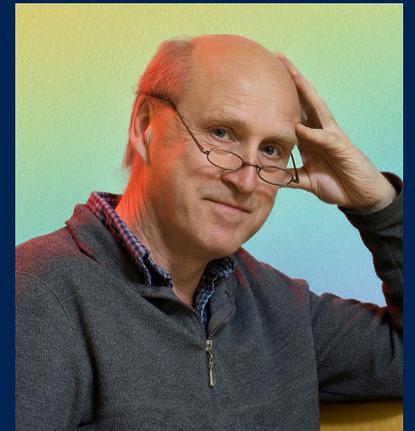
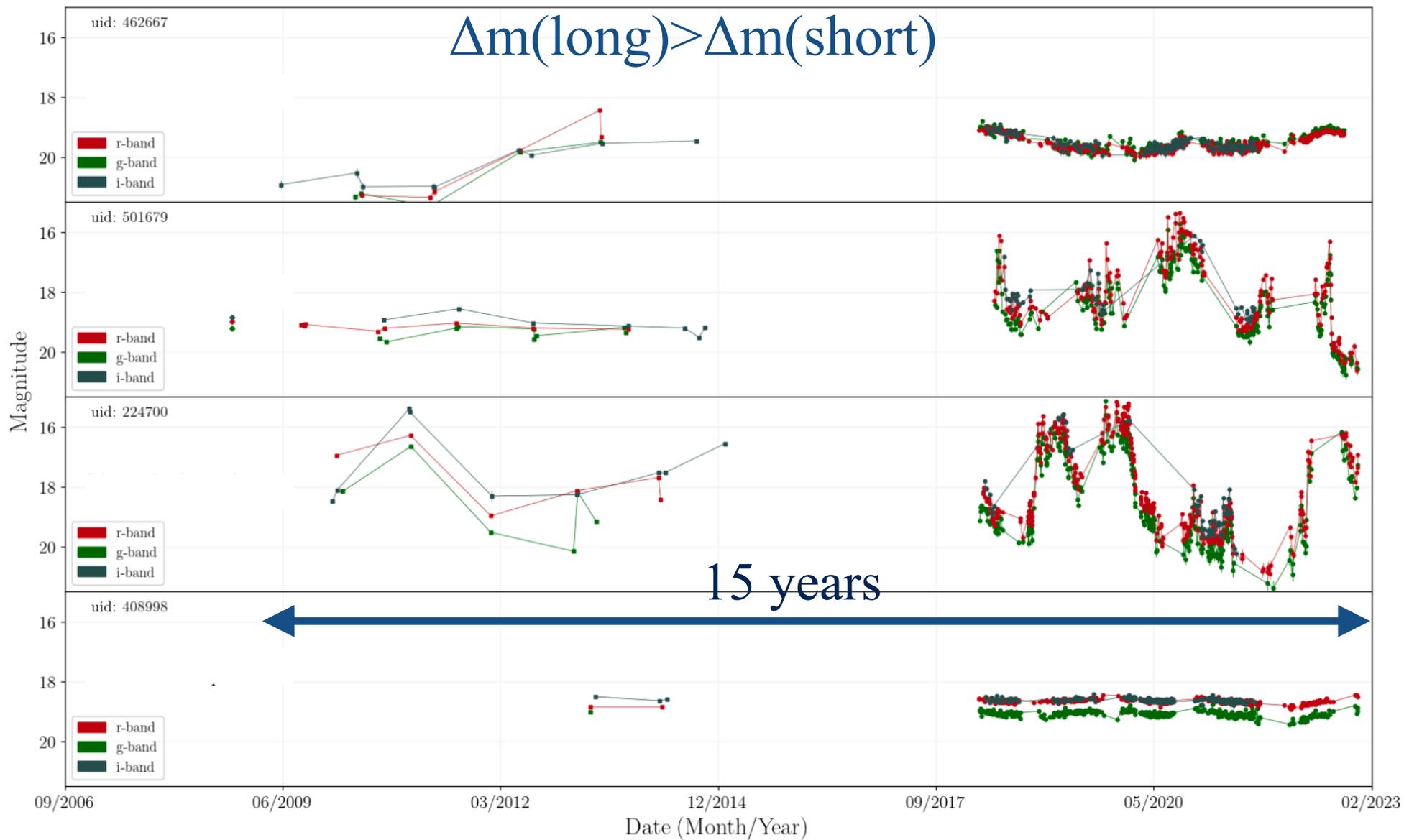


Seven decades of quasar variability



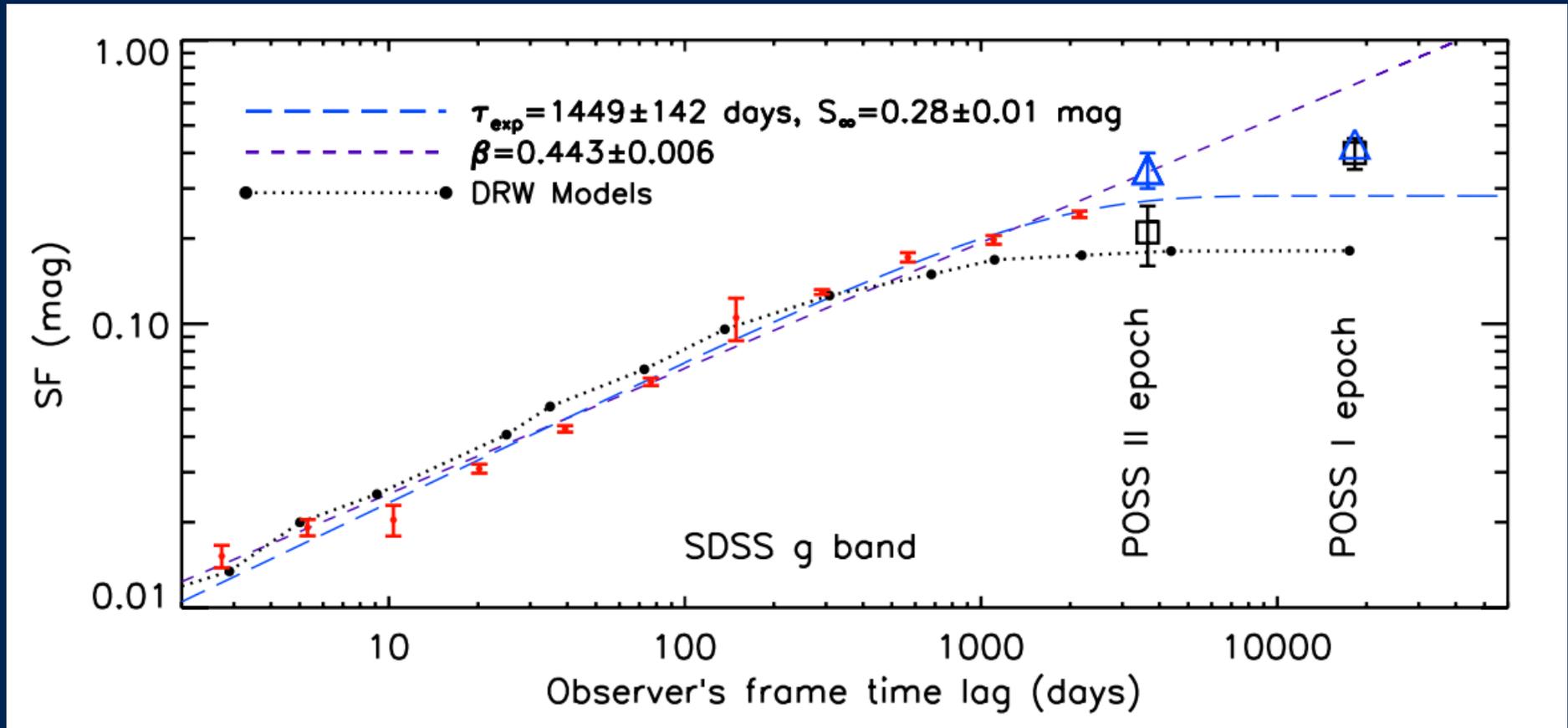
Harry Rendell-Bhatti, Andy Lawrence
RAS AGN Meeting
London, Oct 11th 2024





characterise shape with structure function
 $SF = \sigma(\Delta t)$

Ensemble structure function fills in time gaps



Popular model: Damped Random Walk

McLeod et al 2012

33,000 quasars

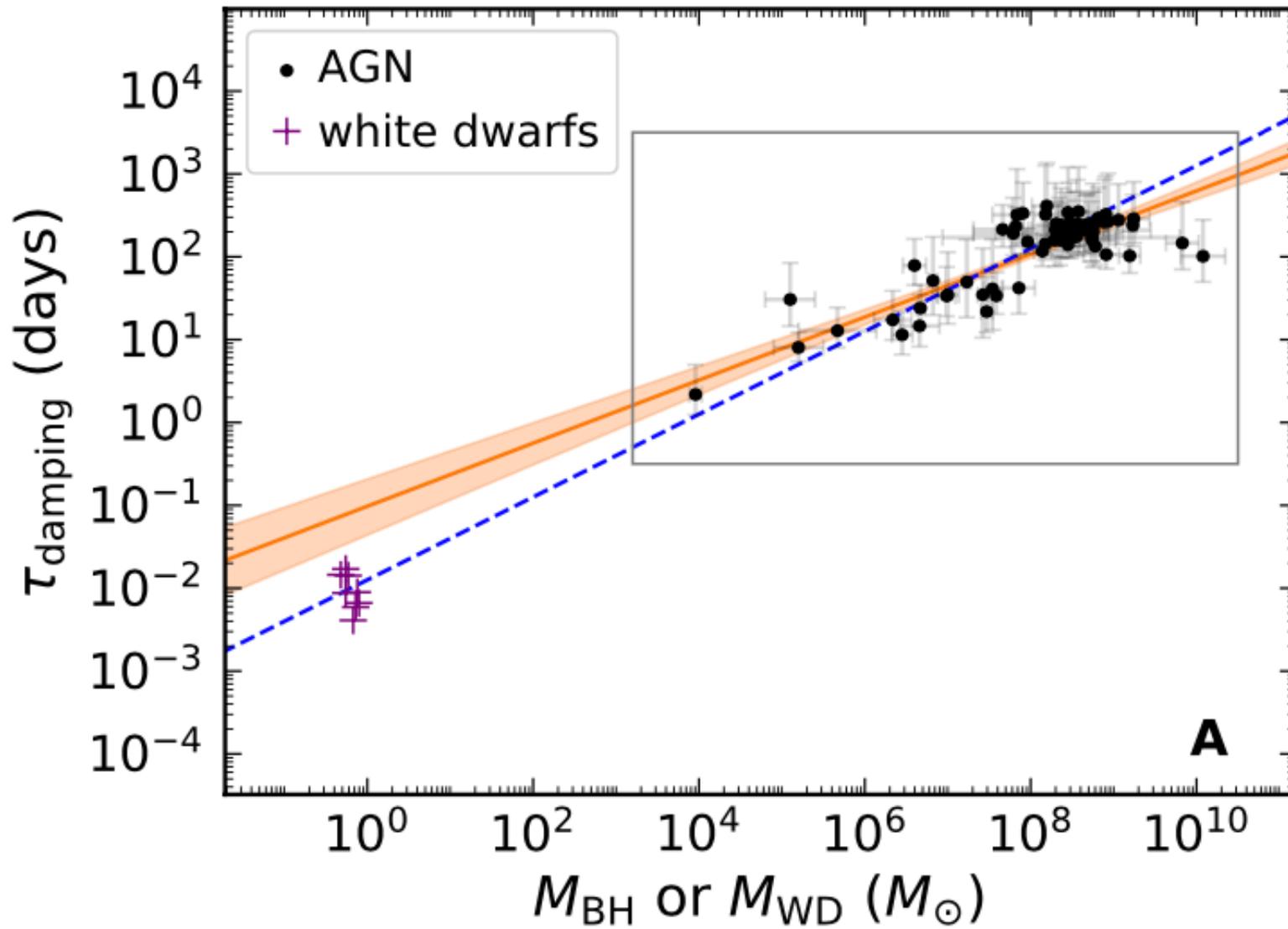
$$SF(\Delta t) = SF_{\infty} \left(1 - e^{-\Delta t/\tau}\right)^{1/2}$$

$$\Delta t < \tau : SF \propto \Delta t^{0.5}$$

$$\Delta t > \tau : SF = \text{const}$$

characteristic timescale τ

Burke et al
2021



claim $\tau \propto M_H^{0.5}$ from white dwarfs to quasars!

7-DQ

526,356 SDSS DR14 quasars $z=0.5-3.5$

SuperCOSMOS, SDSS, PS1, ZTF

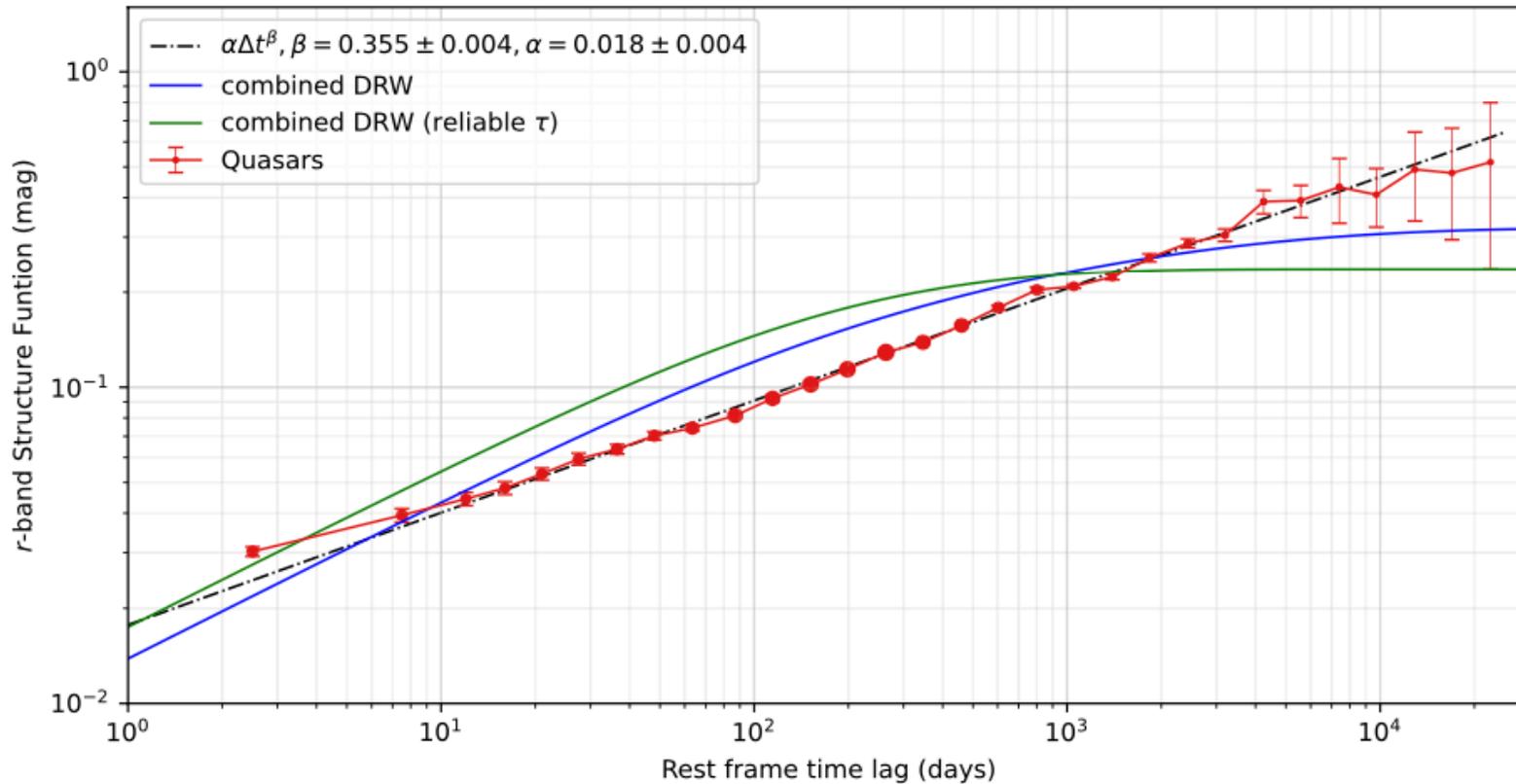
transformed to PS1 gri system

typically ~ 400 epochs

control sample of 400,000 stars

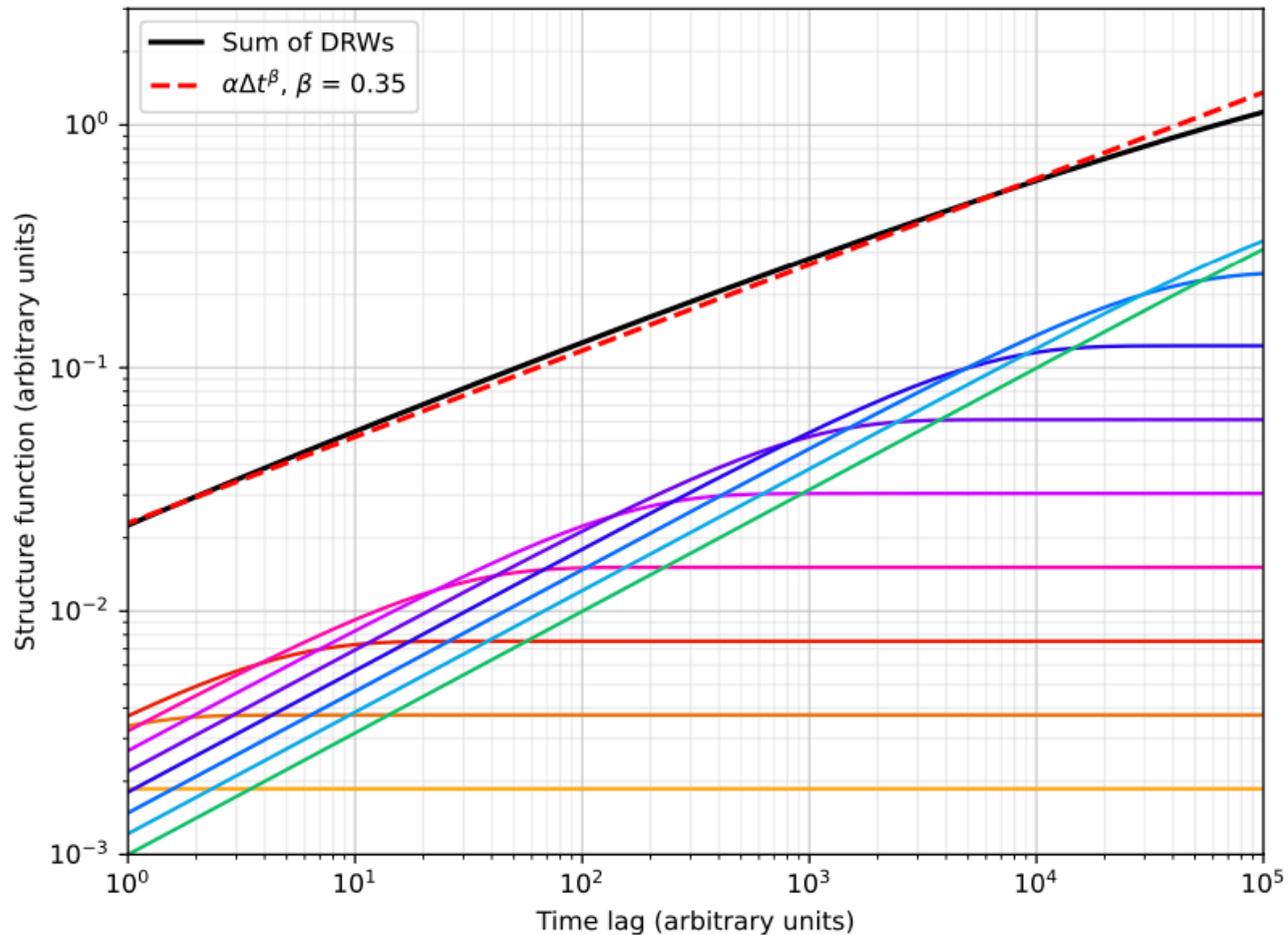
improved variance-weighted method

Ensemble Structure Function



power law $\beta \sim 0.35$
not consistent with DRW
no evidence for knee

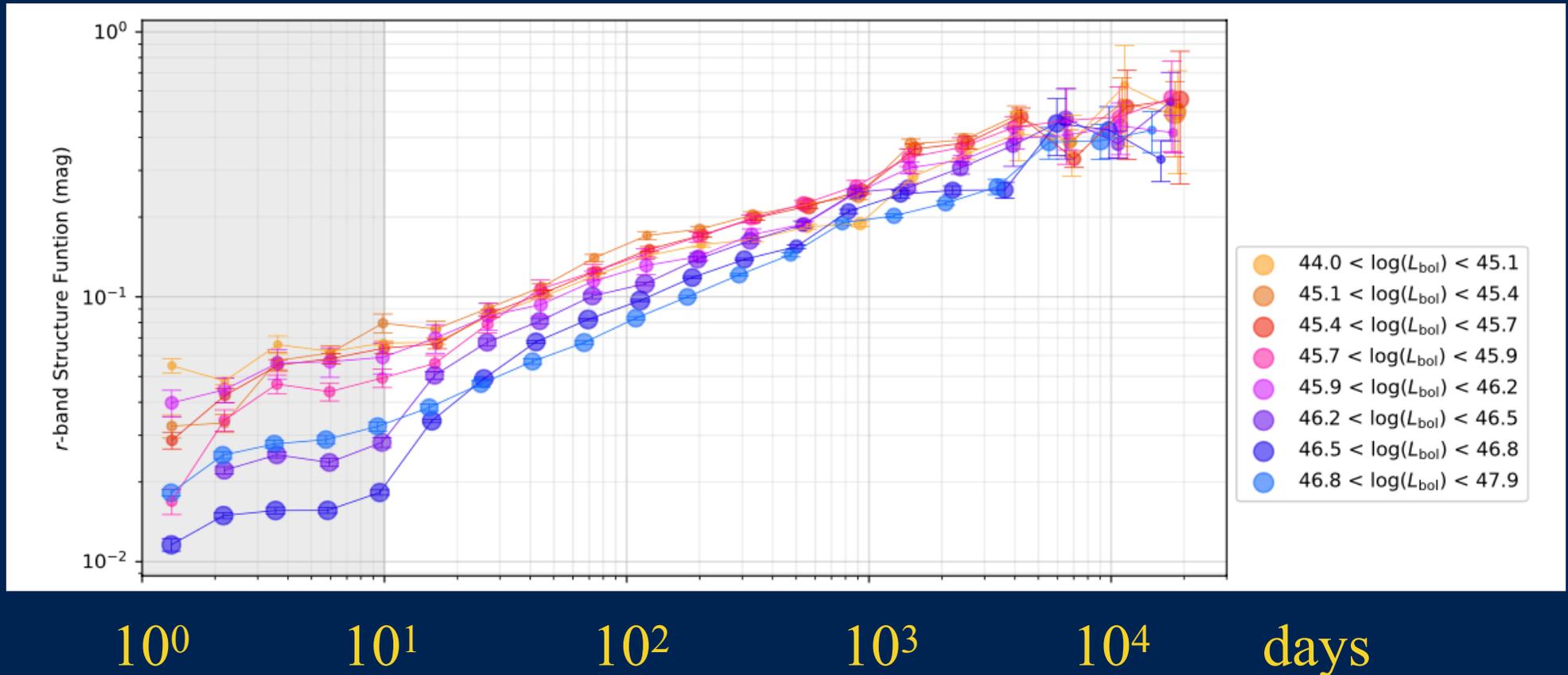
many different τ values?



rather arbitrary distribution
should depend on M , L , or $n\text{Edd}$?

Luminosity Dependence

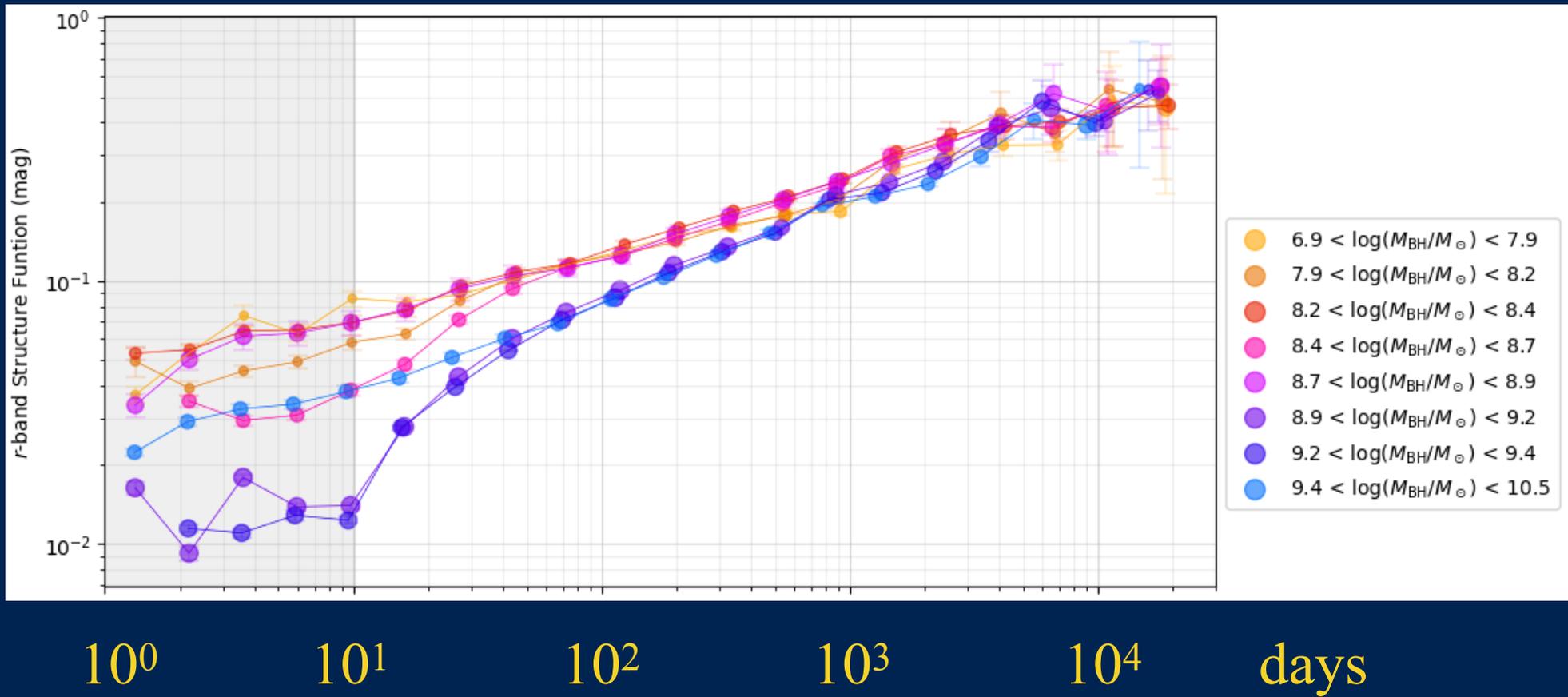
cf De Vries et al 2005



low-L : more variable, flatter SF

roughly $SF_{100d} \propto L^{-0.3}$

M_H Dependence

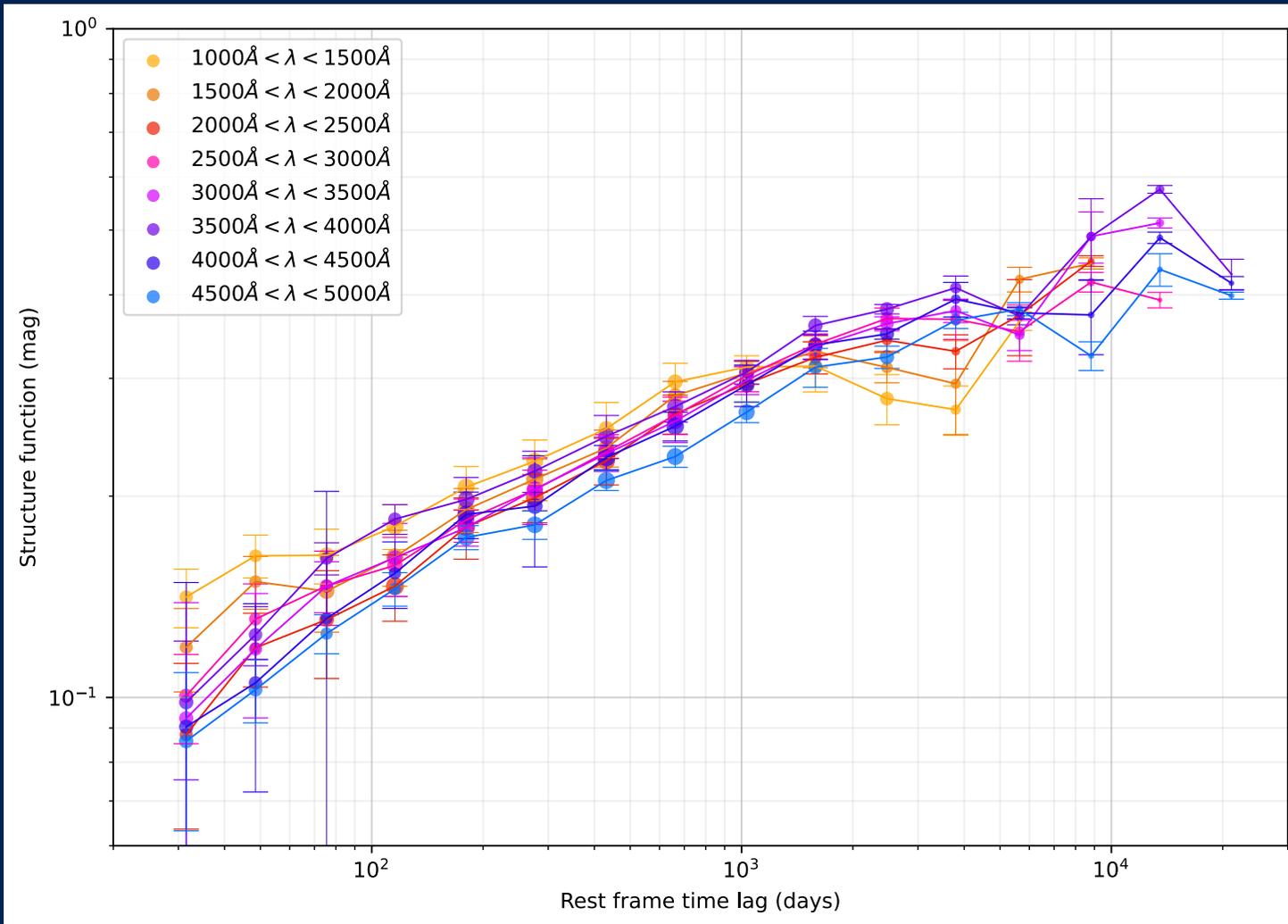


long timescales: ALL THE SAME

no knowledge of mass

short timescales: variability suppressed at high mass

λ dependence

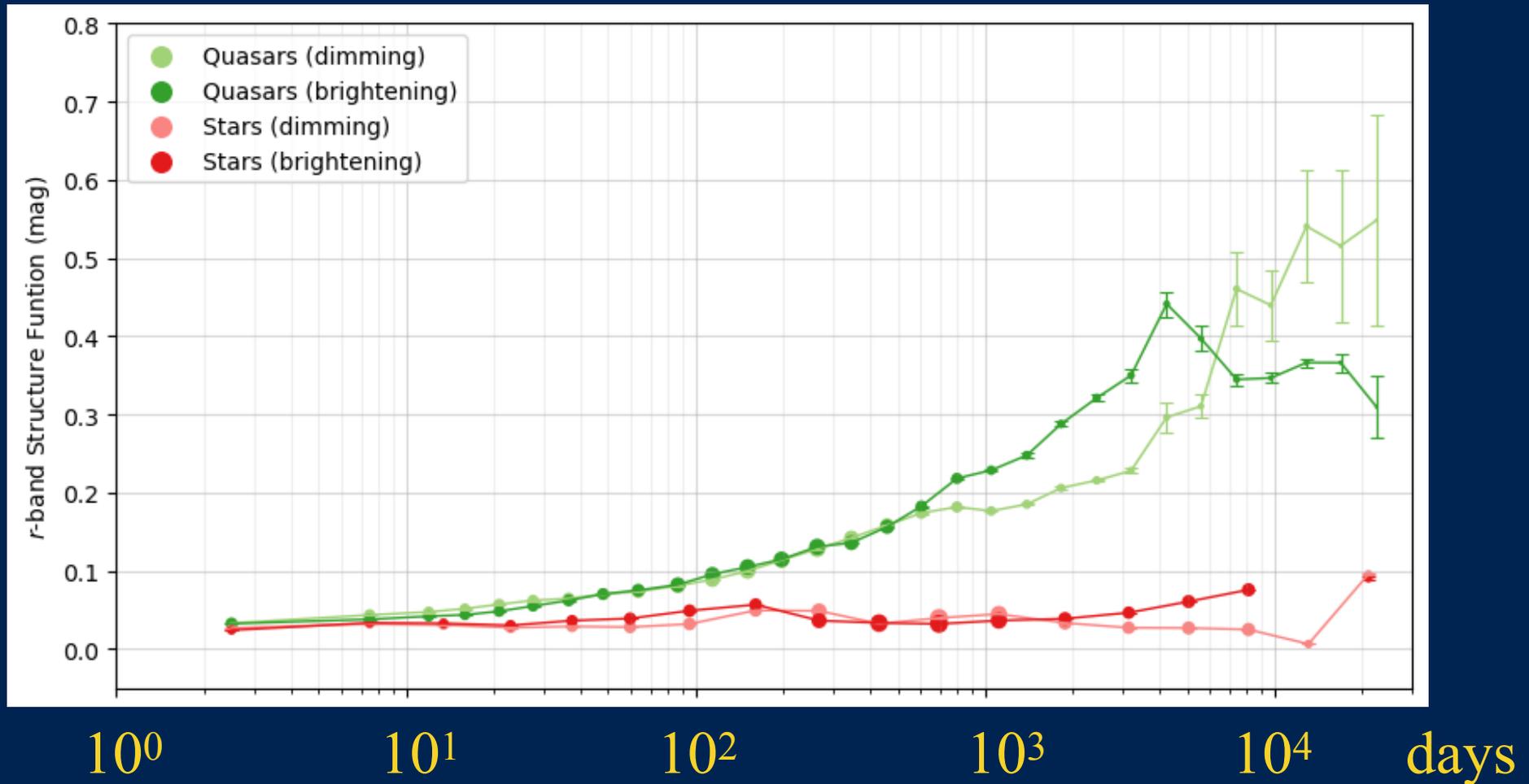


short timescales: blue variability > red

long timescales: no difference or even reversed

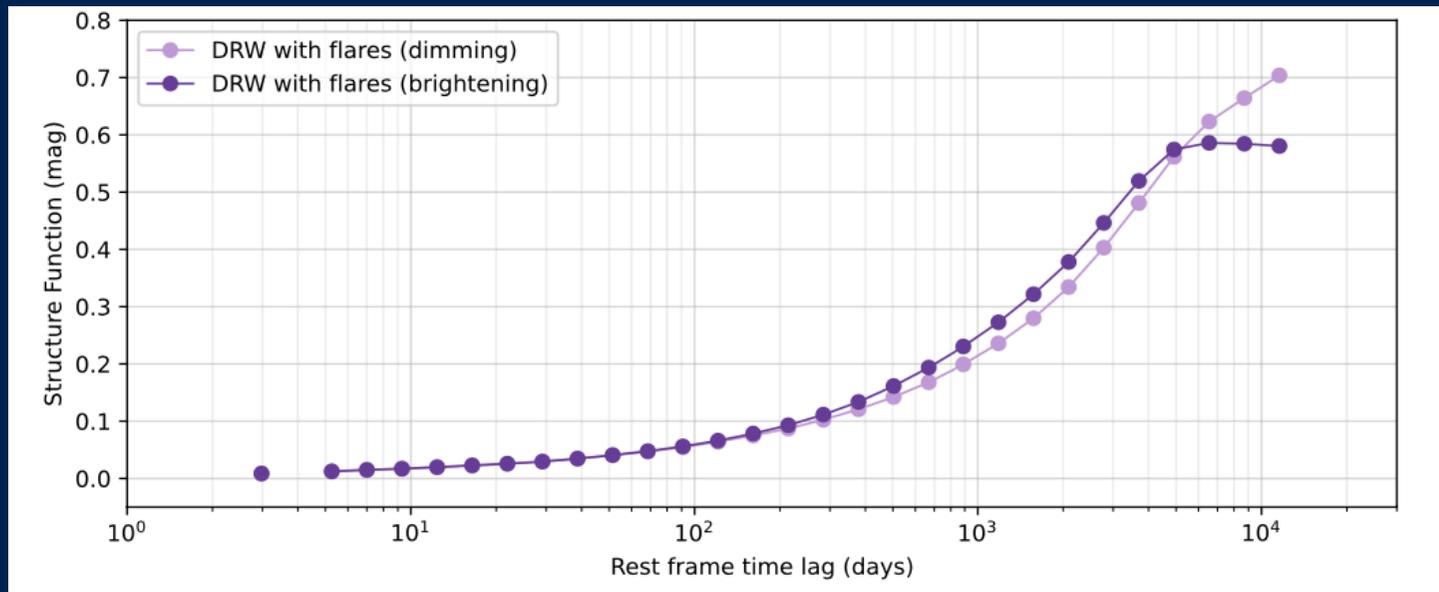
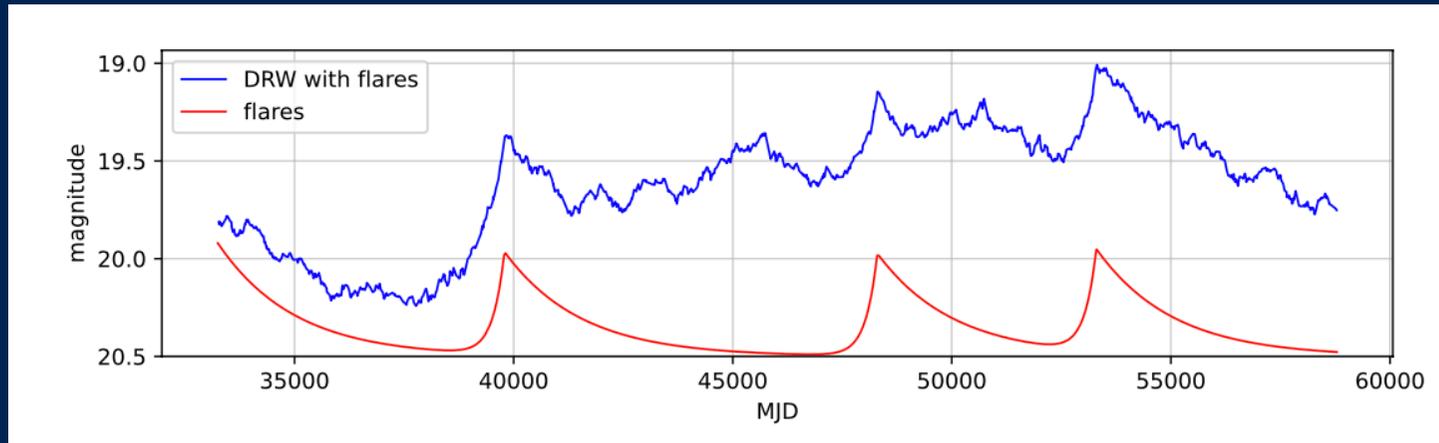
time asymmetry

cf De Vries et al 2005



months: brightening = dimming
years: brightening > dimming
decades: brightening < dimming

simulation: DRW + asymmetric flares



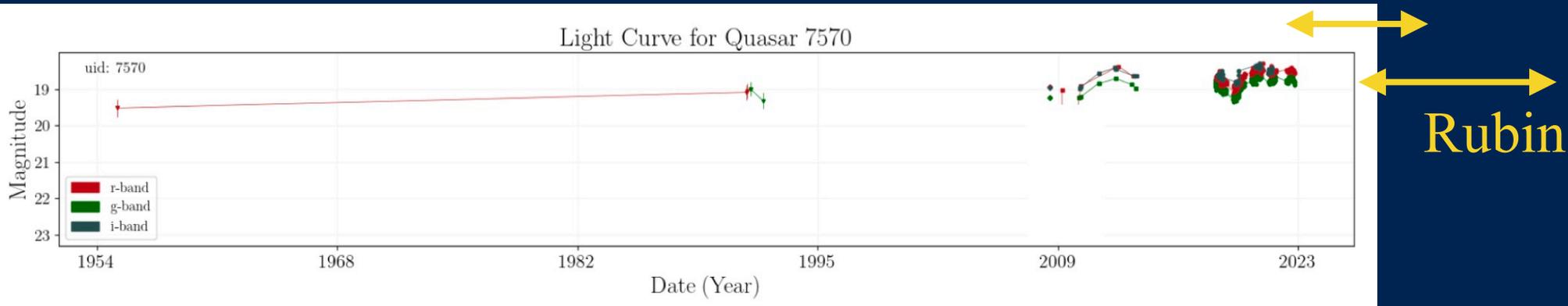
ok but too mild an effect

SuperCOSMOS

SDSS

PS1

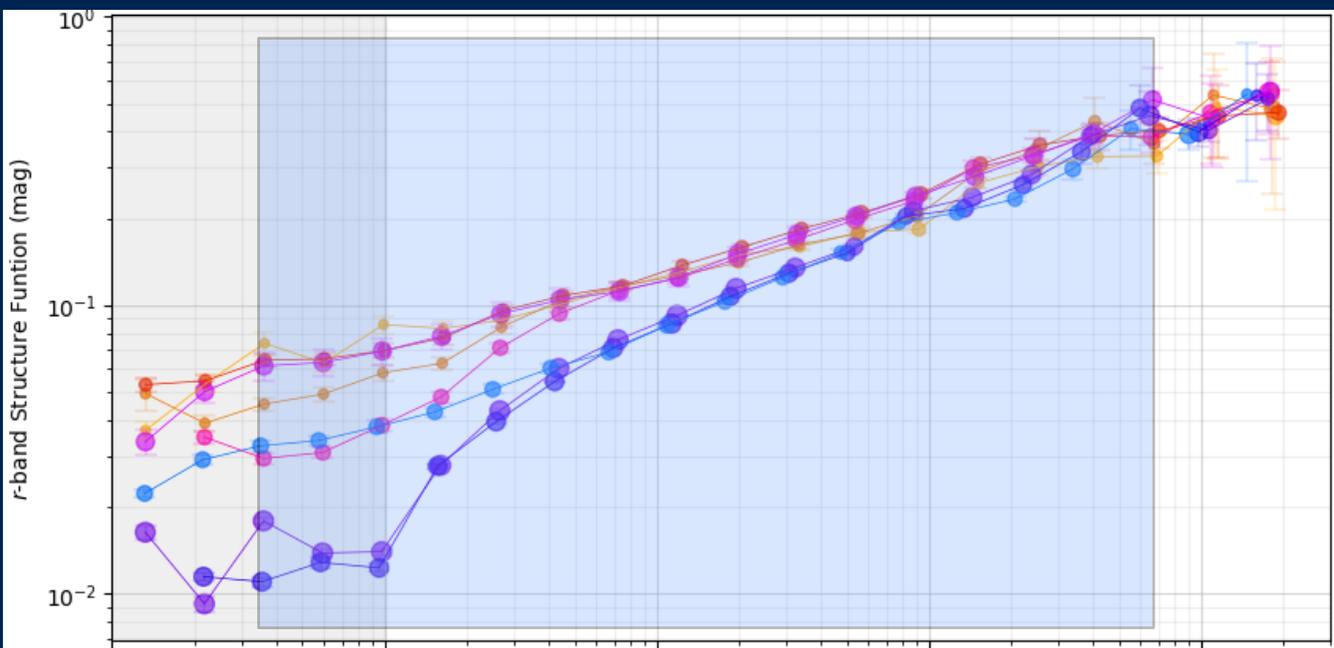
ZTF



1954

2023

Rubin: +17% total length
x3 high cadence up to 6,000 days

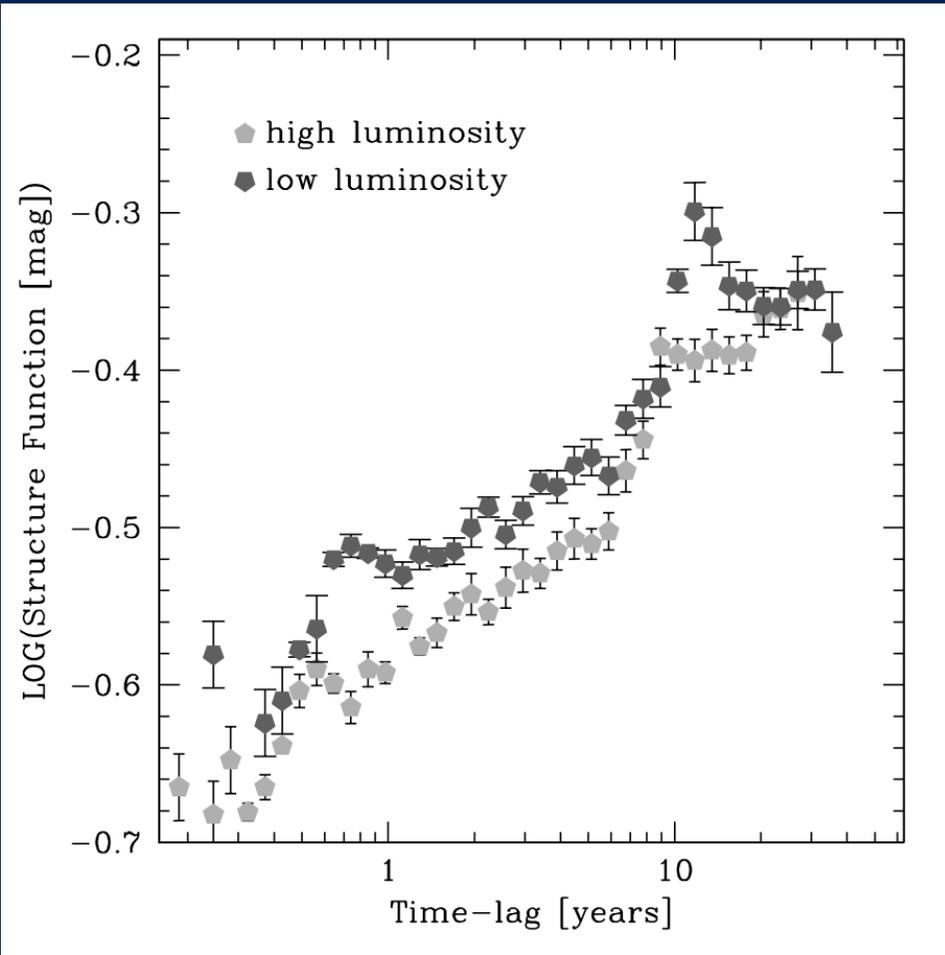


Life beyond the Damped Random Walk

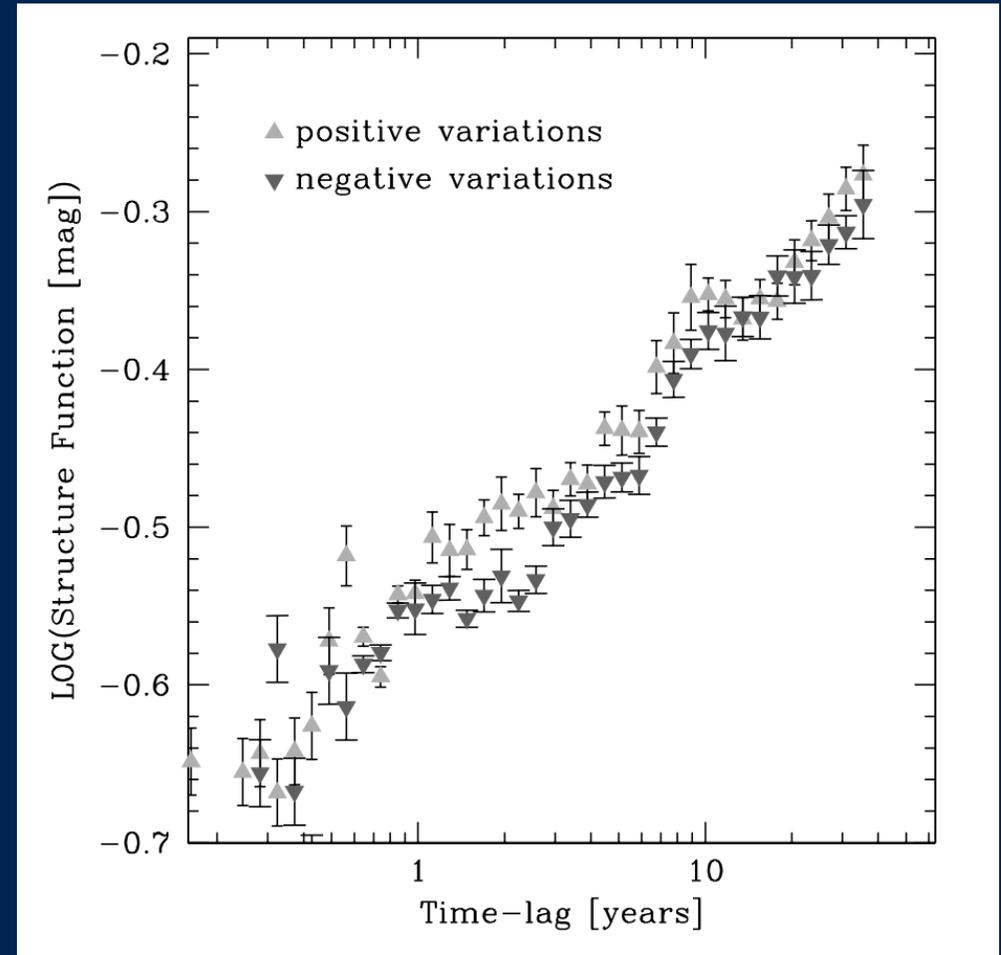
- Overlapping flares : non-exponential shots
- Reprocessing : seed+non-exponential filter
- Feedback : non-linear oscillator
- Flares with feedback : relaxation oscillator

FIN

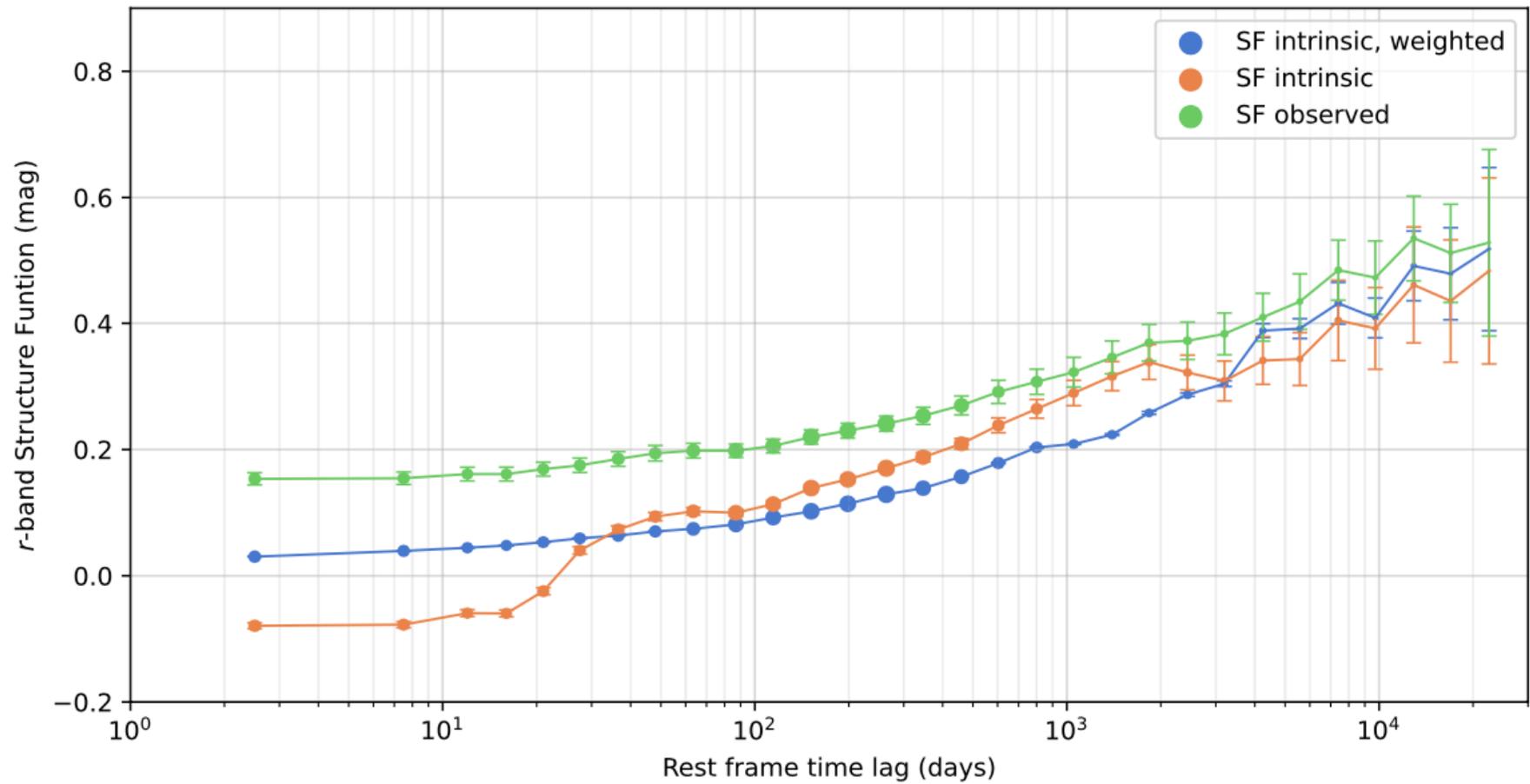
spares



$SF(\text{low-L}) > SF(\text{high-L})$



SF time asymmetric



variance weighted estimation

