Quasar Variability
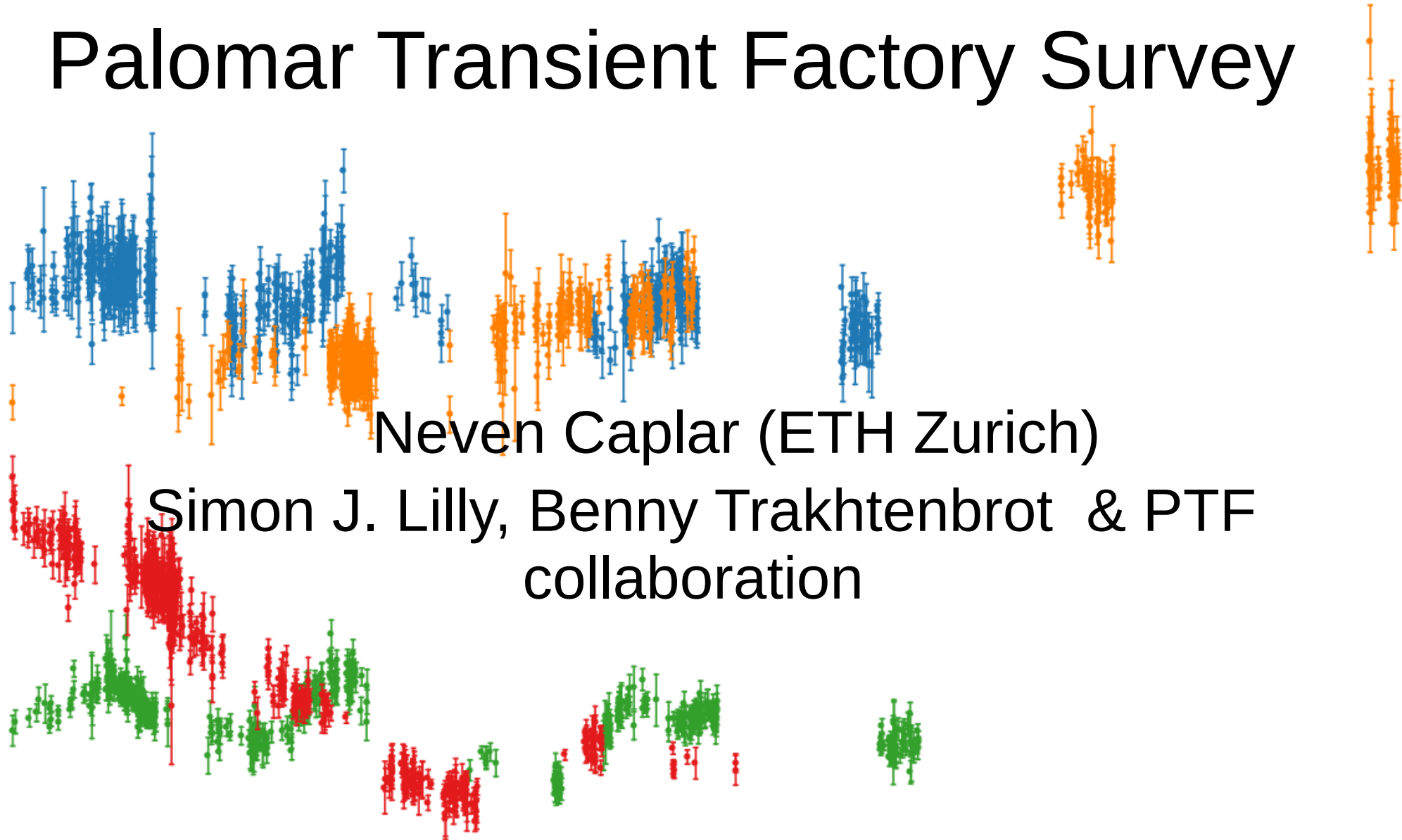# in the
Palomar Transient Factory Survey

Neven Caplar (ETH Zurich)

Simon J. Lilly, Benny Trakhtenbrot & PTF collaboration
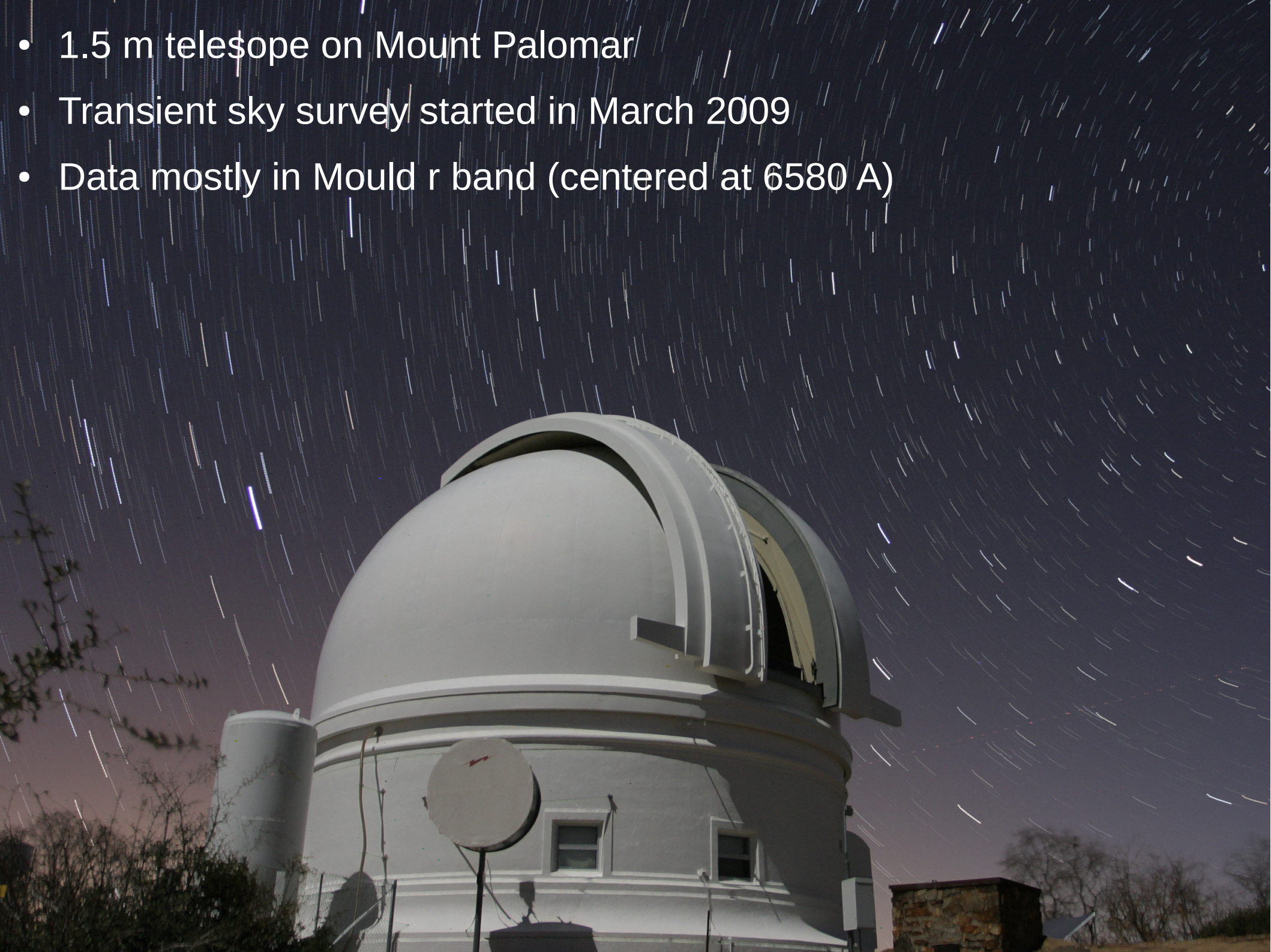
- 1.5 m telesope on Mount Palomar
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Prince-Whelan+ 2013
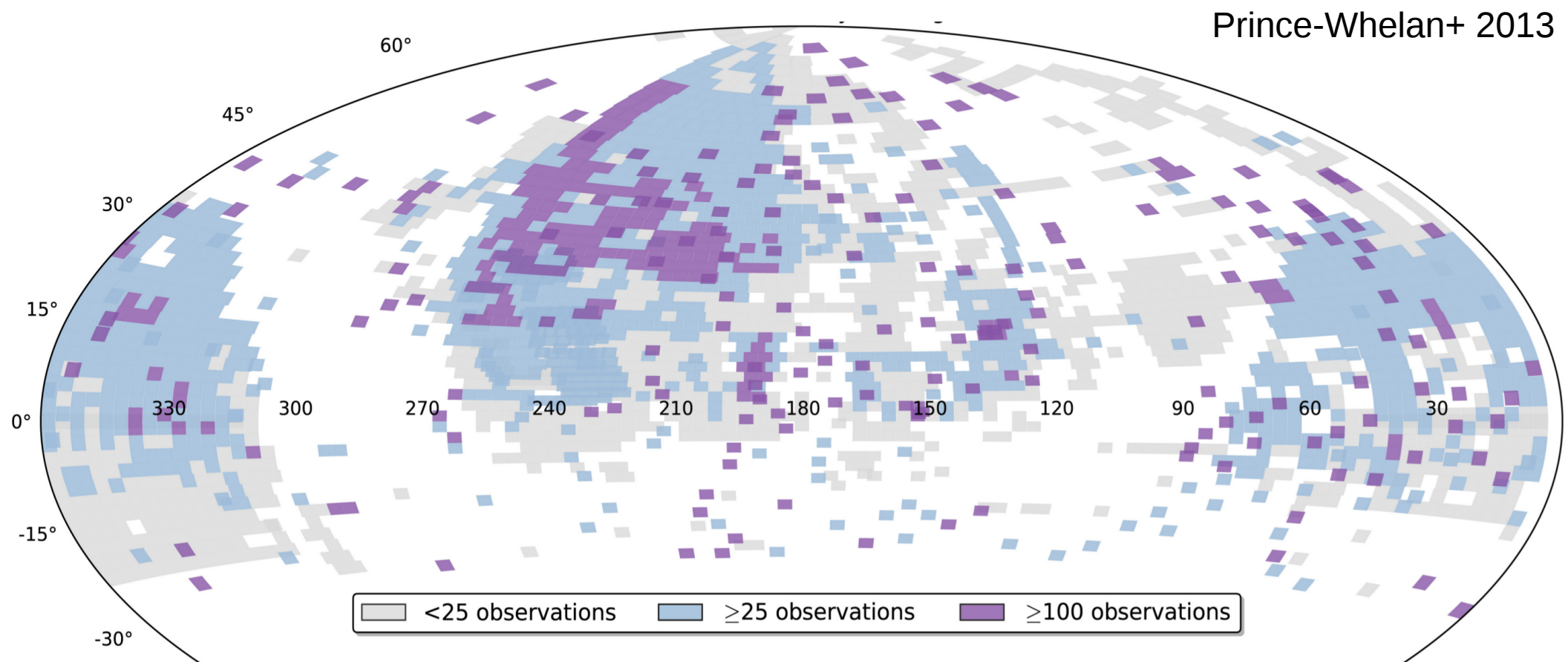
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- Data mostly in Mould r band (centered at 6580 A)

- 25500 AGNs brighter than r=19.1 with more than 10 observations

- 2.2 million data points = largest calibrated single band dataset!
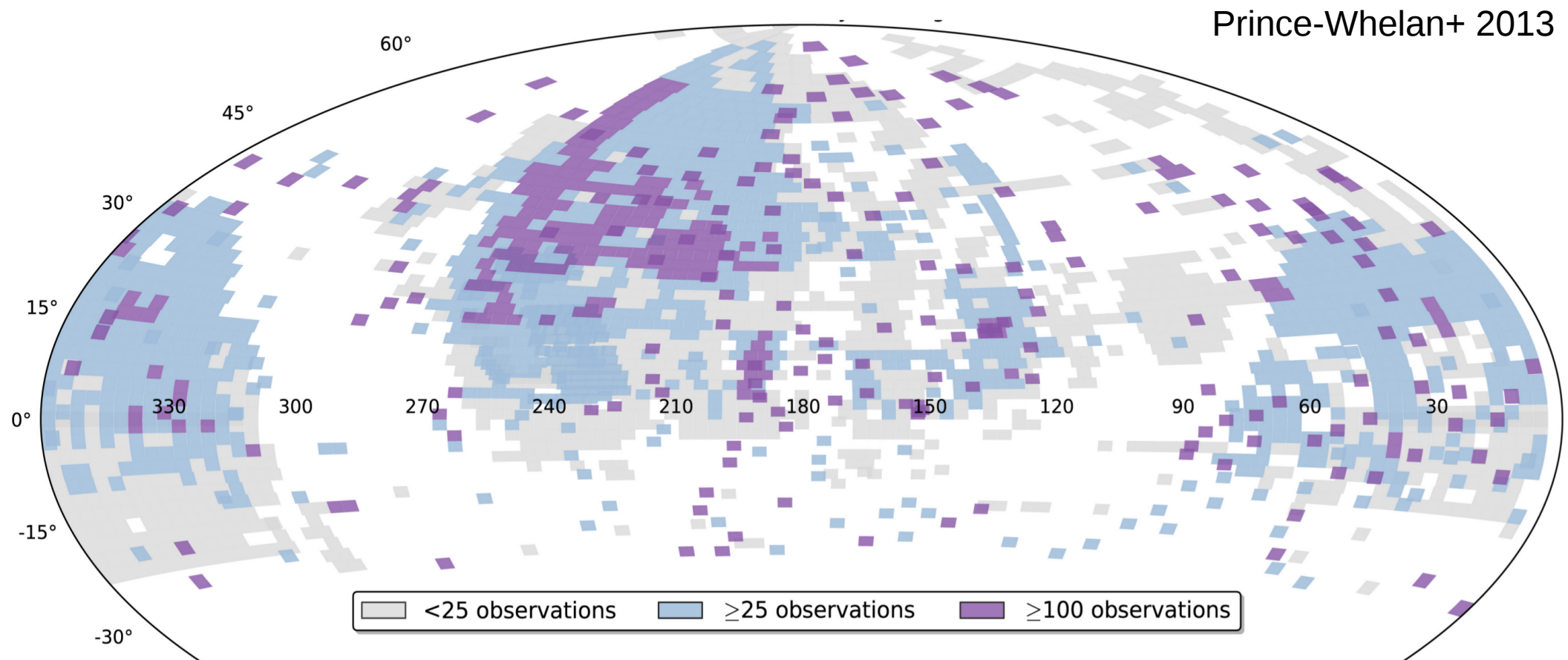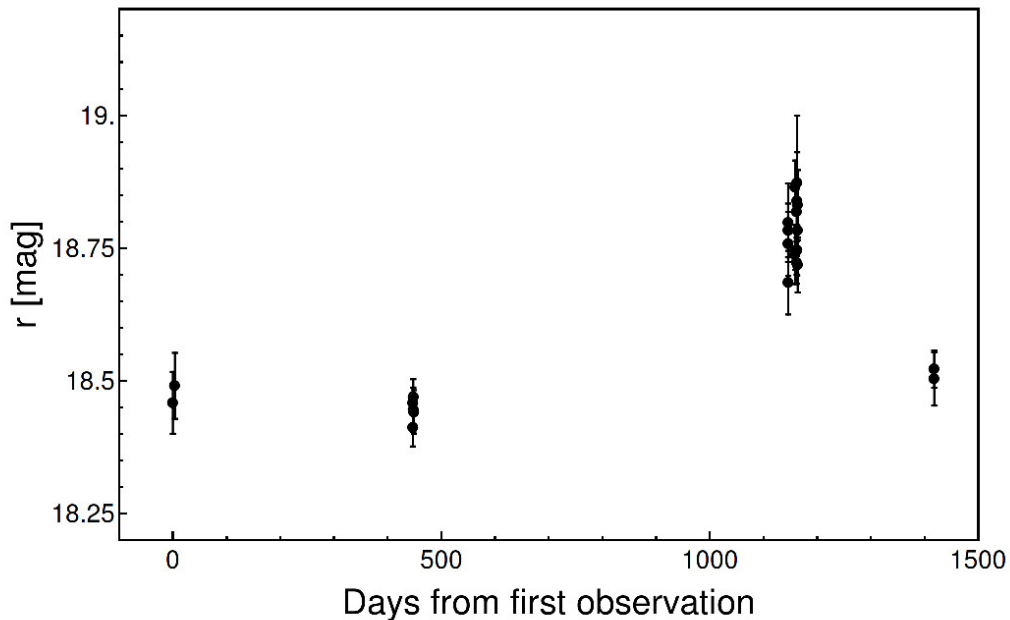
Prince-Whelan+ 2013

Re-calibration of survey

- AGN light-curves were re-calibrated

- We search for zeropoints which minimize the scatter of reference objects (stars)

- We achieve excellent performance; excess variance is consistent with zero for vast majority of AGNs

- Re-calibrated data will be publicly available!

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Calibration from this work — Calibration from Ofek et al. 2012
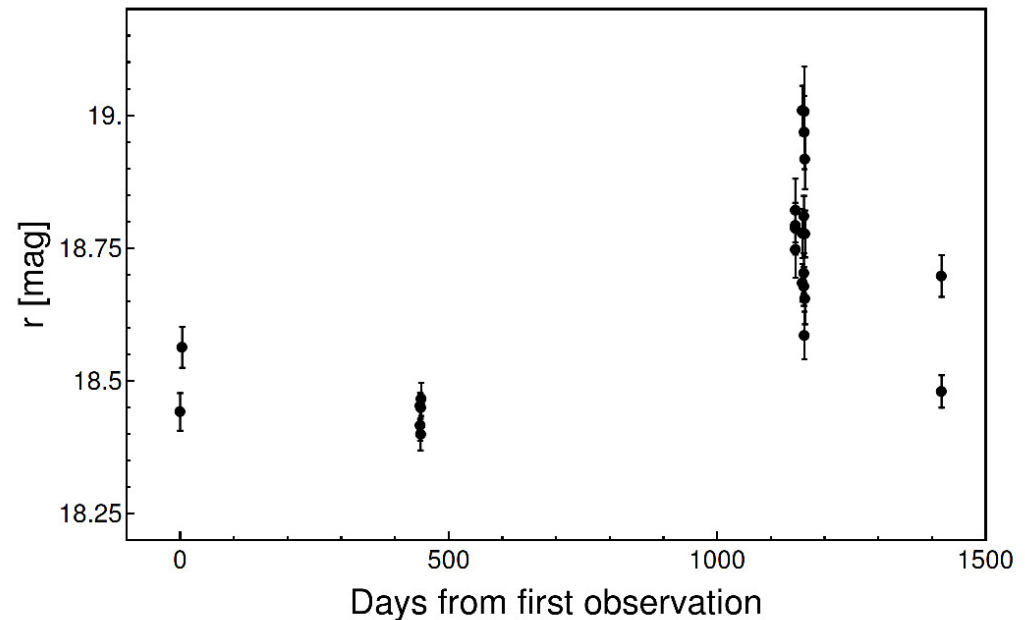
- SF^2 (structure function)^2 analysis
  - Variance of magnitude difference as a function of time lag between measurements
  - We use on ensemble, sample of AGNs with similar physical properties

- Power spectral density (PSD) analysis
  - Variability power per temporal frequency
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  - Used on well sampled, single objects

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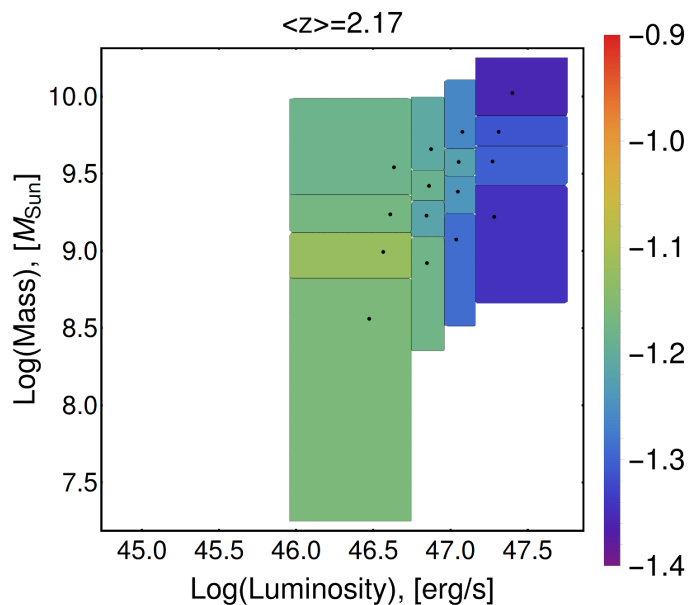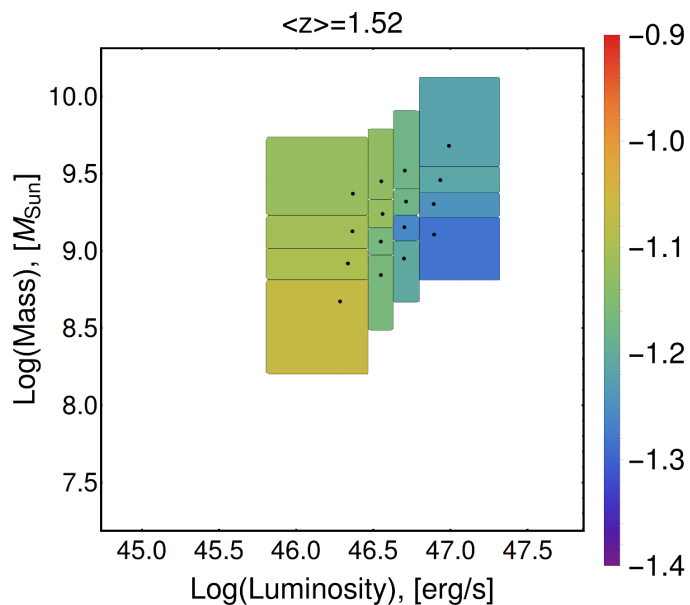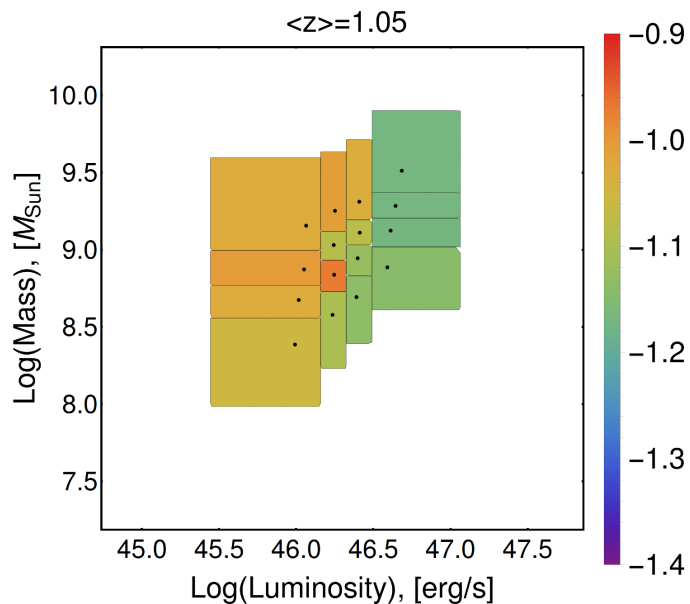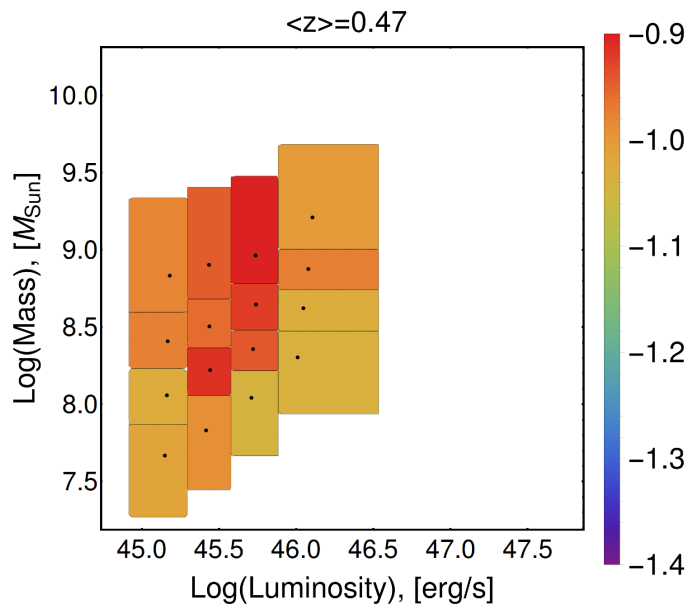- For observational pairs in a single time-bin

$$SF^2 = \left\langle \sum_{i<j} \left(m_i - m_j \right)^2 - err_i^2 - err_j^2 \right\rangle$$

- SF² (structure function)² analysis
  - Variance of magnitude difference as a function of time lag between measurements
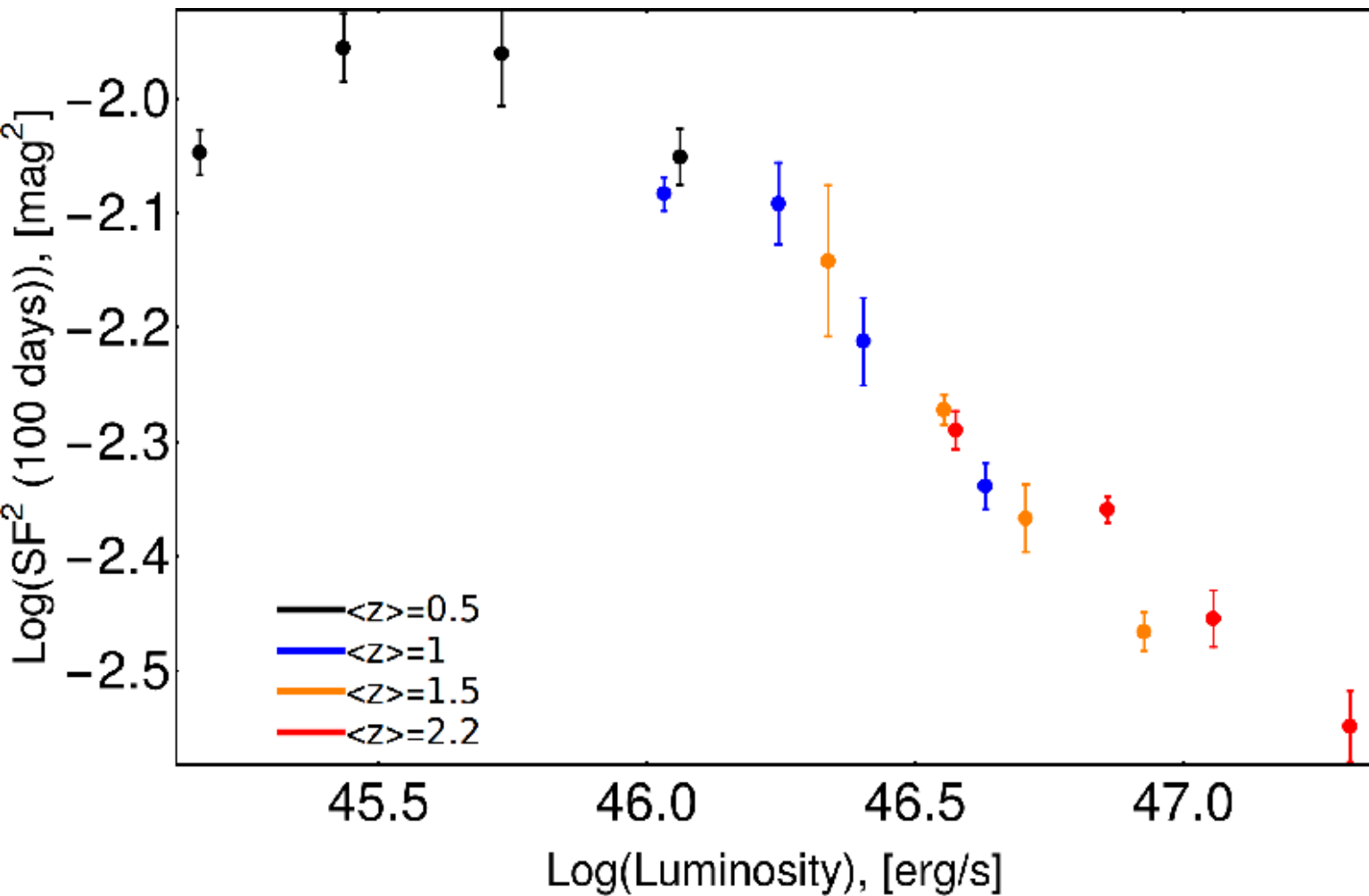 - We use on ensemble, sample of AGNs with similar physical properties
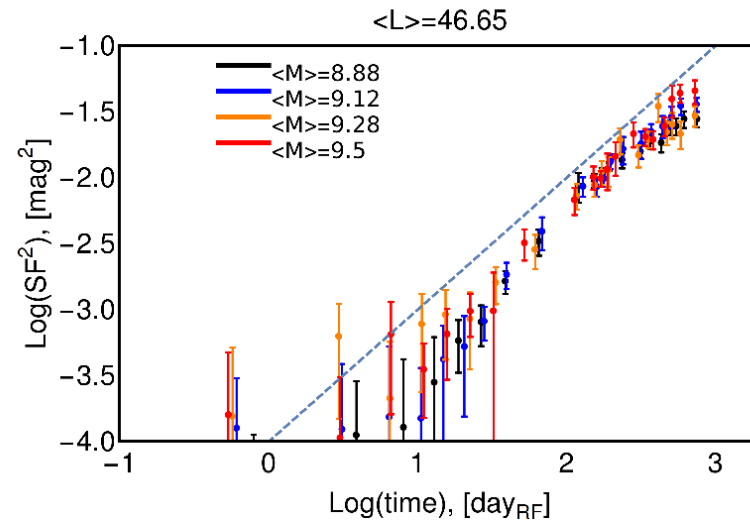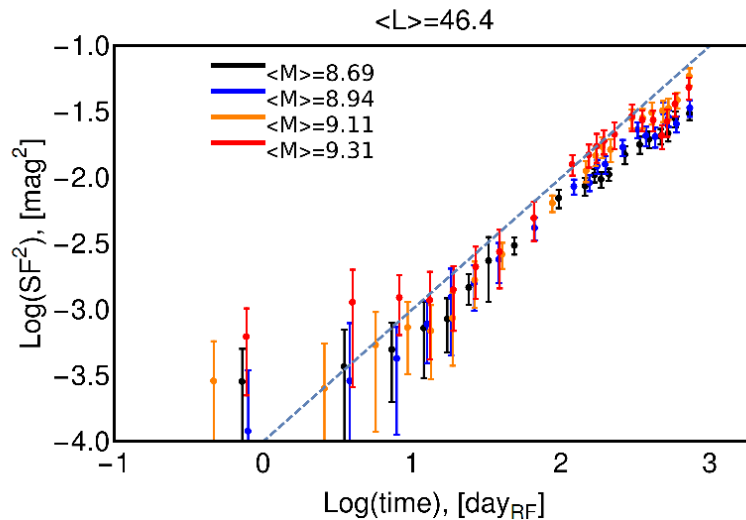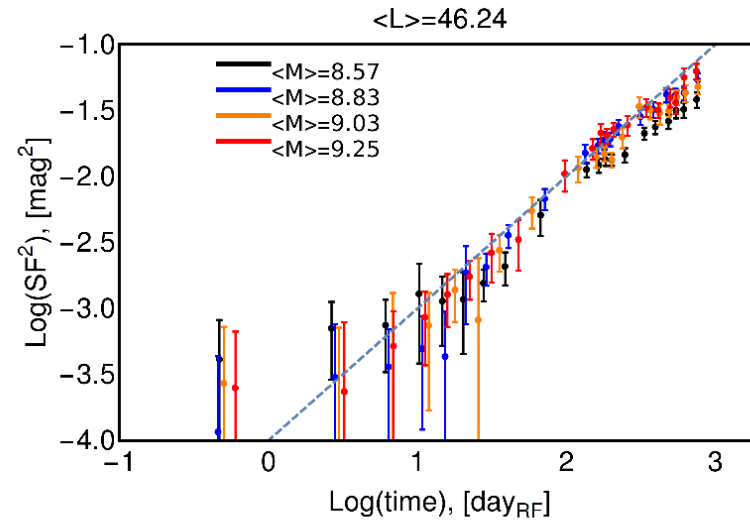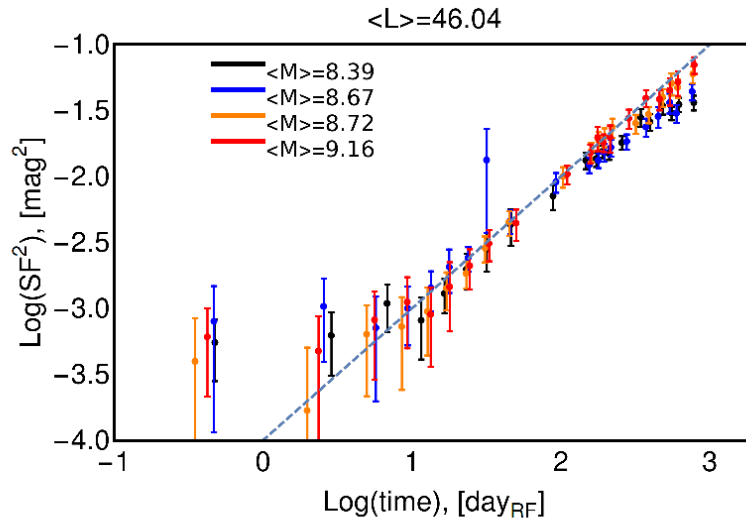

z=1

Log(SF(100 days$_{RF}$)), [mag]

- Wavelength correction estimated from SDSS dataset to normalize to 4000 A

- No correlation with redshift

- Little to no correlation with mass

- Clear dependence with luminosity

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Log[Time_RF] for SF to reach 0.071 mag
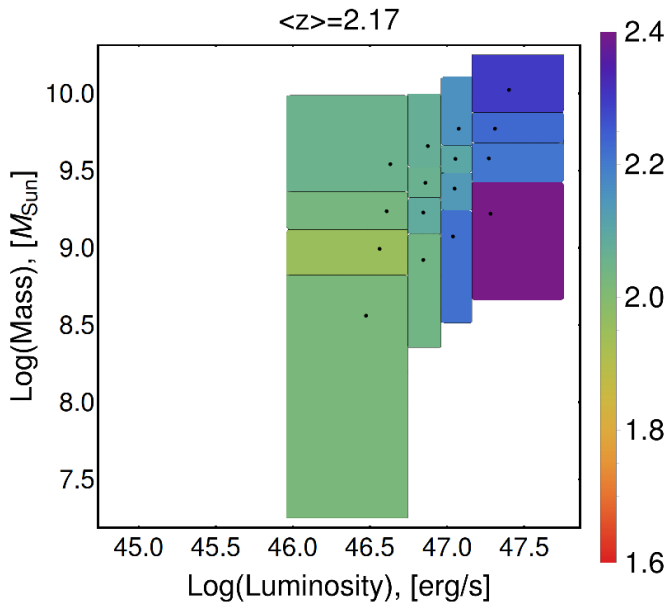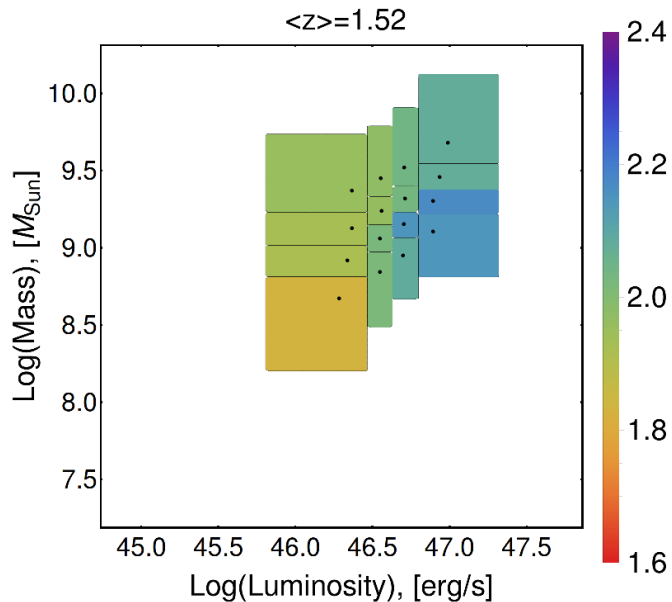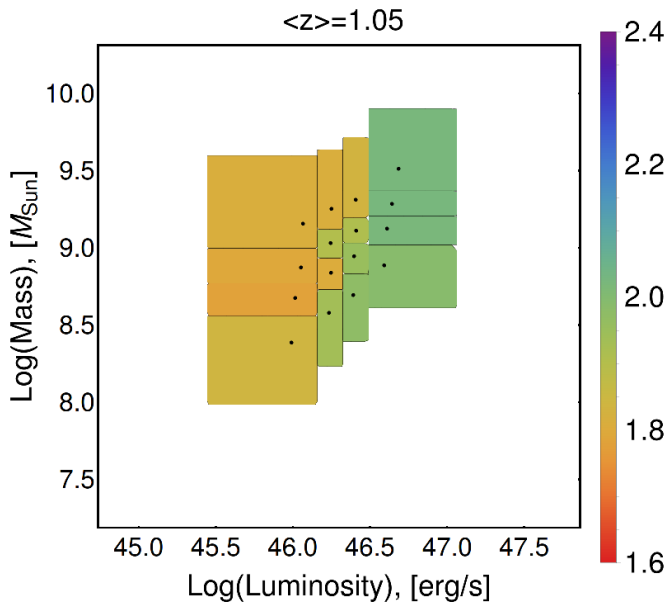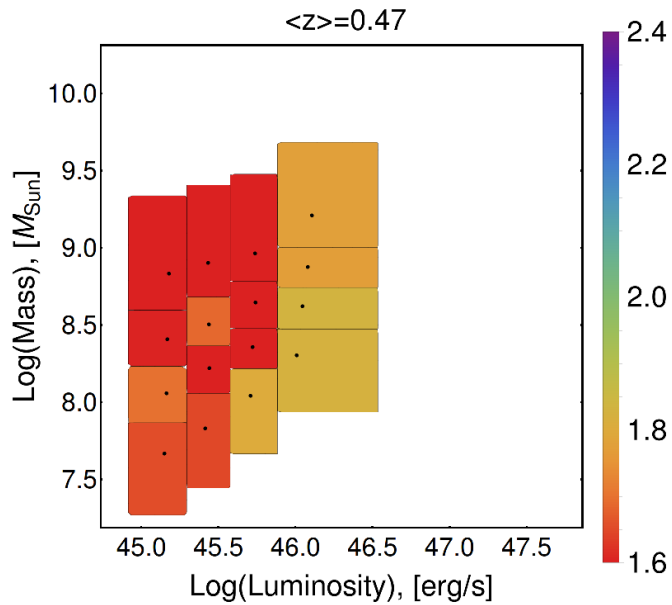
- Alternative way to interpert the data – τ, time to reach certain variability
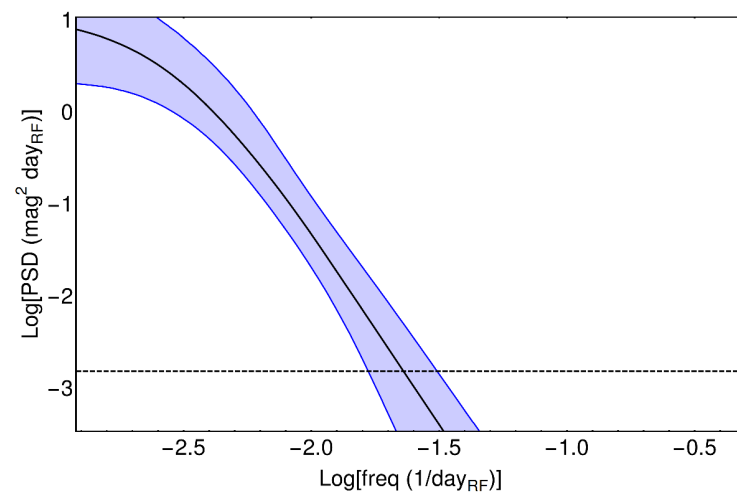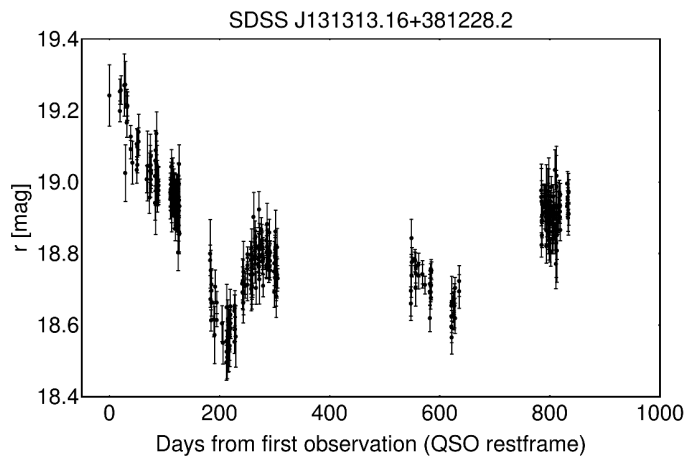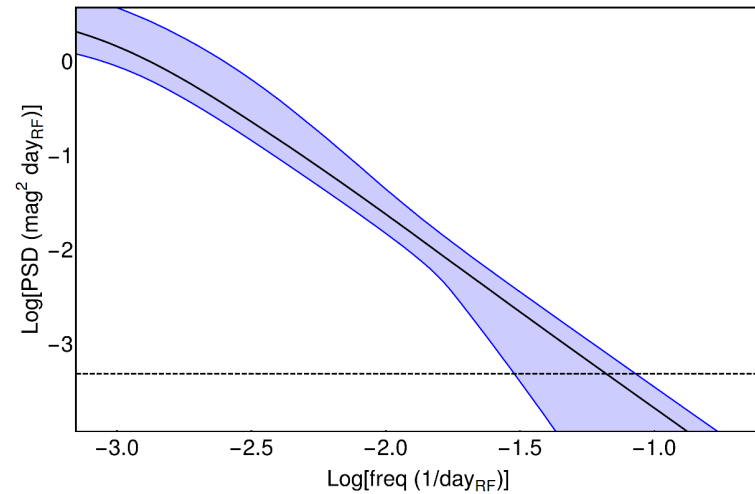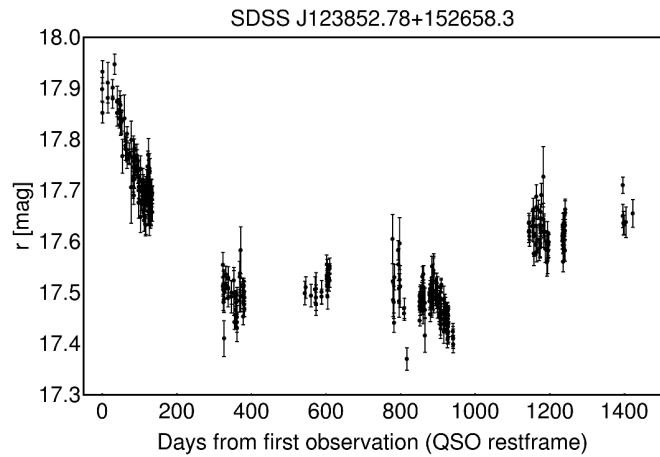
- From data $\tau \propto L^{0.4}$

- Simplest model with thin disc and Kelperian orbits $\tau \propto L^{0.5}$

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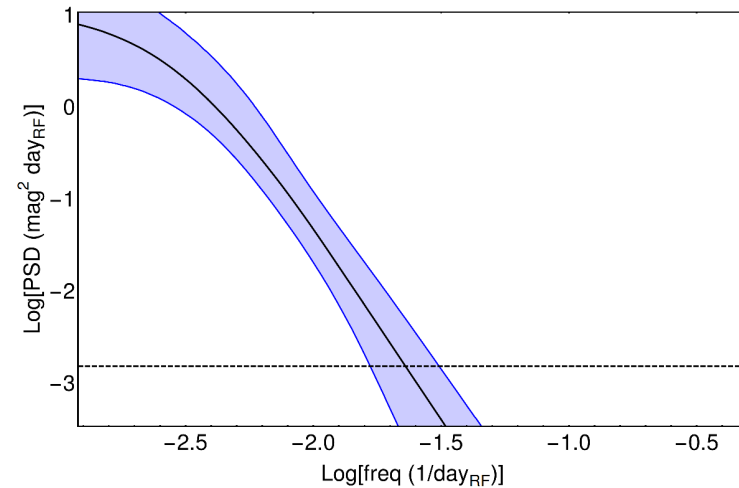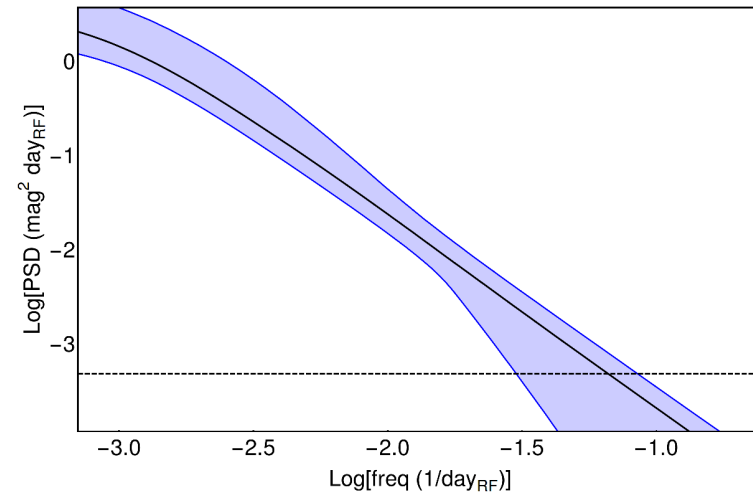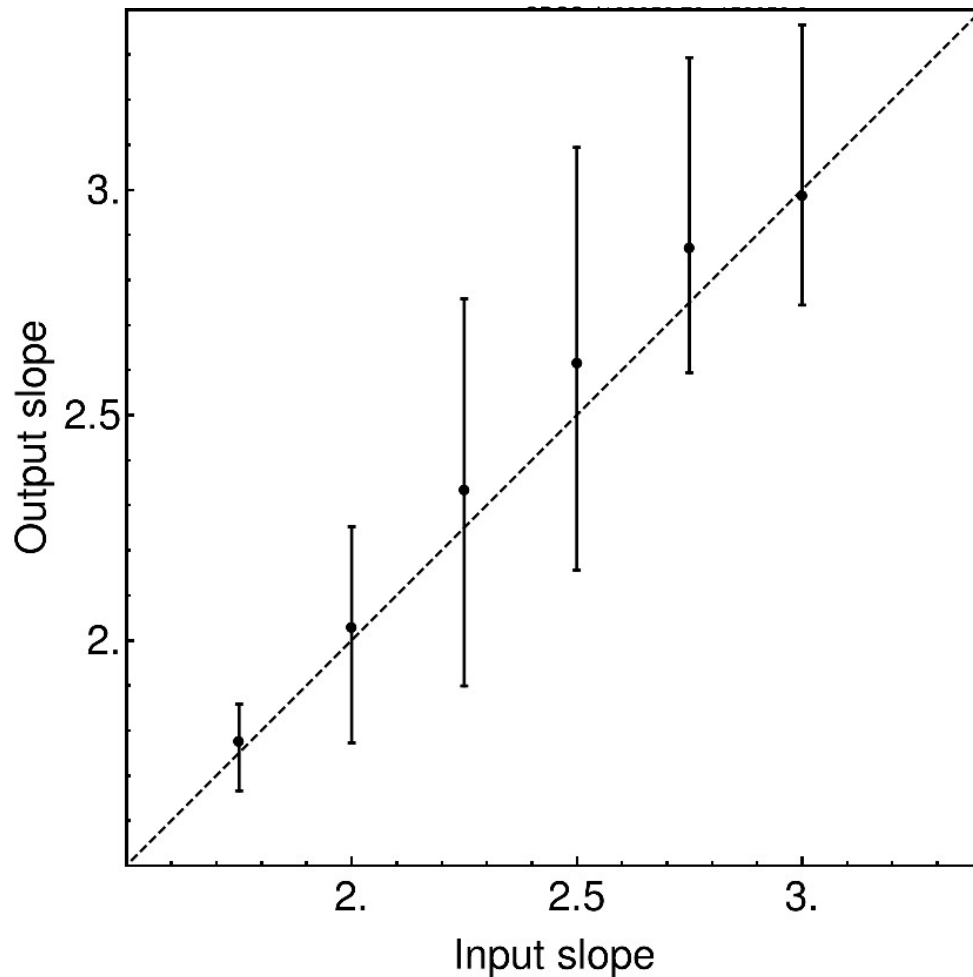 - Used on single, well sampled, objects

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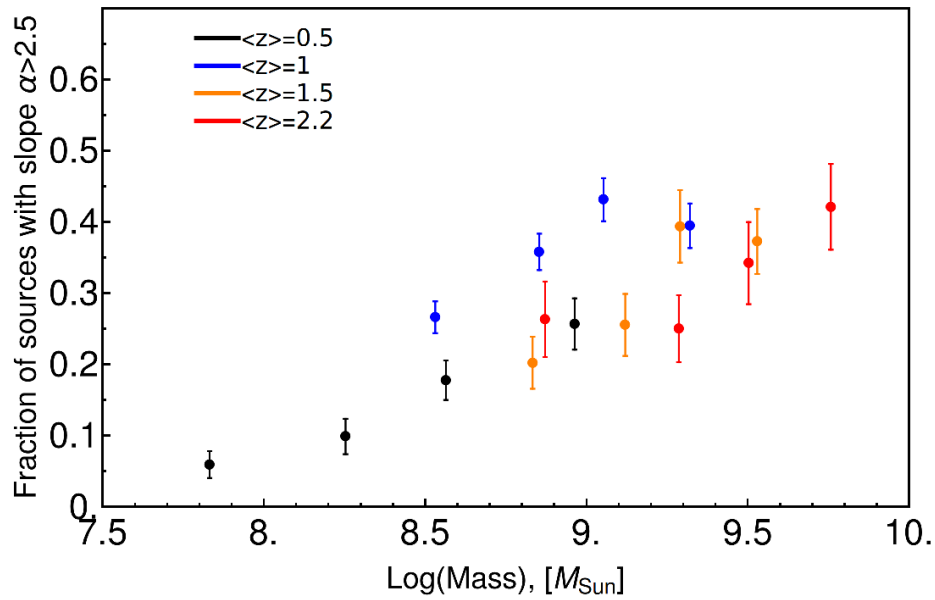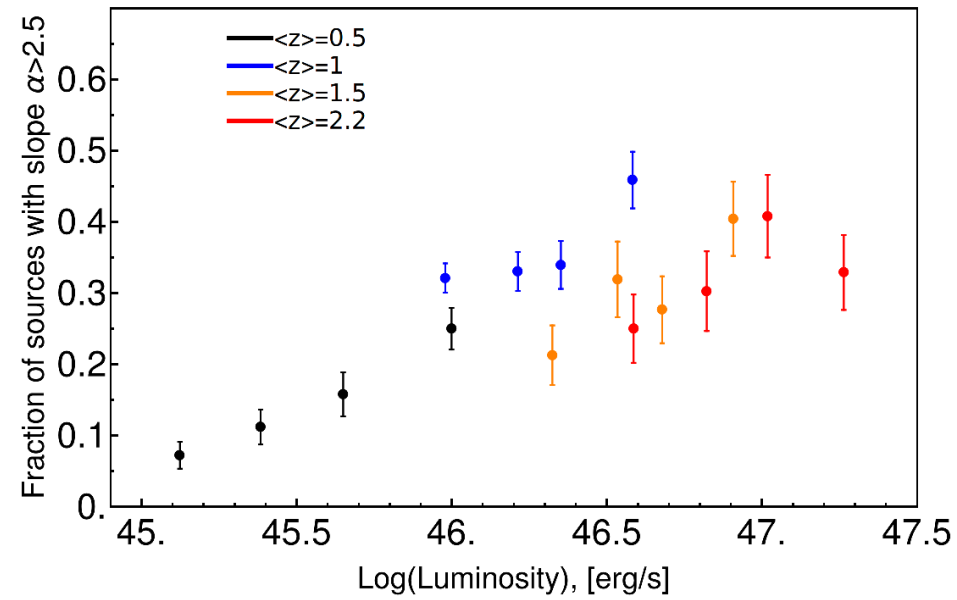 - Used on single, well sampled, objects

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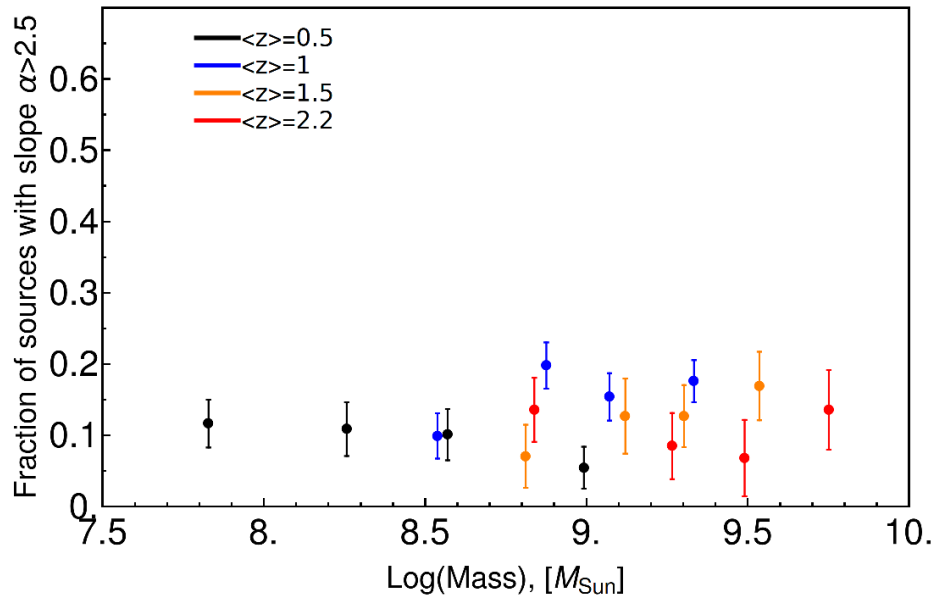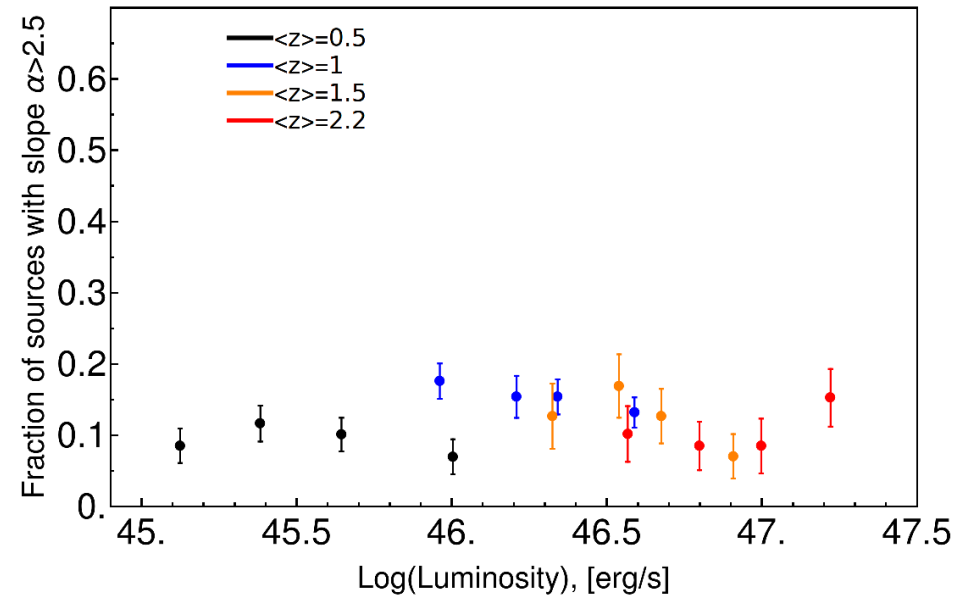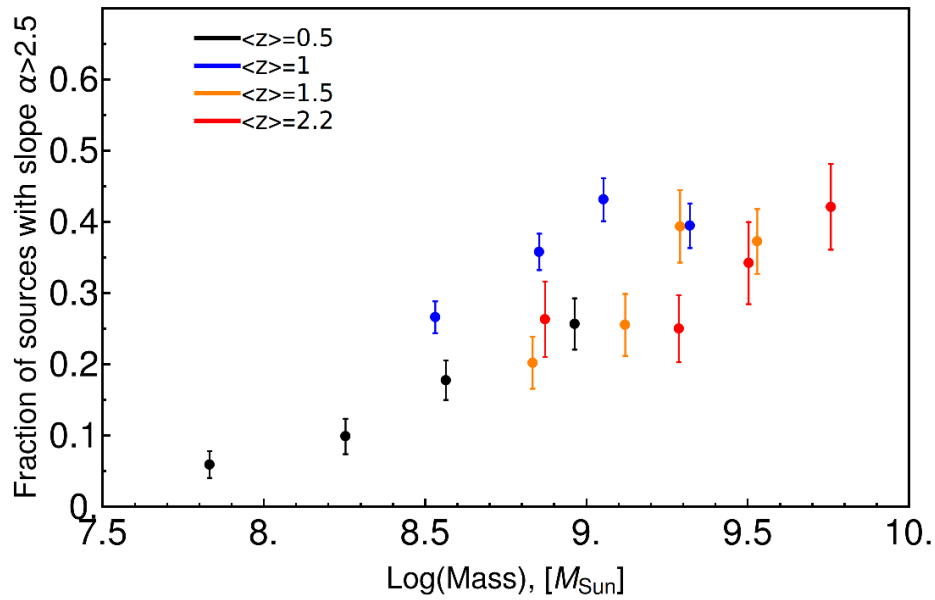 - Used on single, well sampled, objects

- Steepening of the slope with mass/luminosity

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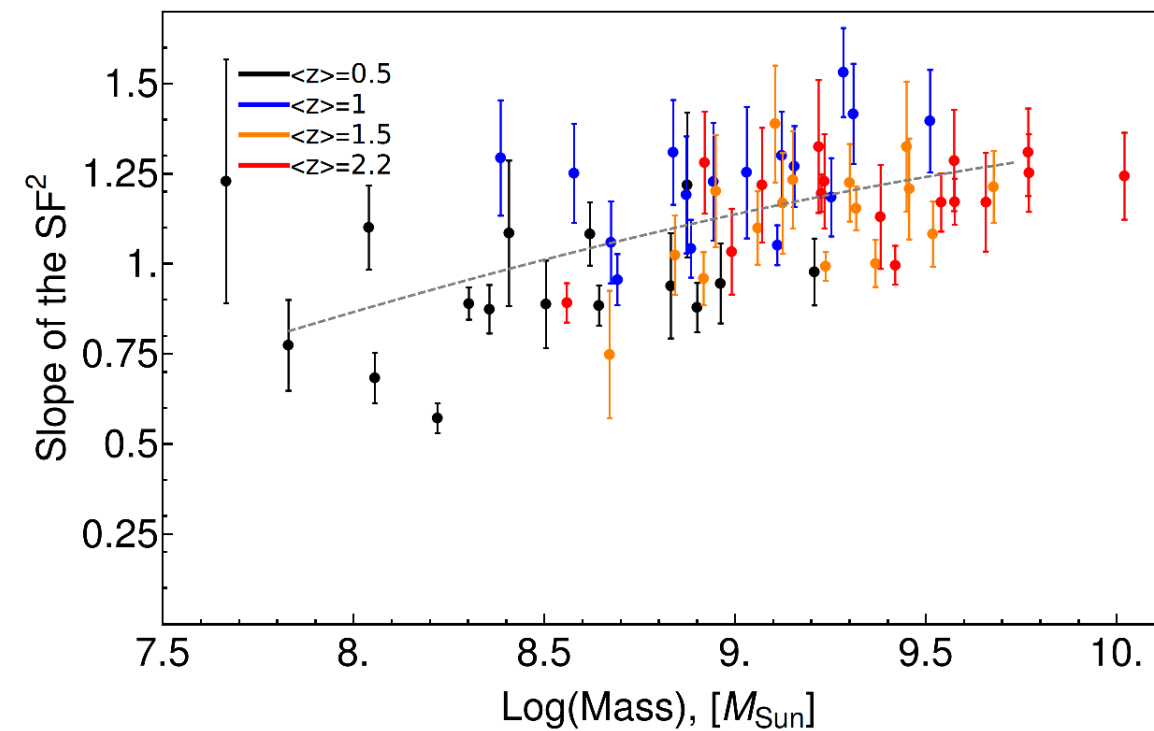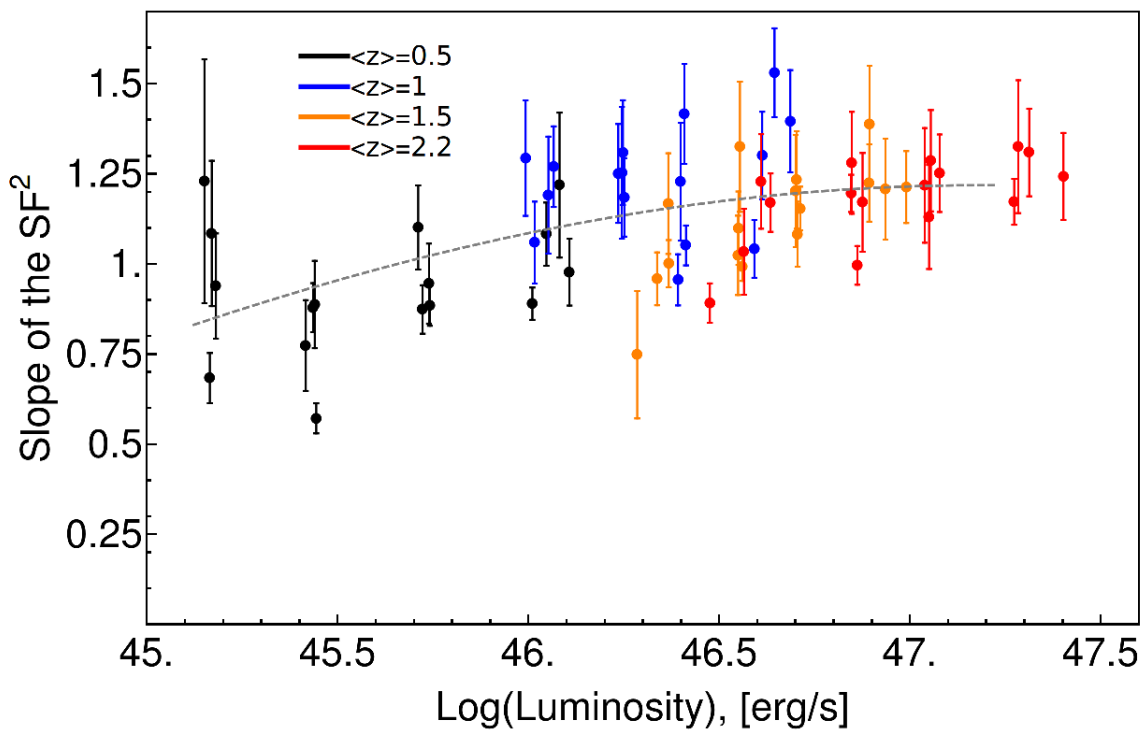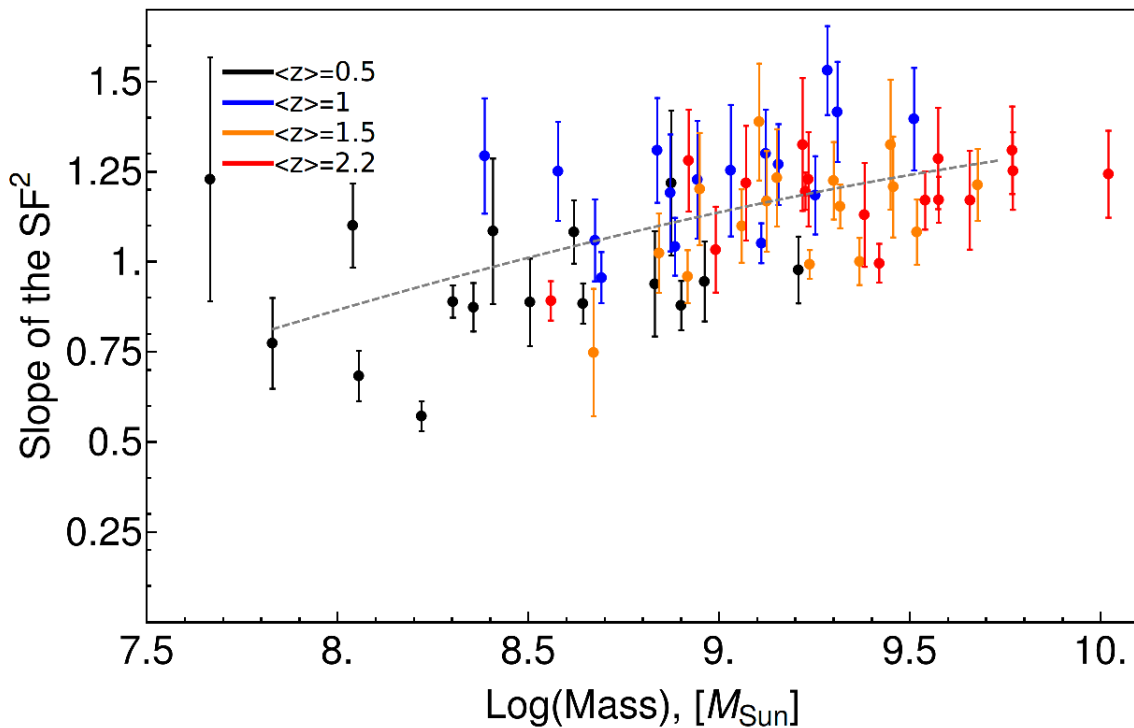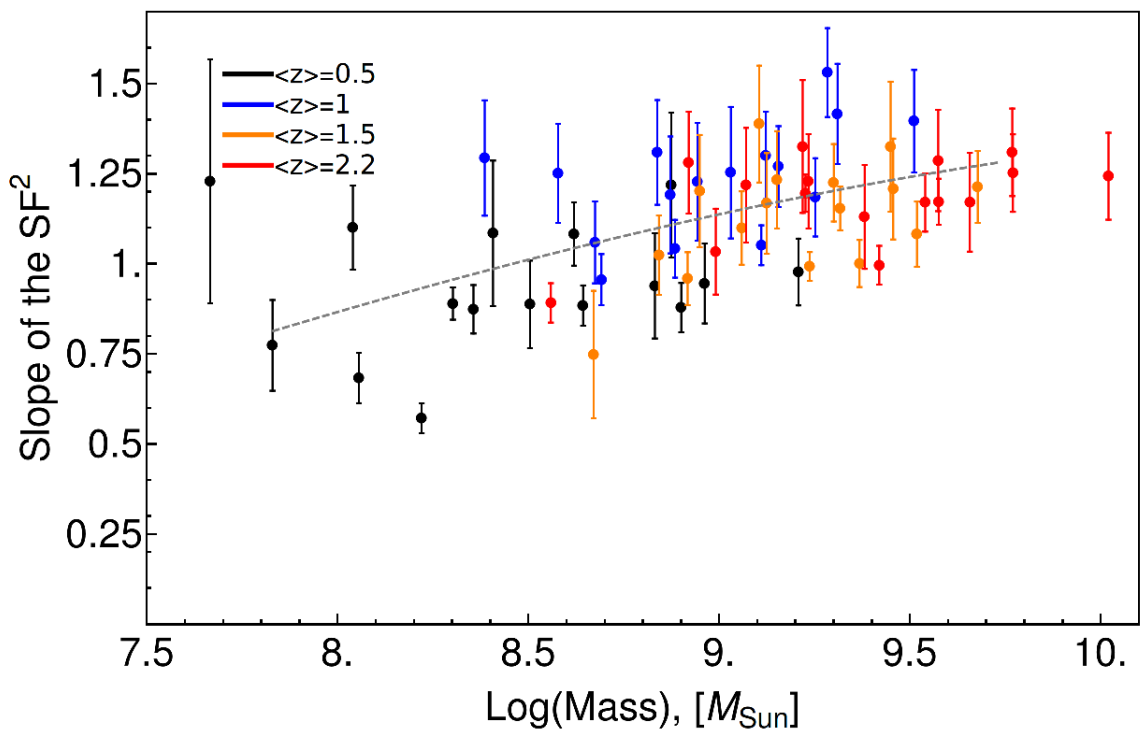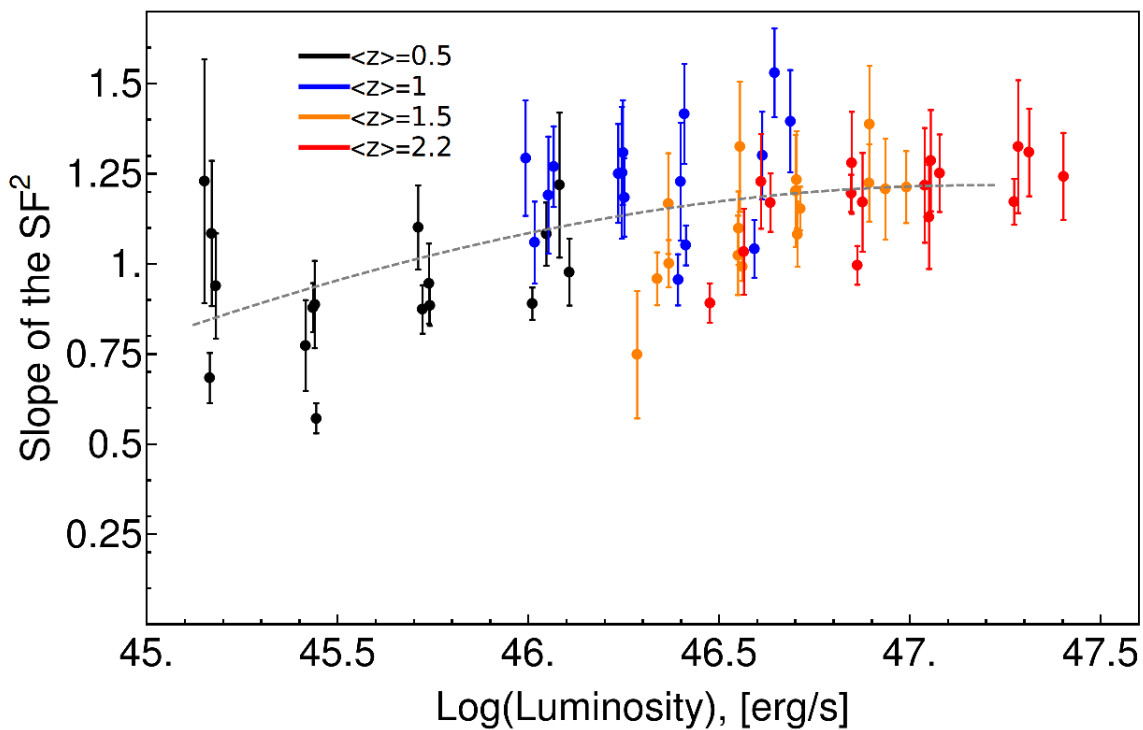$$PSD(f) \propto f^{-\alpha} \rightarrow SF^2 \propto t^{(\alpha-1)}$$

- Same steepening effect can be seen in the structure function analysis!

- Lines are deduced from PSD analysis, not fits!

- Fits in the mass-luminosity plane show preference for the effect to be connected with mass.

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- Effect seen with the SF analysis in PTF & SDSS (Kozlowski 16 and this work)

- Effect also seen with the PSD analysis in PTF, SDSS & Pan-STARRS1 (Simm+ 16 and this work)

- More massive AGNs shows more correlated variability

Summary

- Largest fully calibrated single-band dataset for studying AGN variability
  - Re-calibrated data available during 2016

- Anti-correlation of variability with luminosity
  - If time to reach certain variability interpreted as time-scale $\tau \propto L^{0.4}$, similar to the prediction of simplest model

- Strong evidence for steepening of the PSD slope with mass