Studying Quasar accretion discs with massive optical variability surveys

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The Power spectrum of optical light curves of Quasars

Depends on		shape	normalization	reference
1	Mass	✓	?	• Break timescale grows with black hole mass as $M^{0.5}$ Burke et al 2021 (Science 373, 789)
2	Wavelength	✓	✓	• Break timescale grows with wavelength Stone et al. 2022 (MNRAS, 514, 164) • Bluer bands vary more
3	Accretion rate	?	✓	• Variance is larger for lower accretion rates Kelly et al. 2009 ApJ 698, 895

The sample: Quasars in a narrow redshift bin, mass and REdd by Rakshit et al. (2020)

		range in $\log(R_{\rm Edd})$					
		-2 – -1.7	-1.7 – -1.3	-1.3 – -1	-1 – -0.7	-0.7 – -0.3	-0.3 –0
	7.5–7.8	0	1	2	49	173	58
	7.8–8.2	2	5	102	429	376	71
Range in	8.2–8.5	1	99	580	711	236	45
$\log(M/M_\odot)$	8.5–8.8	40	356	634	333	80	14
	8.8–9.2	126	304	234	65	18	0
	9.2–9.5	74	71	35	4	1	0

number of objects per bin

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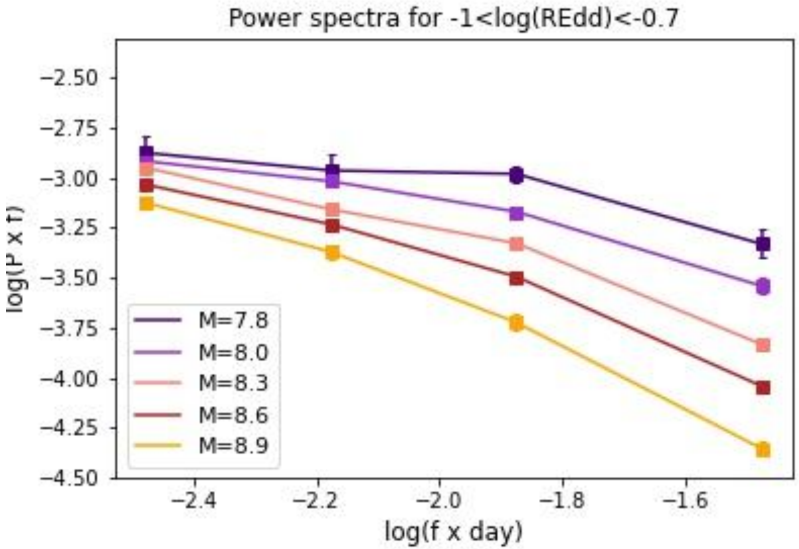
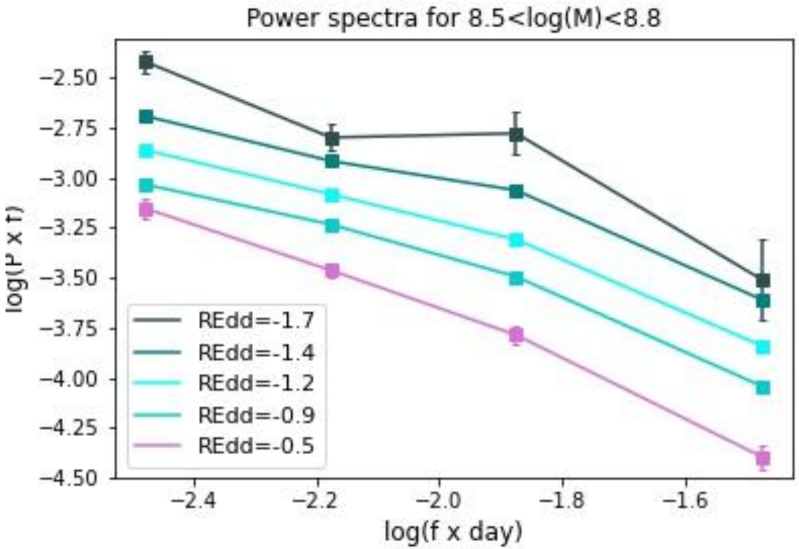
Power spectra of quasars at z~0.65 in the g band with ZTF

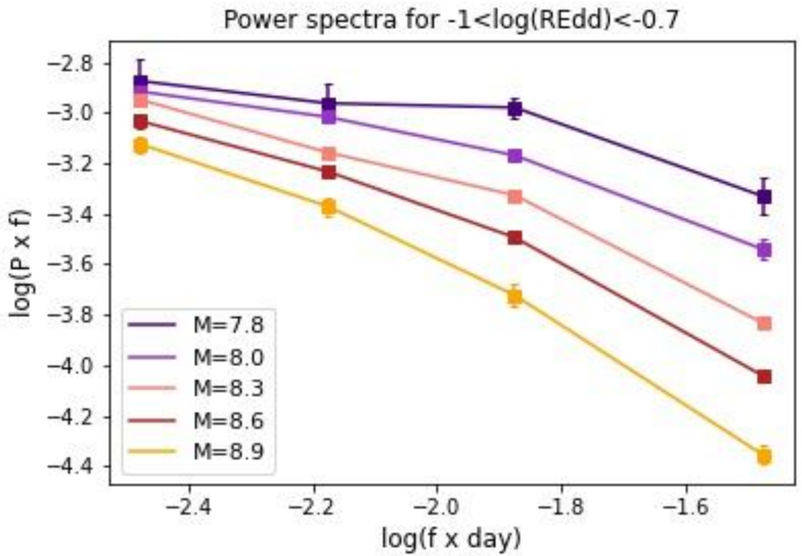


For different masses, same REdd



For different REdd, same mass

Power spectra of quasars, mass scaling



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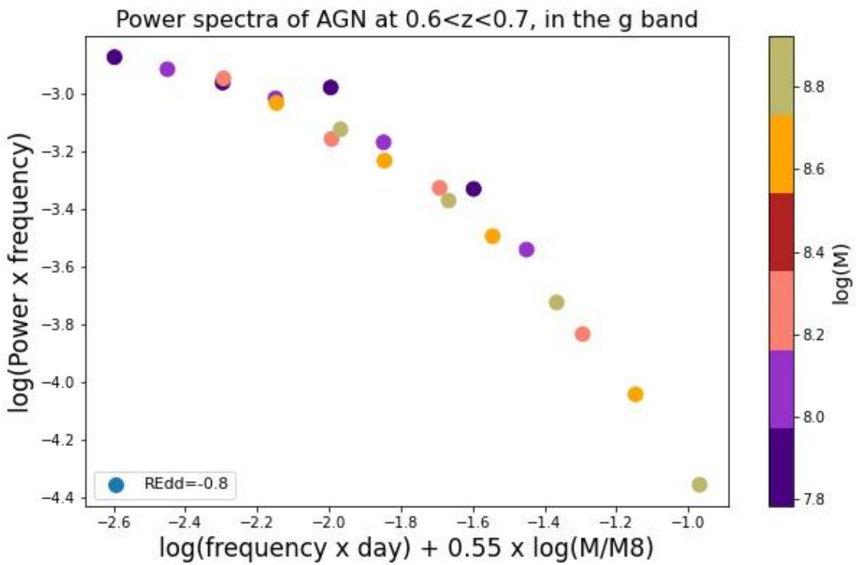
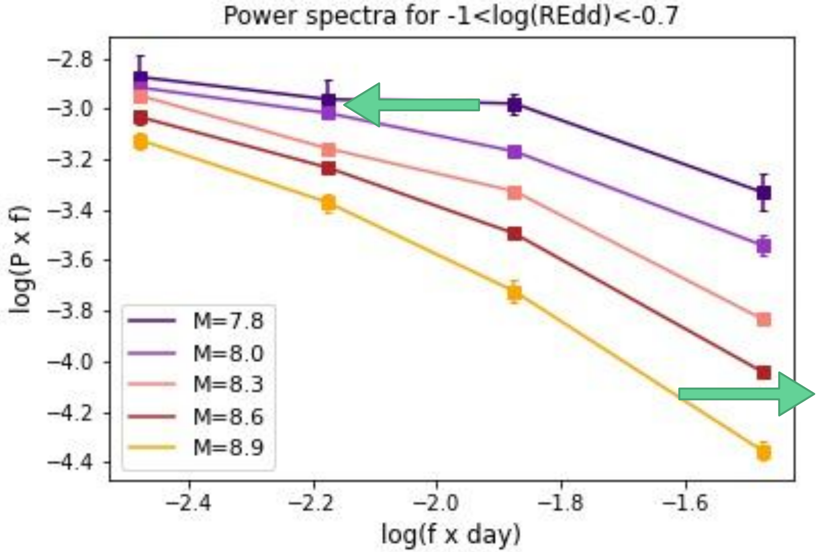
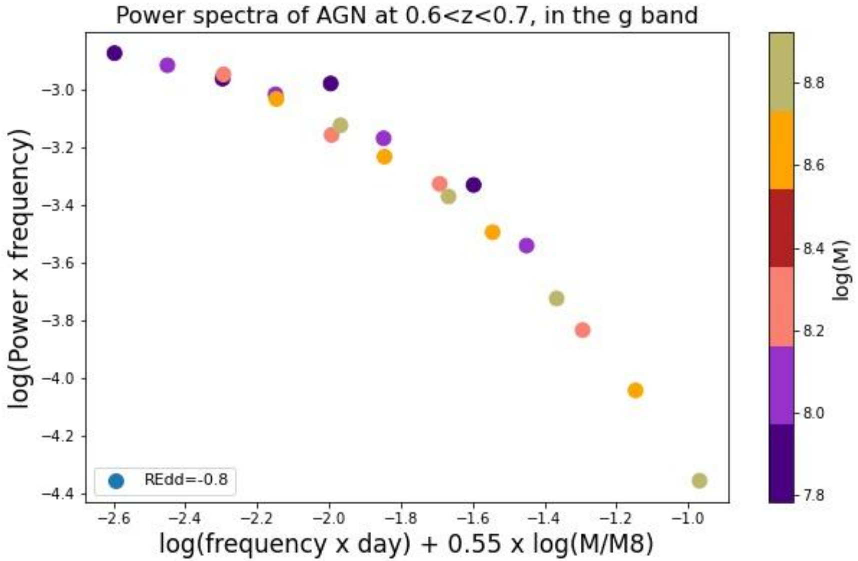


same but scaling frequency by mass

Power spectra of quasars, mass scaling

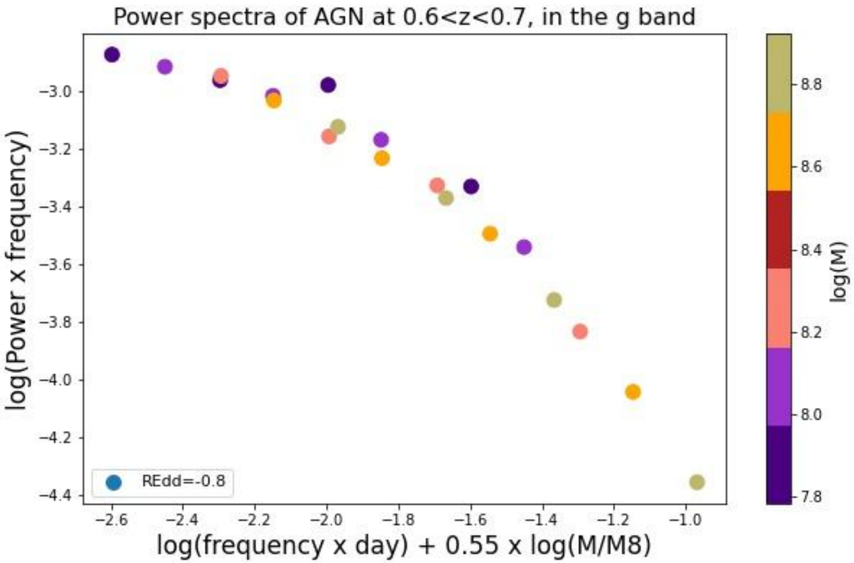


For different masses, same REdd

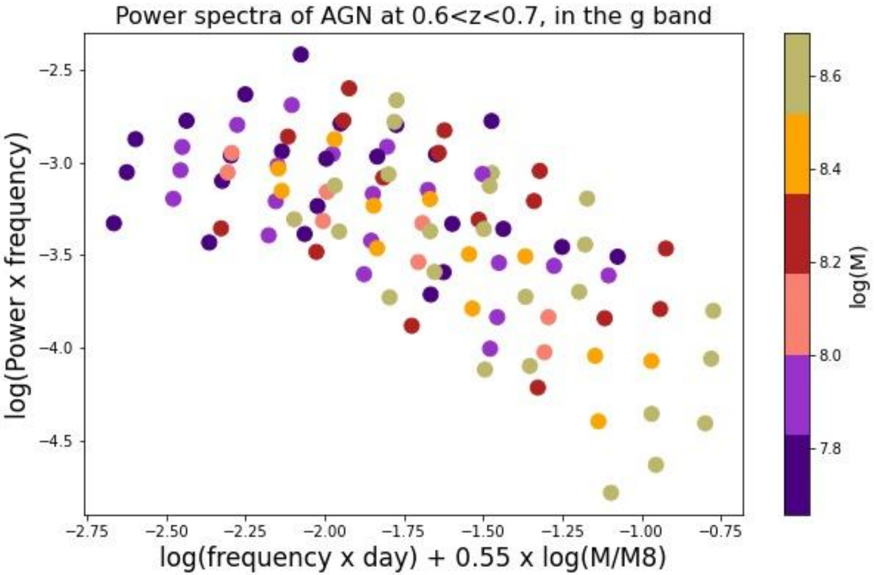


same but scaling frequency by mass

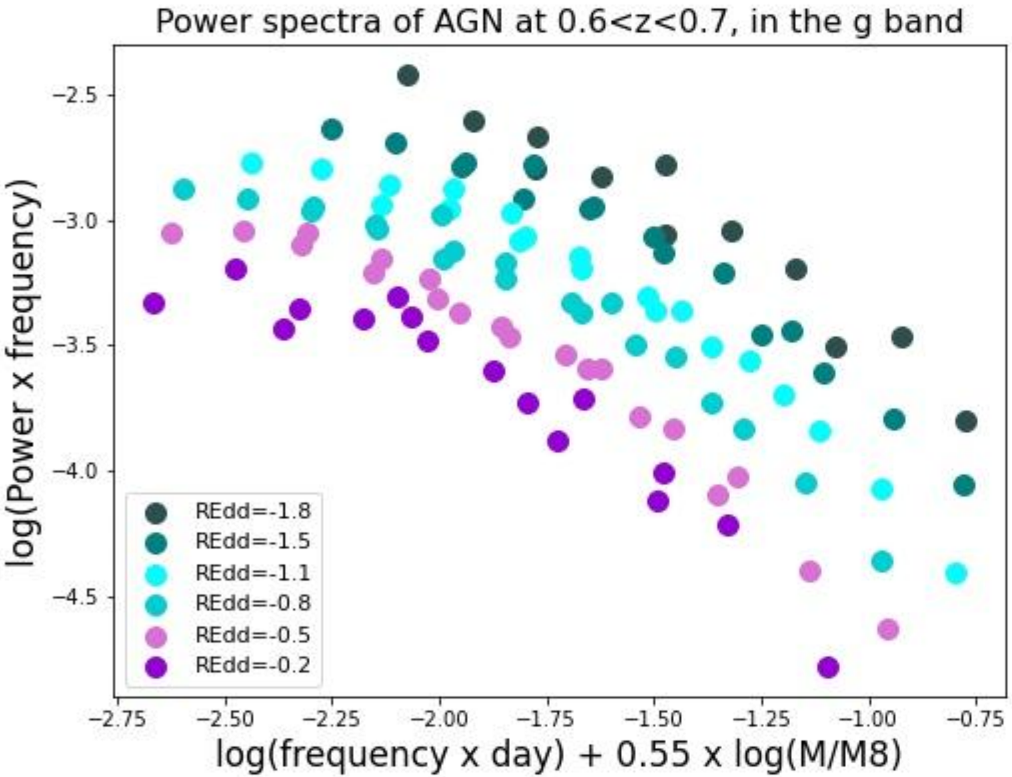
Power spectra of quasars of different accretion rates



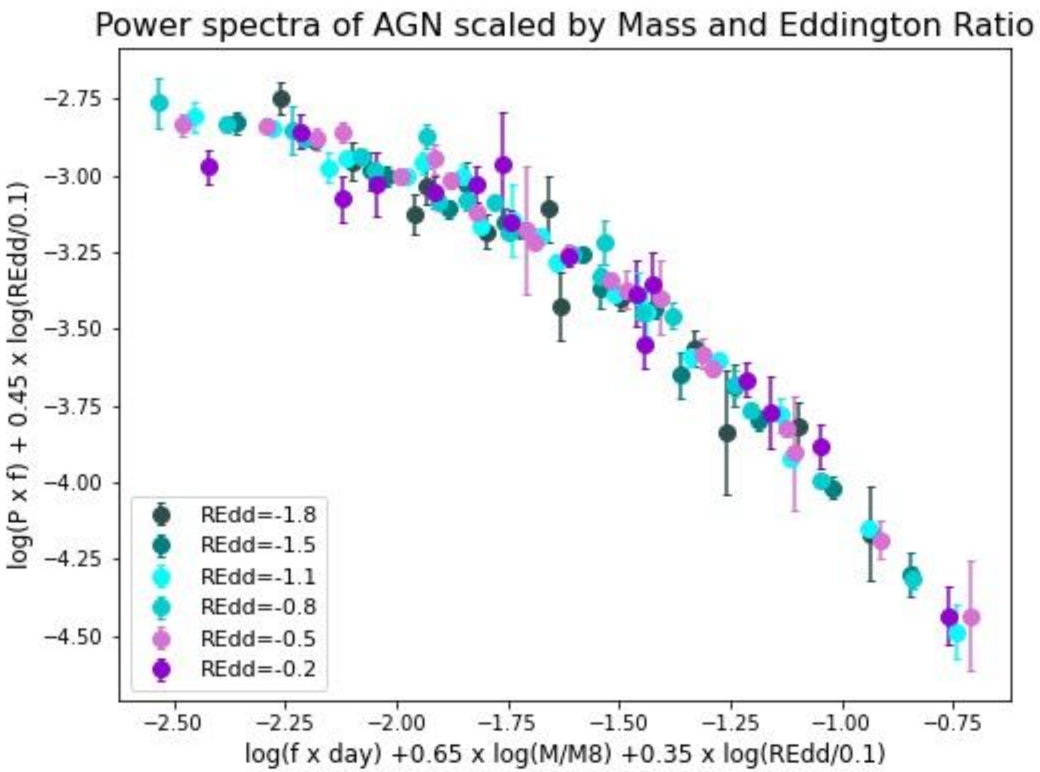
same but scaling frequency by mass



now all levels of accretion rate together

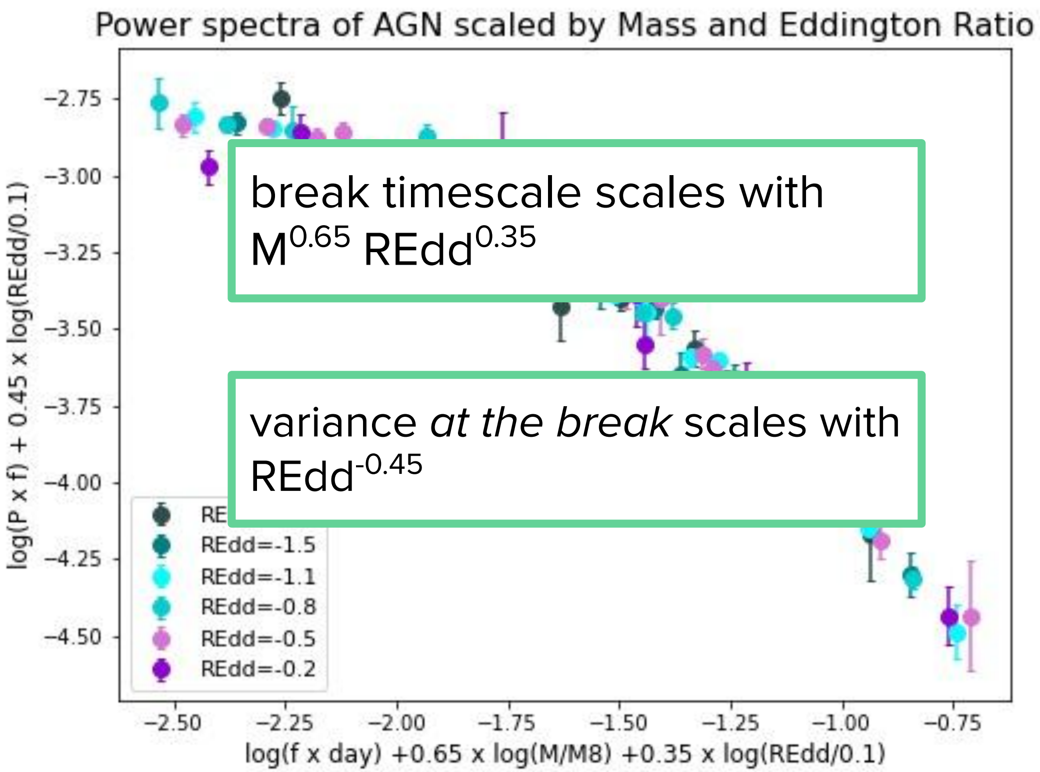


all the bins together but now color coded by accretion rate



all the mass bins together color coded by accretion rate,

now with frequency scaled by mass and accretion rate, and variance scaled by accretion rate



break timescale scales with $M^{0.65}$ $REdd^{0.35}$

variance *at the break* scales with $REdd^{-0.45}$

Now some theory

in our data, break timescale $t_b \propto M^{0.65}$ $REdd^{0.35}$

in terms of the orbital timescale at the ISCO:

$t_b / t_{ISCO} \propto M^{0.65} \, REdd^{0.35} / M$

$= (REdd/M)^{0.35} \propto (T^4)^{0.35}$

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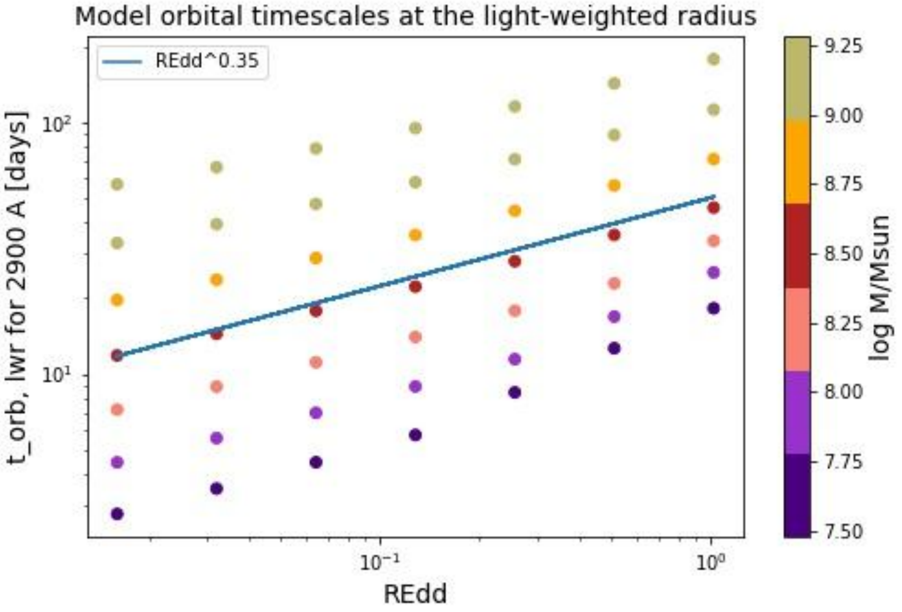
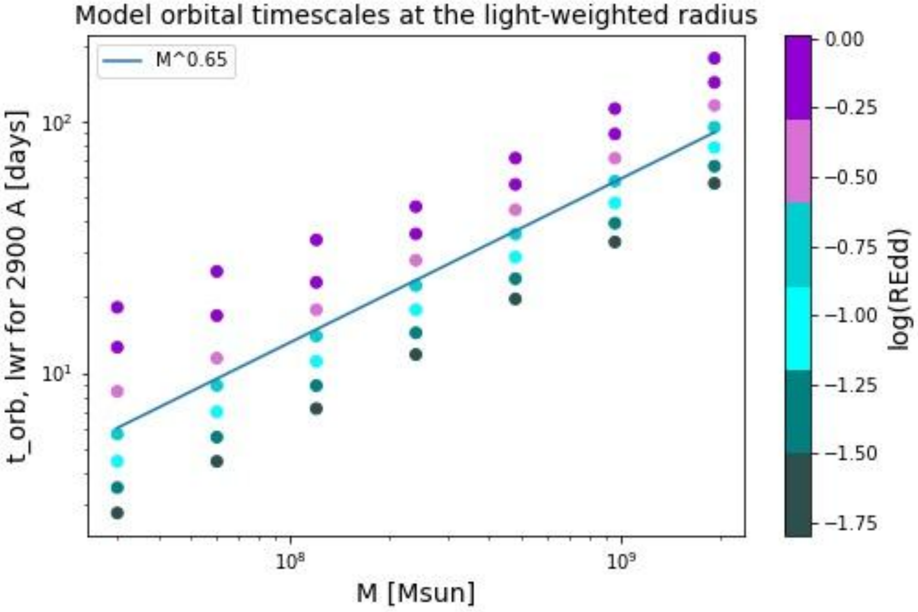
Orbital timescale at the outer edge of the g-band emitting region

$$t_{orbital,outer\ edge} / t_{ISCO} \propto \lambda^2\ (REdd/M)^{0.5}$$

Mass and REdd scaling of the orbital timescale at the light-weighted radius





Conclusions and future work

- The powerspectral shape depends on accretion rate as well as mass, with a different scaling factor.
- The break timescale scales with mass and REdd in the same way as the orbital timescale of the light-weighted radius of the emitting region, for a standard thin disc.
- The normalization of the power spectrum grows with decreasing REdd.
    - Fewer independent clumps (e.g. Dexter & Algol 2011, ApJ, 727, L24) varying in temperature, for equal masses but lower REdd (cooler discs, smaller emitting regions) ?
    - More X-ray reprocessing (e.g. Kammoun et al. 2021, ApJ, 907, 20) for lower REdd objects?