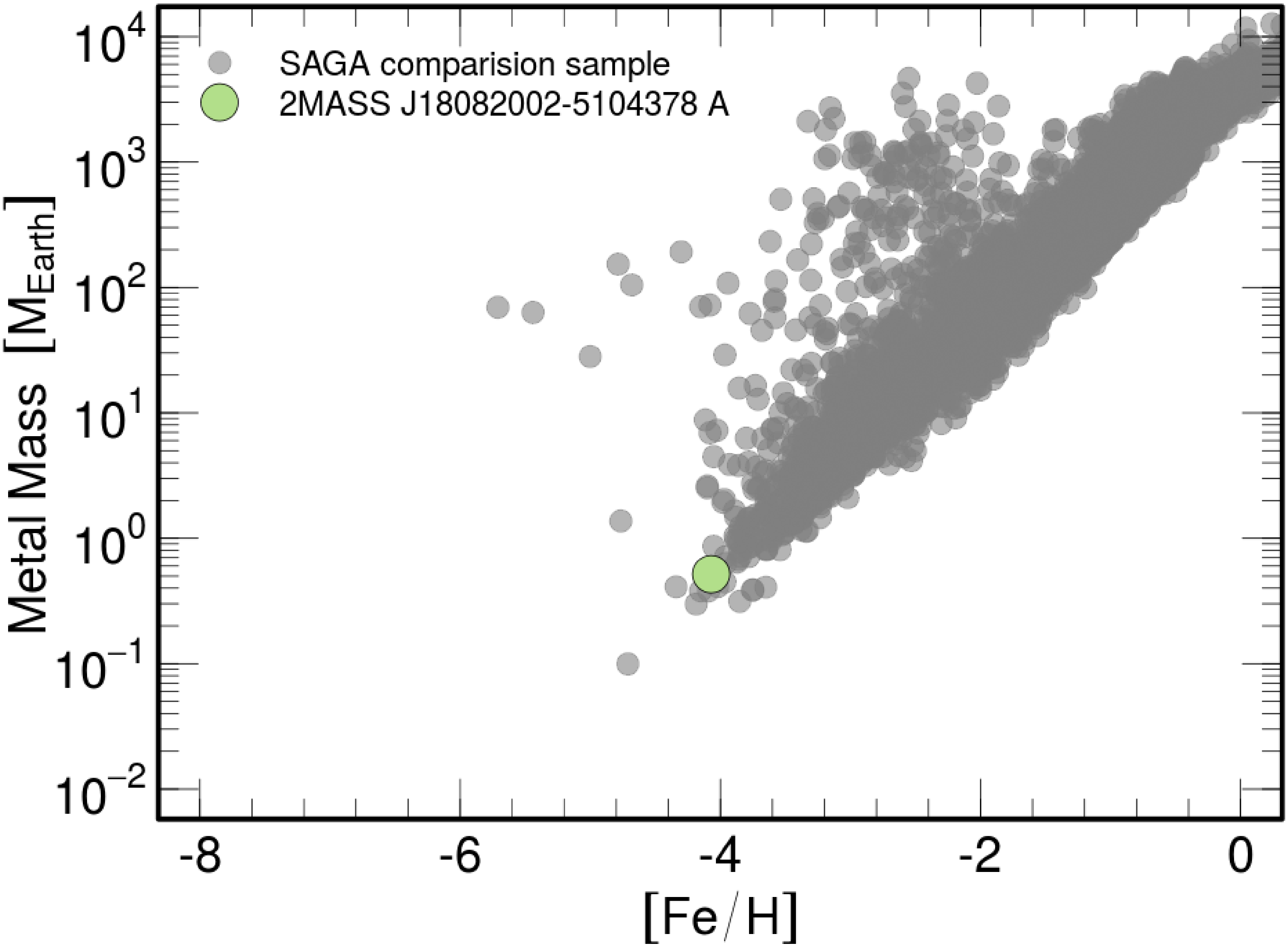


Melendez et al. (2016)

Total Metallicity



A Low-mass UMP Star in a SB1

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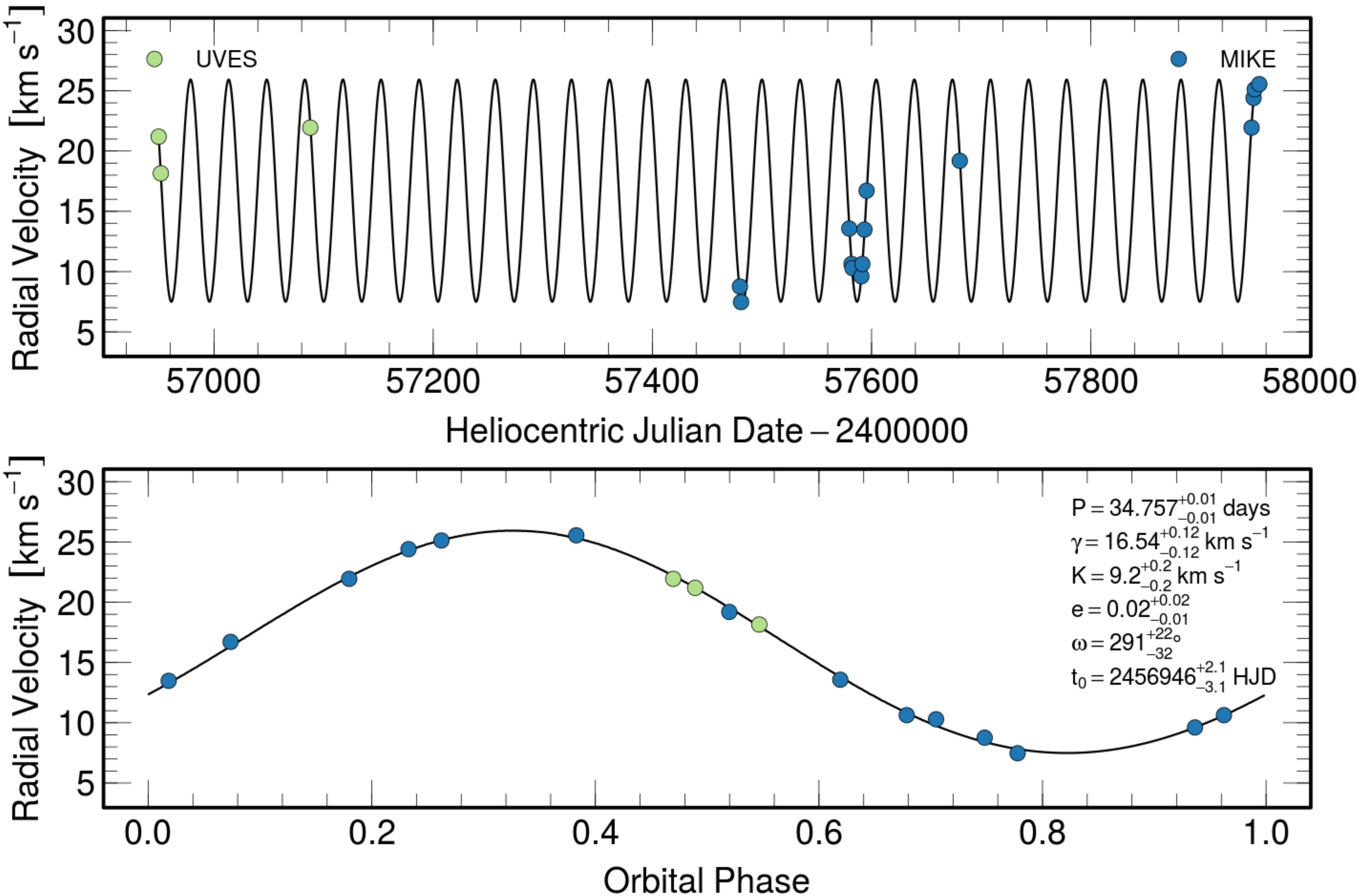
Schlaufman et al. (2018)



A Low-mass UMP Star in a SB1

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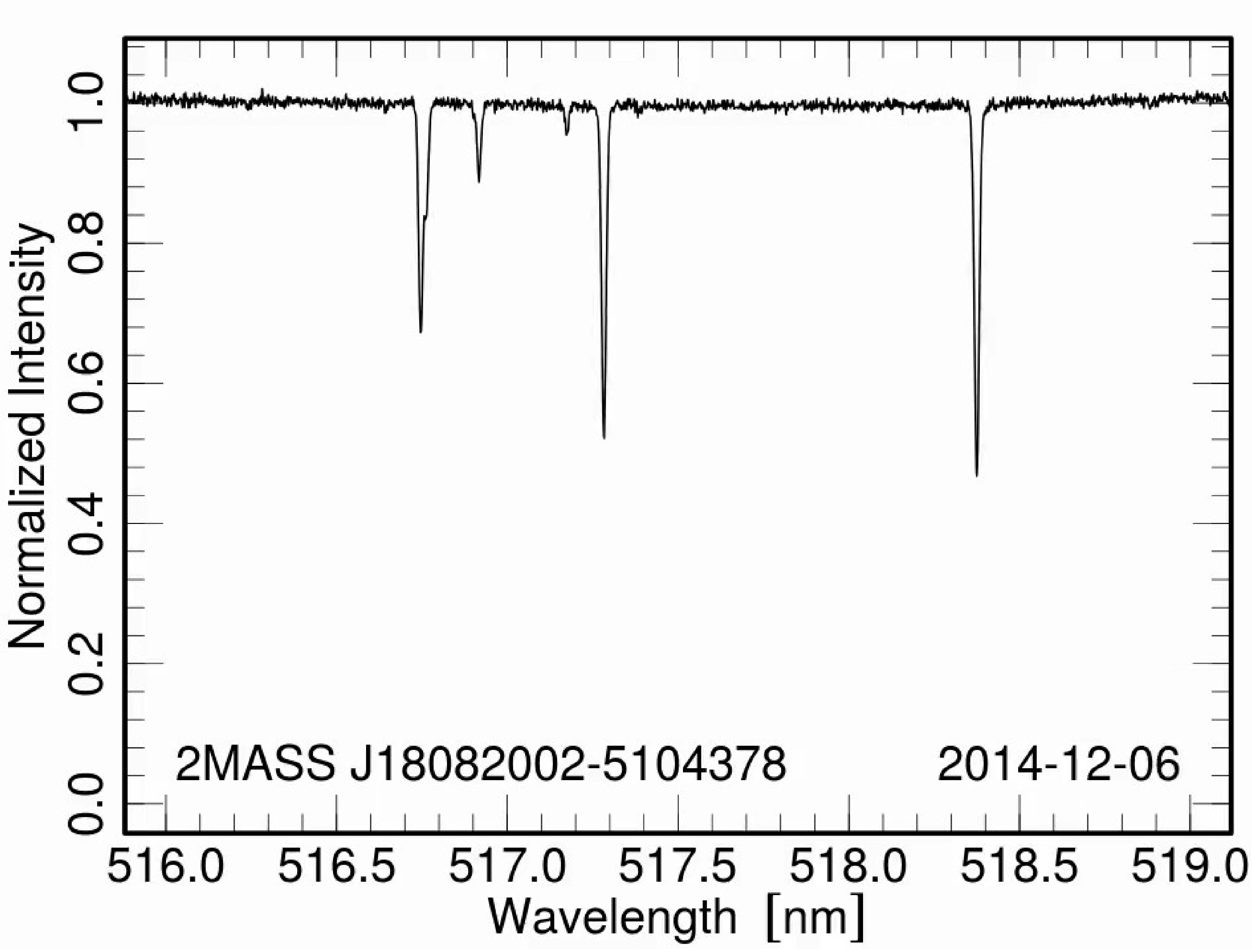

2MASS J18082002–5104378

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Inferred Properties		
Primary mass M_1	0.7599 ± 0.0001	$M_\odot$
System age τ	13.53 ± 0.002	Gyr
Minimum secondary mass $M_{2,\mathrm{min}}$	0.131 ± 0.002	$M_\odot$
Secondary mass M_2	$0.14^{+0.06}_{-0.01}$	$M_\odot$
Semimajor axis a	$0.202^{+0.004}_{-0.001}$	au
Total Galactic velocity v	$207.5^{+1.1}_{-1.2}$	km s^{-1}
Pericenter of Galactic orbit R_{peri}	5.56 ± 0.07	kpc
Apocenter of Galactic orbit R_{apo}	7.66 ± 0.02	kpc
Eccentricity of Galactic orbit e_{G}	$0.158^{+0.005}_{-0.004}$	
Maximum distance from Galactic plane z_{max}	$0.126^{+0.005}_{-0.003}$	kpc

System is on a Thin Disk Orbit!

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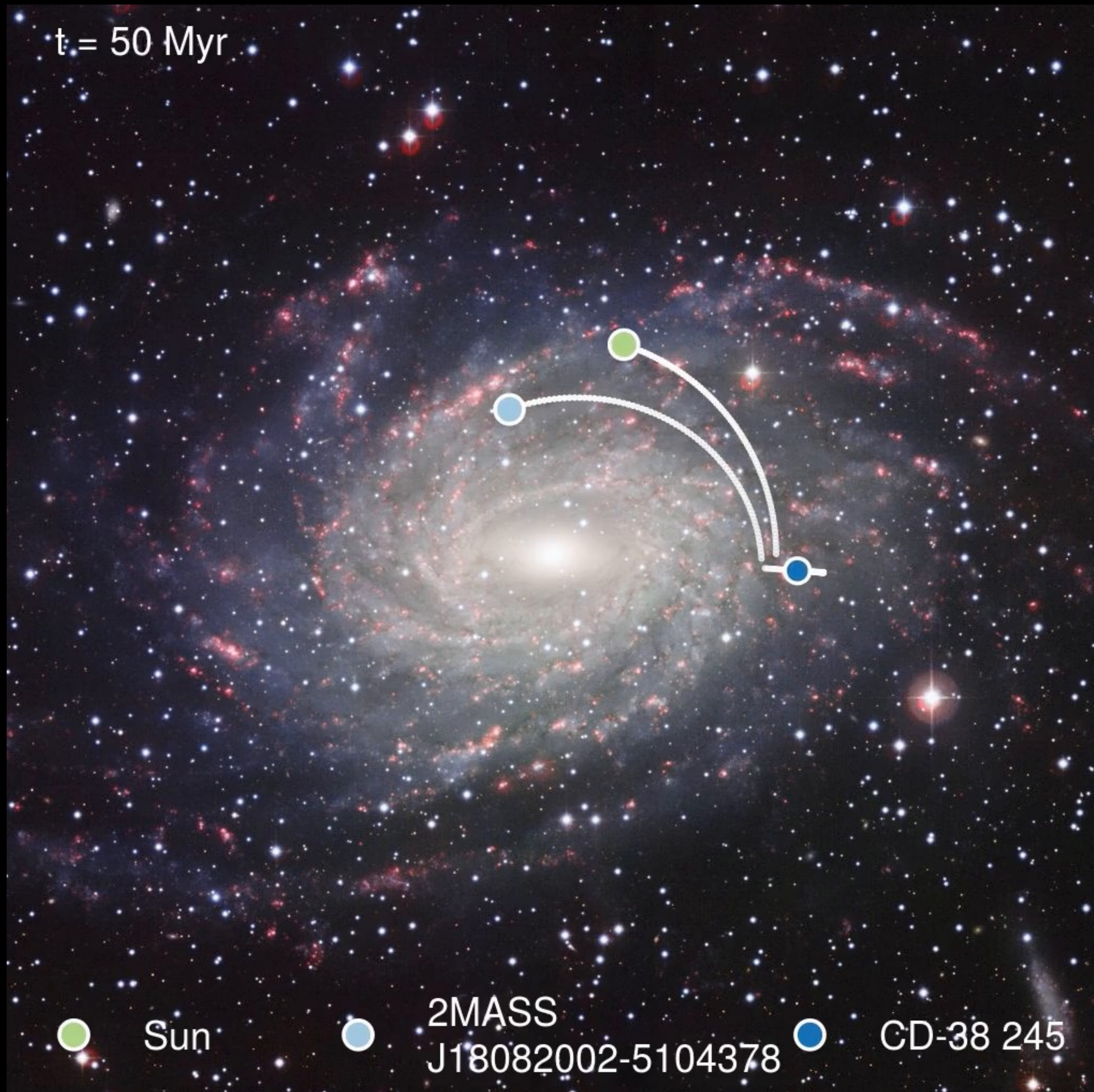

Total Metallicity

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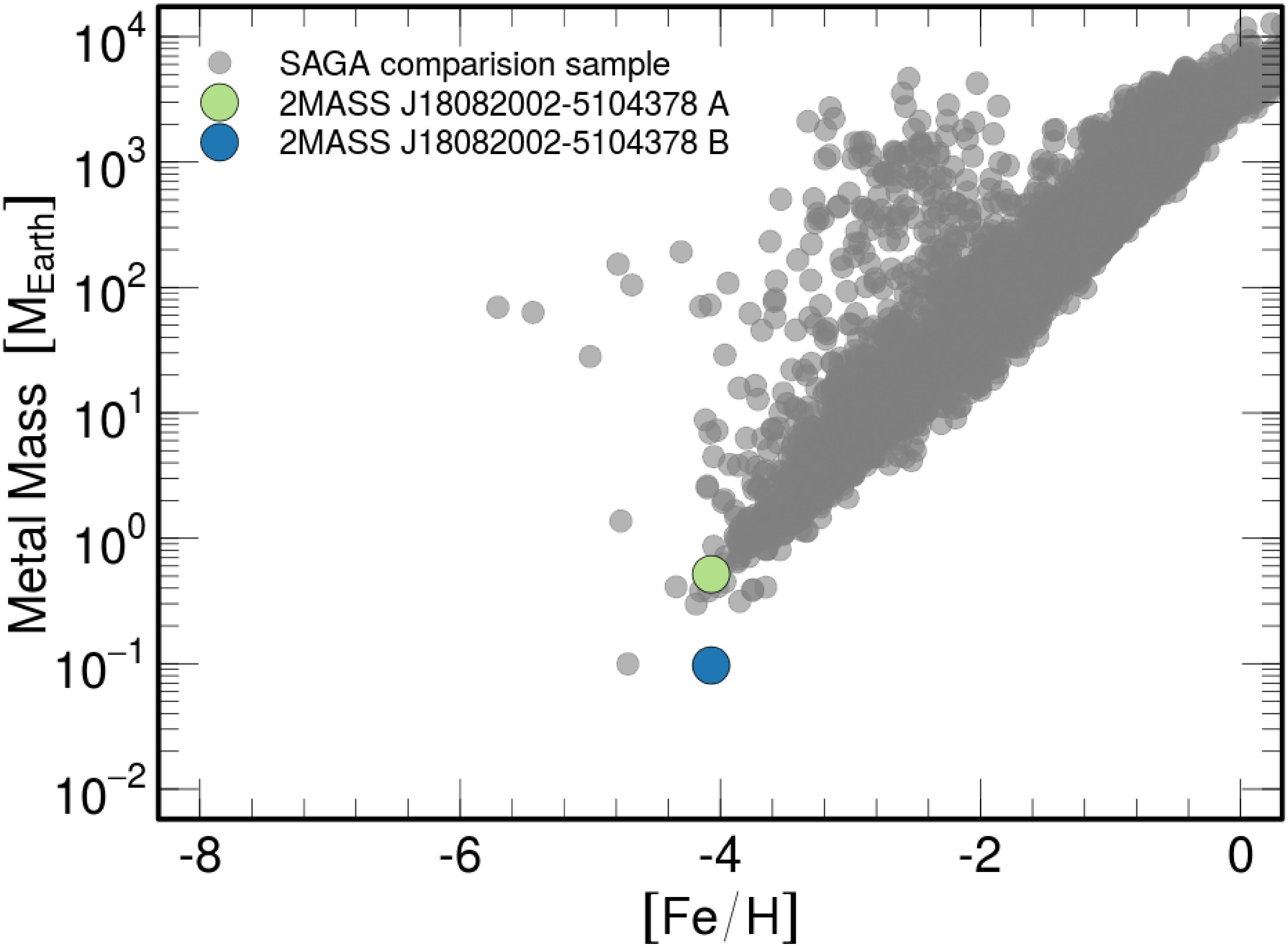

Fewest Grams of Heavy Elements

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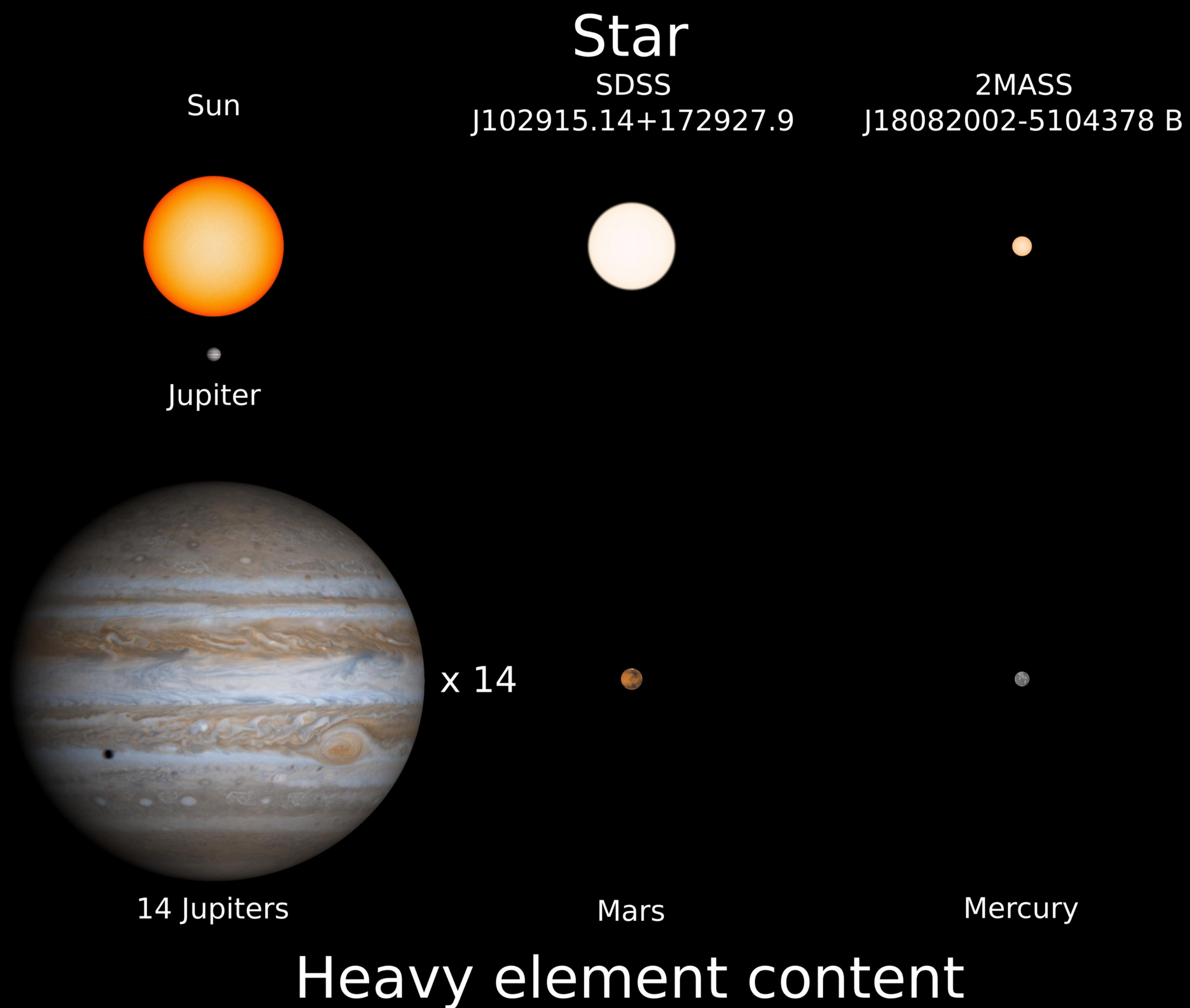

UMP and Pop III Protostellar Disks

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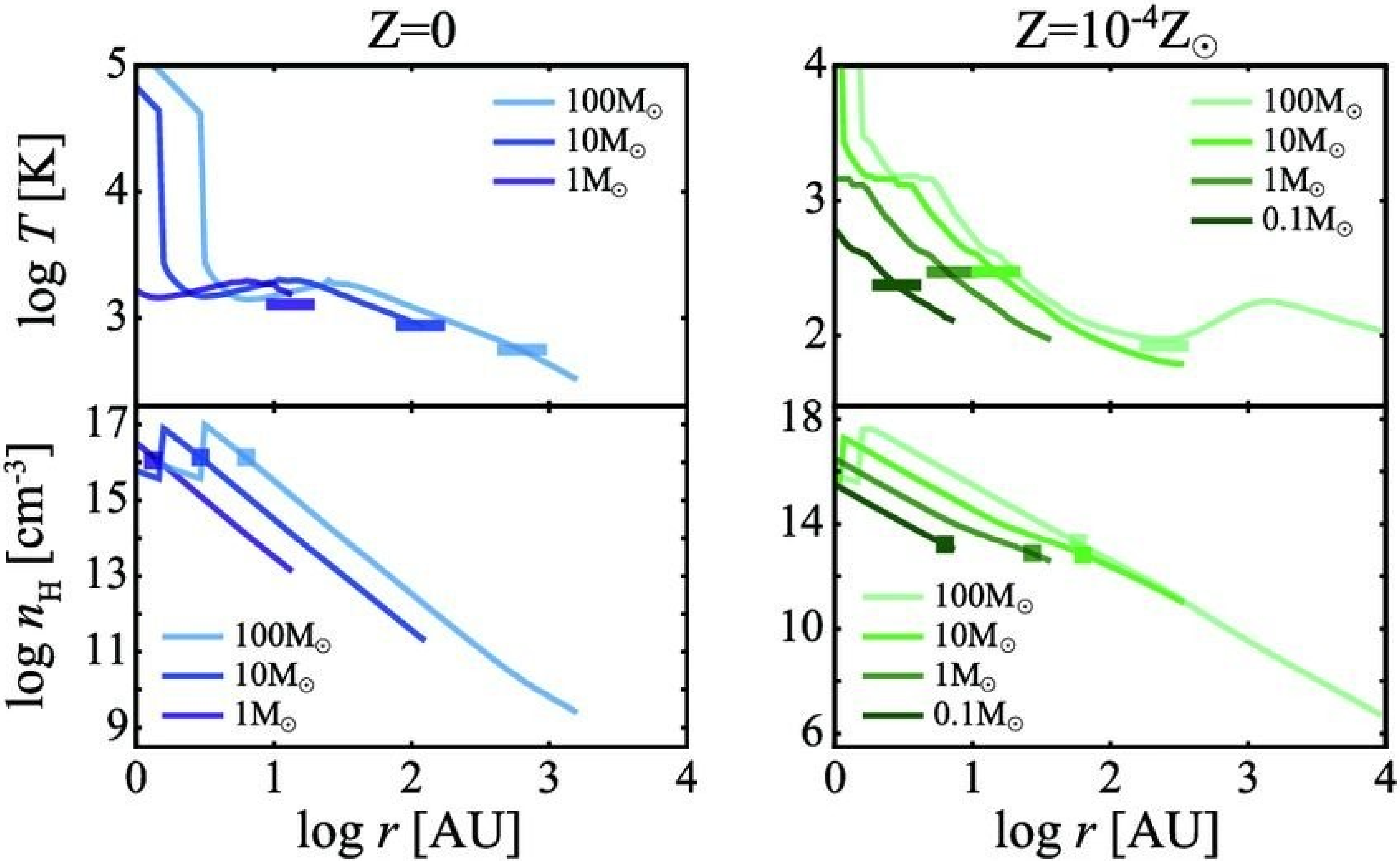

Tanaka & Omukai (2014)

Fragment Mass and Migration Time

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Schlaufman et al. (2018)

$$M_{\rm frag} \sim \Sigma H^2 \Rightarrow \frac{M_{\rm frag,2}}{M_{\rm frag,1}} = \left(\frac{\Sigma_2}{\Sigma_1}\right)\left(\frac{H_2}{H_1}\right)^2$$

$$t_{\rm mig} = \frac{h^2}{q}\frac{M_*}{r^2\Sigma}\Omega^{-1} \Rightarrow$$

$$\frac{t_{\rm mig,2}}{t_{\rm mig,1}} = \left(\frac{h_2}{h_1}\right)^2\left(\frac{q_1}{q_2}\right)\left(\frac{M_{*,2}}{M_{*,1}}\right)\left(\frac{r_1}{r_2}\right)^2\left(\frac{\Sigma_1}{\Sigma_2}\right)\left(\frac{\Omega_1}{\Omega_2}\right)$$

Fragment Mass and Migration Time

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Schlaufman et al. (2018)

10 M_{Sun} Pop III Star	3 AU	10 AU	130 AU
Fragment Mass	0.25 M_{Sun}	0.88 M_{Sun}	0.18 M_{Sun}
Migration Time t_2/t_1	1.7	1.4	12

100 M_{Sun} Pop III Star	3 AU	10 AU	1600 AU
Fragment Mass	1.0 M_{Sun}	0.25 M_{Sun}	1.6 M_{Sun}
Migration Time t_2/t_1	22	3.5	52

Conclusions

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Schlaufman et al. (2018)

(1) 2MASS J18082002–5104378 B has $M_* = 0.14$ M_{Sun} and is the first known low-mass UMP star. It has the fewest grams of heavy elements of any star known.

(2) The system is on a thin disk orbit and is the most metal-poor thin disk star system by some margin.

(3) The survival of low-mass secondaries around solar-mass UMP primaries implies the survival of solar-mass secondaries around Pop III primaries with masses $10\ M_{Sun} < M_* < 100\ M_{Sun}$.