SDSS and K2 Variability Timescales: Damped Random Walk vs. Damped Harmonic Oscillator

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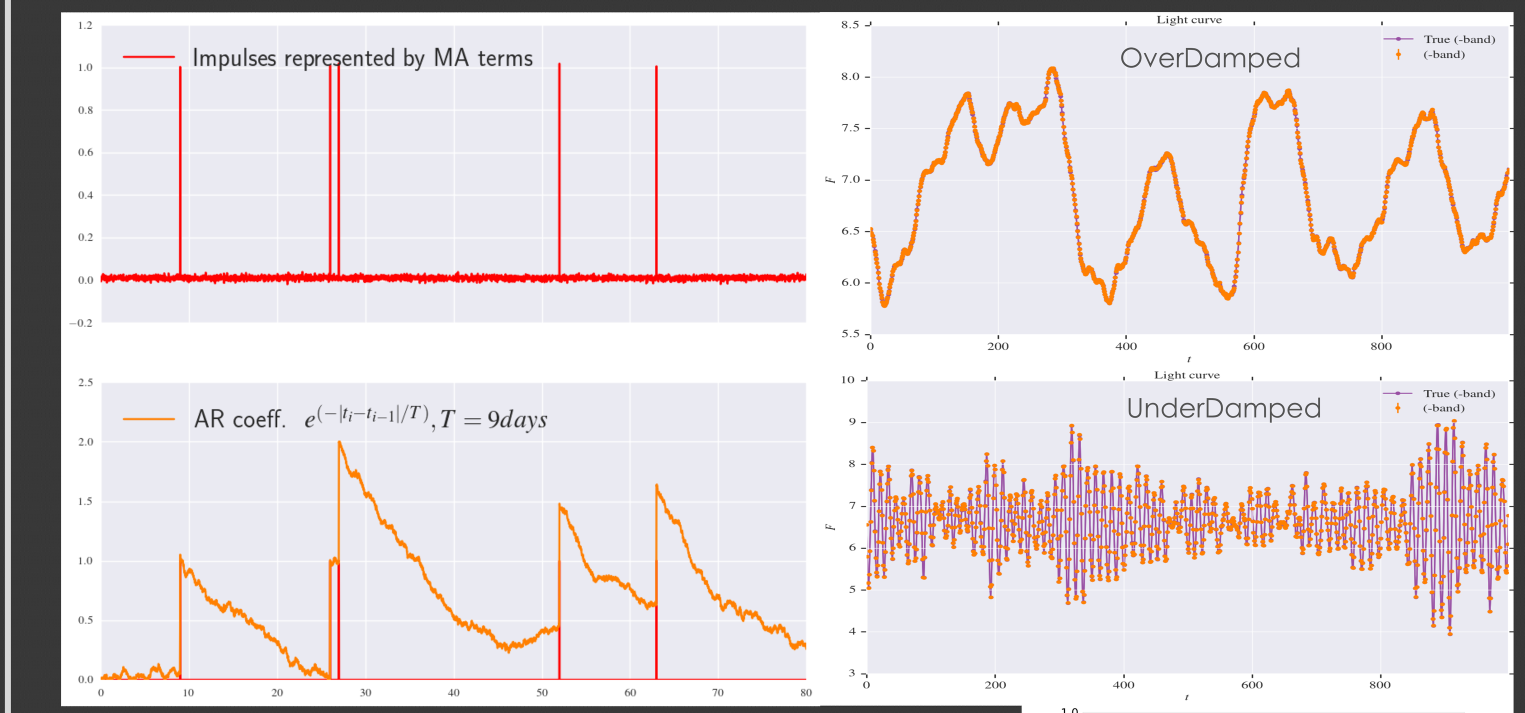
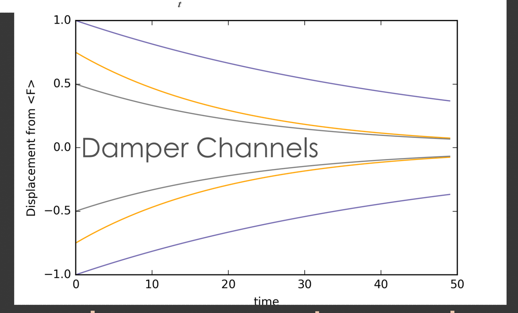
Method

DRW and Higher Order CARMA Models

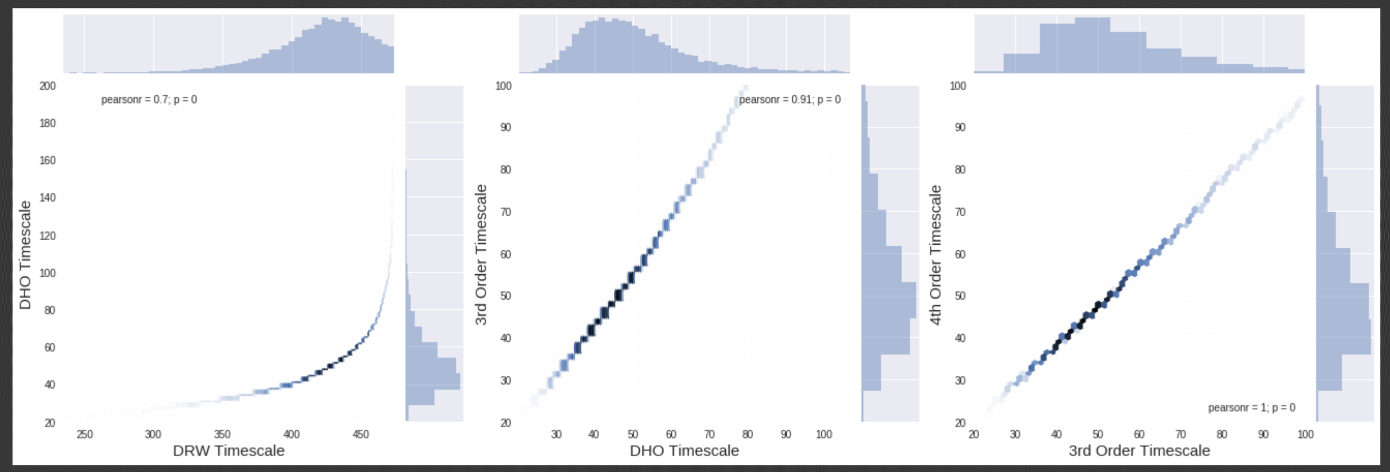
- MA = colored noise impulses that drive up the flux
- AR = response + relaxation timescales or underdamped QPOs



Nested Models

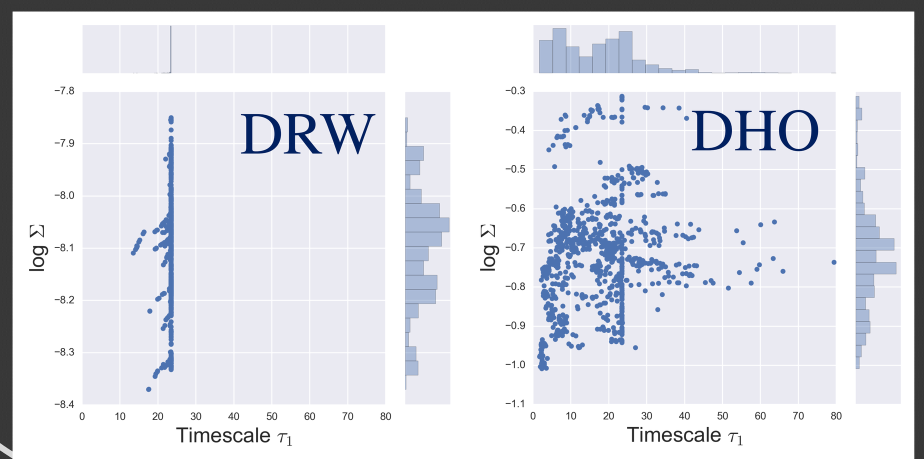


- DRW and DHO timescales are exponentially related
- DHO and higher order model timescales are strongly correlated
- Additional timescales from higher order models act as additional damper channels, smoothing disturbances from shock terms (MA)

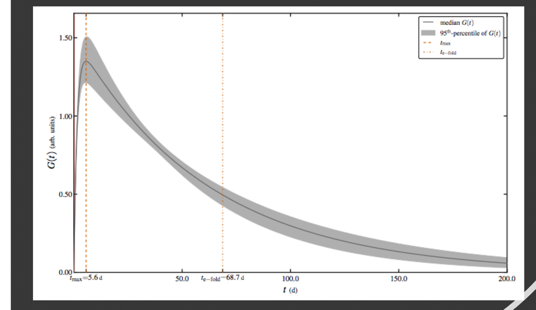


DRW vs Driven DHO

Below we reproduce Kozlowski's [5] finding that the DRW is sensitive to the length of the lightcurve (statistical artifact timescale ~ 30% of the lightcurve length). We compare the DRW and DHO timescales for 1000 (k2-like) 80 day chunks of the 3.5 yr Kepler lightcurve Zwicky 229.15. The DHO is sensitive to length, however we also reproduce Kasliwal's [3] result of ~ 5 day time delay from unit perturbations to flux peaking. This is characteristic of a mechanism that is resisting a rise in flux rather than relaxing or dissipating energy. This is the response time in a green's function projection of the DHO.



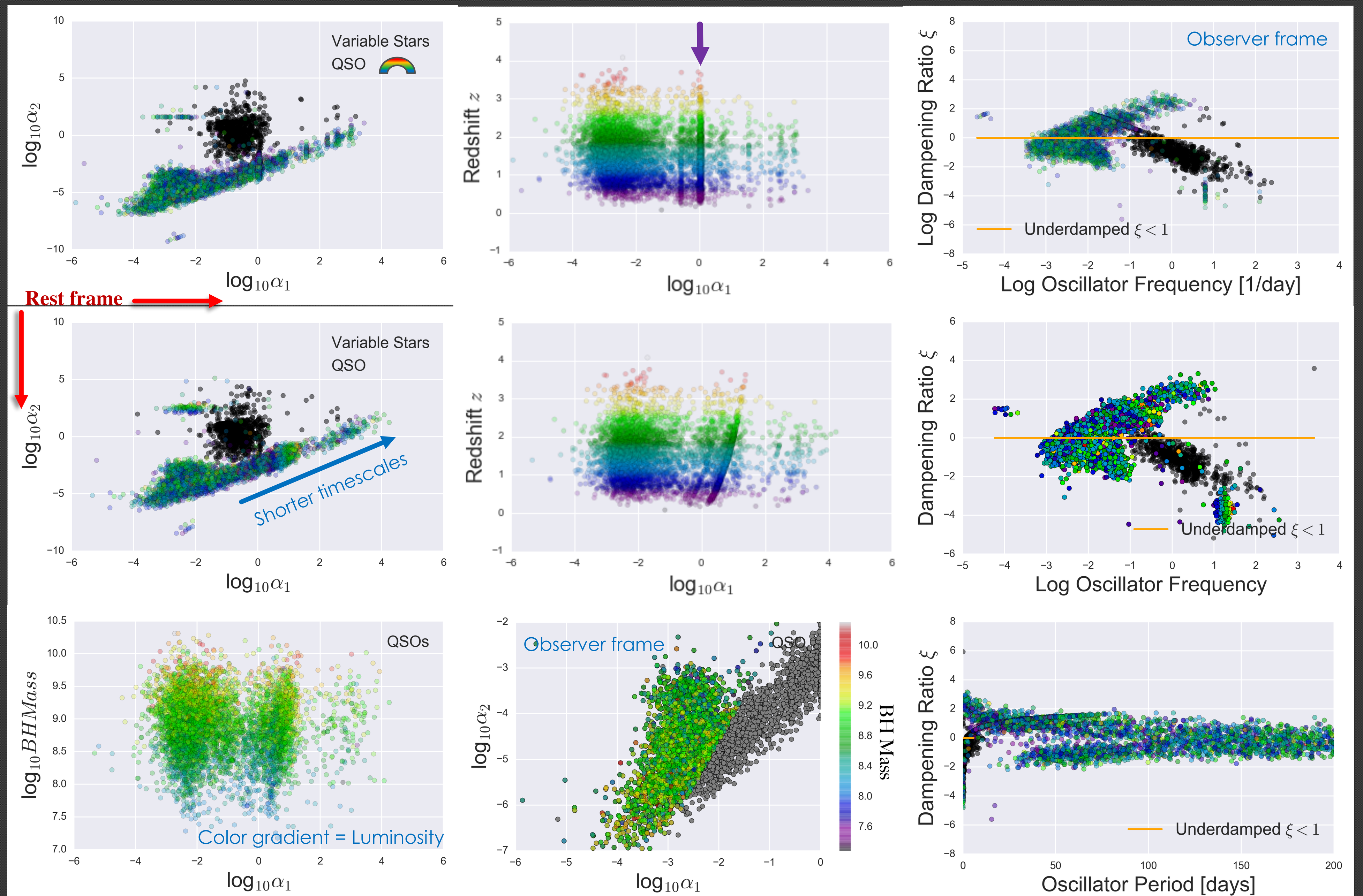
Green's function (DHO) Kasliwal et al 2017



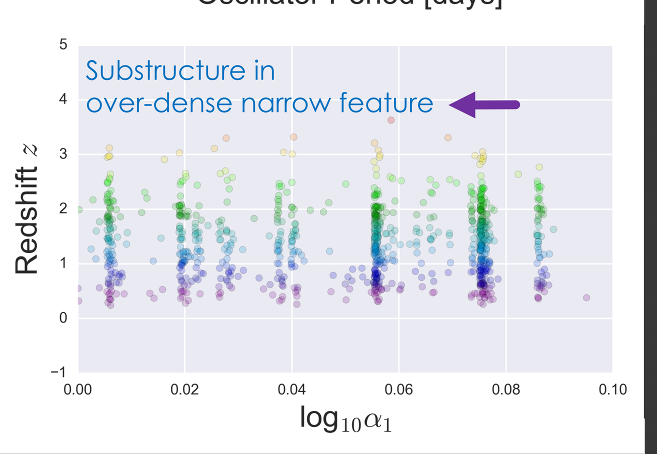
Abstract

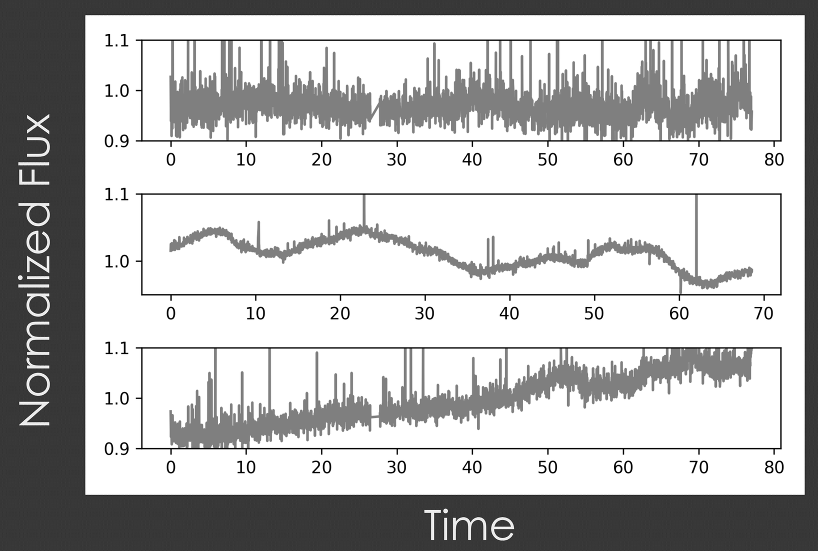
We investigate short and long term AGN optical variability using Continuous -ARMA models [4] to characterize response and relaxation timescales in lightcurves. These timescales may be related to heating and cooling processes in the accretion disk surrounding thermal instabilities, shocks or incident X-ray driven variability. We demonstrate the flexibility of the CARMA(2,1) model (Driven Damped Harmonic Oscillator) and its effectiveness at separating variable stars and quasars using Sloan Stripe 82 lightcurves. Sloan Stripe 82 quasars modelled by the DHO reveal trends coupled to redshift related properties in both the rest-frame corrected lightcurves and (weakly) in the observer-frame. We also present preliminary work in combining Kepler/K2 data overlapping Stripe 82 to better constrain short term and long term variability for well studied quasars with estimates of physical properties including virial black hole mass and luminosities [9,10].

Single point draws from DHO MCMC fits for ~7000 SDSS S82 quasars and variable stars (r-band).



- Variable stars and QSOs [9] separate cleanly in α_2(related to oscillator frequency) because they are periodic.
- QSOs group strongly in α_1 (related to α_2 & dampening ratio.) α_1 shows tracks potentially related to an observational systematic not due to length (see figure on right).
- Virial BH Mass [8] for underdamped systems shows a weak gradient in the observer-frame, mass increases as oscillator frequency decreases.



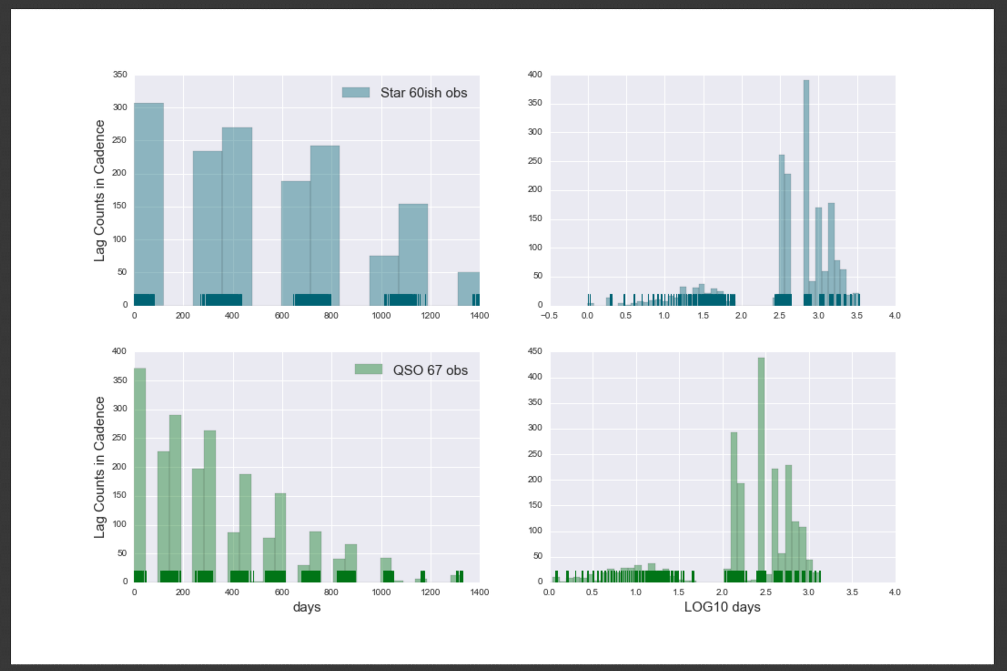


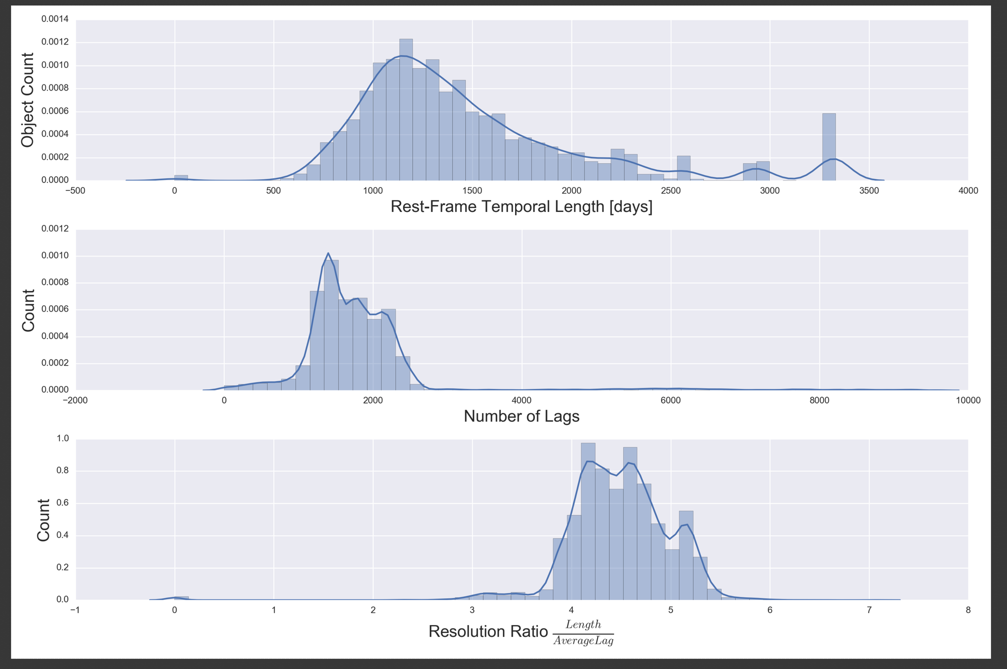
[Left] **Preview of K2 lightcurves** With 30 min sampling we see that some quasars vary with high amplitude over timescales of a few days and some simply appear flat and quiet in the k2 time window. High cadence data can resolve response timescales that Sloan S82 does not resolve.

Work is ongoing to combine the K2 + SDSS to overcome the CARMA length bias that poses a problem for K2.

Is DHO clustering a cadence systematic?

The quasar groups shown here are not due to light curve length. Moving up the quasar track we find the objects with the highest number of lags based on sampling over a particular field. This merely indicates that more observations in the lightcurve resolve shorter timescale variability. Similarly, high redshift quasars have shorter cadence sampling in the rest-frame than lower redshift quasars but they sit in very cluster. More cadence metrics should be investigated for sparse-irregular survey data.





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