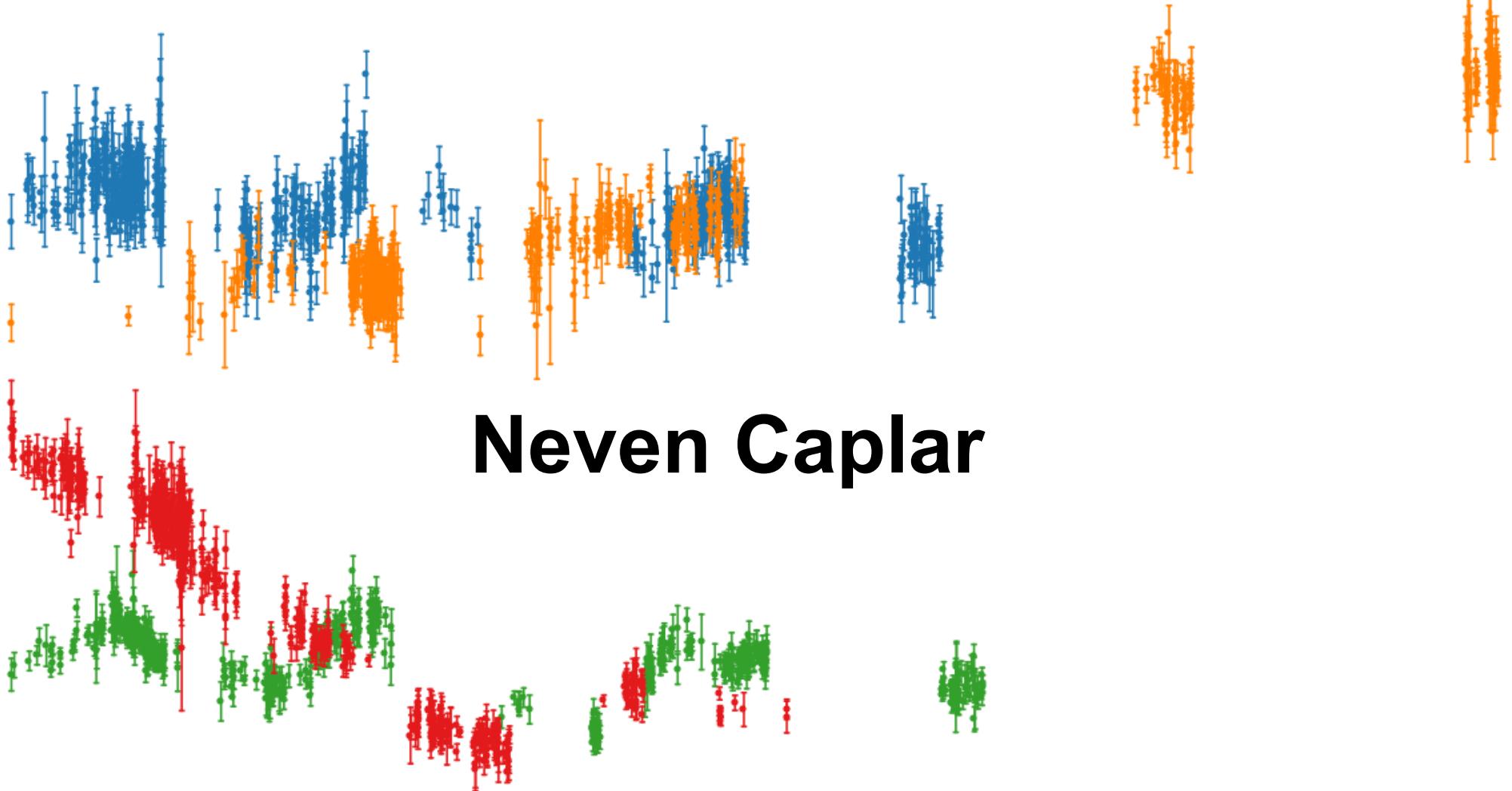
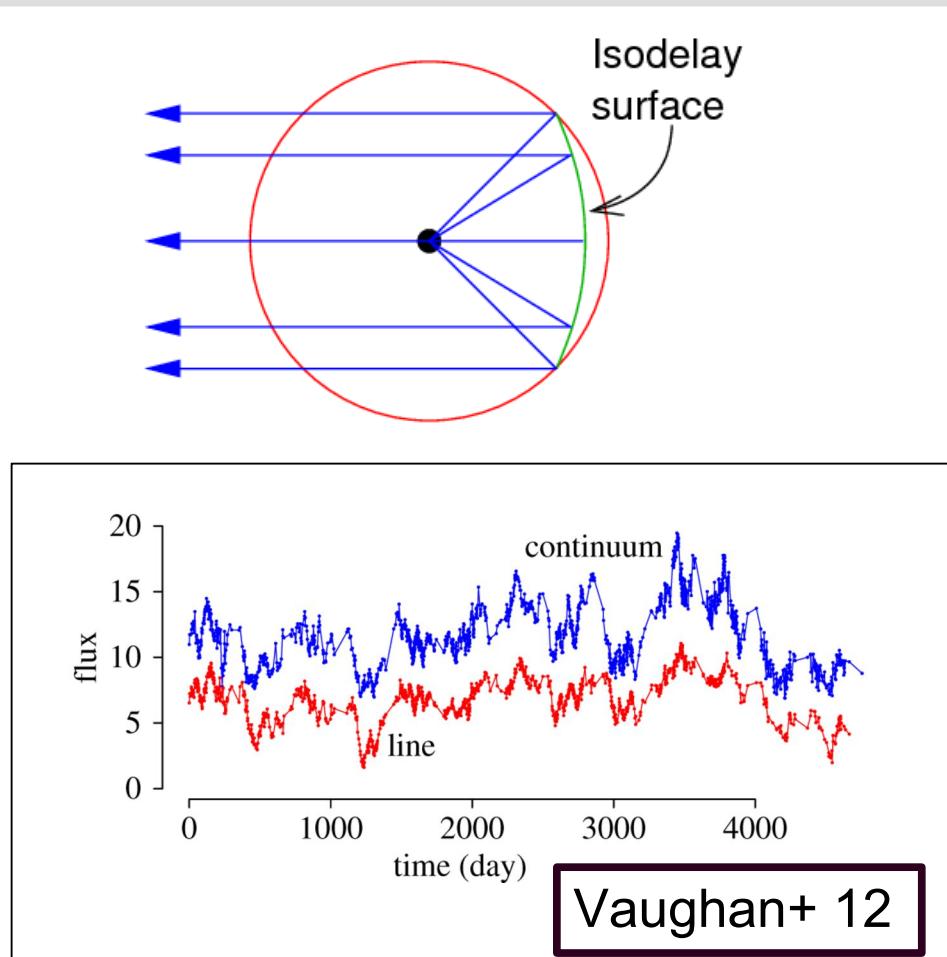


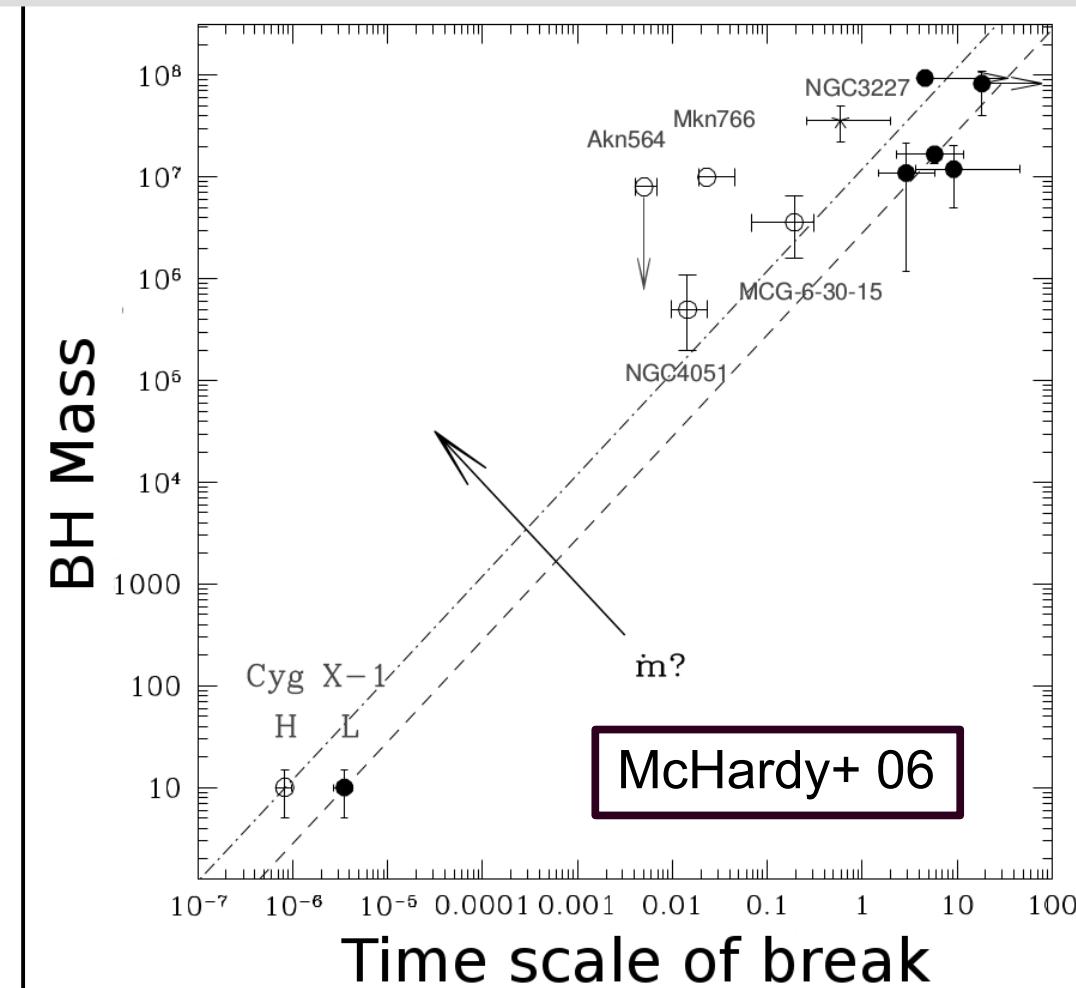
Stochastic variability of AGN in time domain



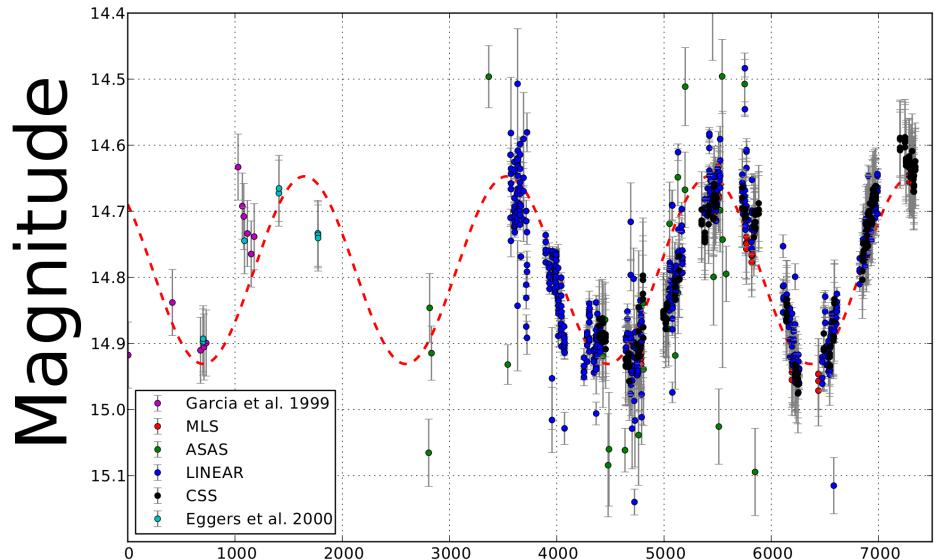
Why quasar variability?



- Reverberation mapping
- Probes structure of broad-line region
- Method to measure BH mass

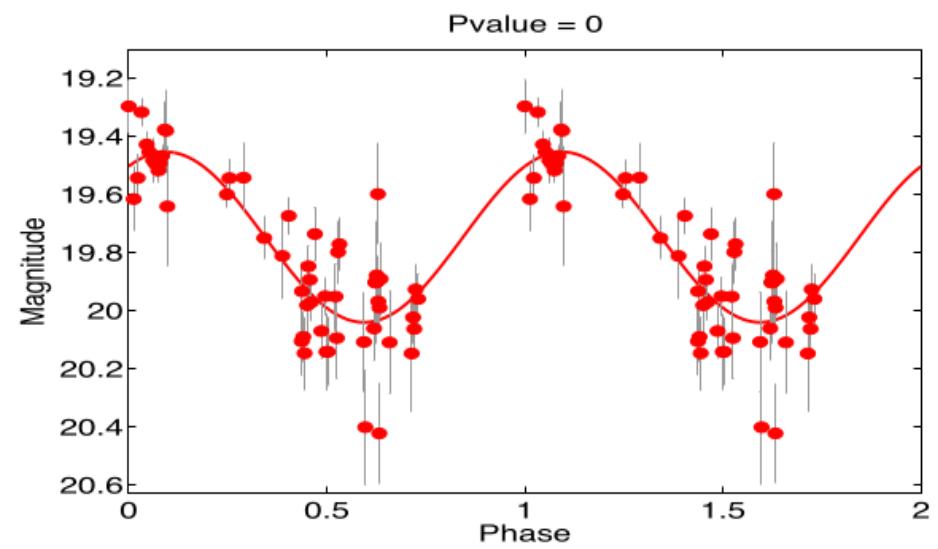
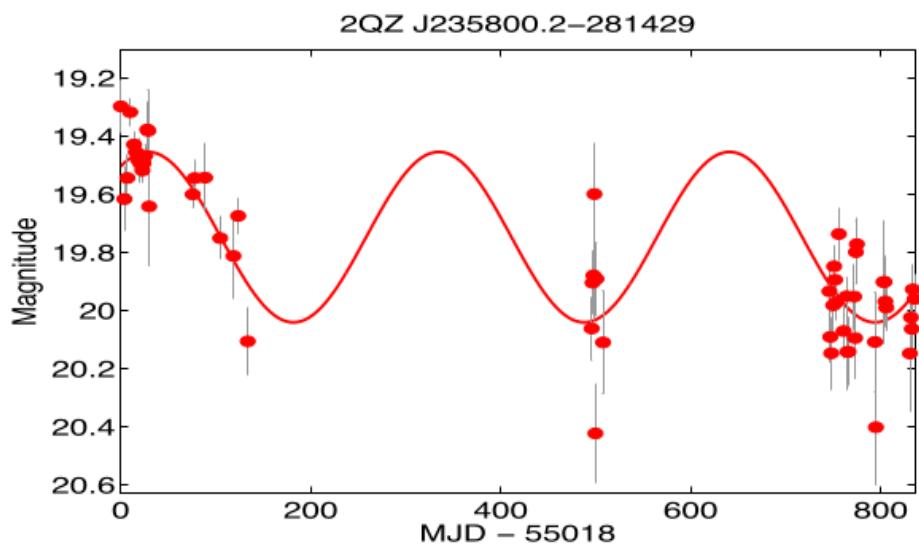


- BH mass correlated with with break in the X-ray power spectrum density

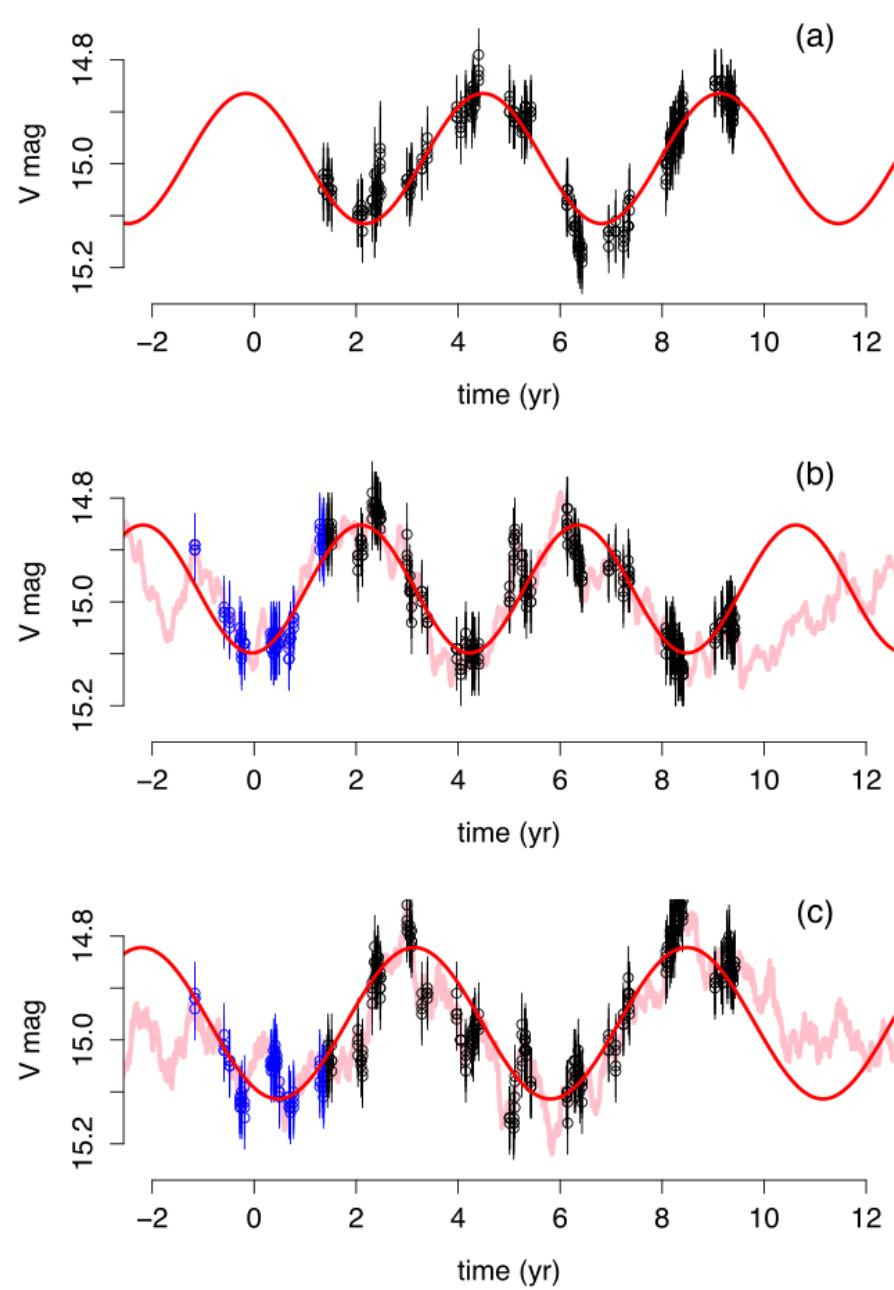


- Search for binaries of supermassive black holes with a sub-parsec separation
- Expected as a consequence of galaxy mergers

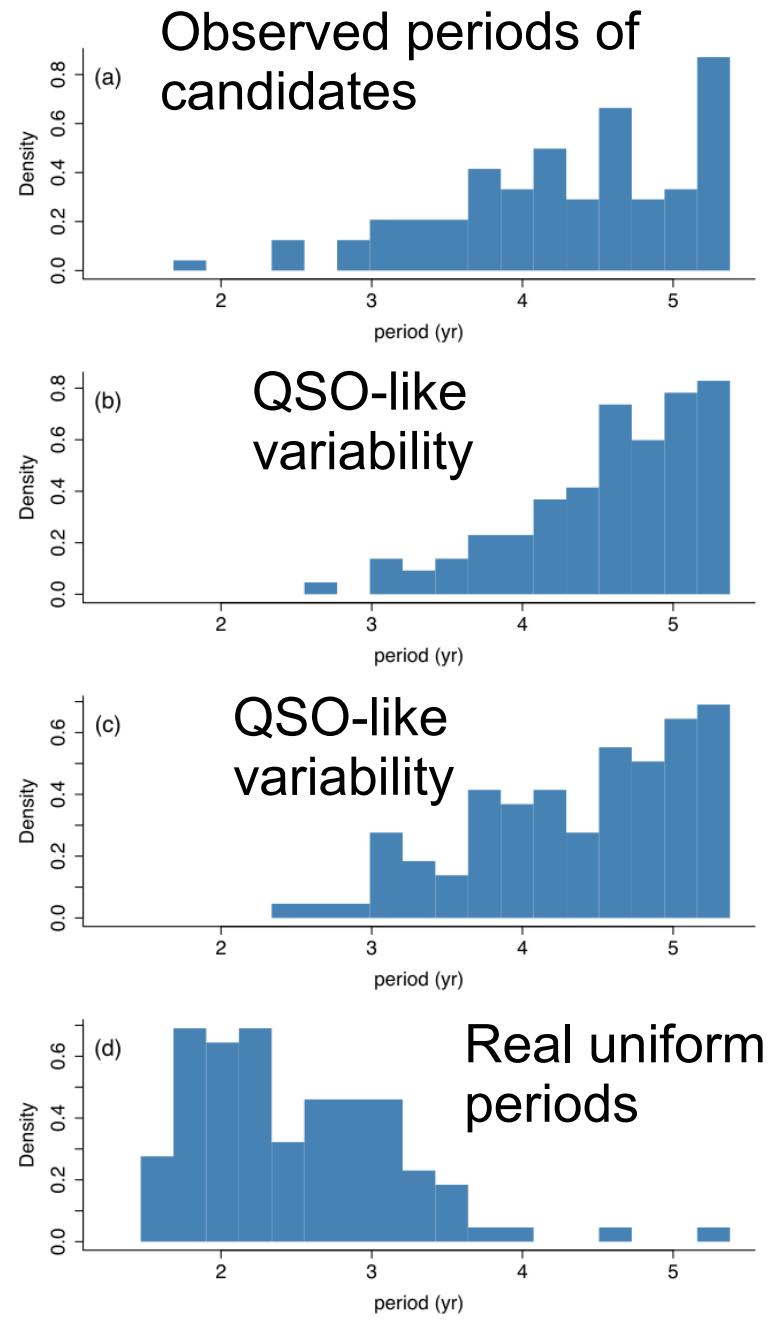
DATE Graham+ 15



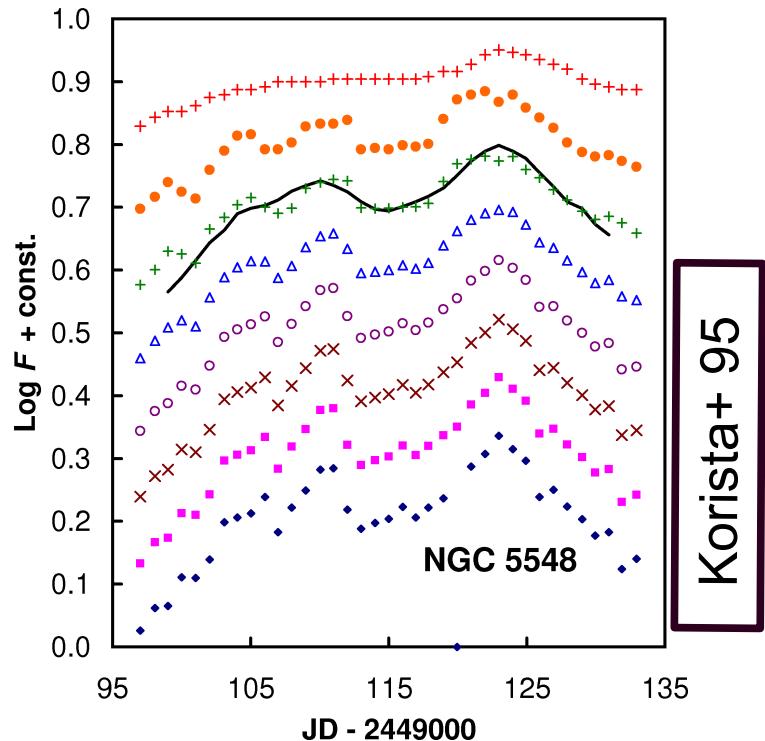
Charisi+ 16



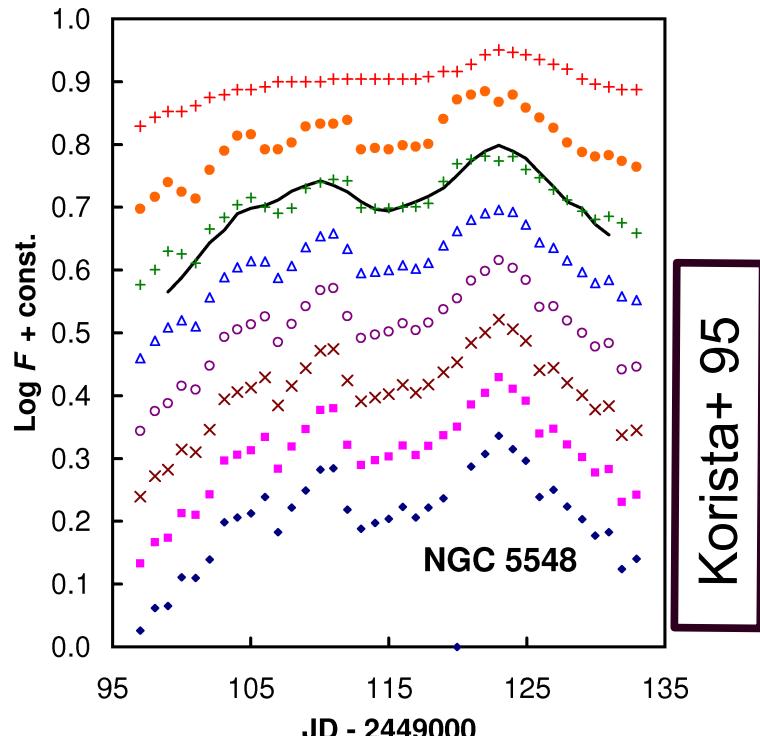
- But stochastic process can also mimic periodicity!



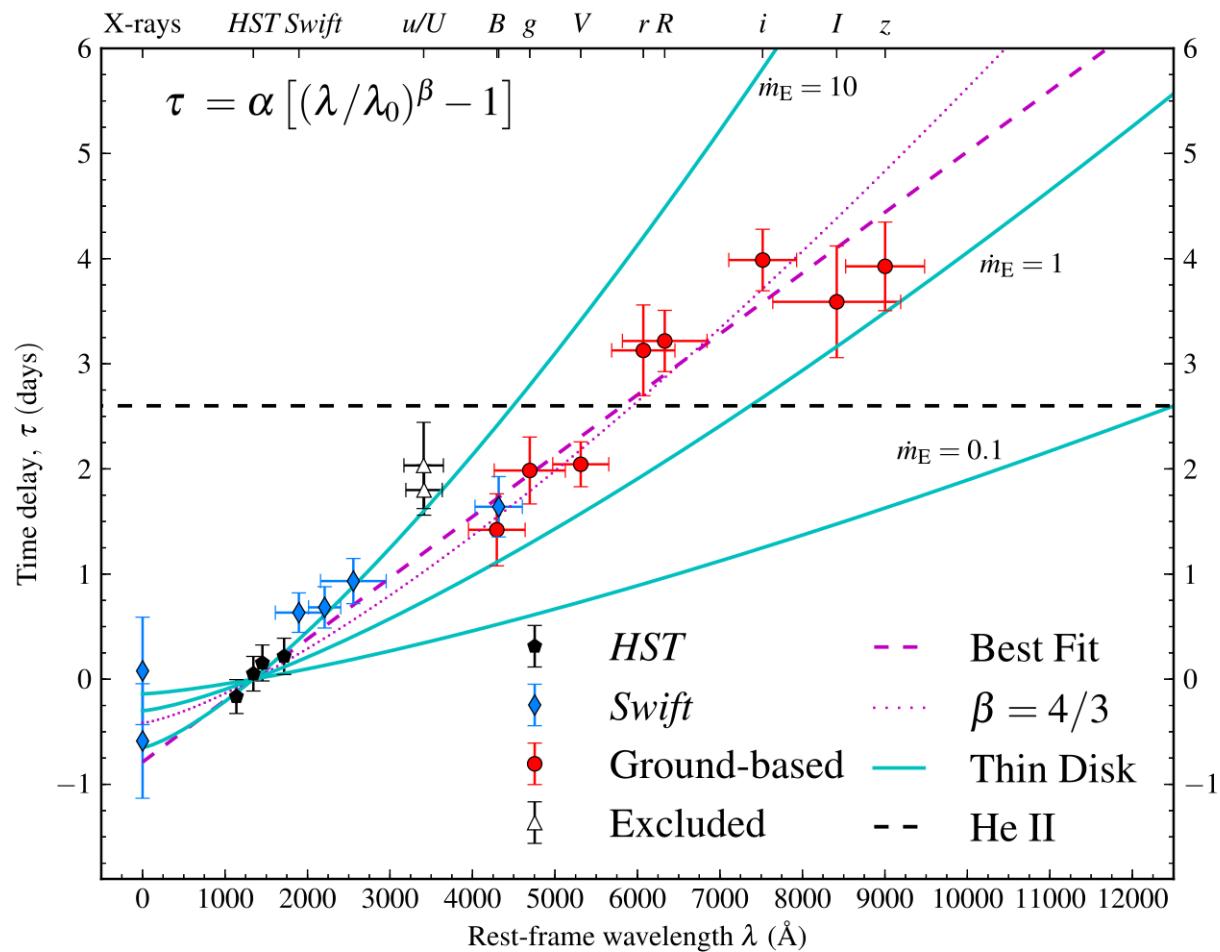
Vaughan+ 16



- Quasar variability as a test of accretion disk physics



- Quasar variability as a test of accretion disk physics



- Different wavebands are correlated
- Time delays of several days
- Comparable to light-travel time?

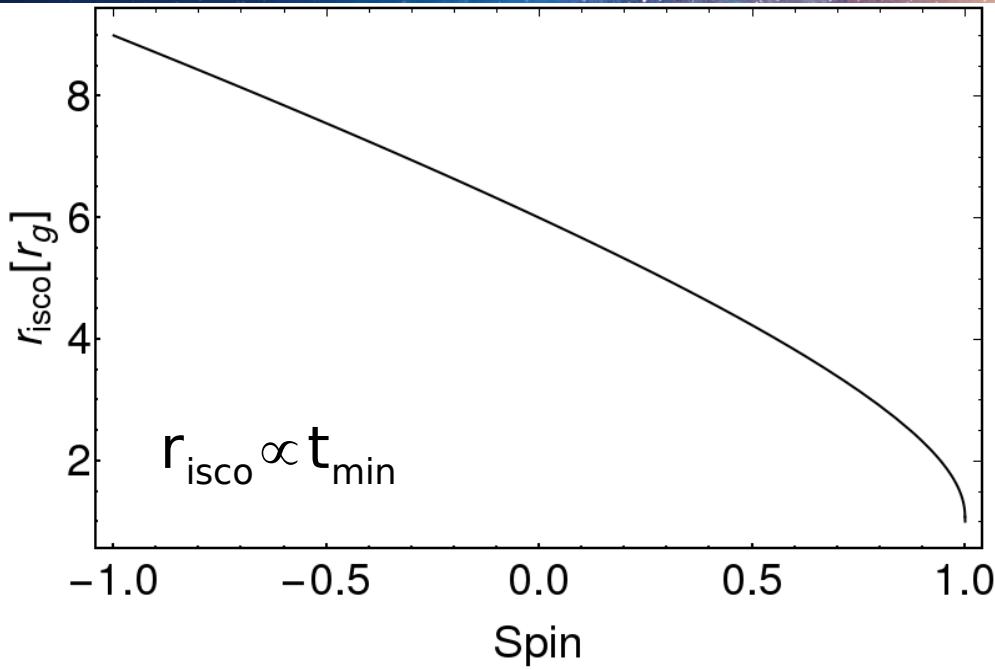
Fausnaugh+ 16

- Quasar variability as a method to measure spin



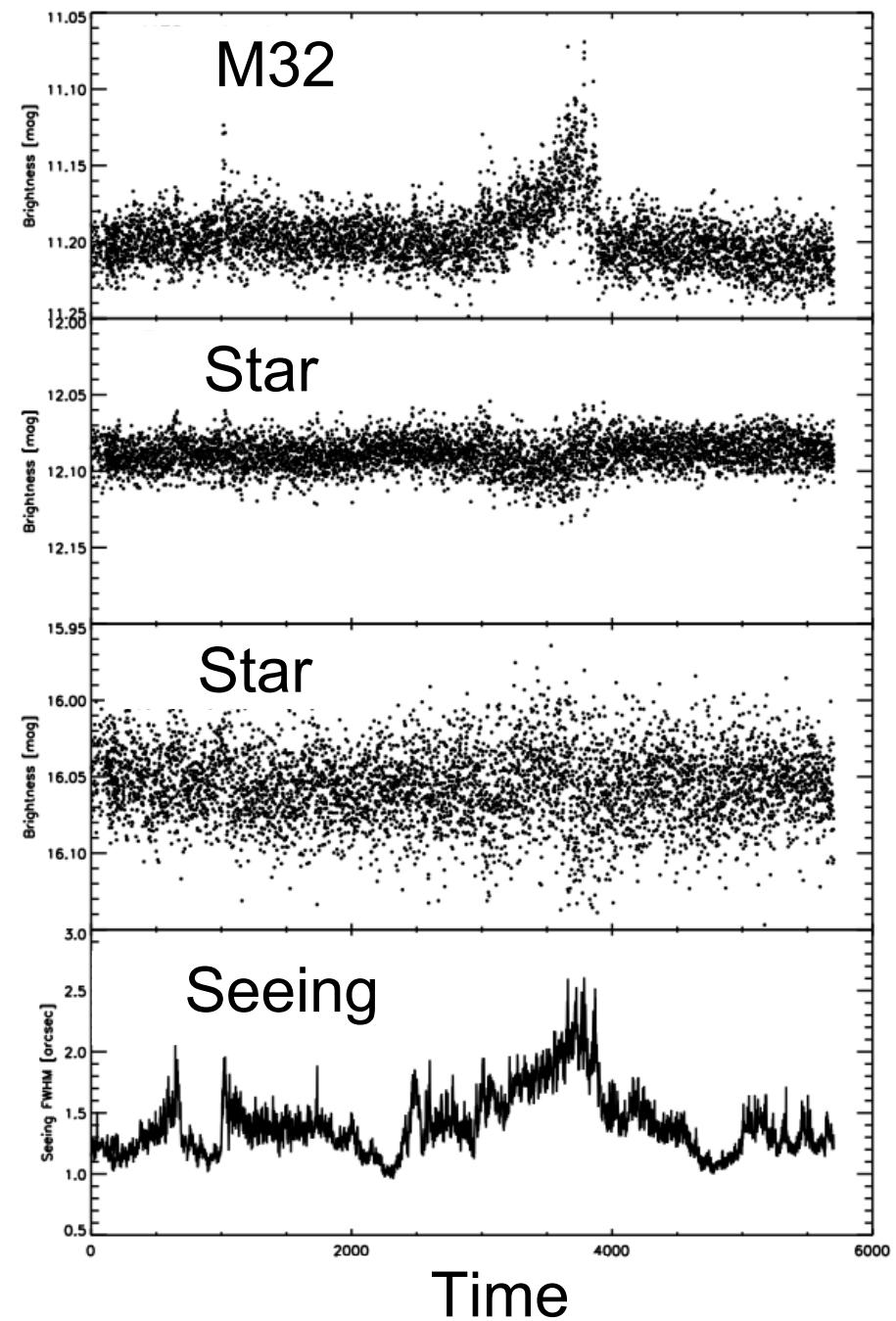
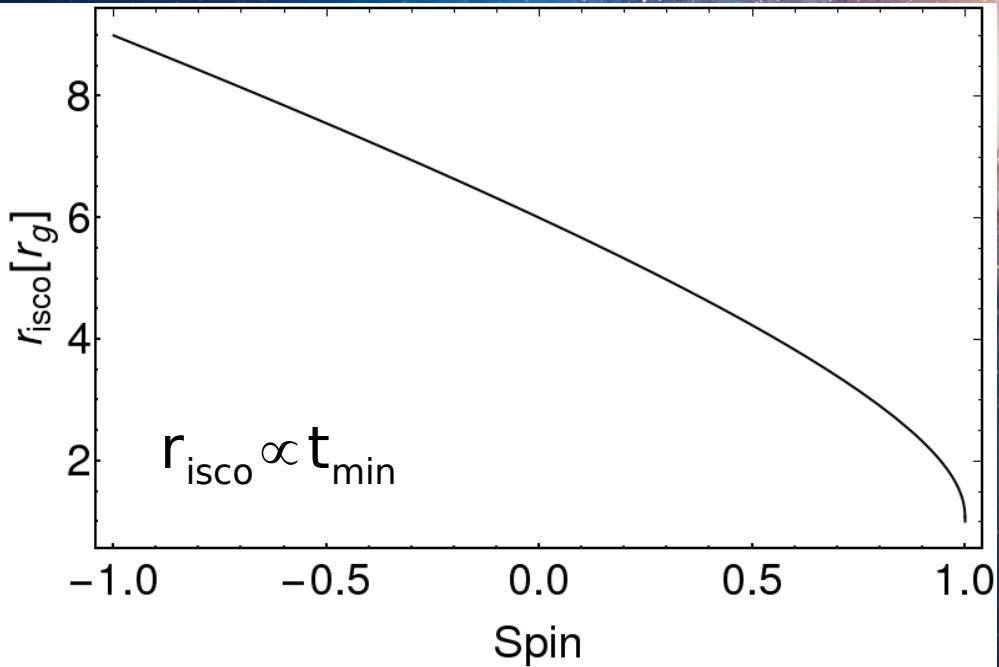
- Quasar variability as a method to measure spin

Measure the shortest time-scale of variability; connected with radius of last stable orbit

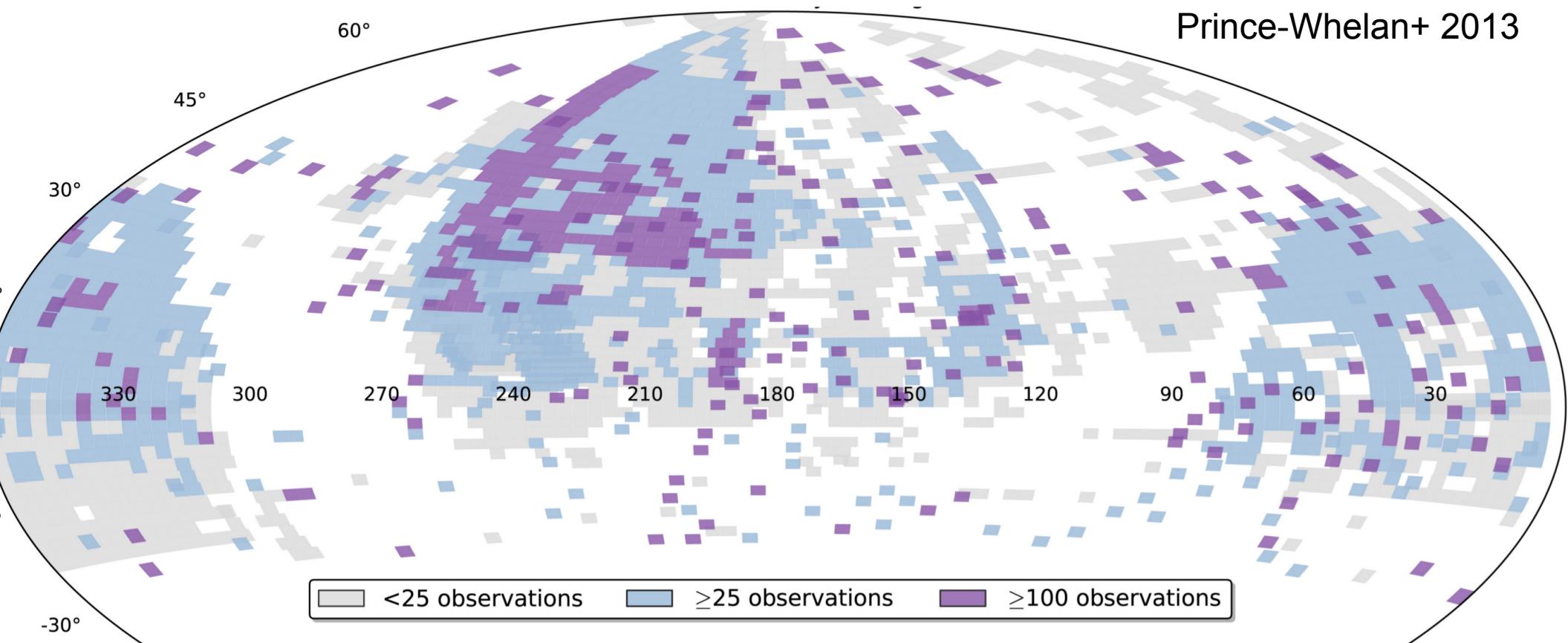


- Quasar variability as a method to measure spin

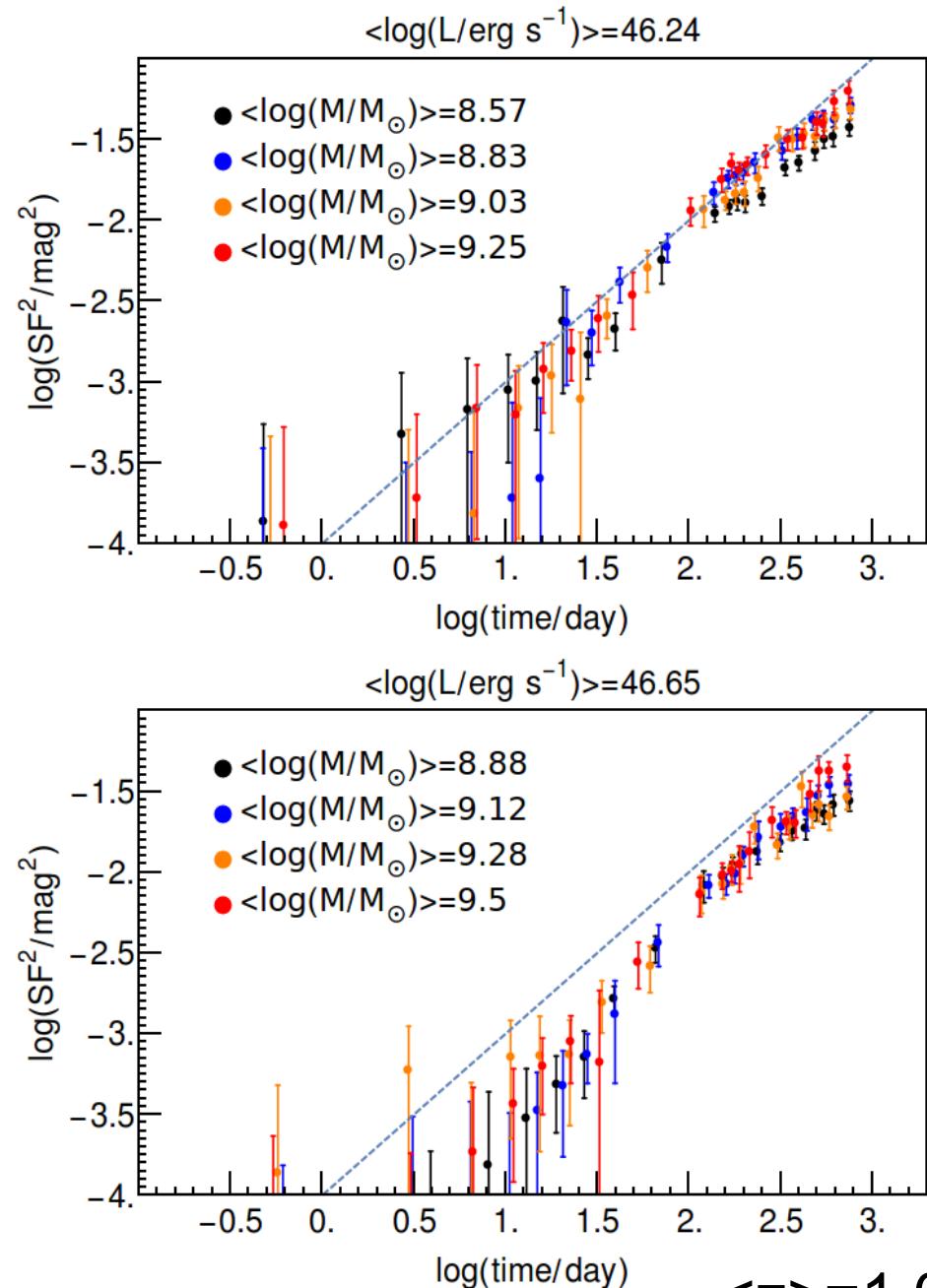
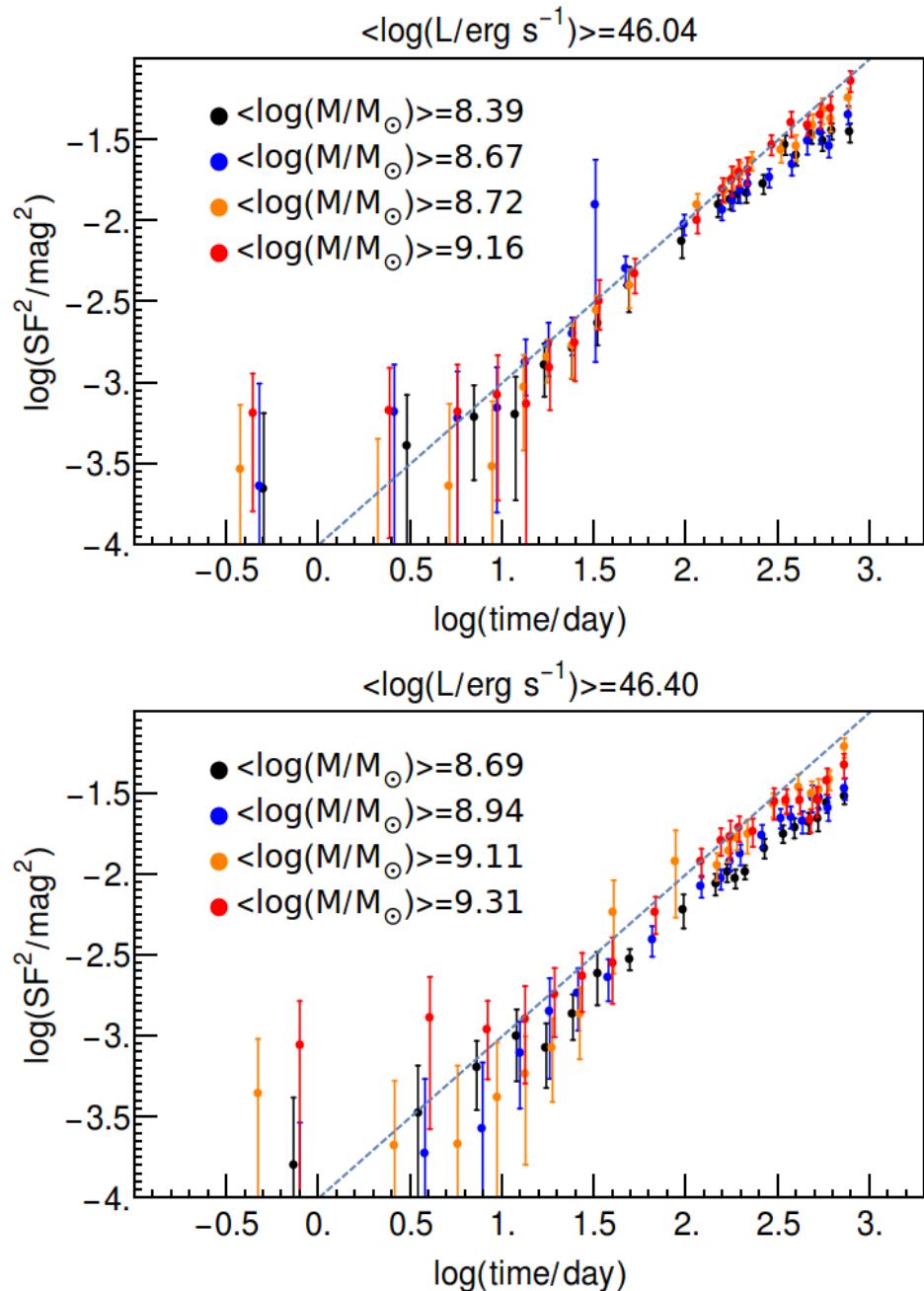
Measure the shortest time-scale of variability; connected with radius of last stable orbit



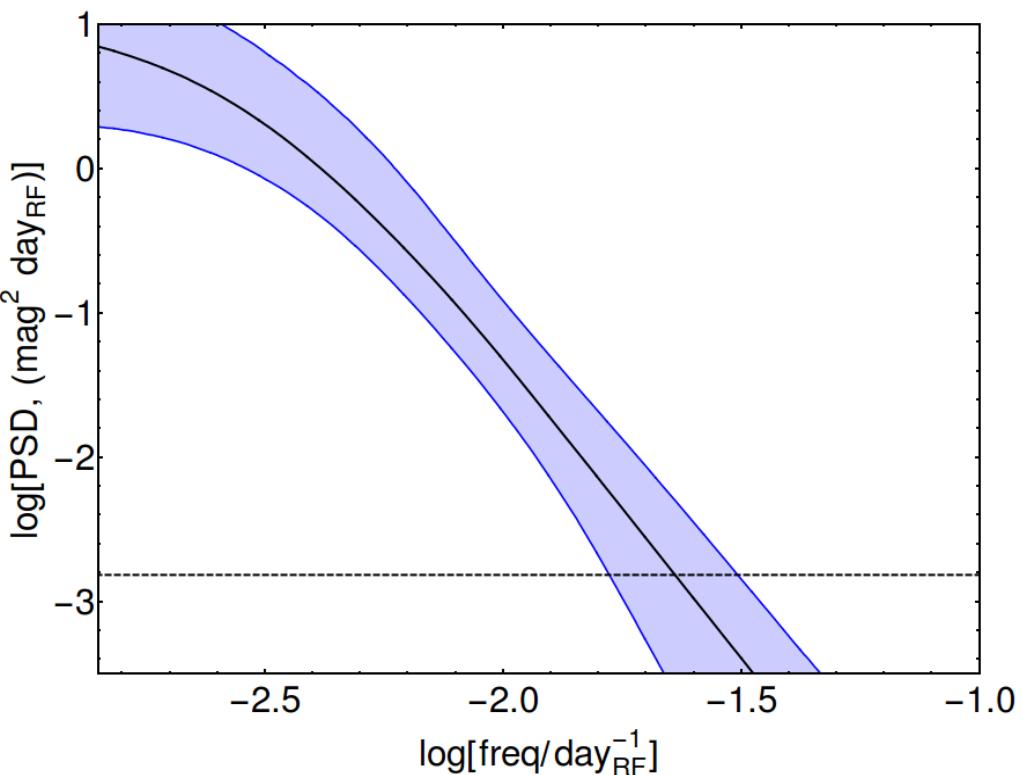
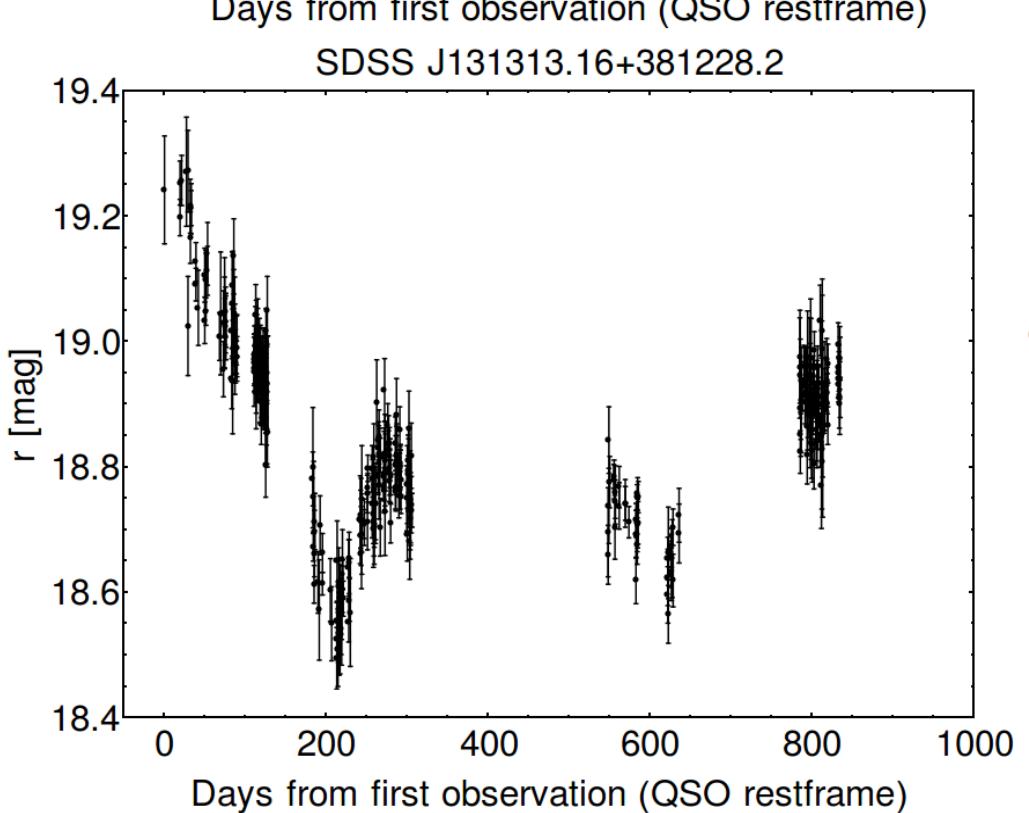
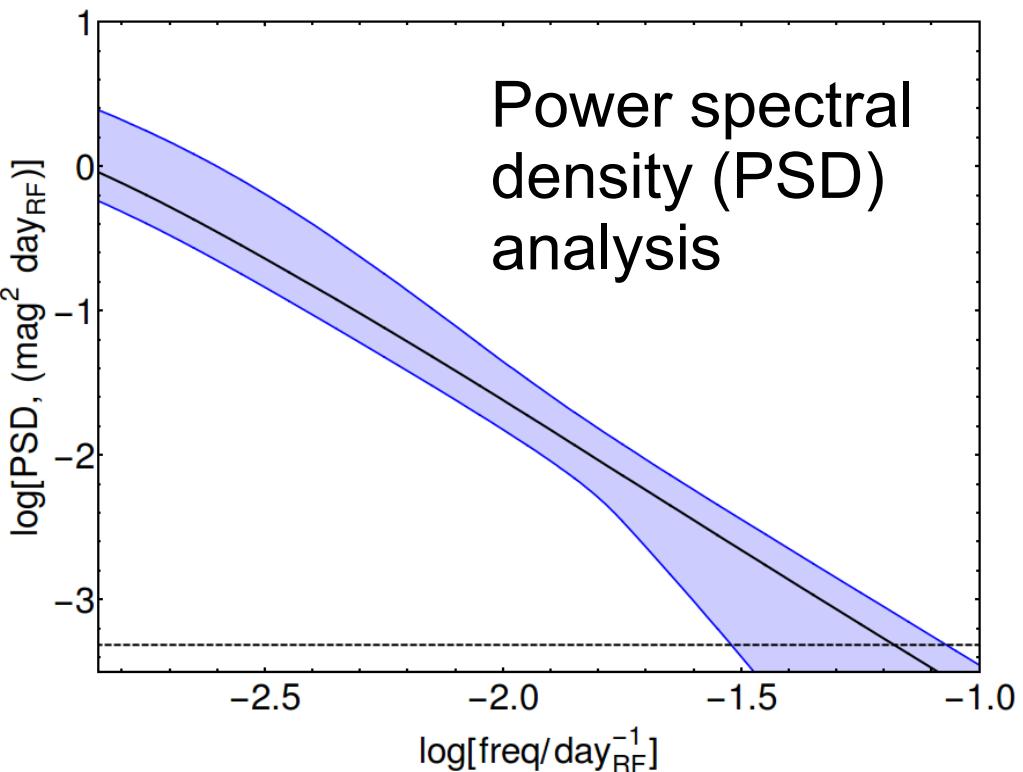
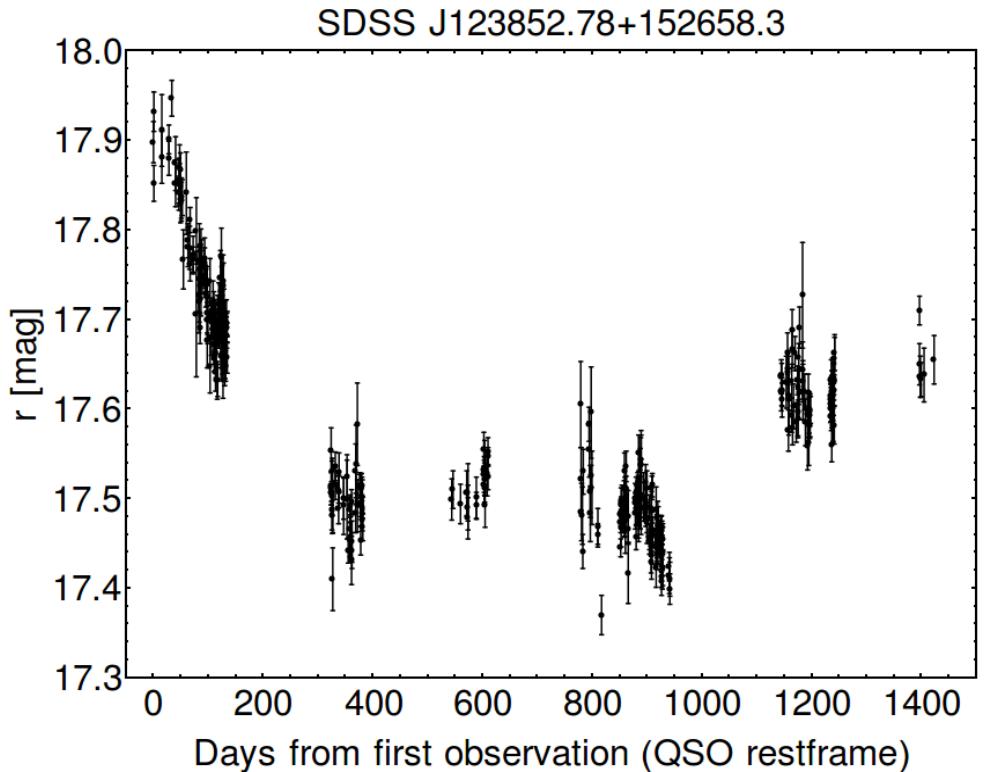
- 1.5 m telescope on Mount Palomar in south California
- Transient sky survey started in March 2009
- Data mostly in r band (centered at 6580 Å)
- 28000 AGNs brighter than $r=19.1$
- 2.4 million data points = largest calibrated single band dataset!

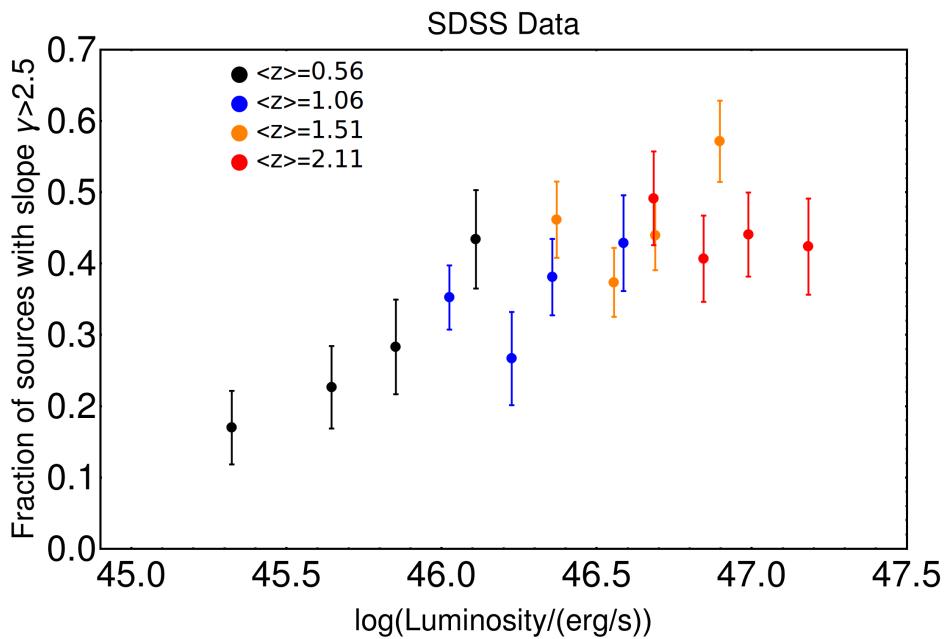
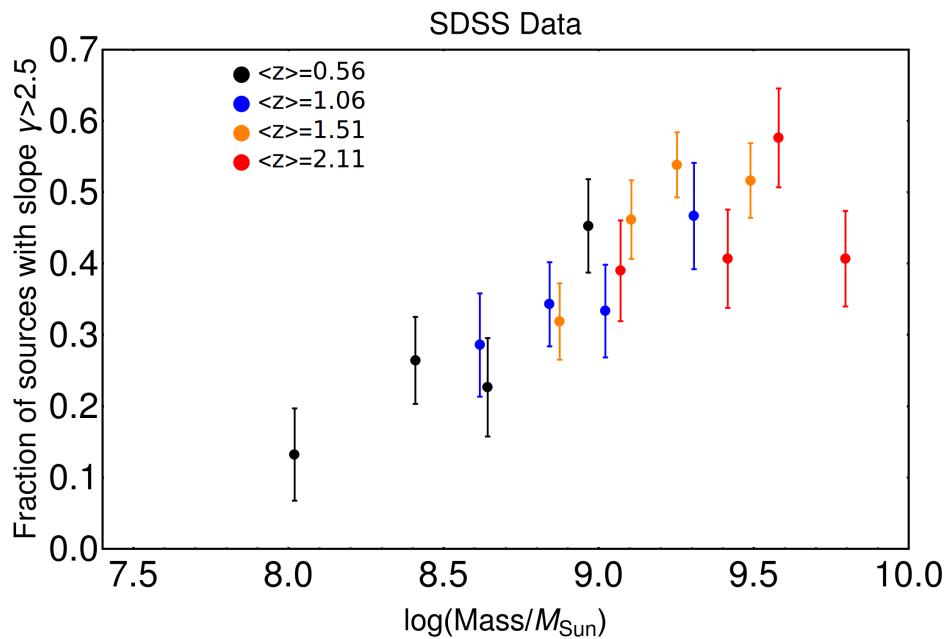
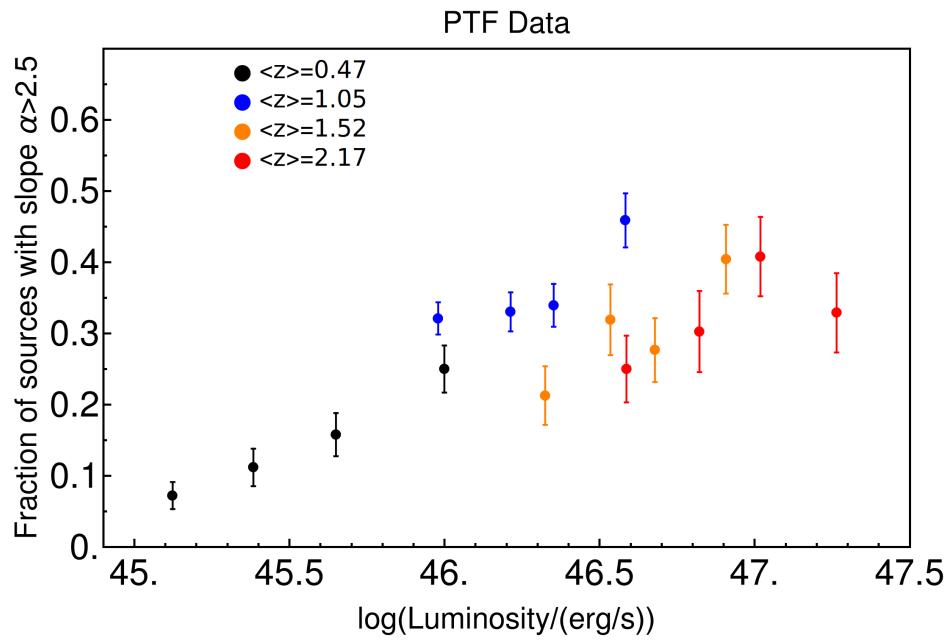
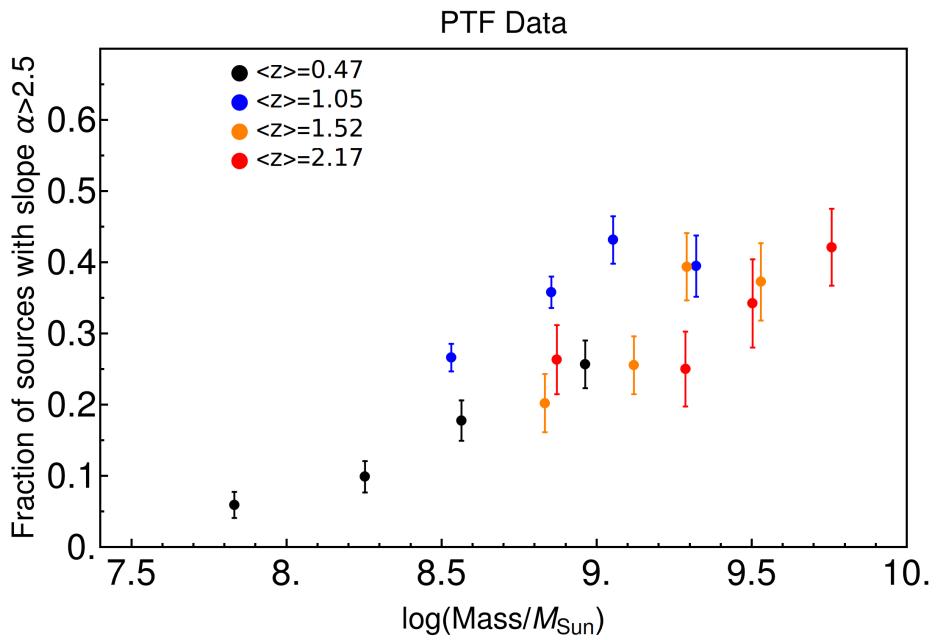


Variance of magnitude difference as a function of time lag between measurements

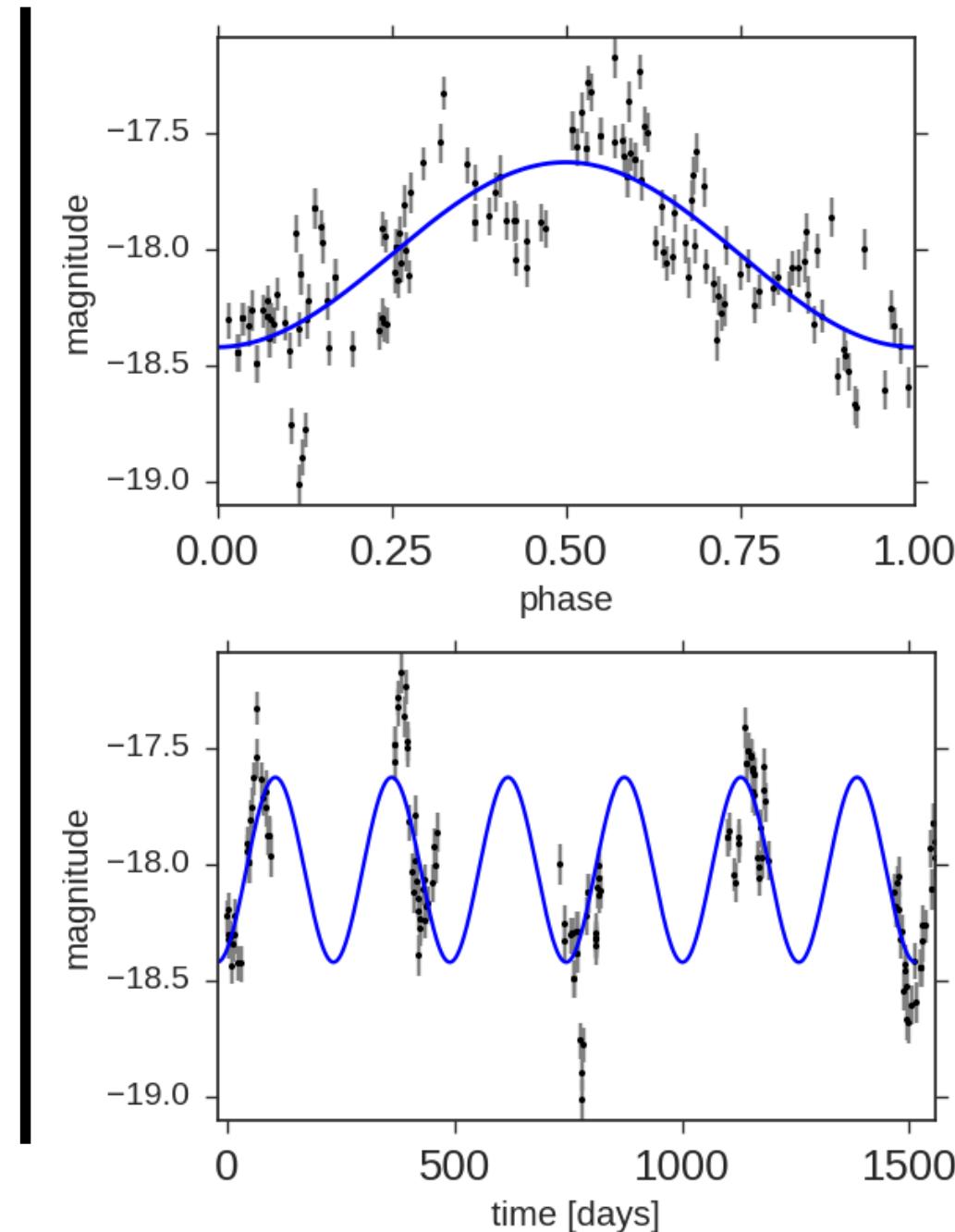
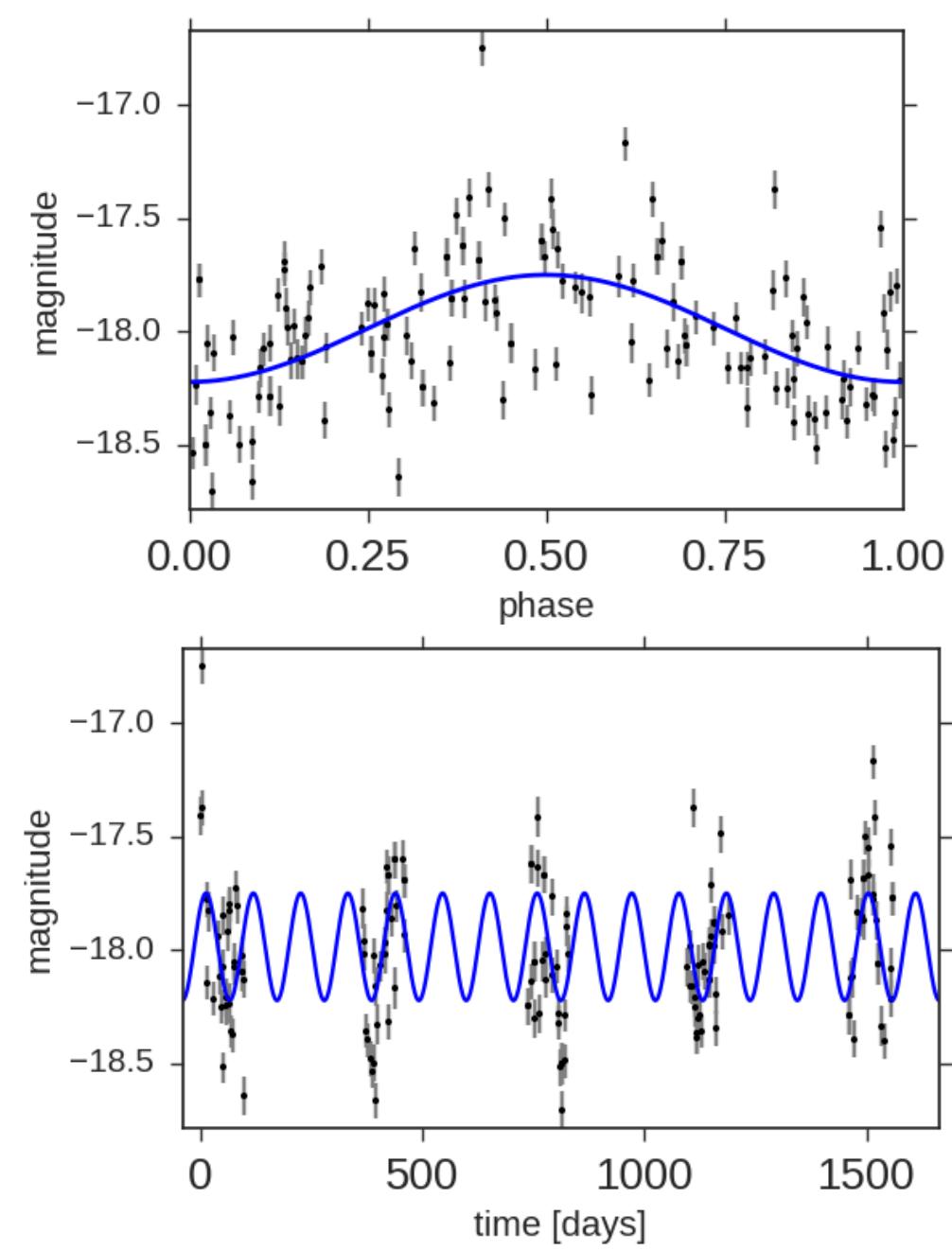


$\langle z \rangle = 1.05$



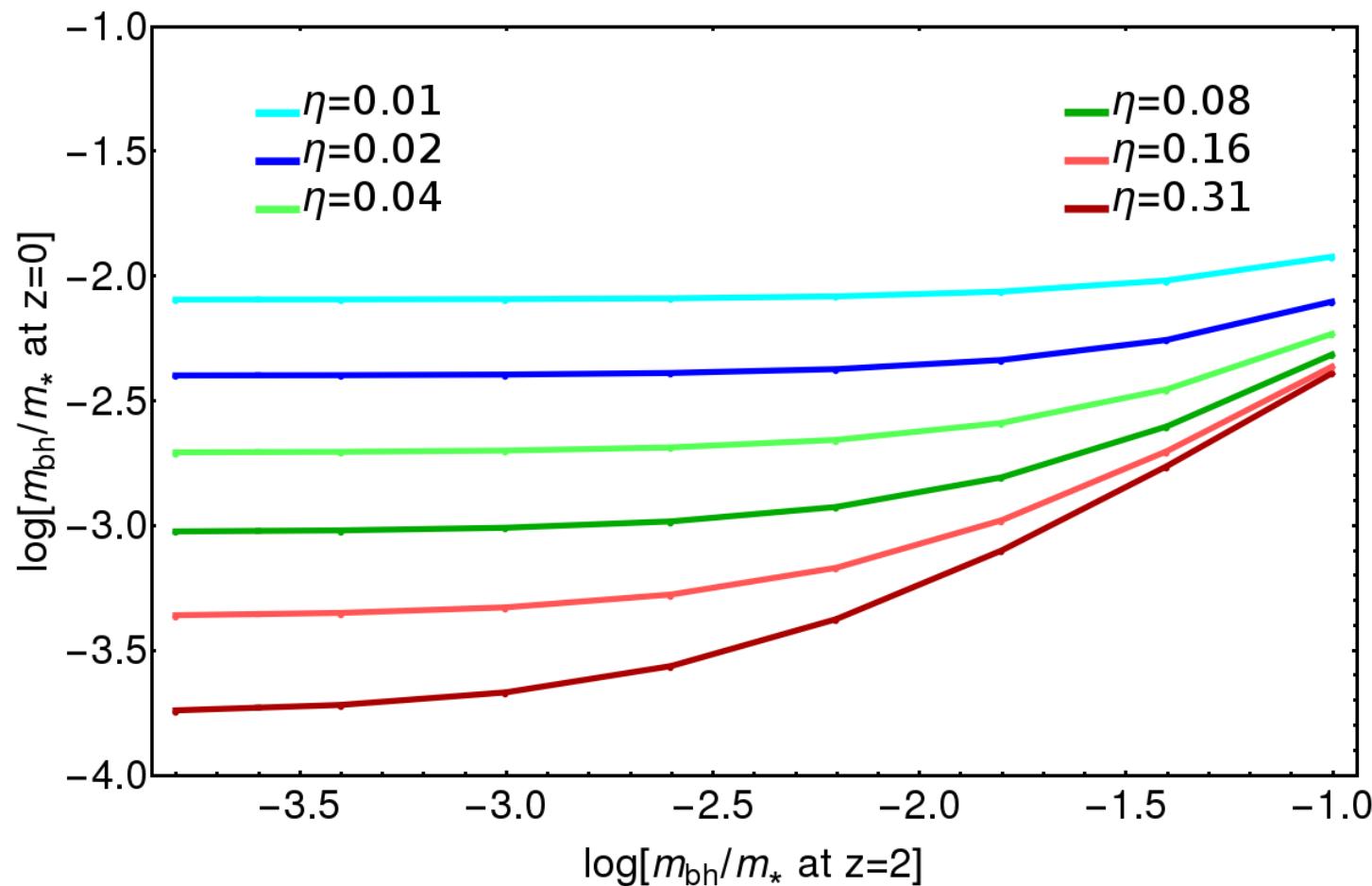


I. Quantify influence of the PSD effect on AGN periods

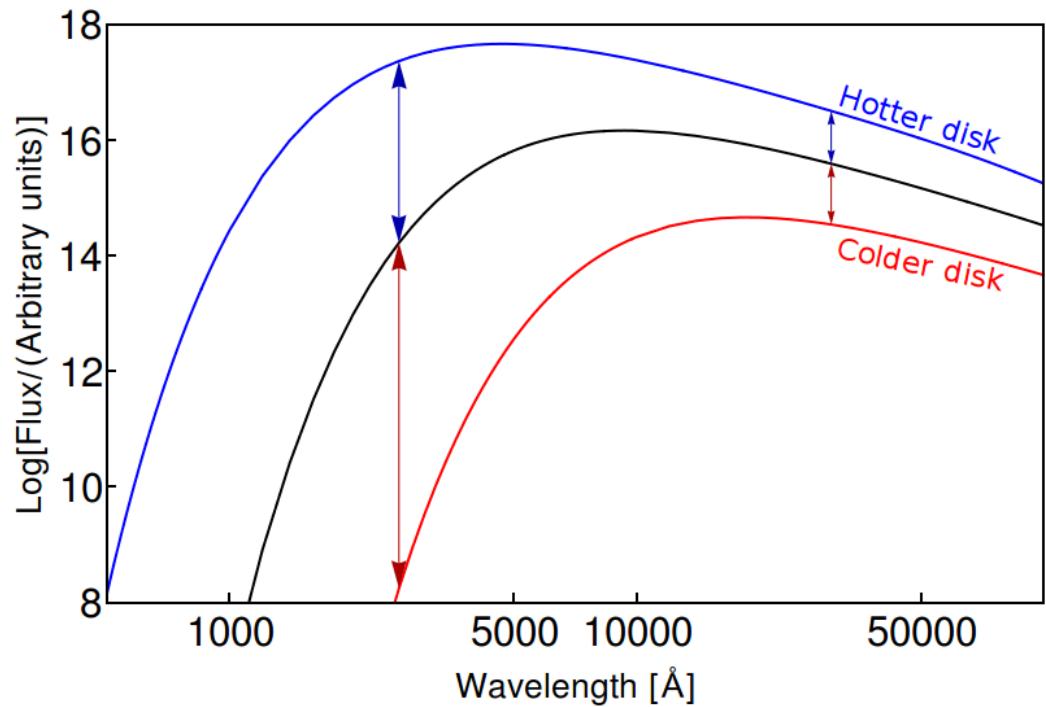
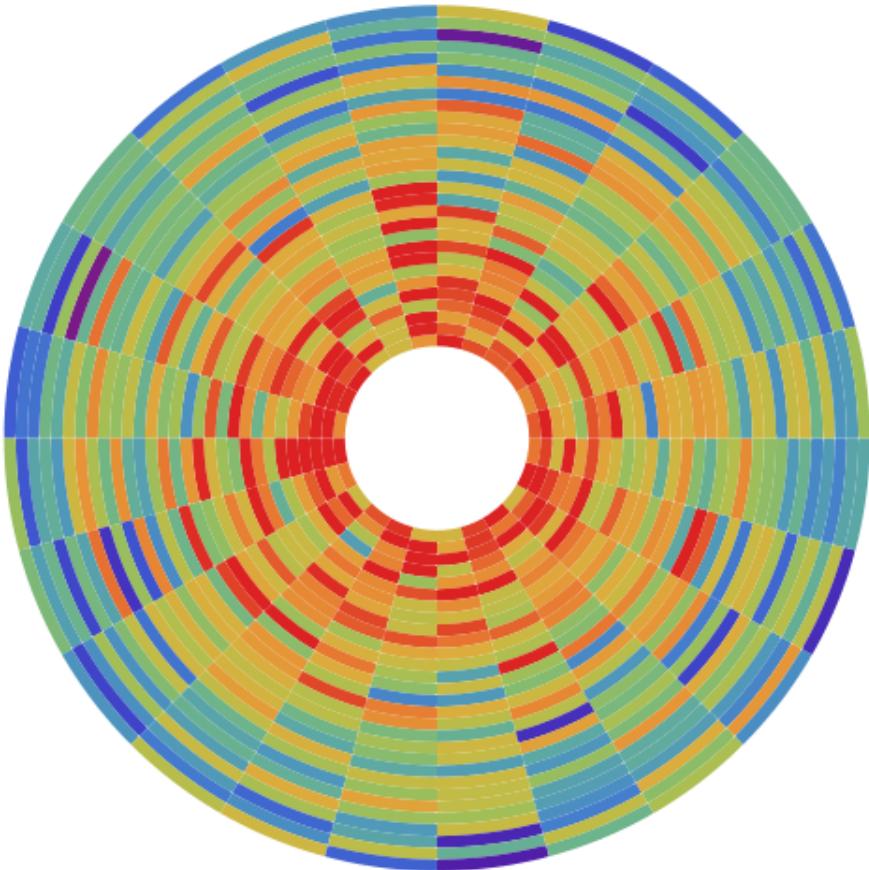


II. Constrain spin from variability

- Accretion efficiency is dependent on the AGN spin
 - Considerable effect on the black hole-galaxy co-evolution
- AGN spins are observationally poorly constrained

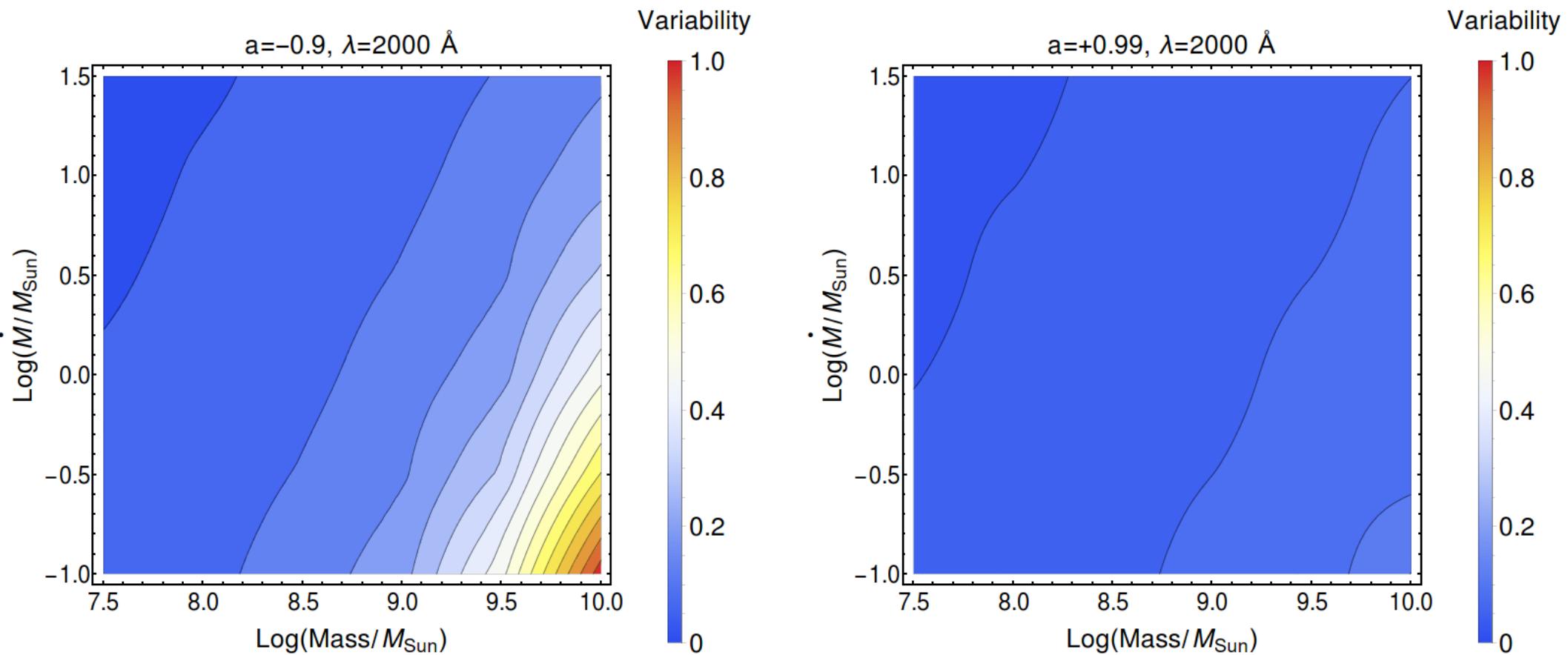


II. Constrain spin from variability



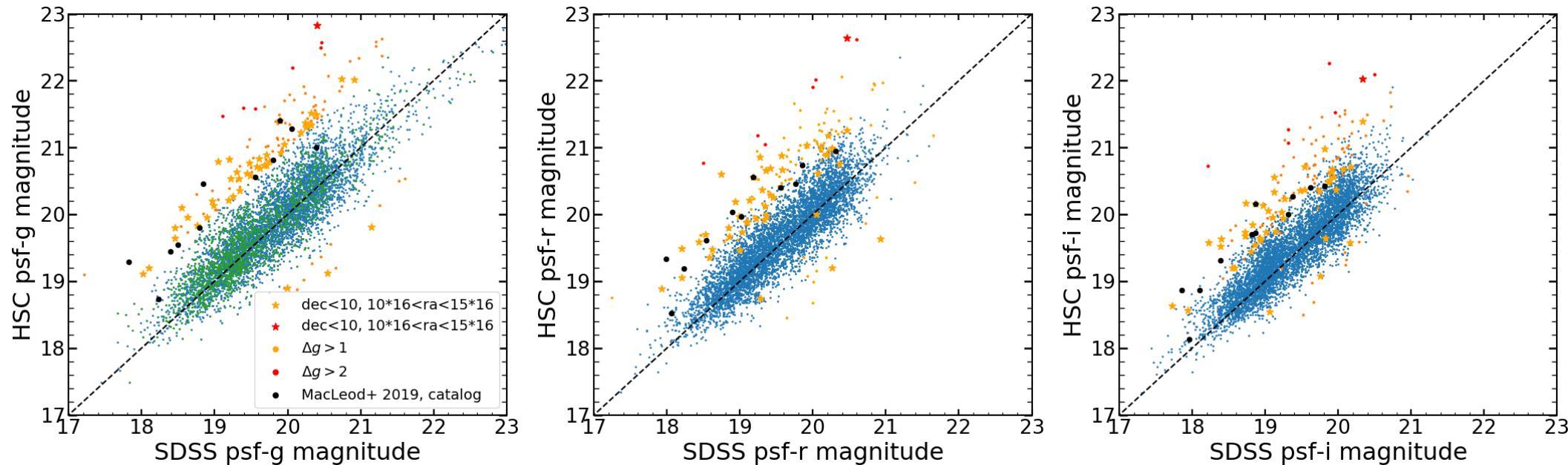
- Optical variability as a consequence of temeperature variations in the disk (Dexter & Agol, 2011)
- Temperature: $T(r) \propto \Delta M^{1/4} M^{-1/2} f(r)^{3/4} (r/r_g)^{-3/4}$
 - Temperature correlated with spin (f parameter in equation above)

II. Constrain spin from variability



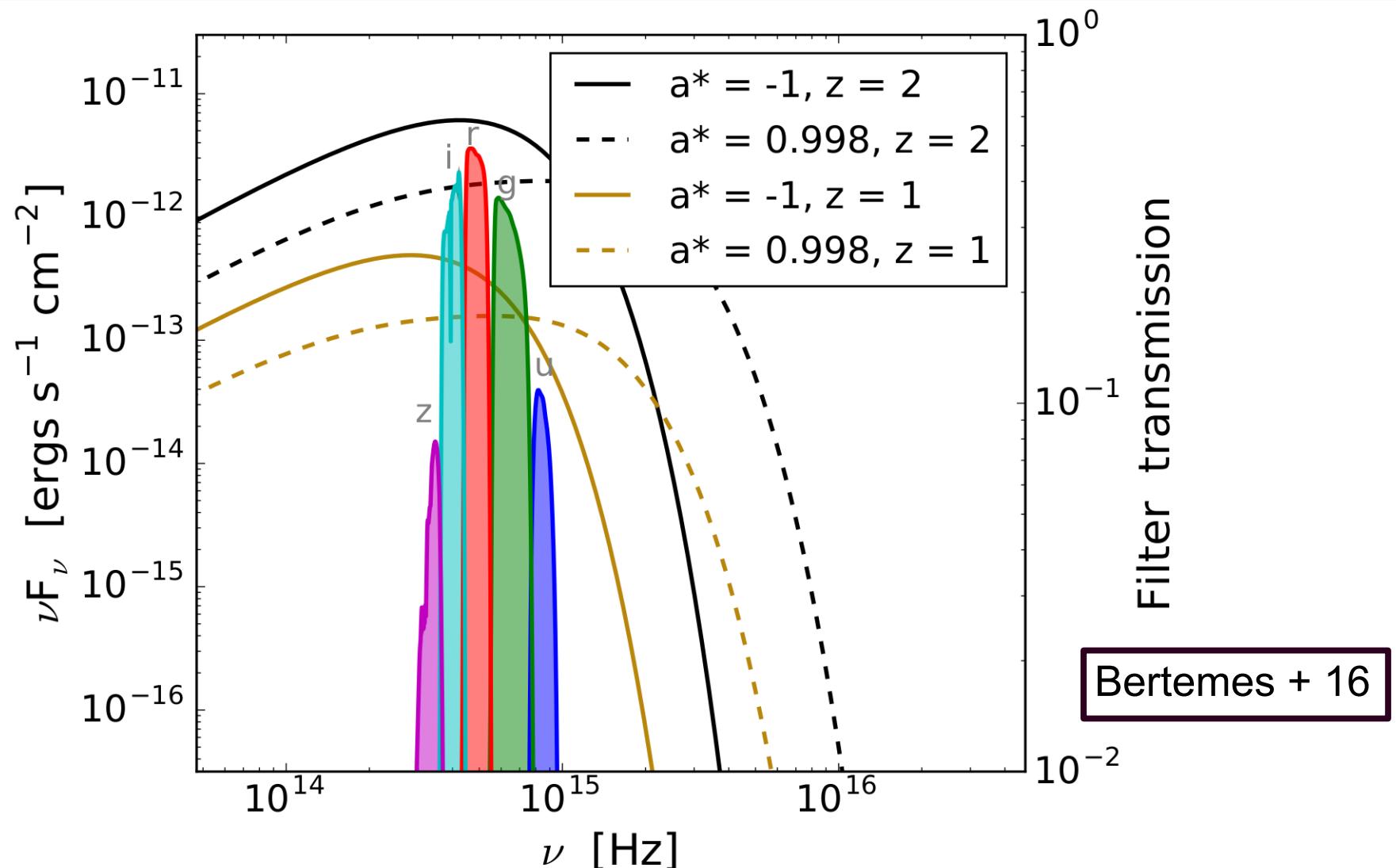
- Temperature: $T(r) \propto \Delta M^{1/4} M^{-1/2} f(r)^{3/4} (r/r_g)^{-3/4}$
 - Temperature correlated with spin (f parameter in equation above)

III. Changing look AGN in Hyper-Suprime Cam

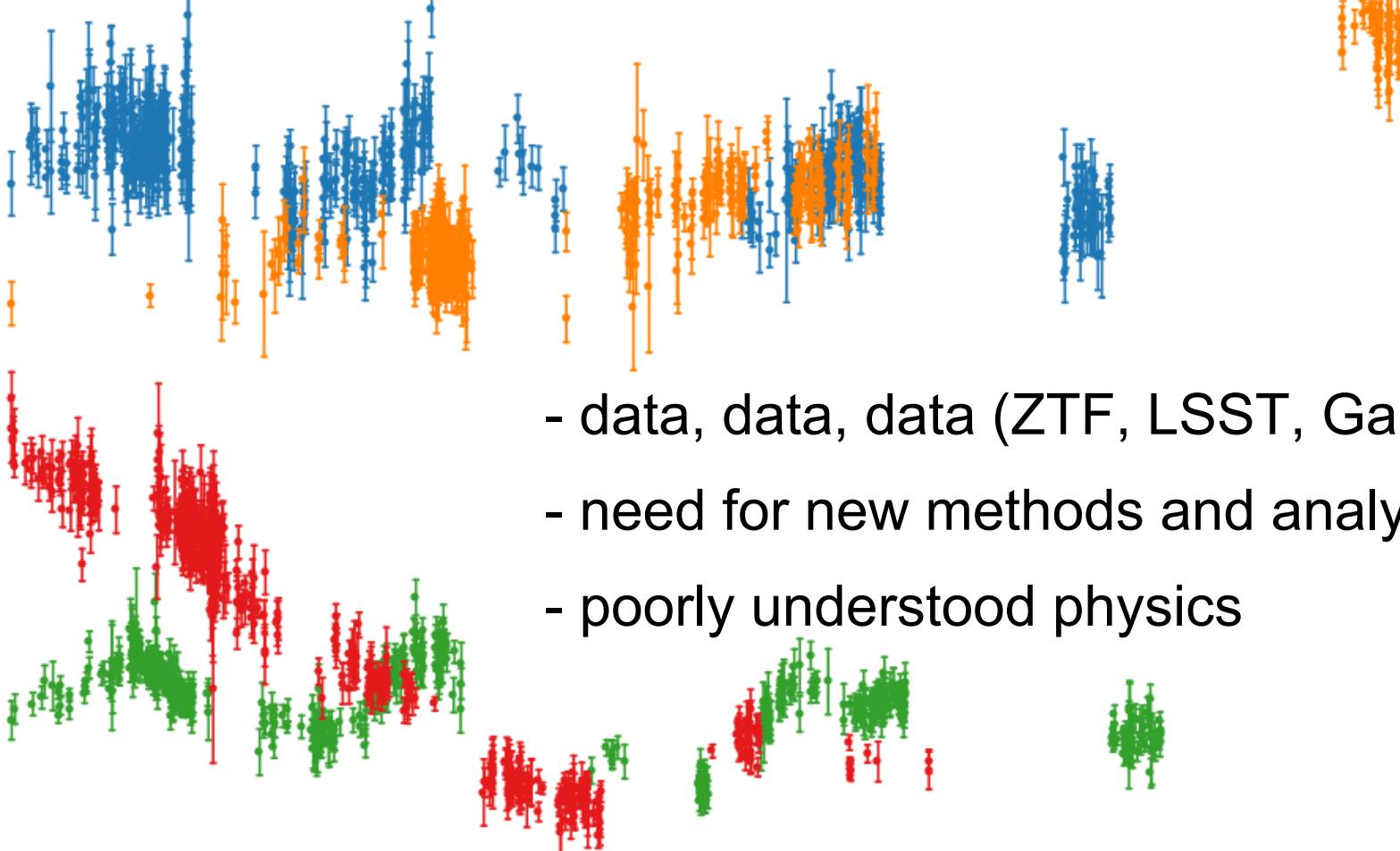


- AGN that exhibit extreme variability - changing look candidates
- Sean is taking data on Magellan tomorrow, Jenny, Andy and company are also interested... Renyue interested in physical explanation!
- There are also deep-drilling fields (COSMOS)

IV. Select extraordinary AGN with variability



- No obvious reason that variability would be suppressed or different!
- Study large number of objects – high risk, high reward!



- data, data, data (ZTF, LSST, Gaia...)
- need for new methods and analysis
- poorly understood physics

- I. Quantify influence of the PSD effect on AGN periods
- II. Constrain spin from variability
- III. Changing look AGN in Hyper-suprime Cam
- IV. Select extraordinary AGN with variability