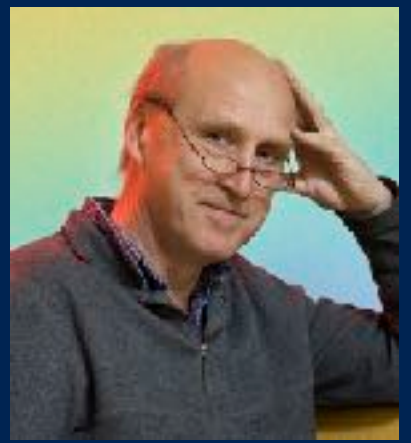
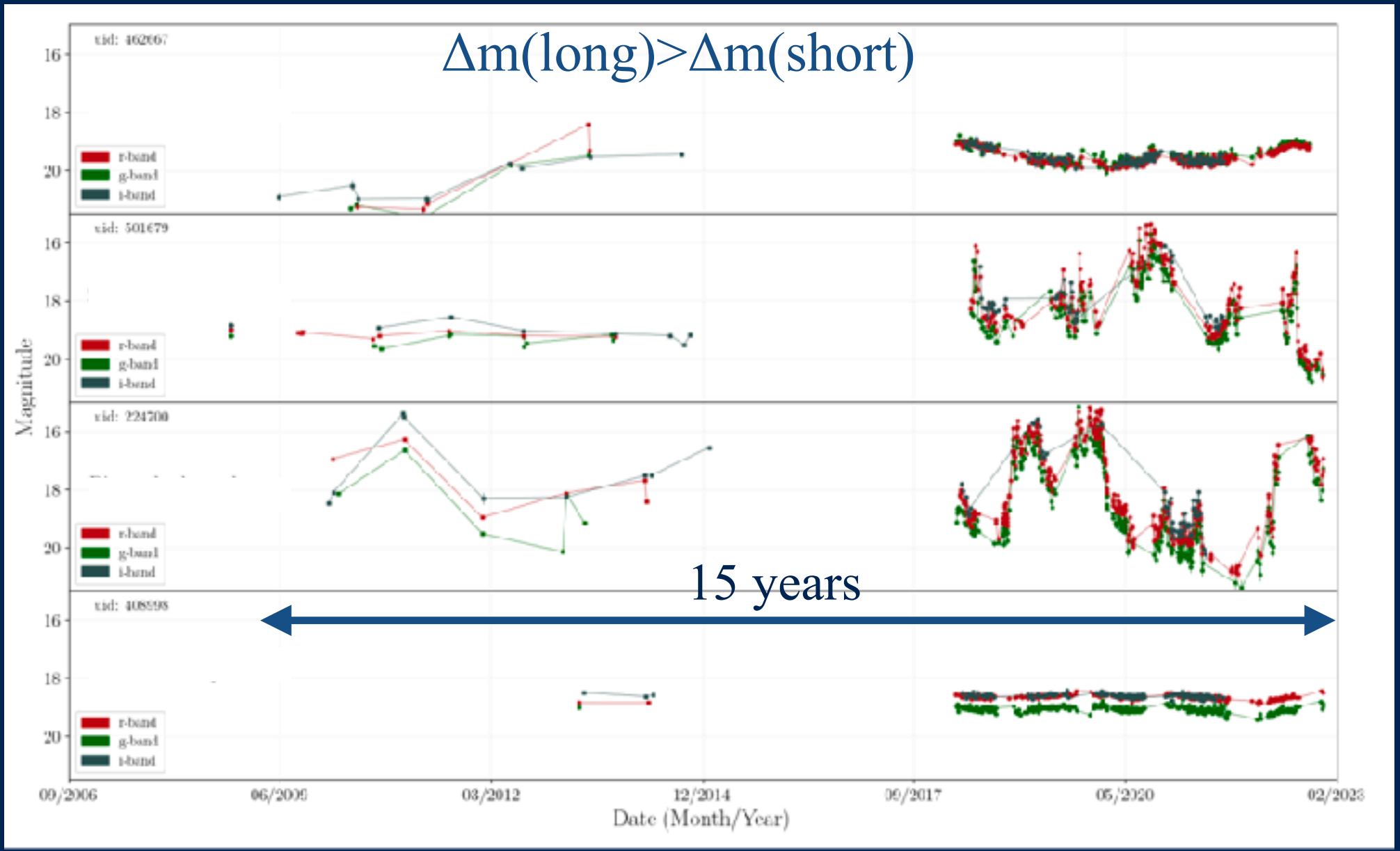
Seven decades of quasar variability

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

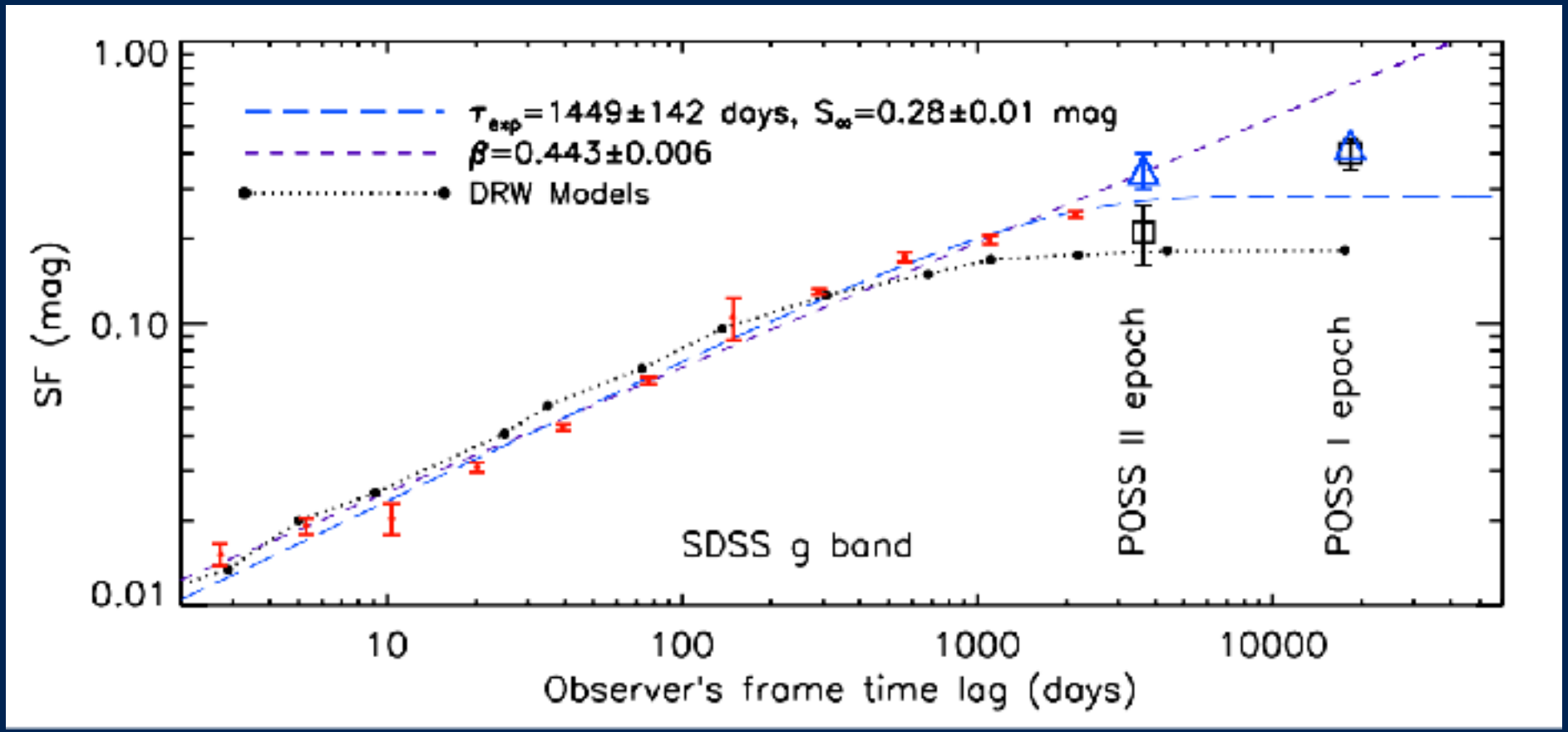




characterise shape with structure function

$SF = \sigma(\Delta t)$

Ensemble structure function fills in time gaps



Popular model: Damped Random Walk

McLeod et al 2012

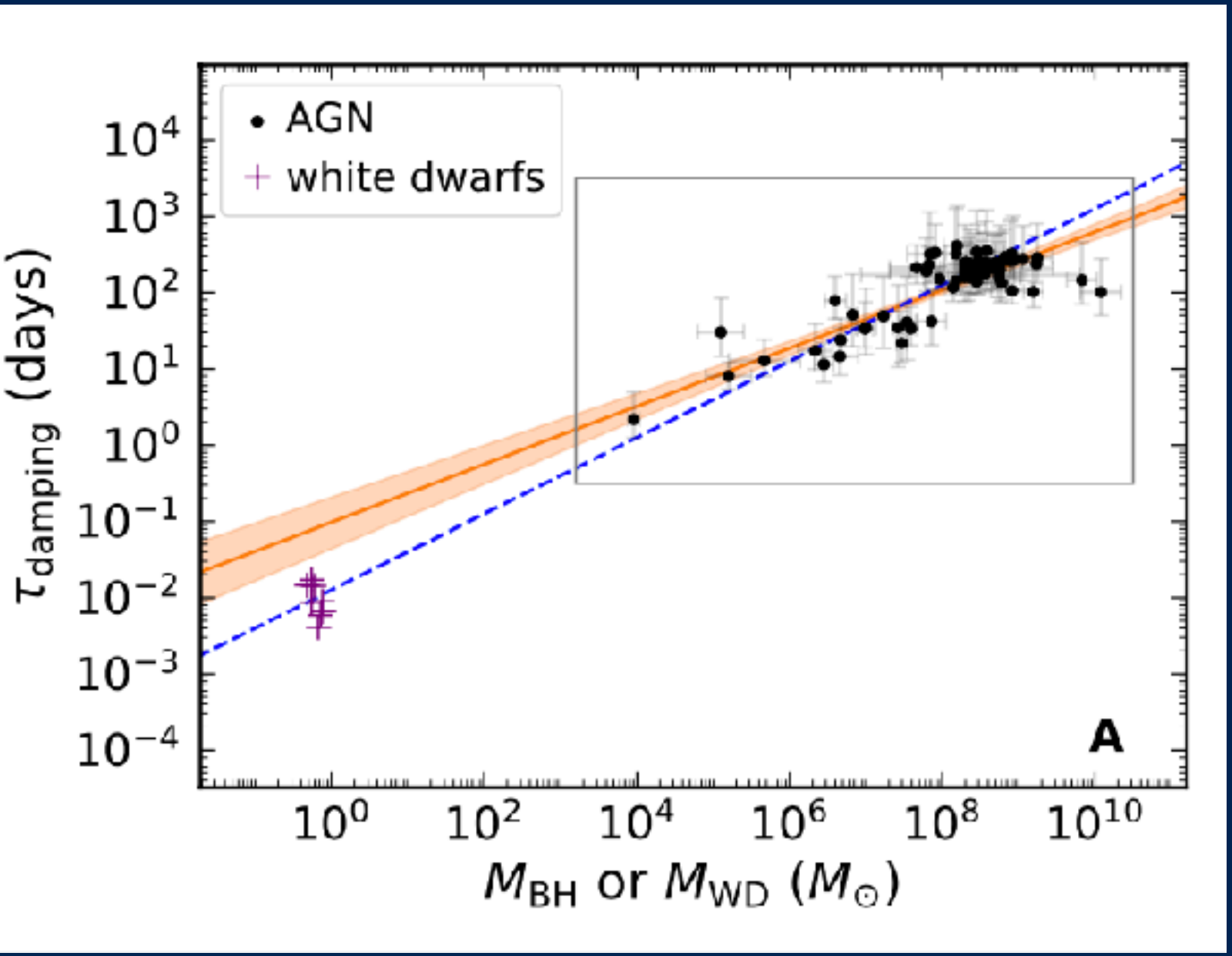
33,000 quasars

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

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

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

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

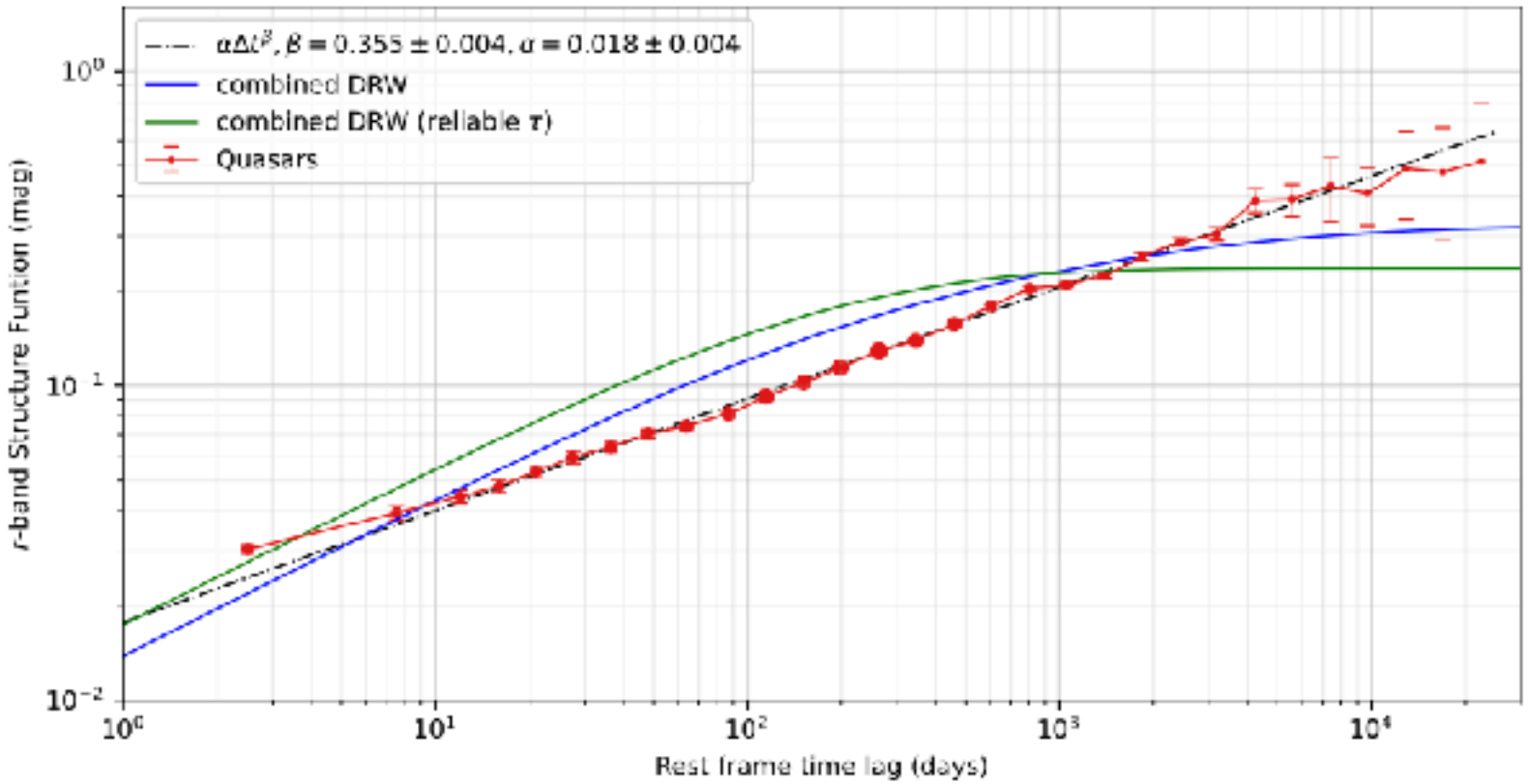
transformed to PS1 gri system

typically ~400 epochs

control sample of 400,000 stars

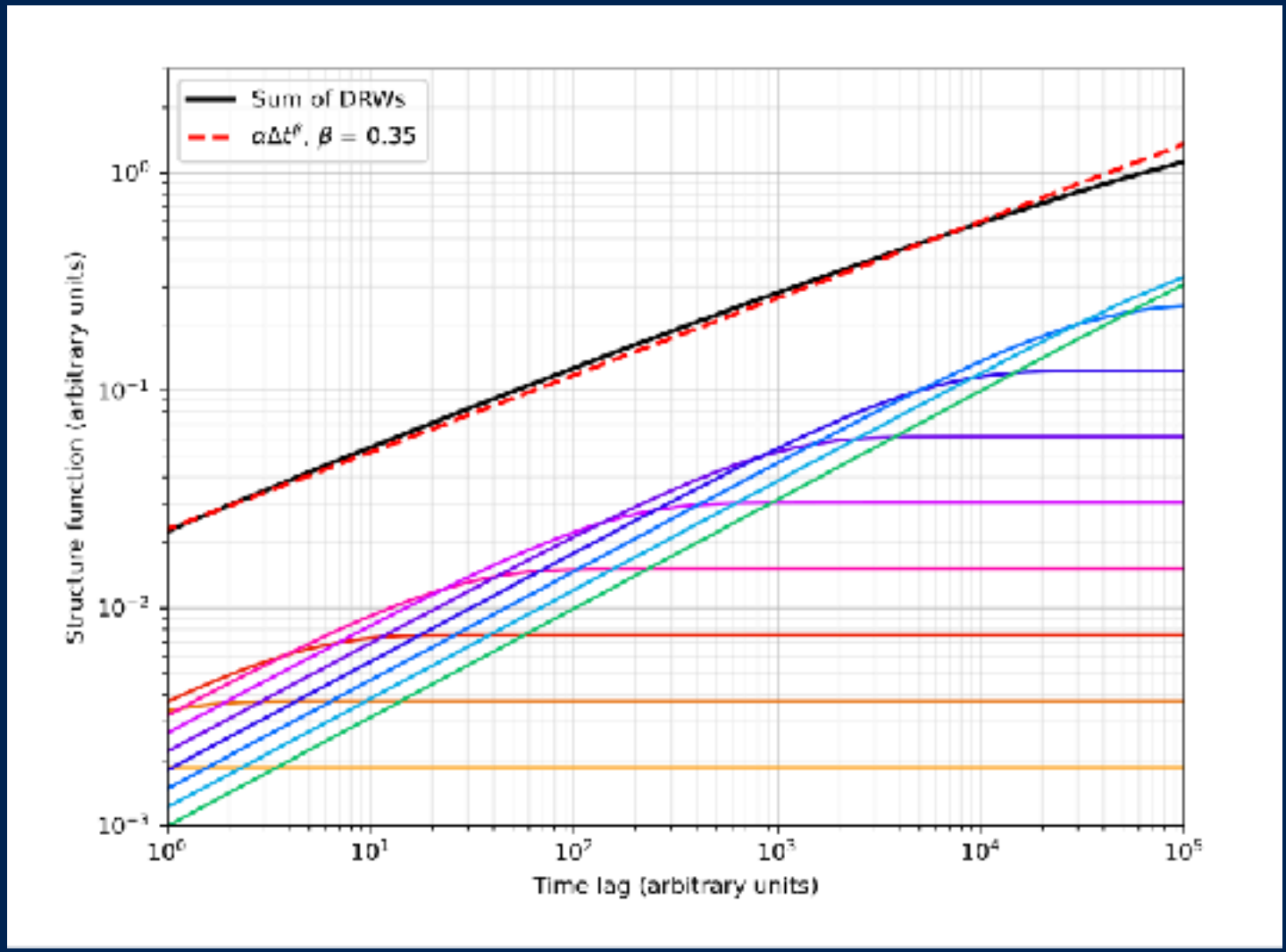
improved variance-weighted method

Ensemble Structure Function



power law β~0.35
not consistent with DRW
no evidence for knee

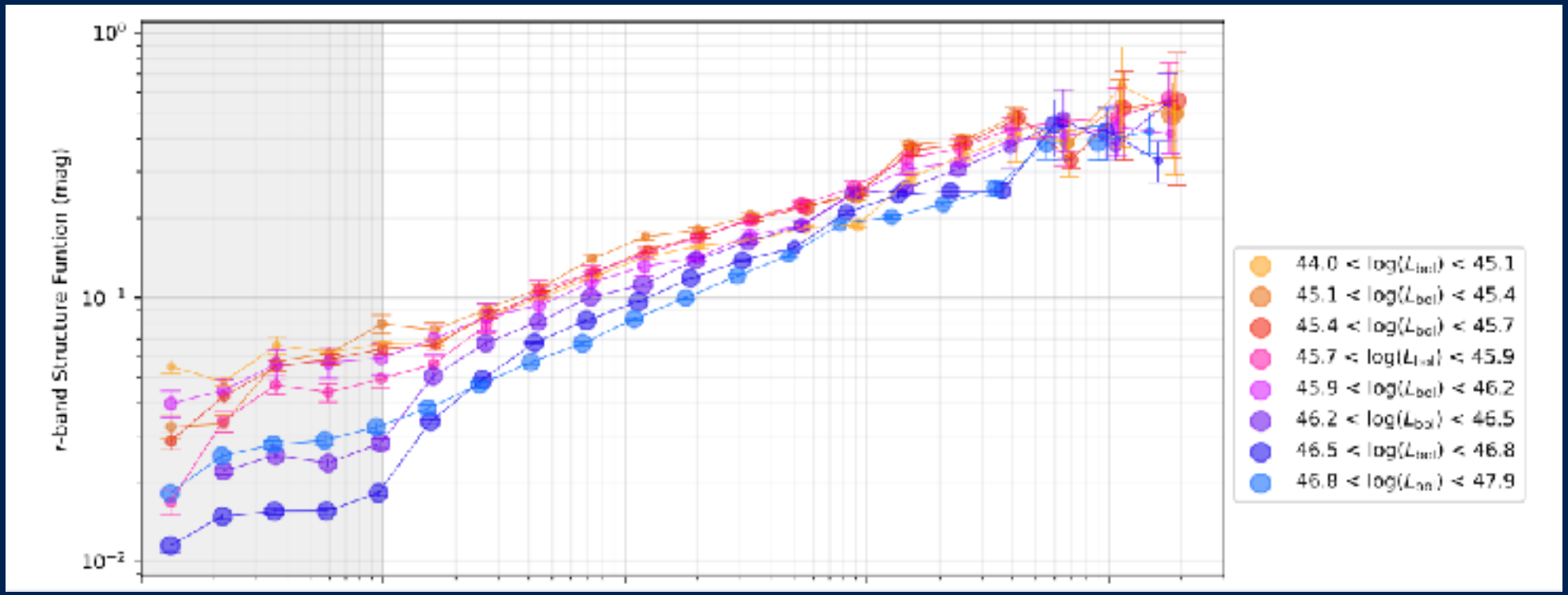
many different τ values?



rather arbitrary distribution
should depend on M, L, or nEdd?

Luminosity Dependence

cf De Vries et al 2005

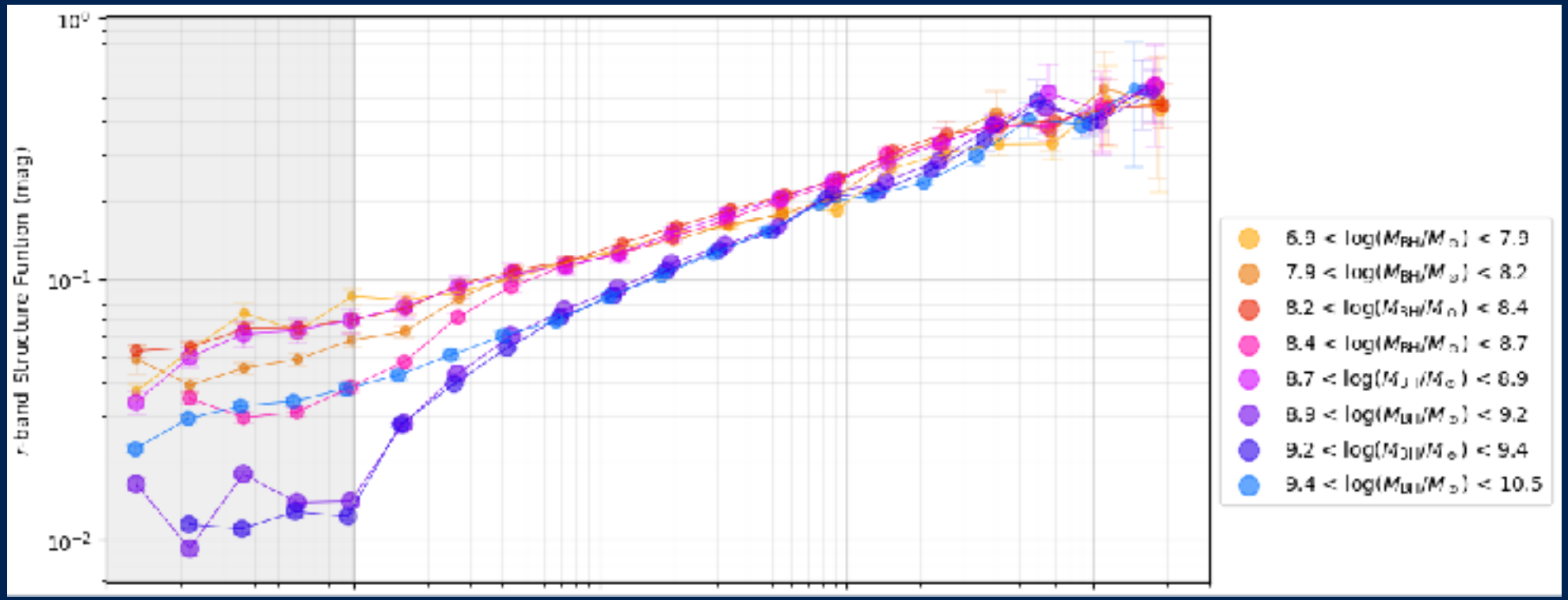


10^0 10^1 10^2 10^3 10^4 days

low-L : more variable, flatter SF

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

M_H Dependence

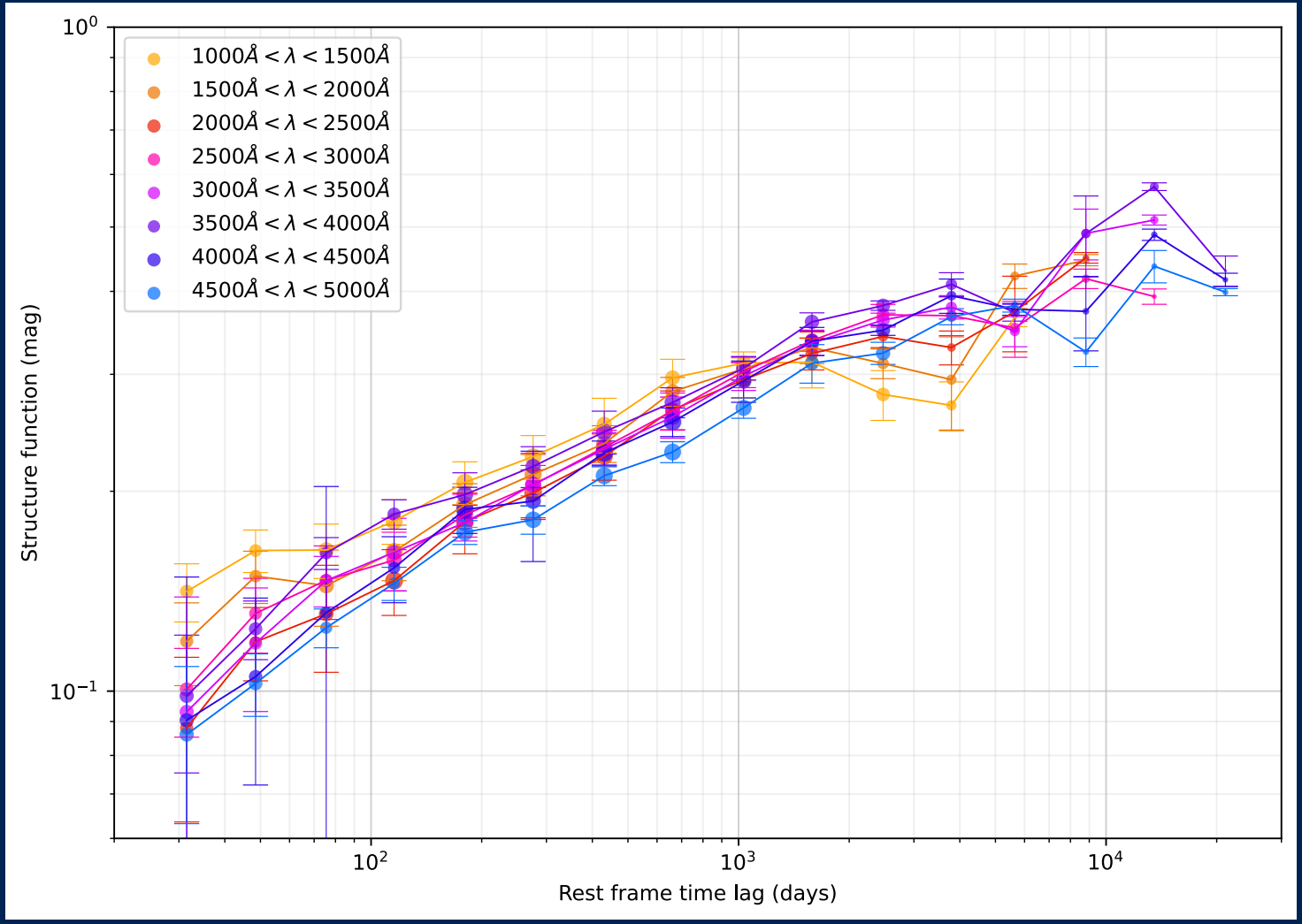


10^0 10^1 10^2 10^3 10^4 days

long timescales: ALL THE SAME no knowledge of mass

short timescales: variability suppressed at high mass

λ dependence

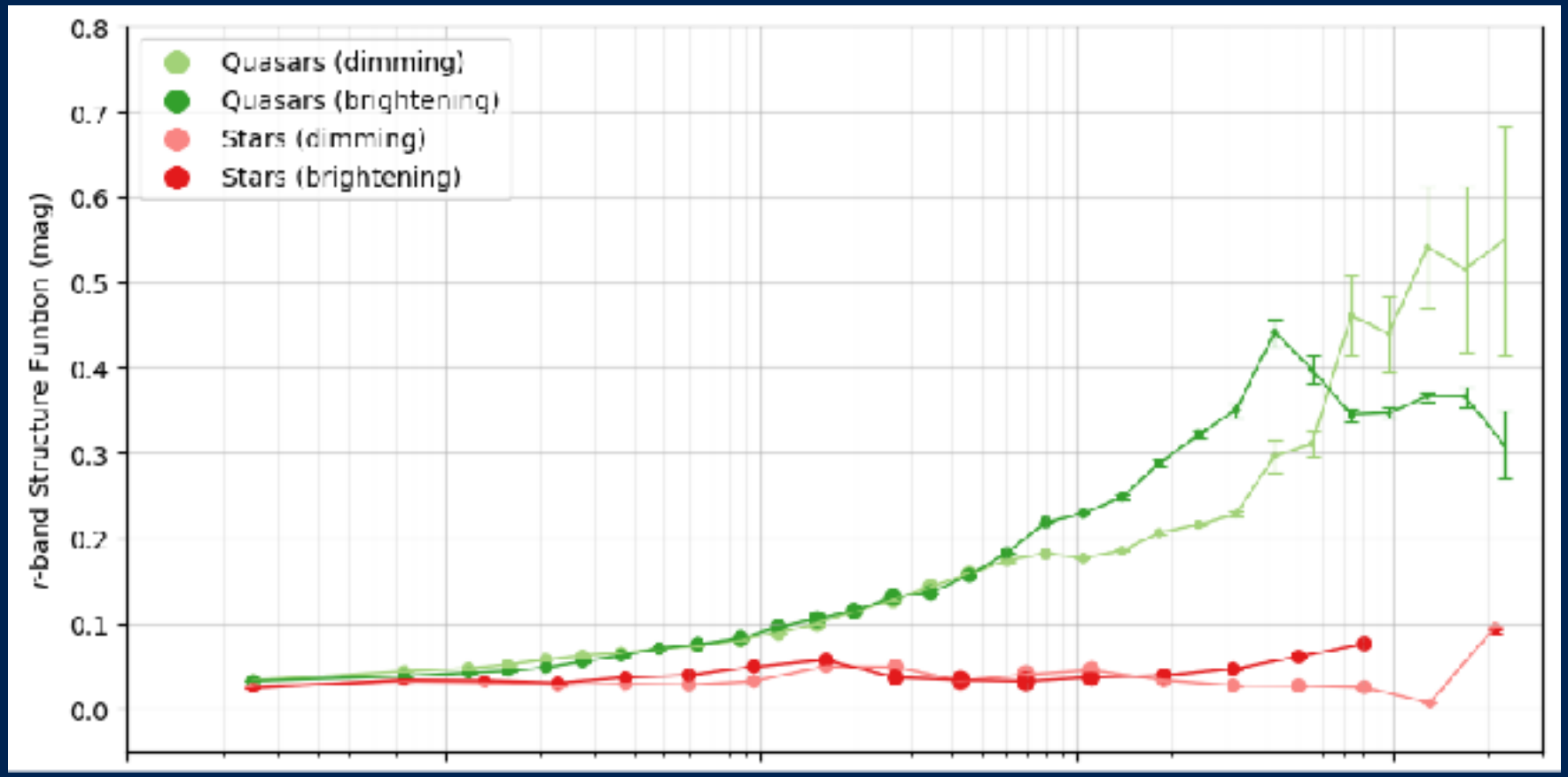


short timescales: blue variability > red

long timescales: no difference or even reversed

time asymmetry

cf De Vries et al 2005

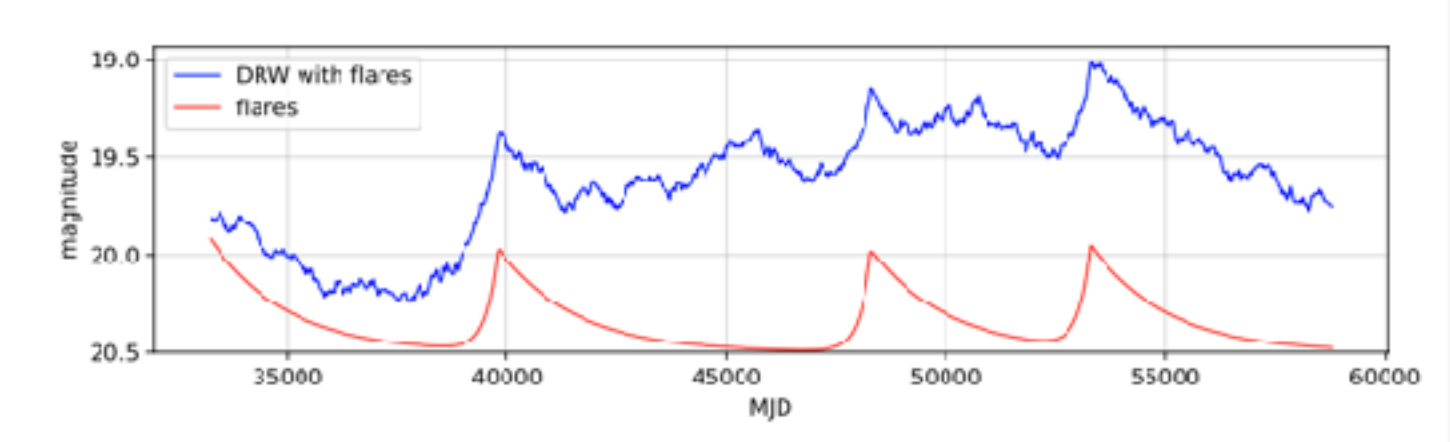


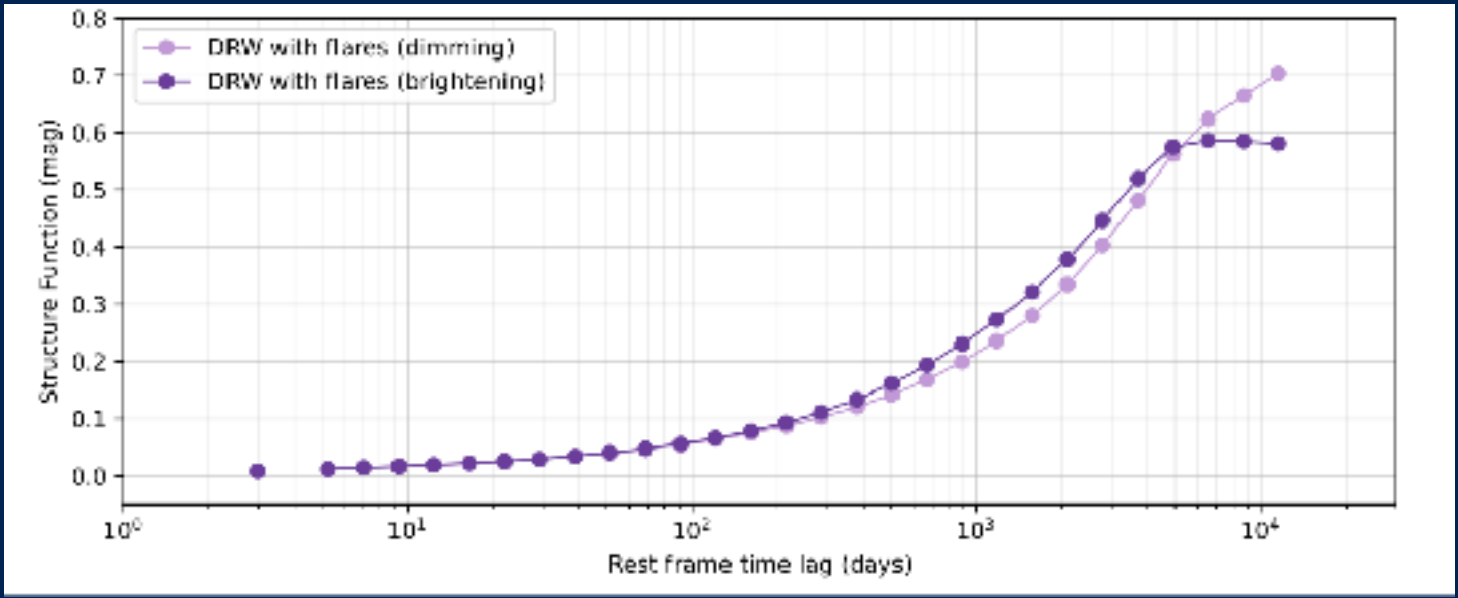
months: brightening = dimming

years: brightening > dimming

decades: brightening < dimming

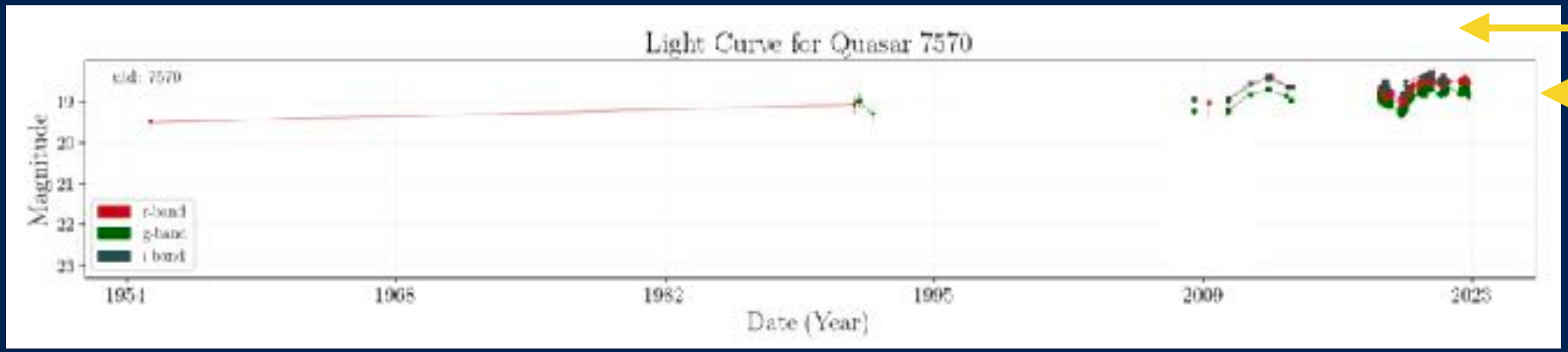
simulation: DRW + asymmetric flares





ok but too mild an effect

SuperCOSMOS SDSS PS1 ZTF

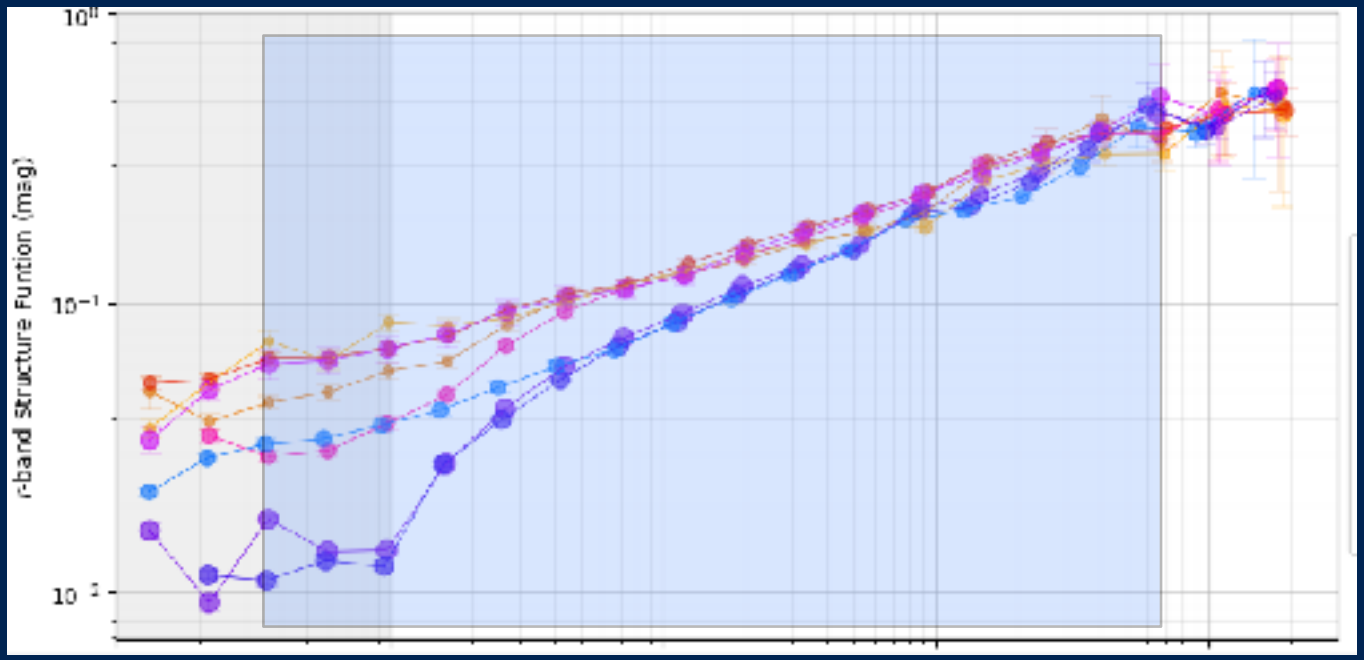


Rubin

1954 2023

Rubin: +17% total length

x3 high cadence up to 6,000 days



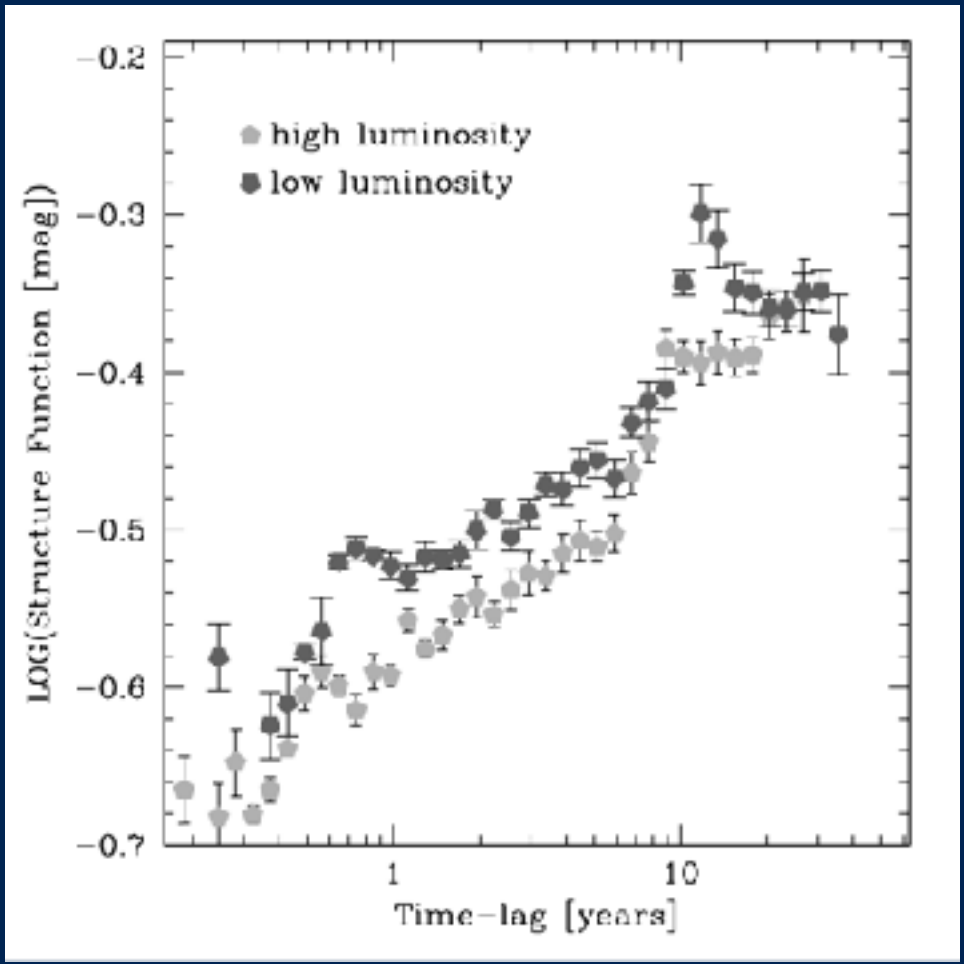
Life beyond the Damped Random Walk

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

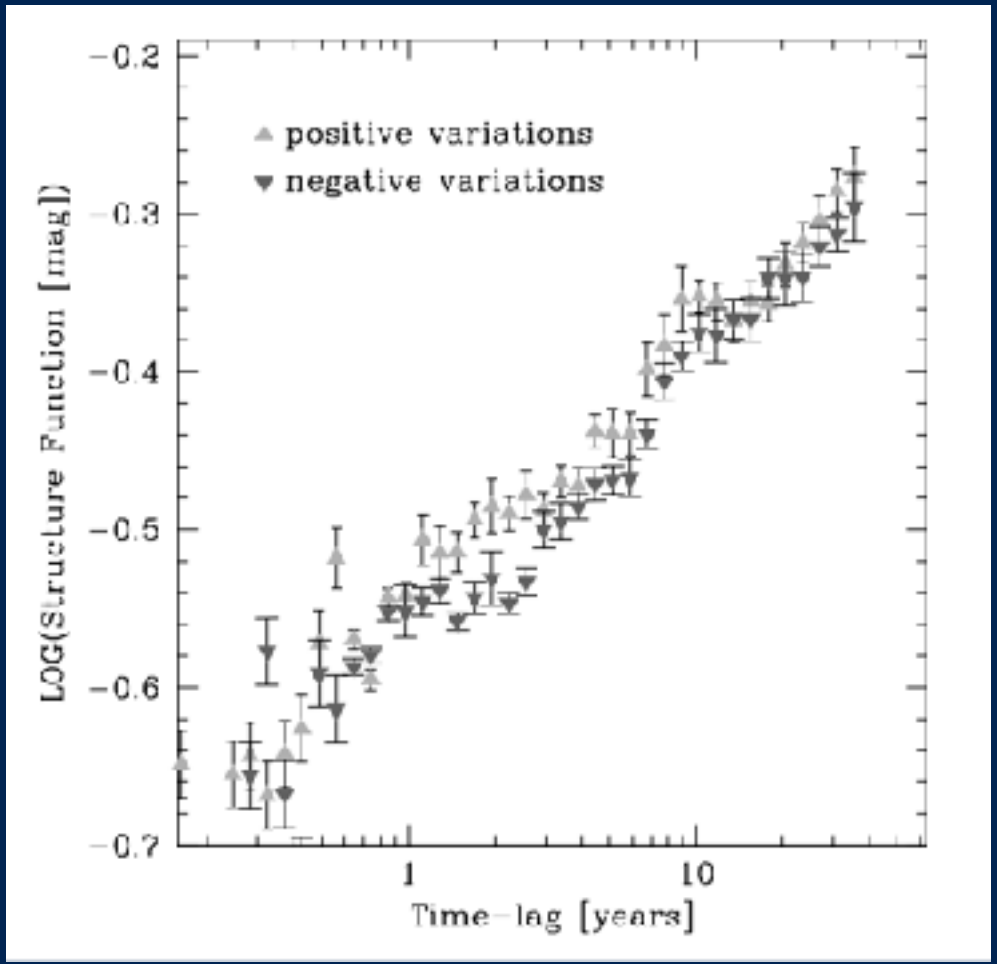
FIN

spares

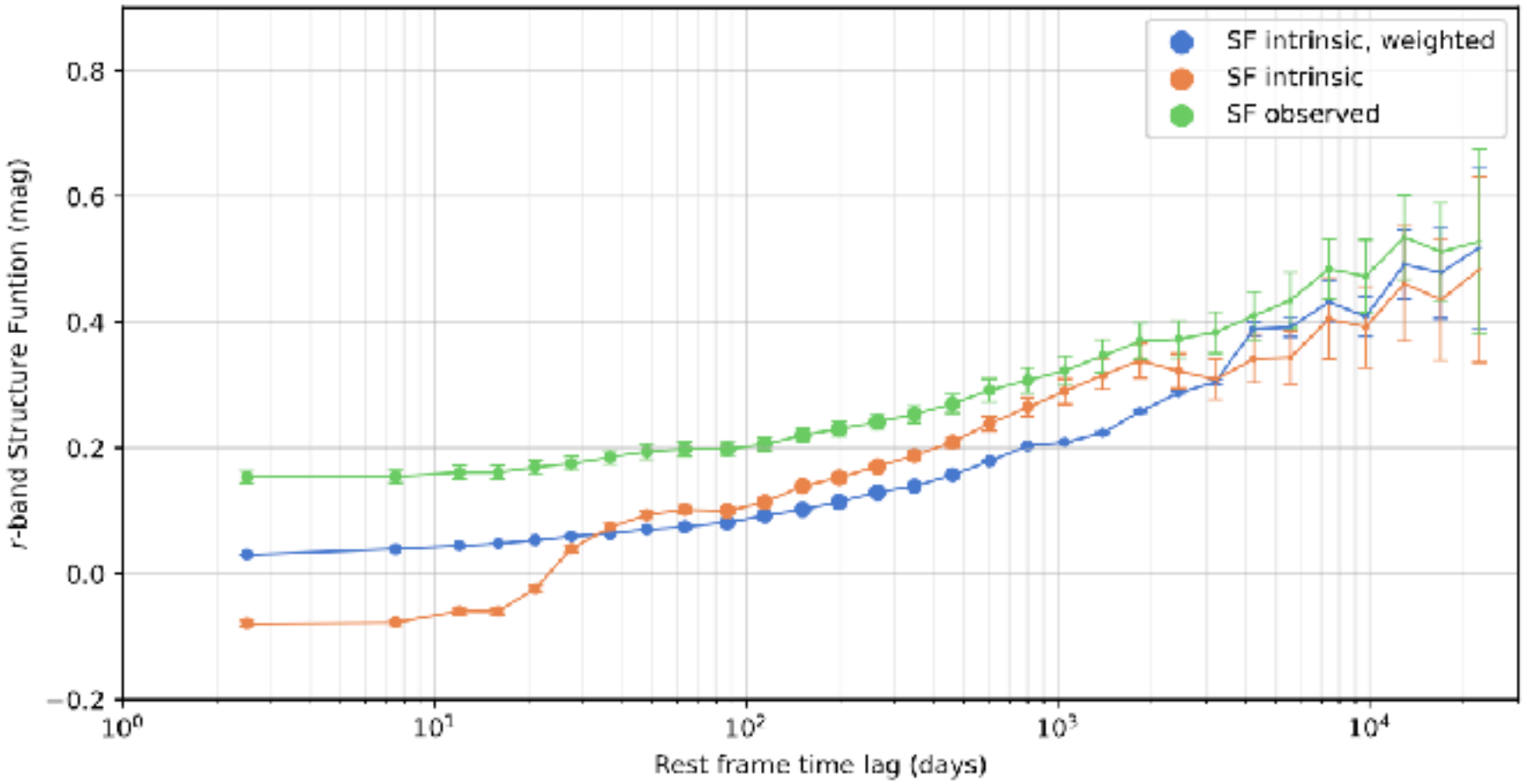
de Vries et al 2005



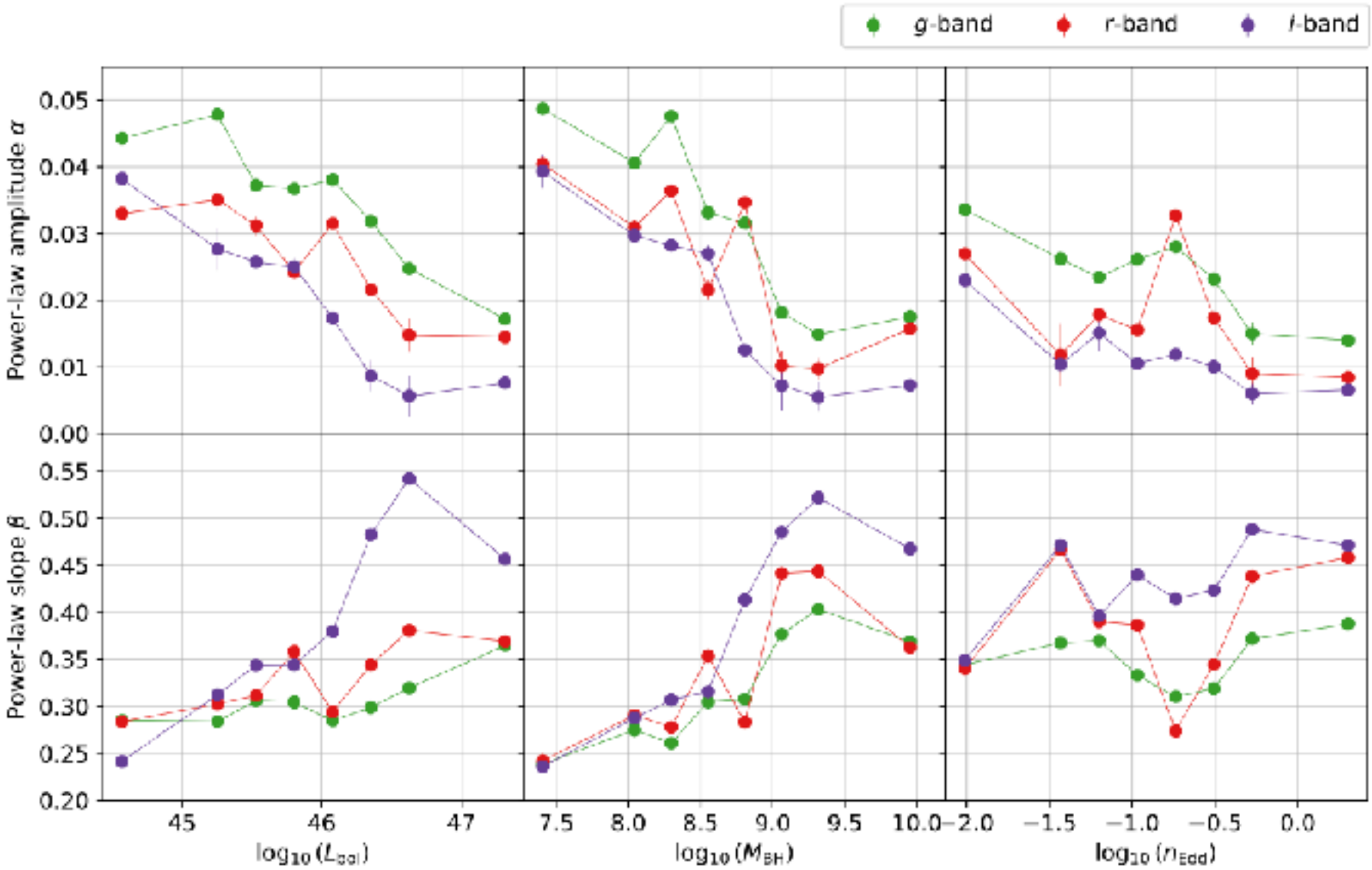
SF(low-L) > SF(high-L)



SF time asymmetric



variance weighted estimation


g-band
r-band
i-band
Power-law amplitude α
Power-law slope β
0.05
0.04
0.03
0.02
0.01
0.00
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
45
46
47
7.5
8.0
8.5
9.0
9.5
10.0
−2.0
−1.5
−1.0
−0.5
0.0
log10 (L5100)
log10 (MBH)
log10 (nEdd)