# Optical Variability of AGN
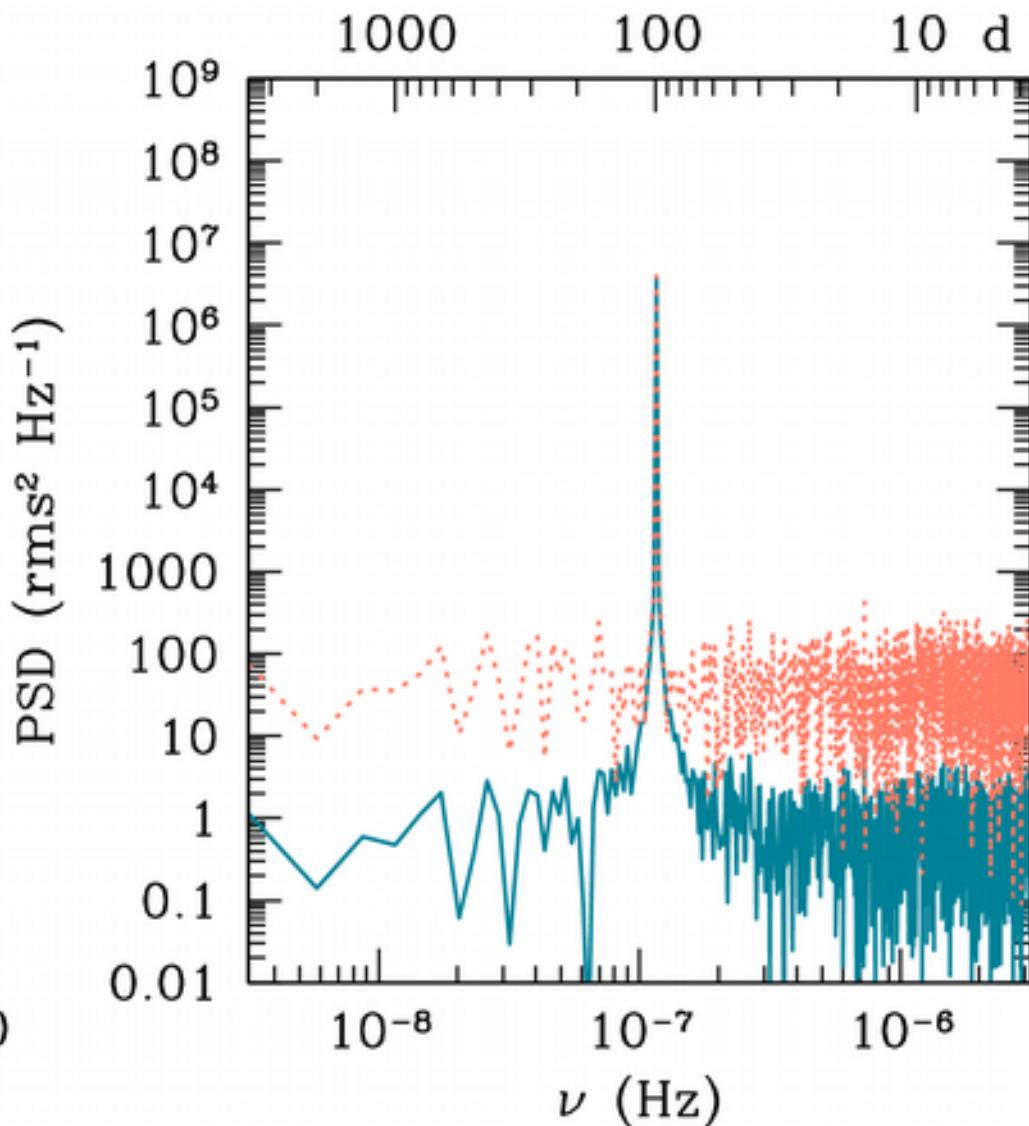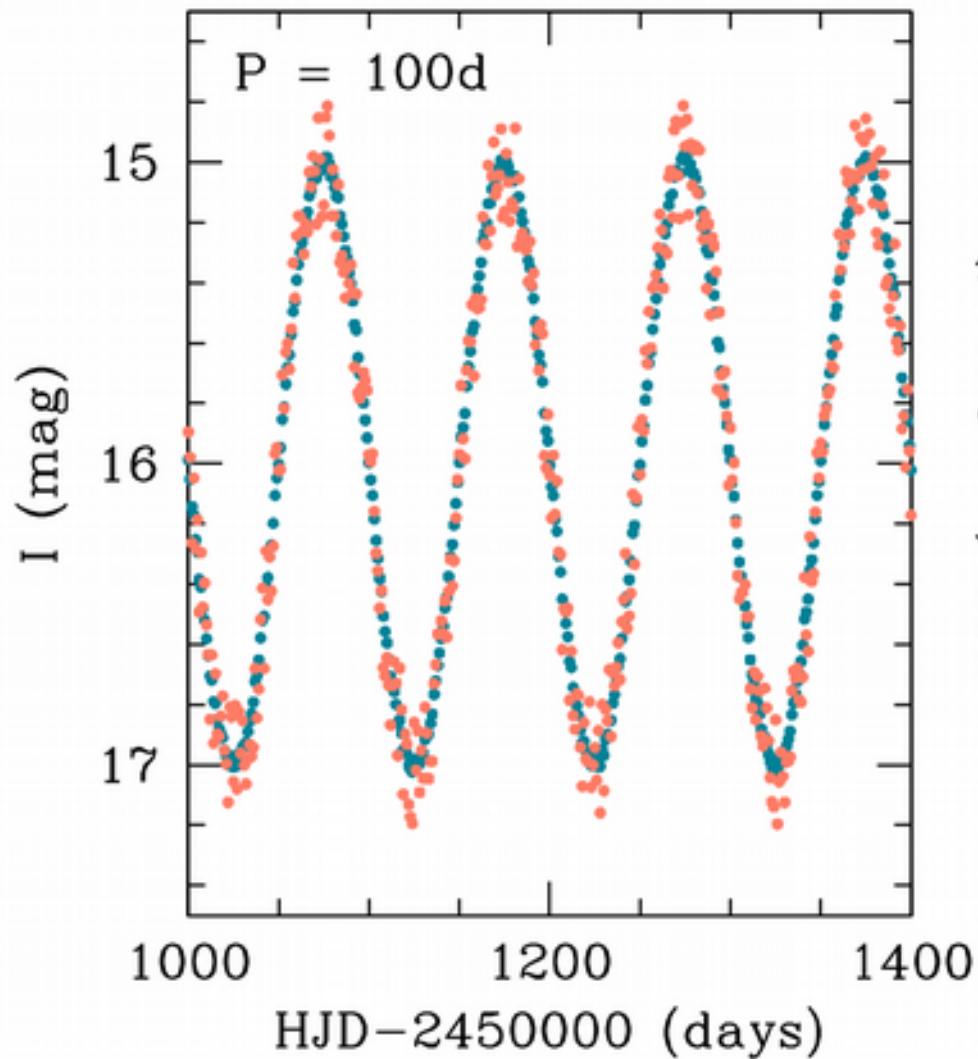
Szymon Kozłowski

Unveiling the Physics Behind Extreme AGN Variability
10-14 July 2017
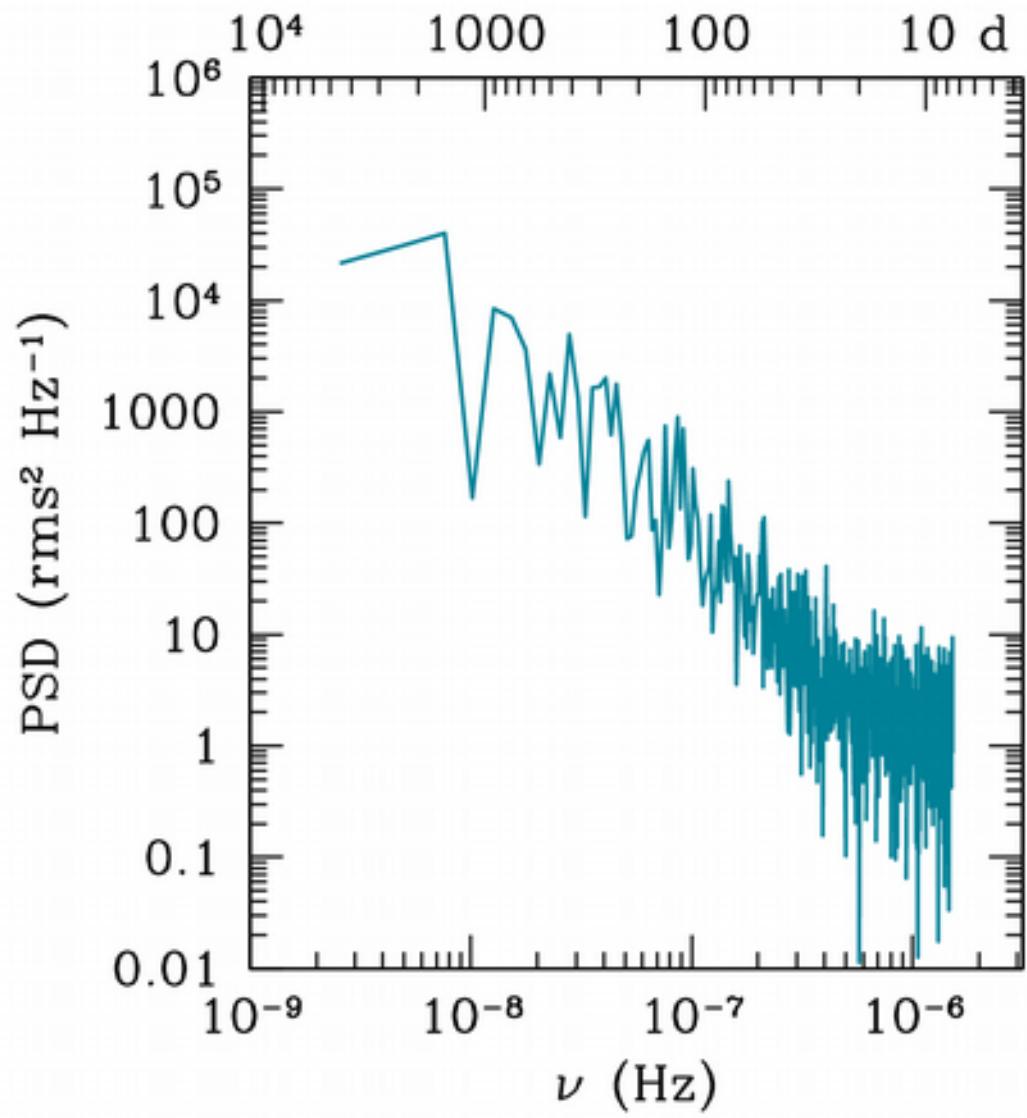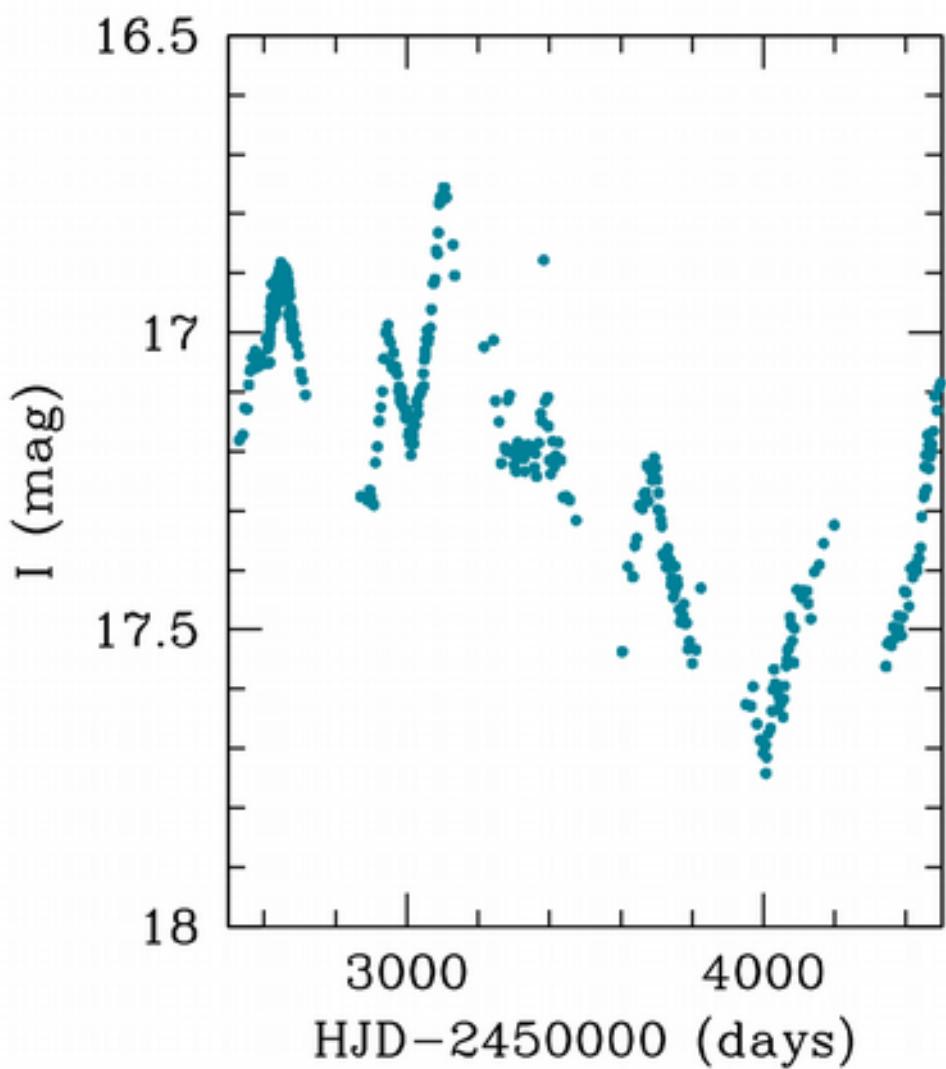
Quasar Variability

# PERIODIC OBJECT

P = 100d
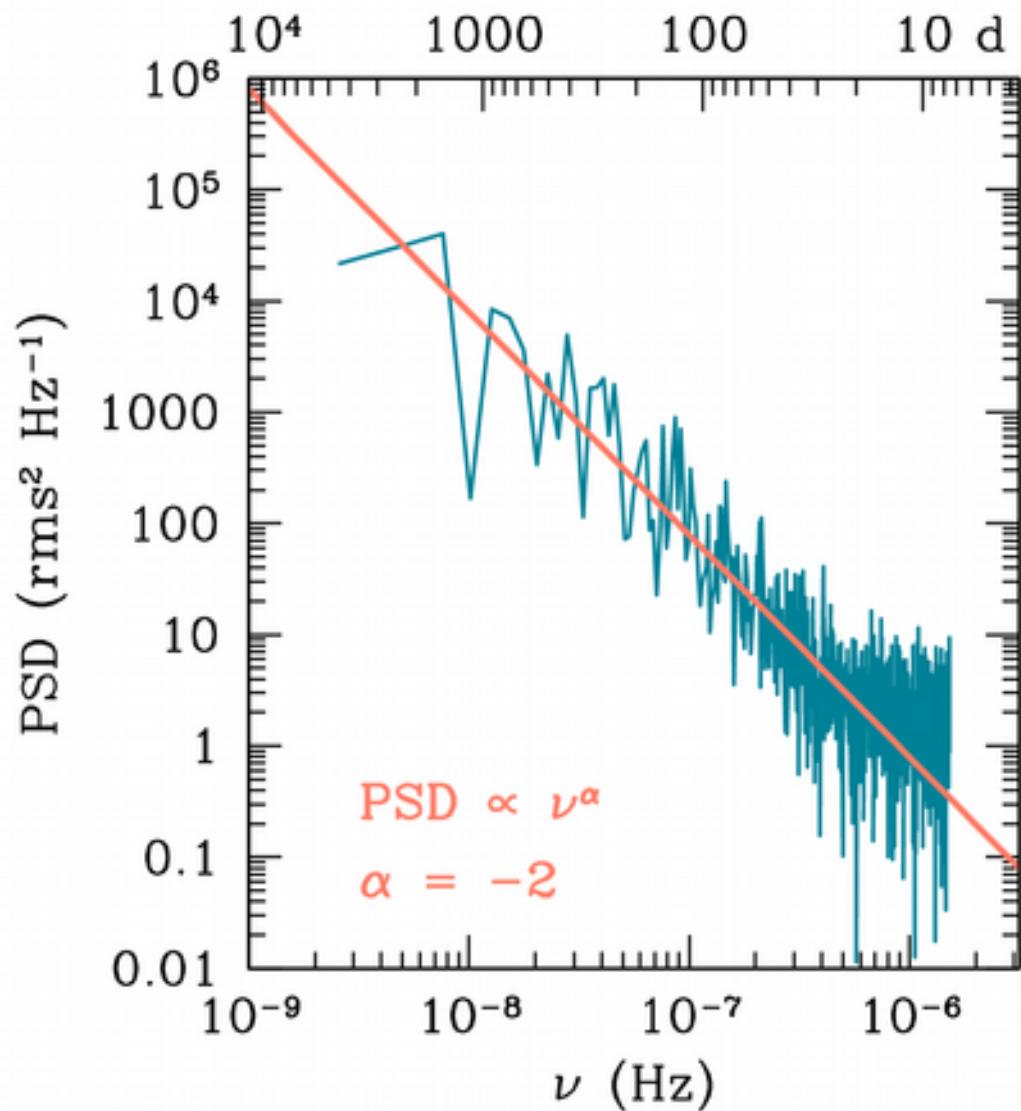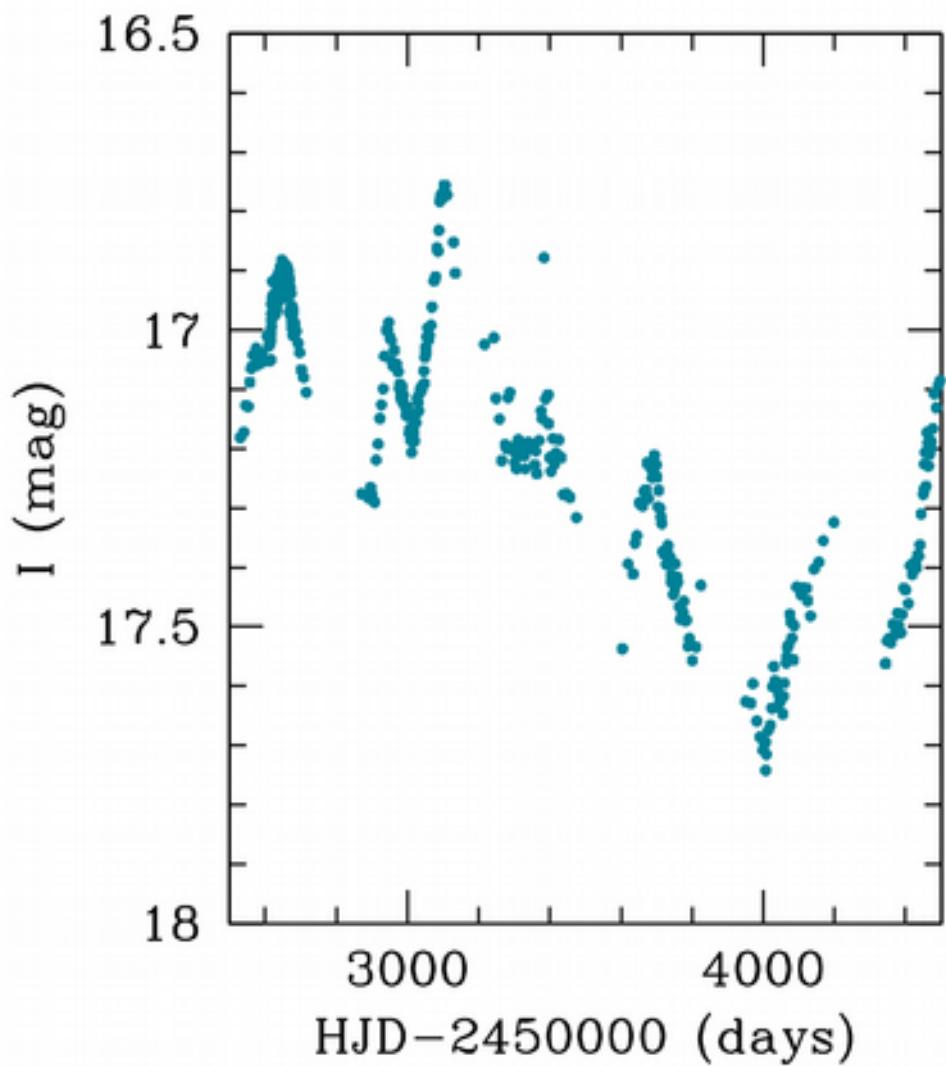
# NON-PERIODIC OBJECT

NON−PERIODIC OBJECT

Power Spectral Density (PSD)
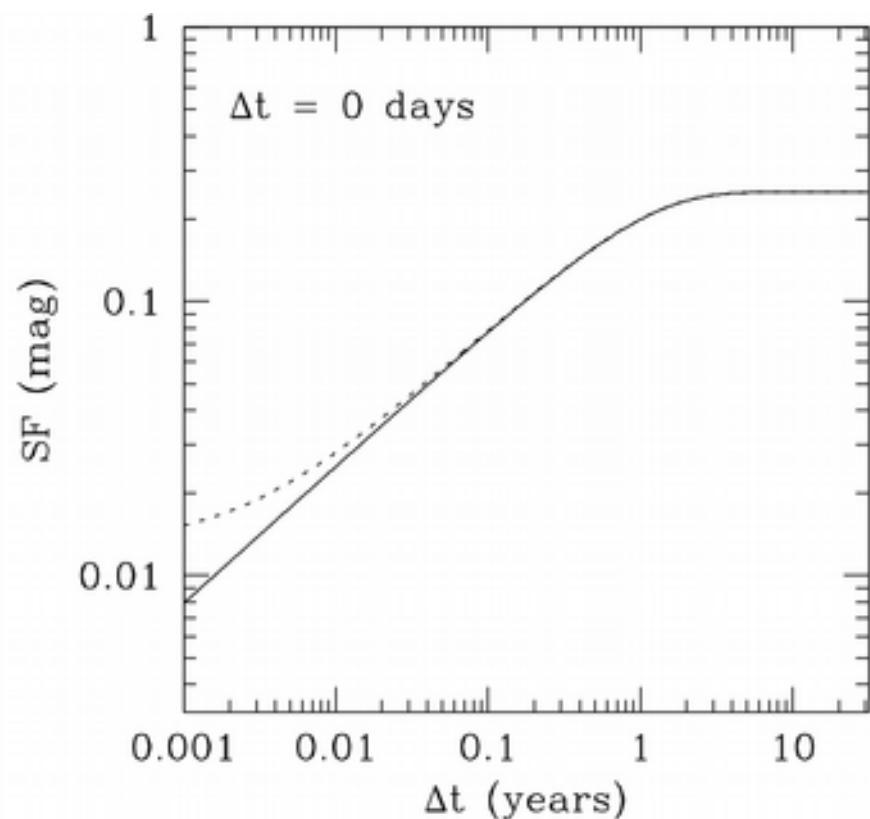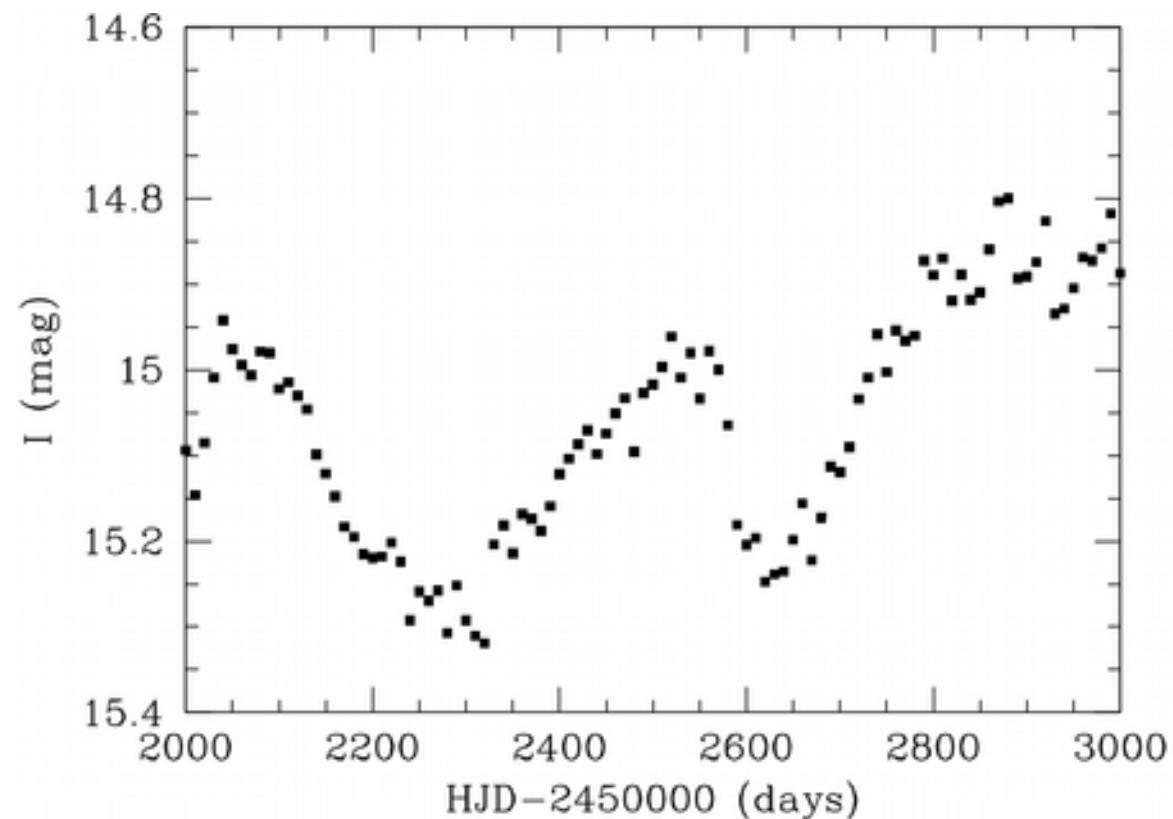
and

Auto-Correlation Function (ACF)
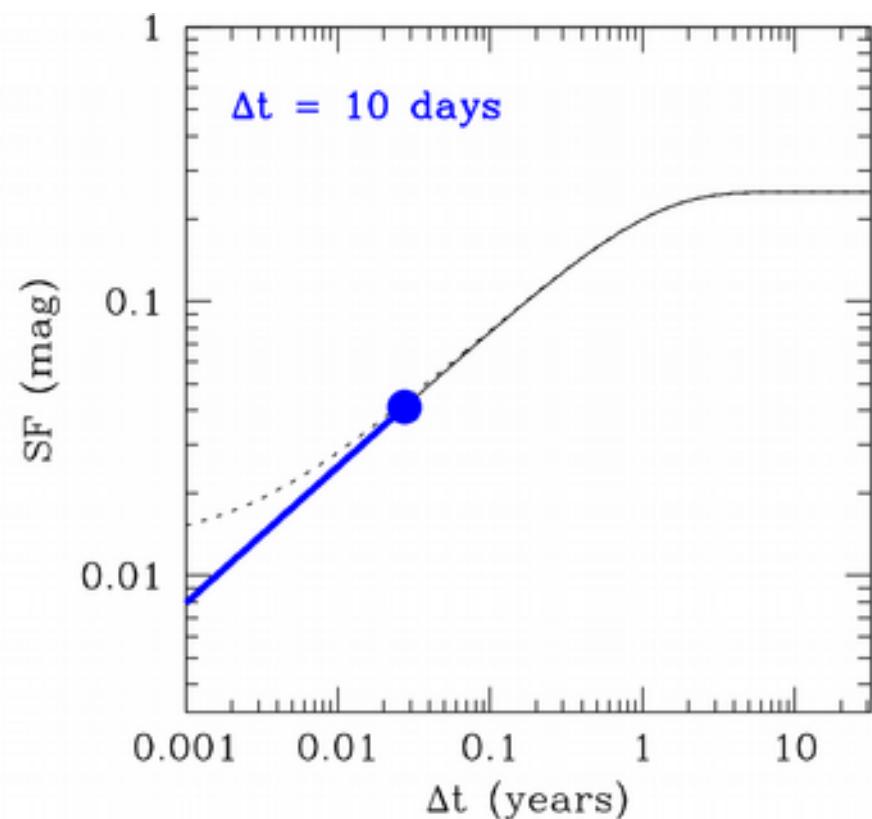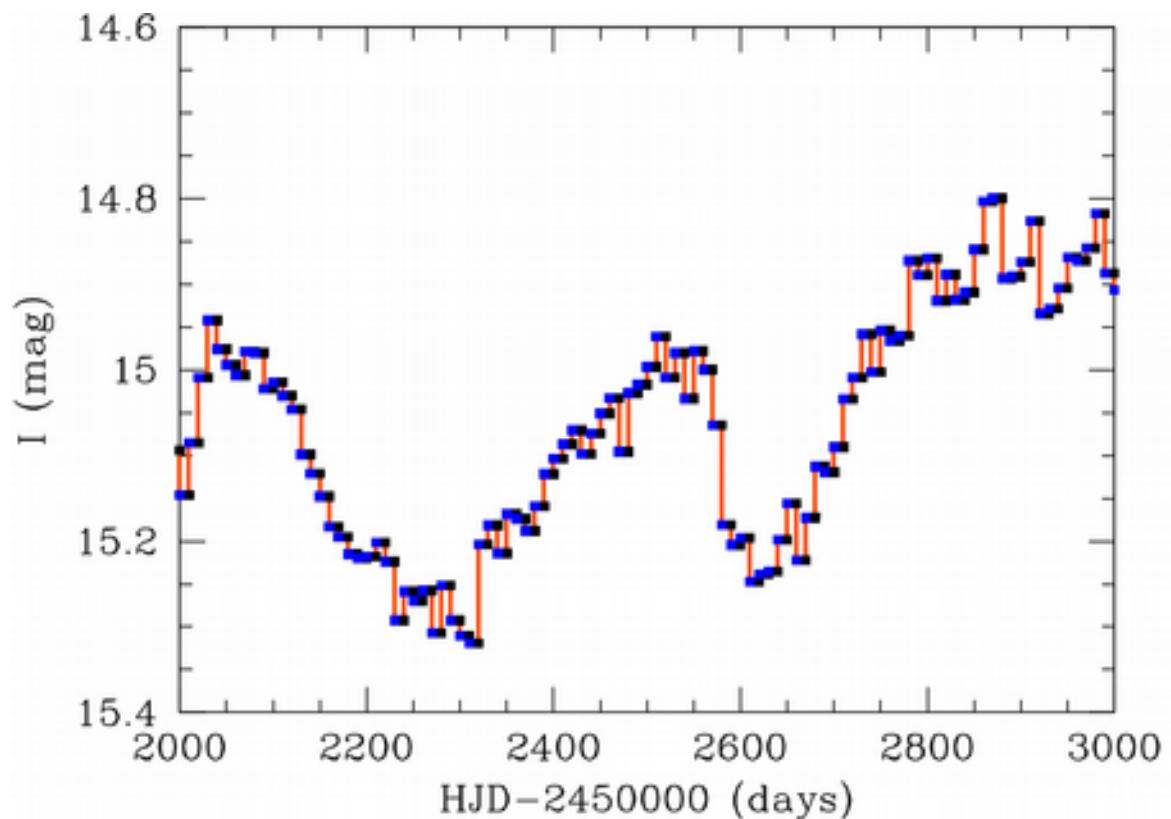
$$\text{PSD}(\nu) = \int_{-\infty}^{\infty} \text{ACF}(t) \, e^{-2\pi i \nu t} dt$$

$$\text{ACF}(t) = \int_{-\infty}^{\infty} \text{PSD}(\nu) \, e^{2\pi i \nu t} d\nu$$
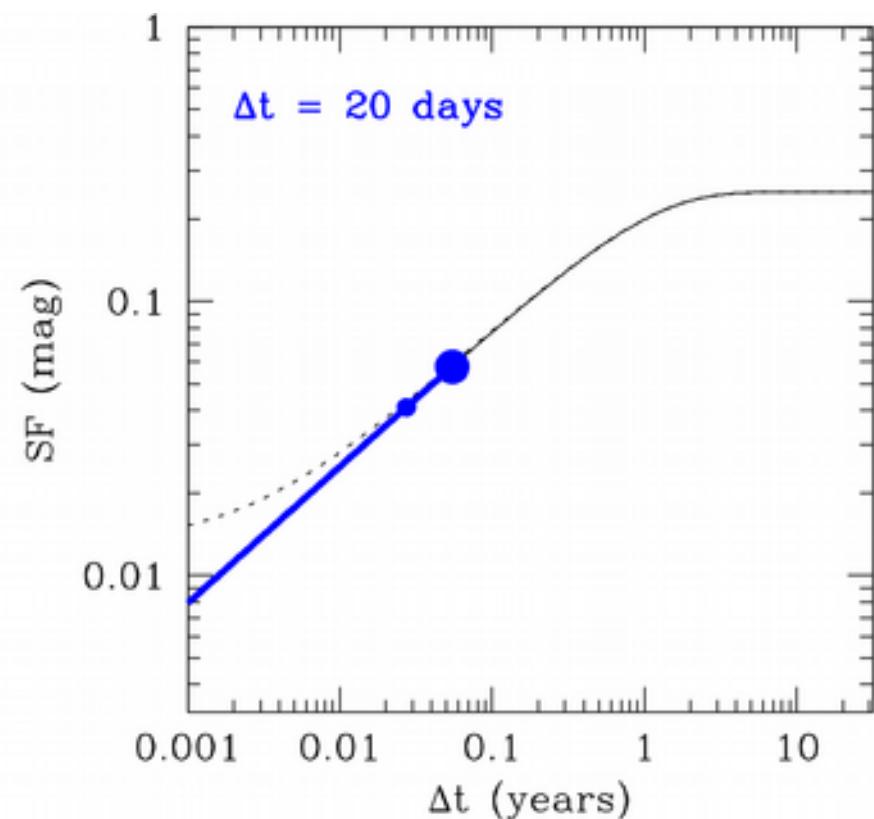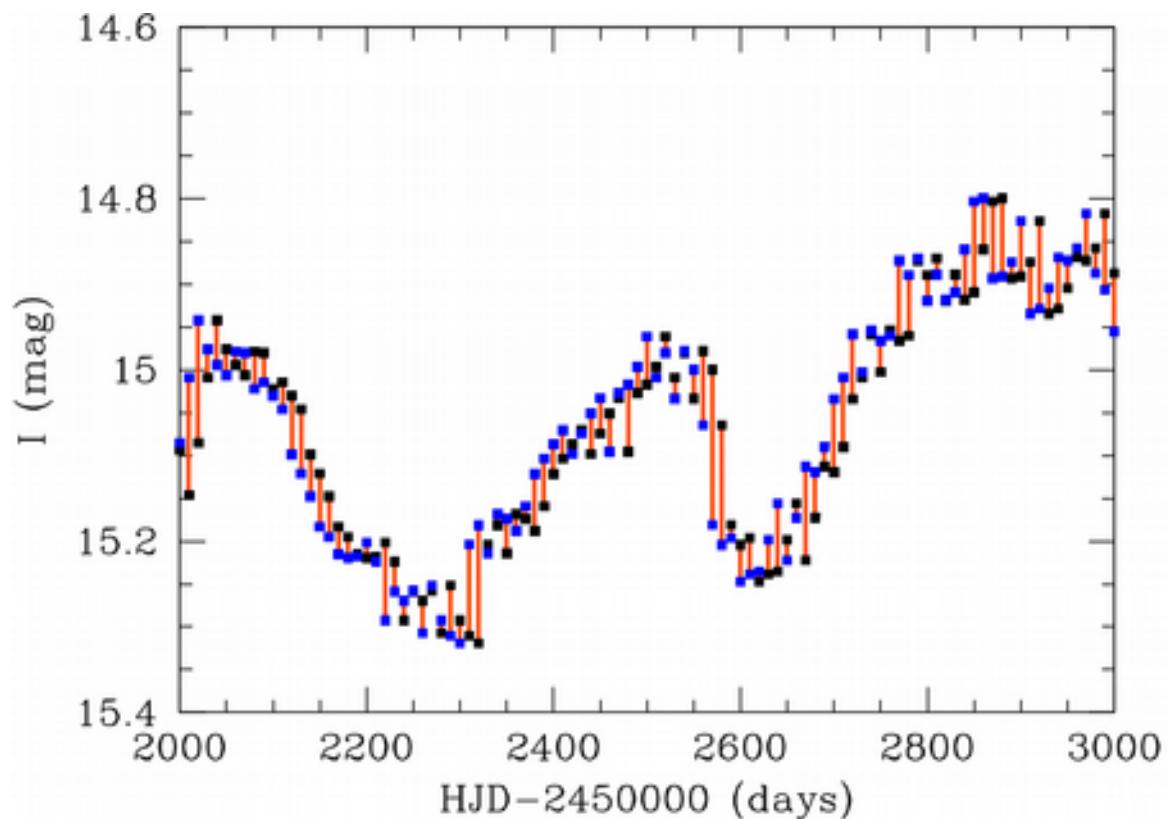
Structure Function
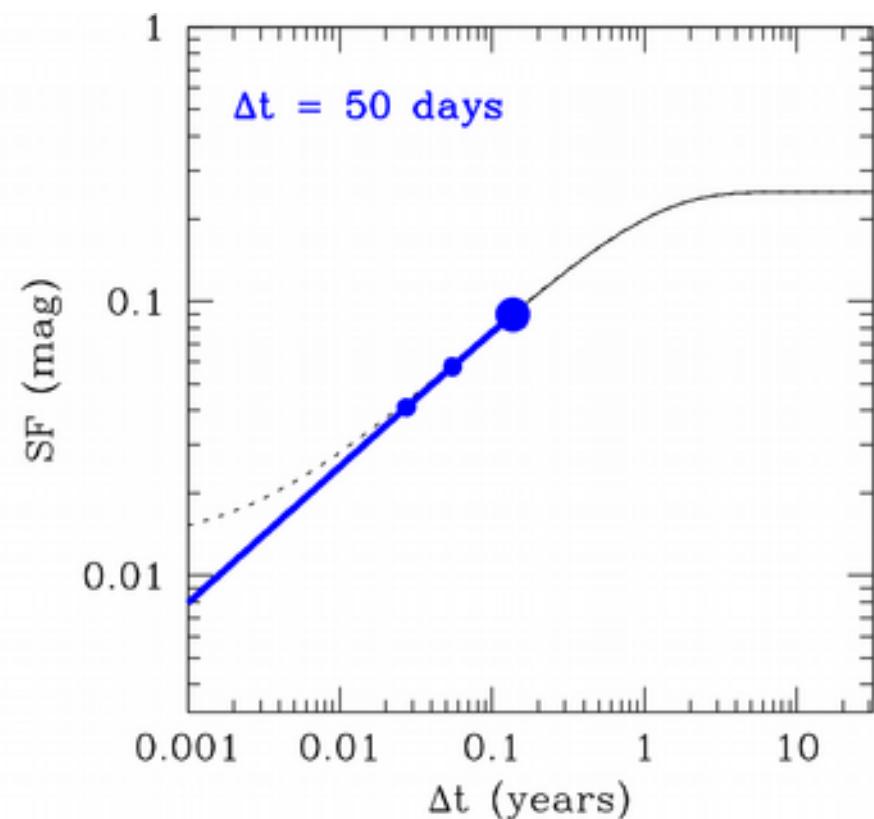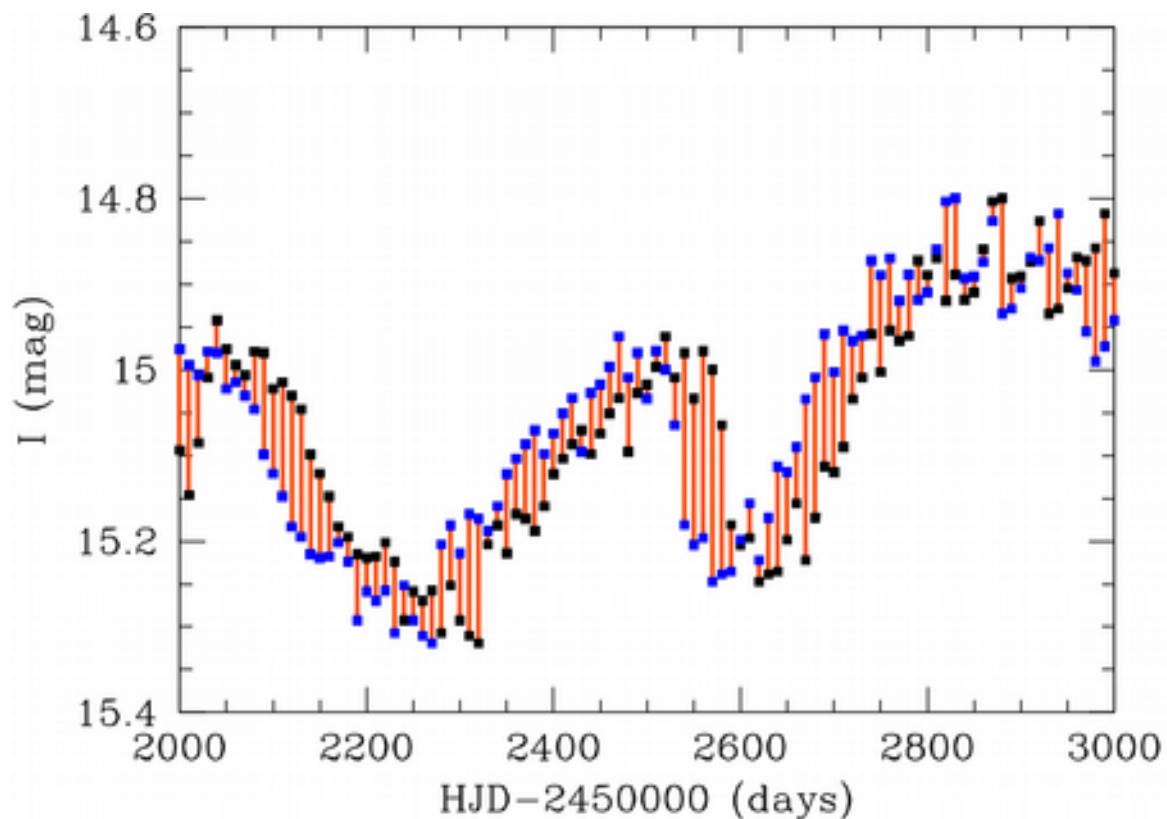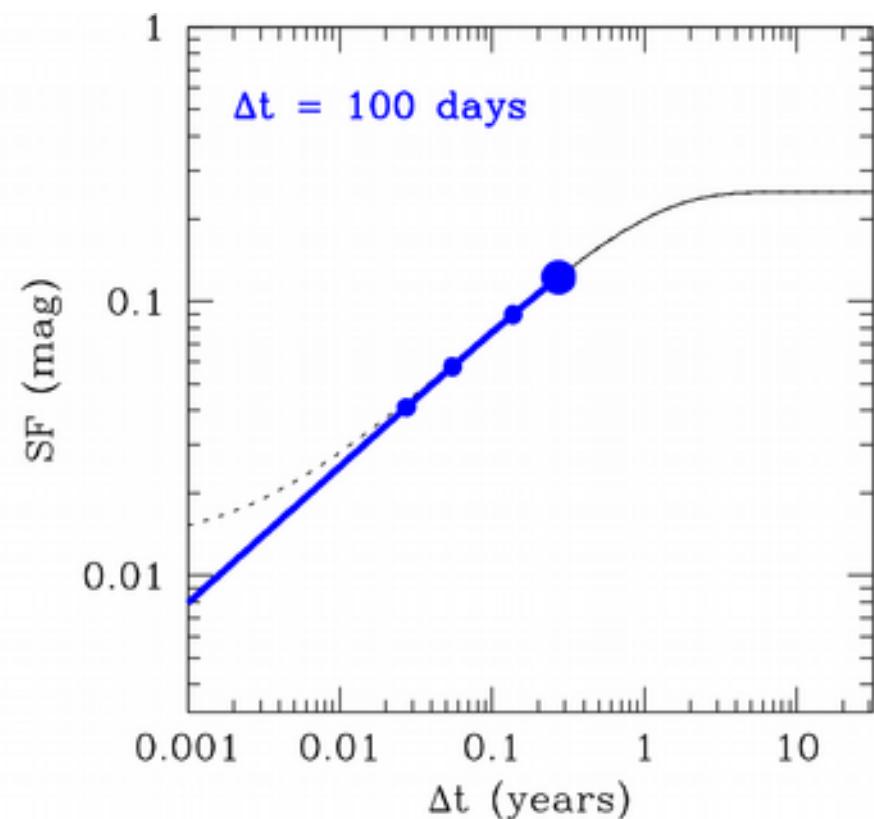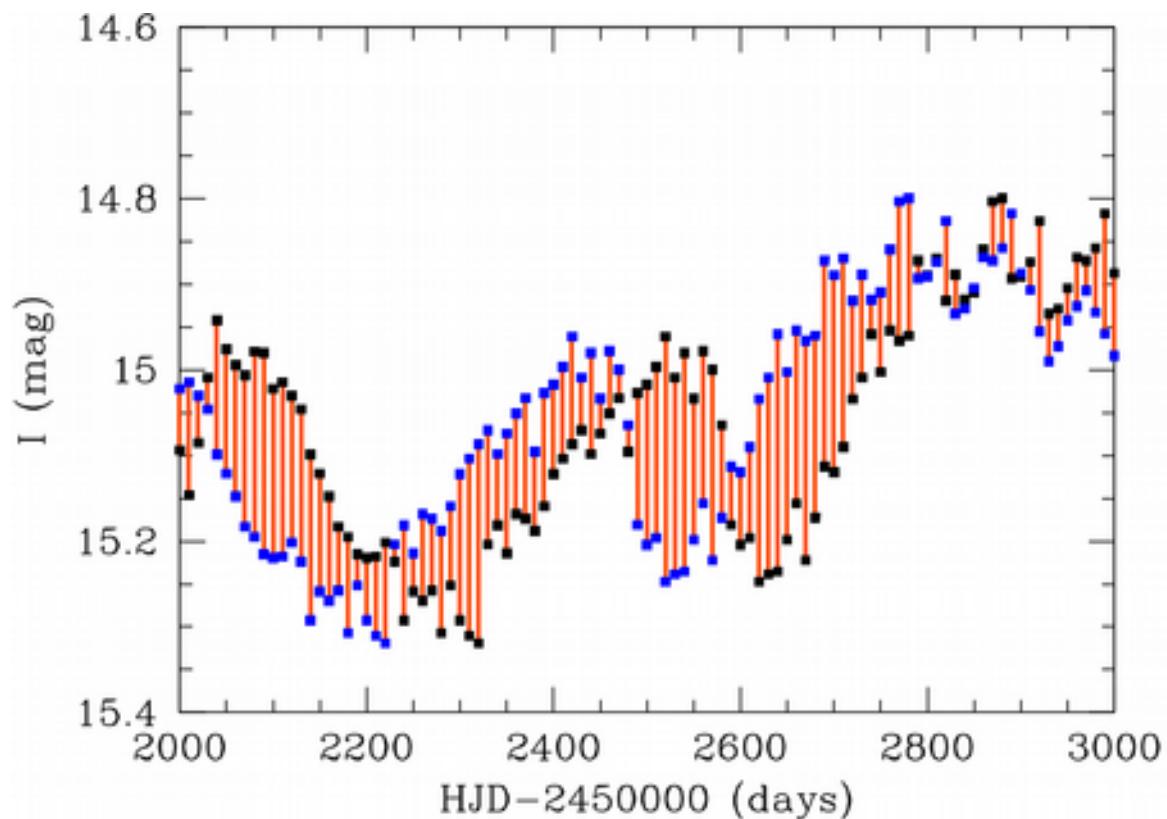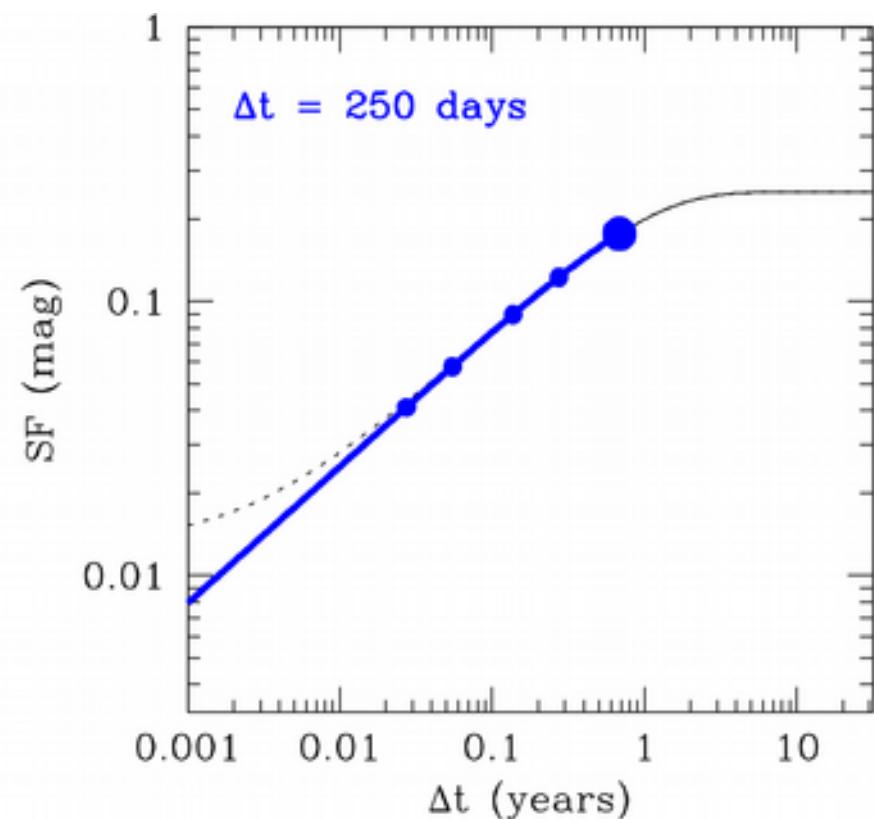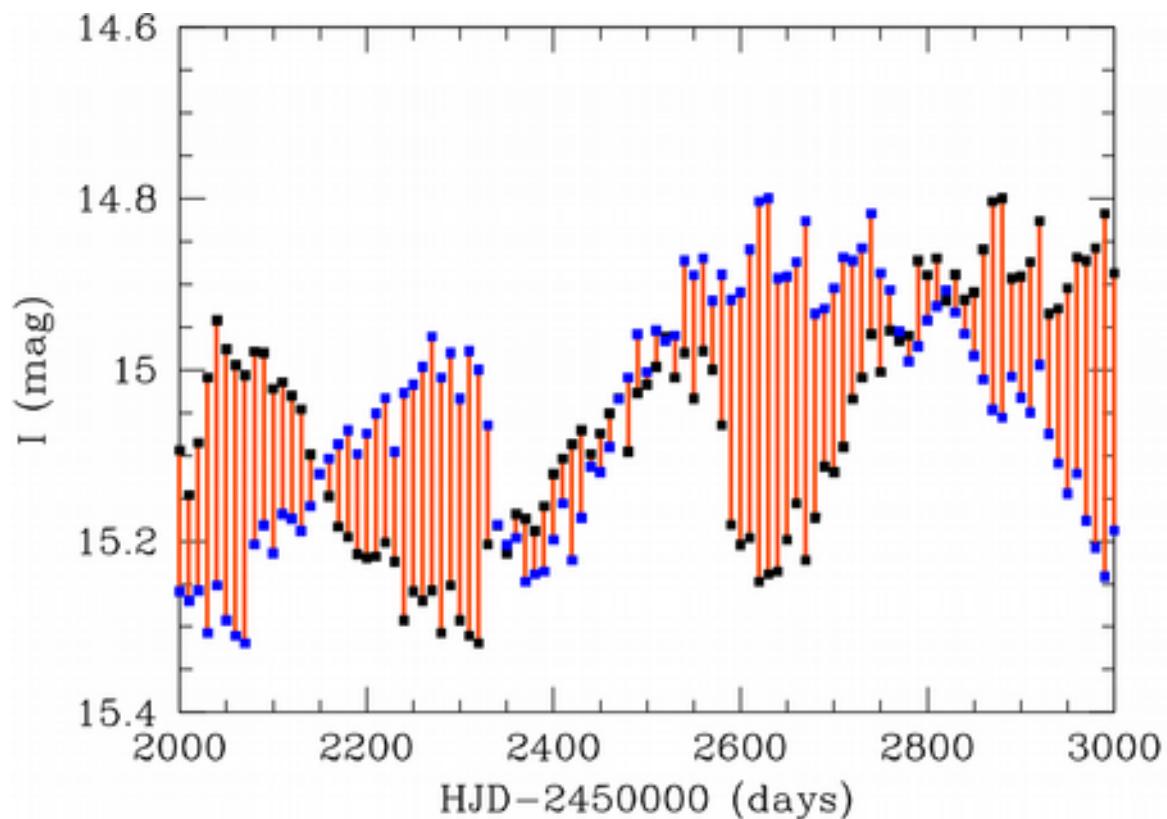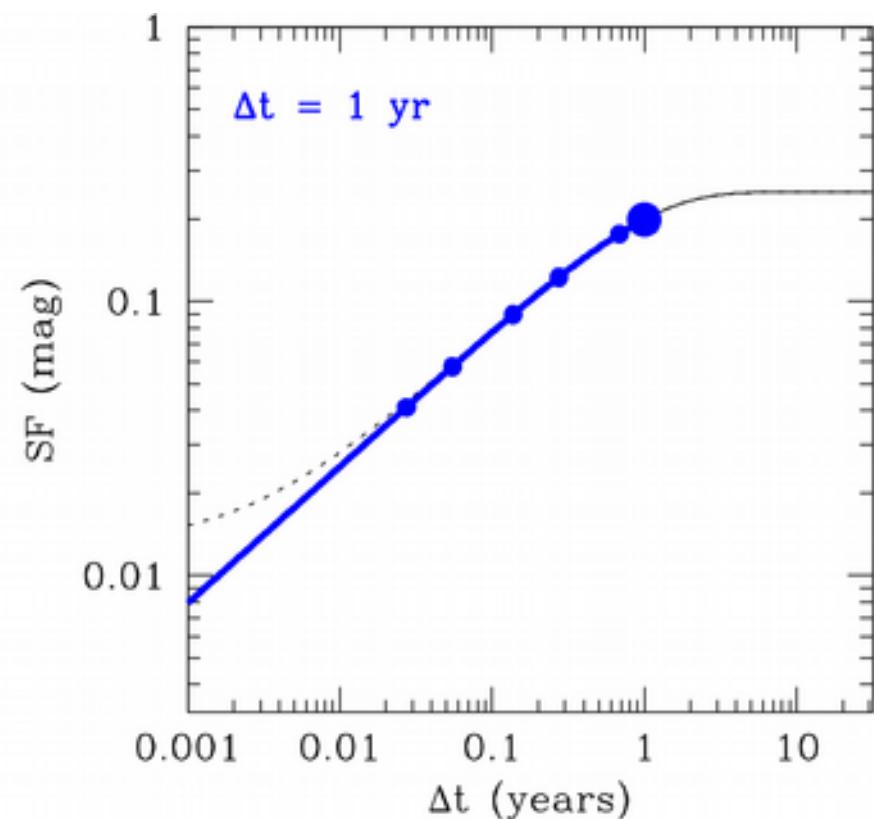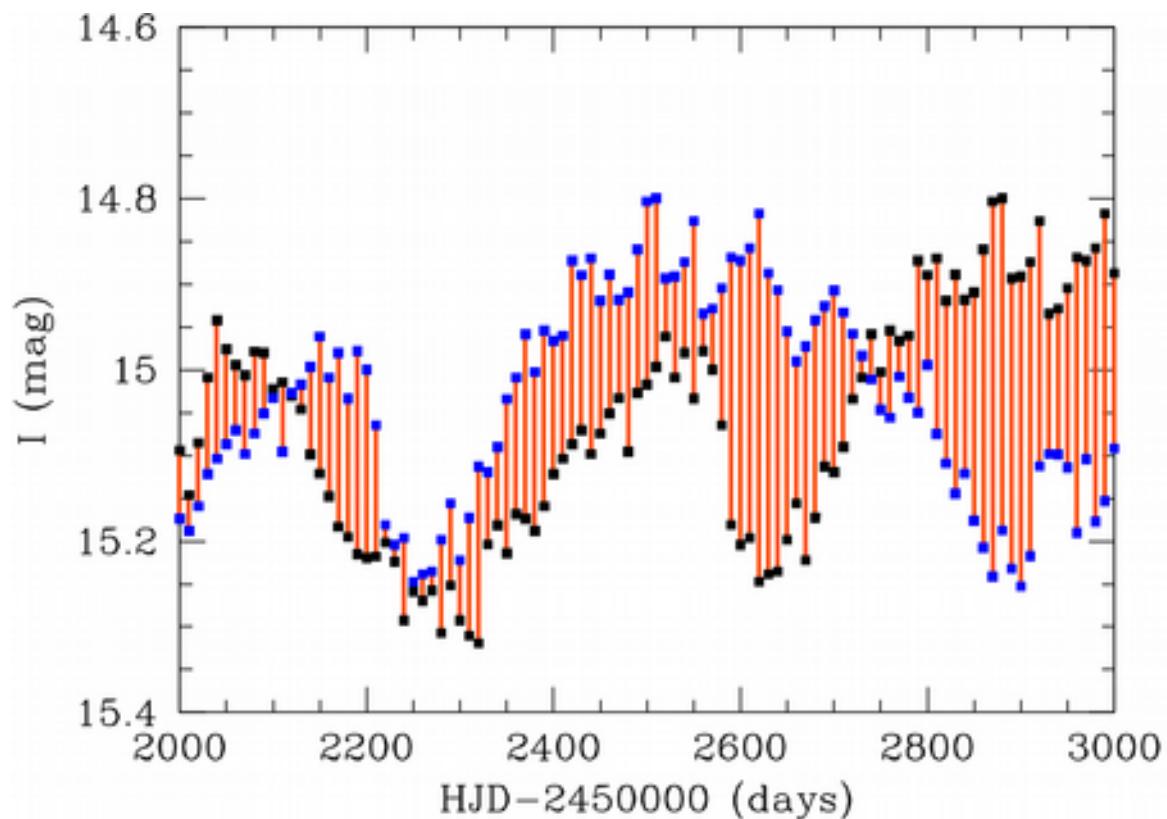
Structure Function

Structure Function

Structure Function

Structure Function
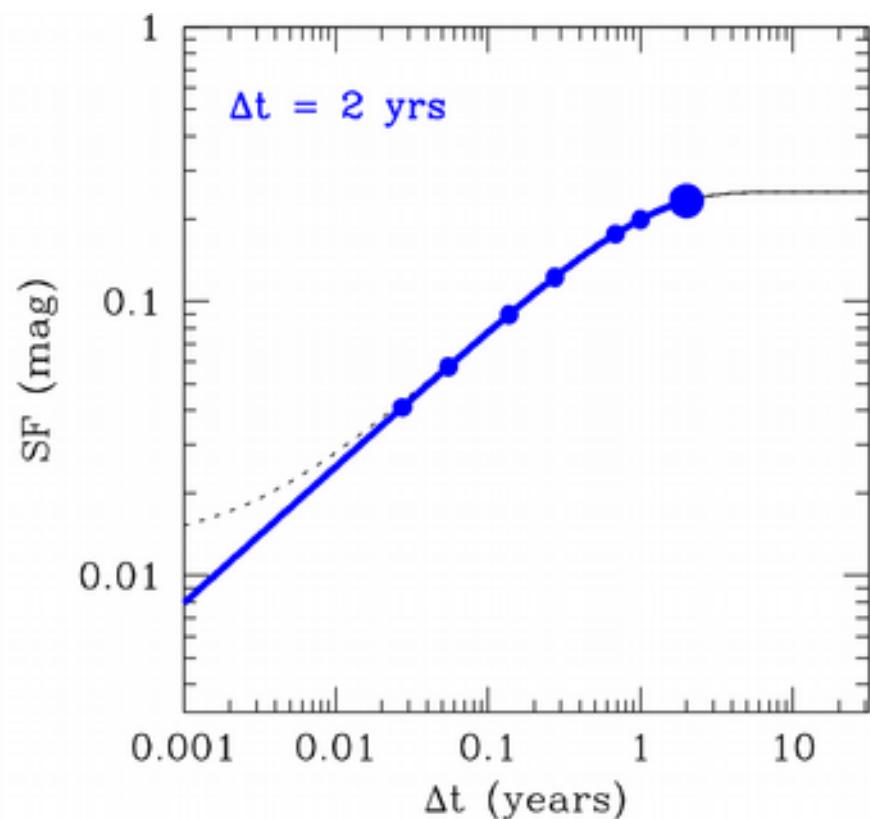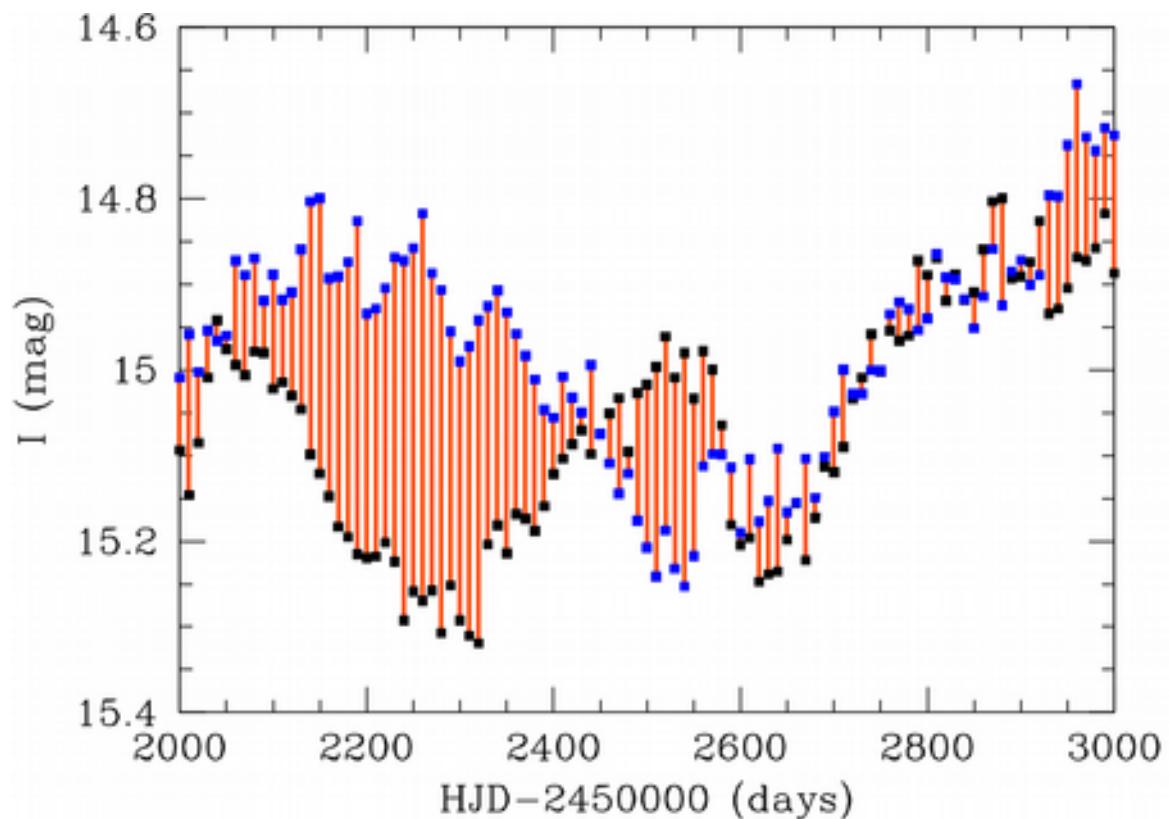
Structure Function
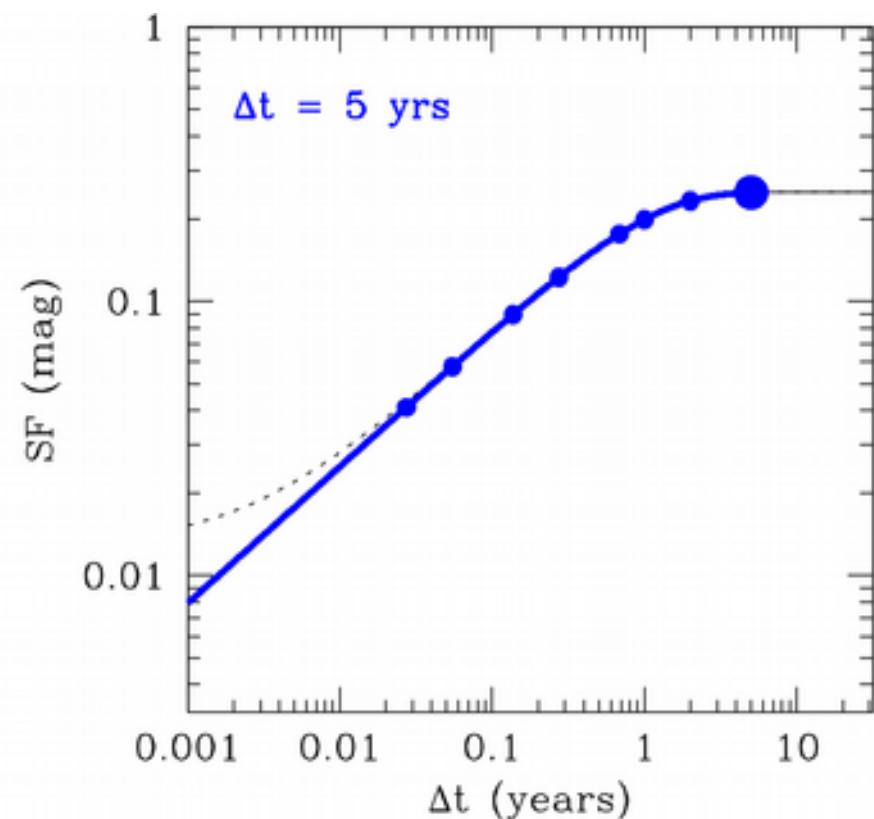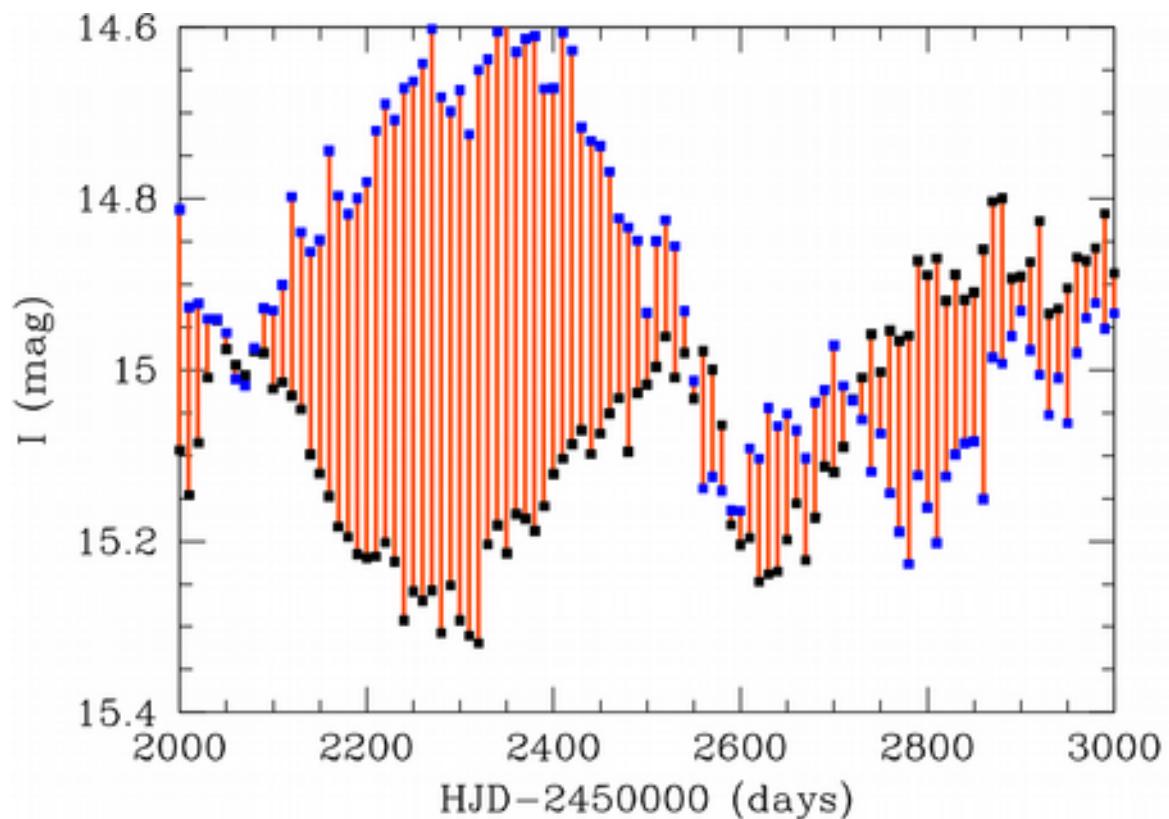
Structure Function

Structure Function

# Structure Function
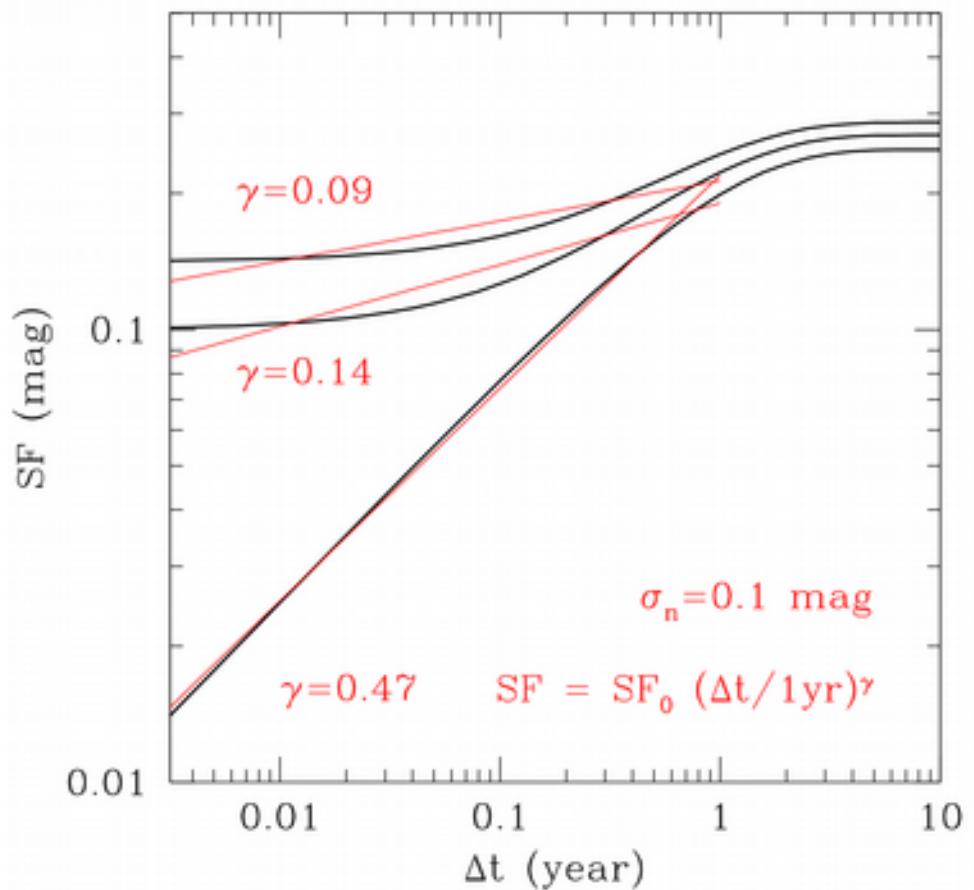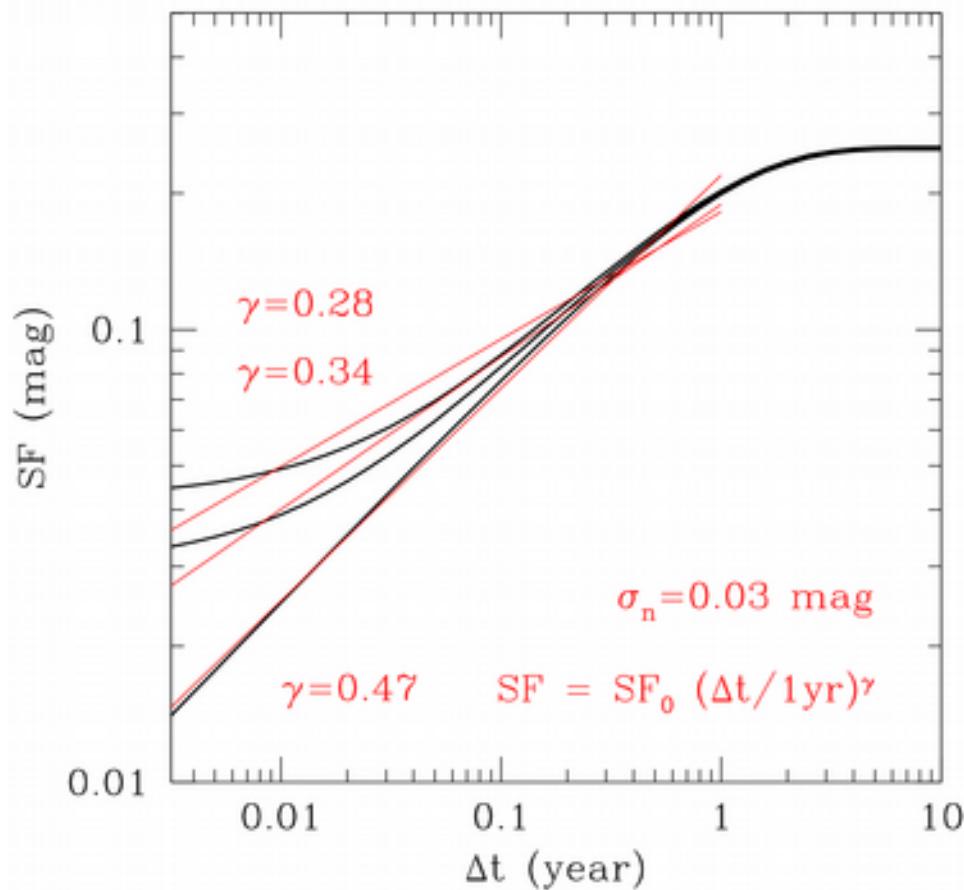
Structure Function

$$\mathrm{cov}(y_i, y_j) \equiv \mathrm{var}(y_i) - V(y_i, y_j)$$

$$V(y_i, y_j) = \frac{1}{2}\langle(y_i - y_j)^2\rangle$$
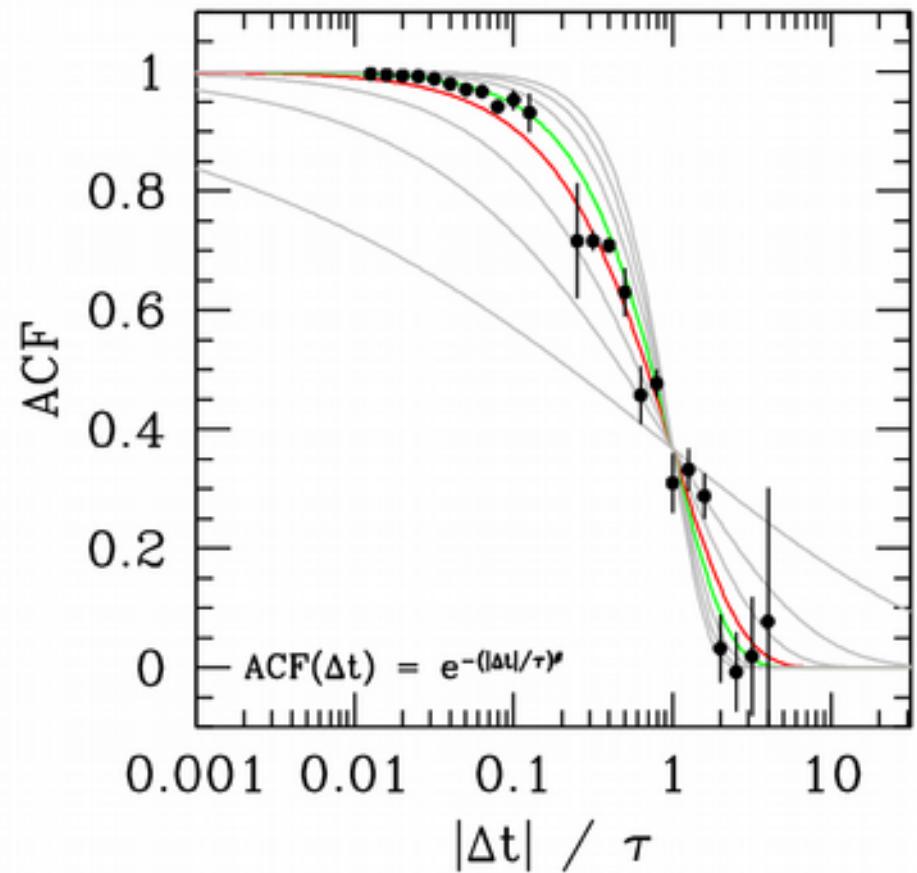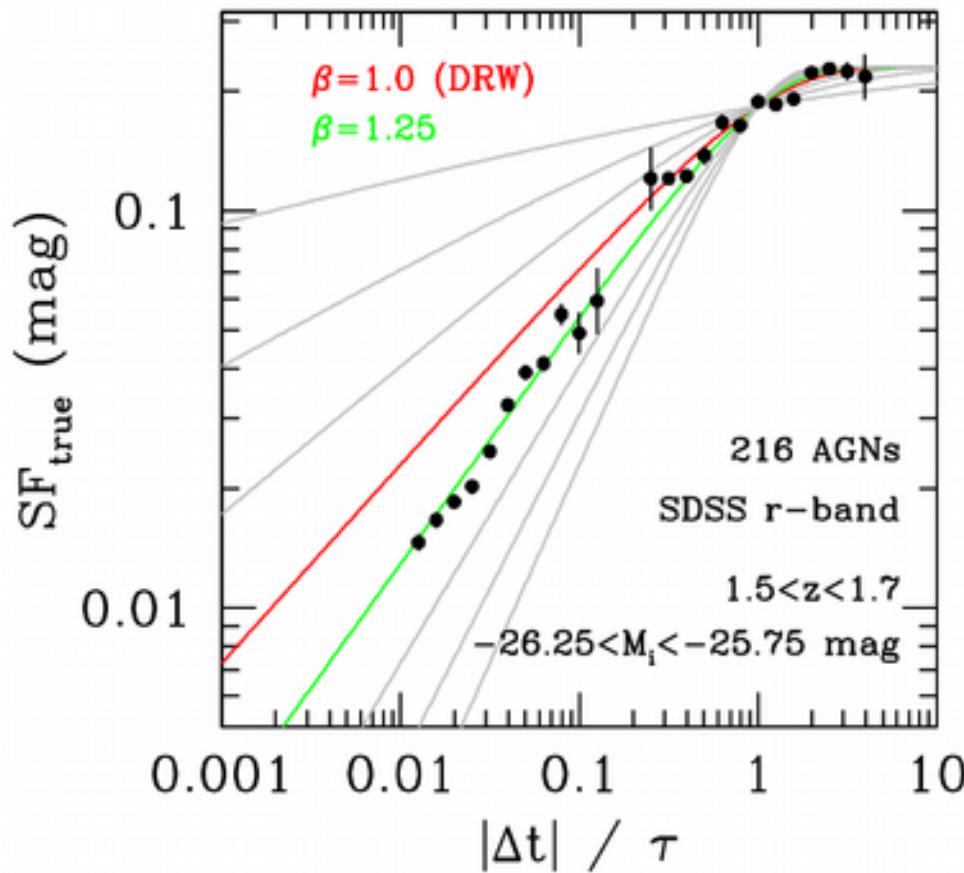
$$SF = \sqrt{2V}$$

Structure Function

$$SF = \sqrt{SF_\infty^2 (1 - ACF) + 2\sigma_n^2}$$
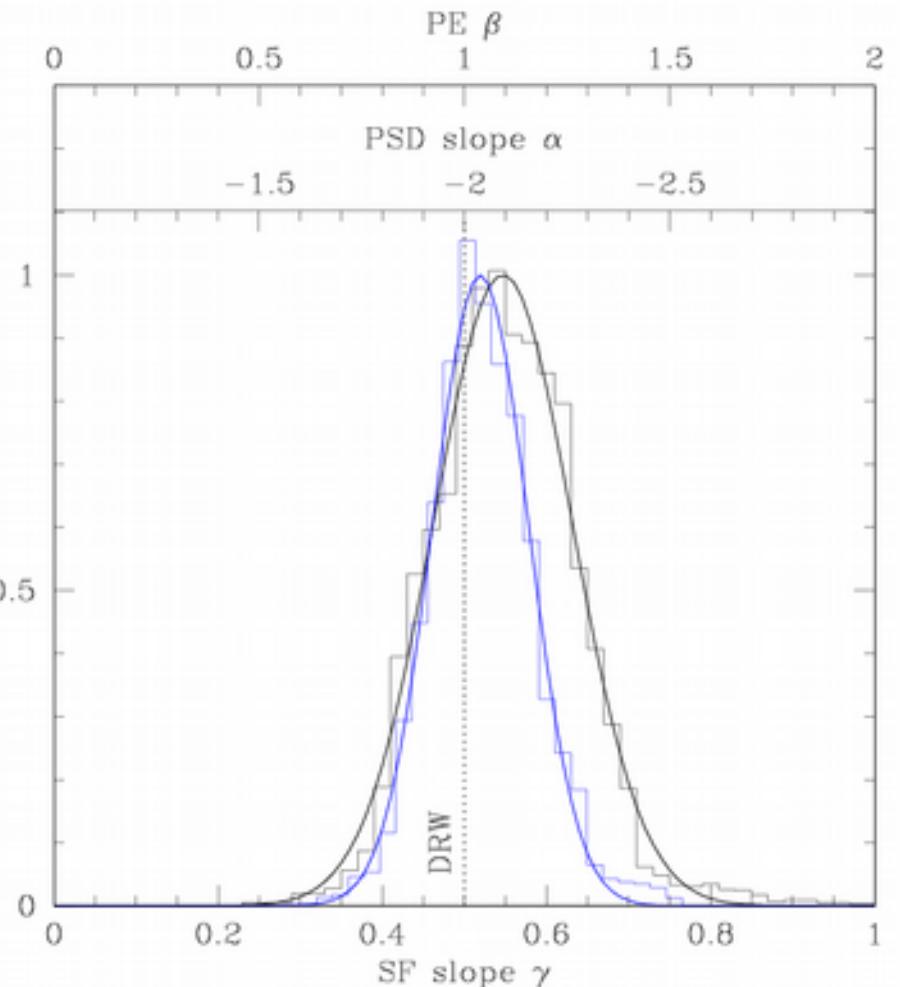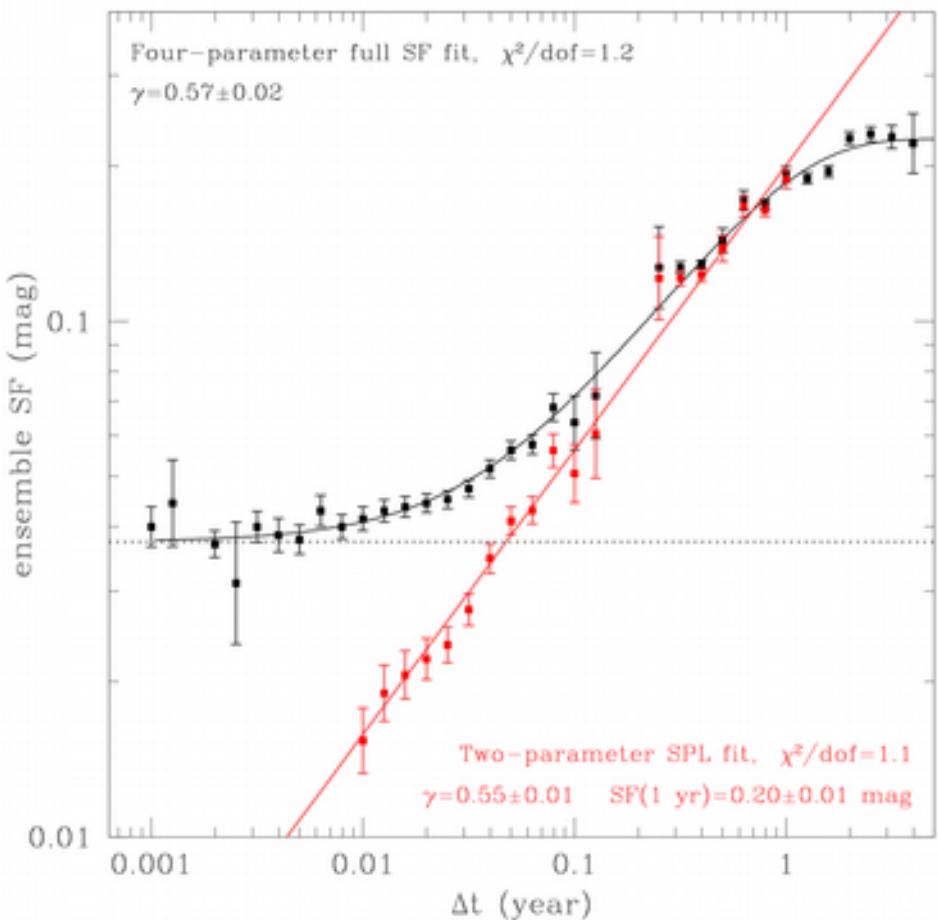
Structure Function and ACF

$$SF = \sqrt{SF_\infty^2 \left(1 - ACF\right) + 2\sigma_n^2}$$

$$ACF = e^{-\left(\frac{|\Delta t|}{\tau}\right)^\beta}$$

SDSS (9200 AGN, 8 yrs, 60 epochs)

Kozłowski 2016, ApJ, 826, 118
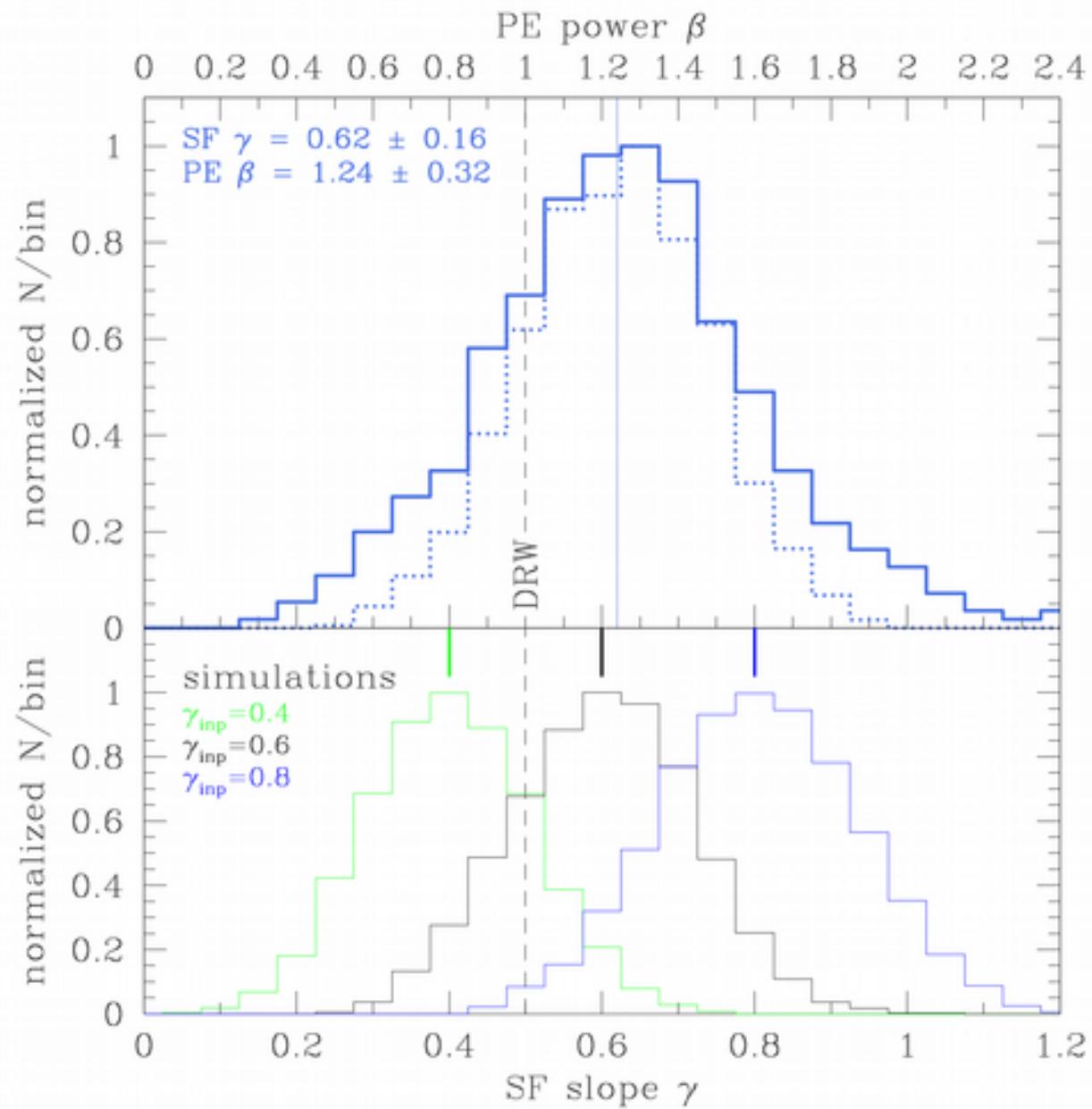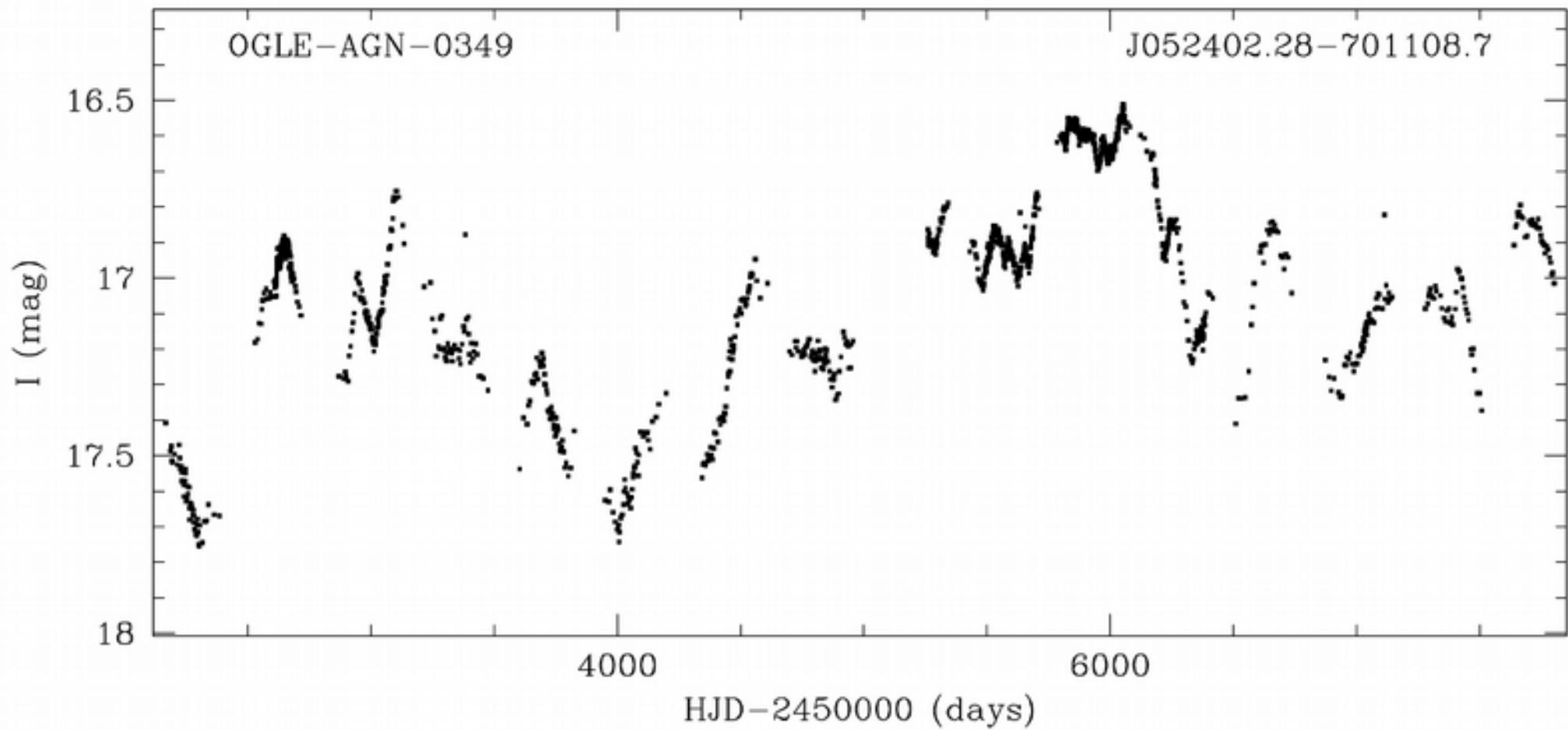
Structure Function: OGLE-III + OGLE-IV
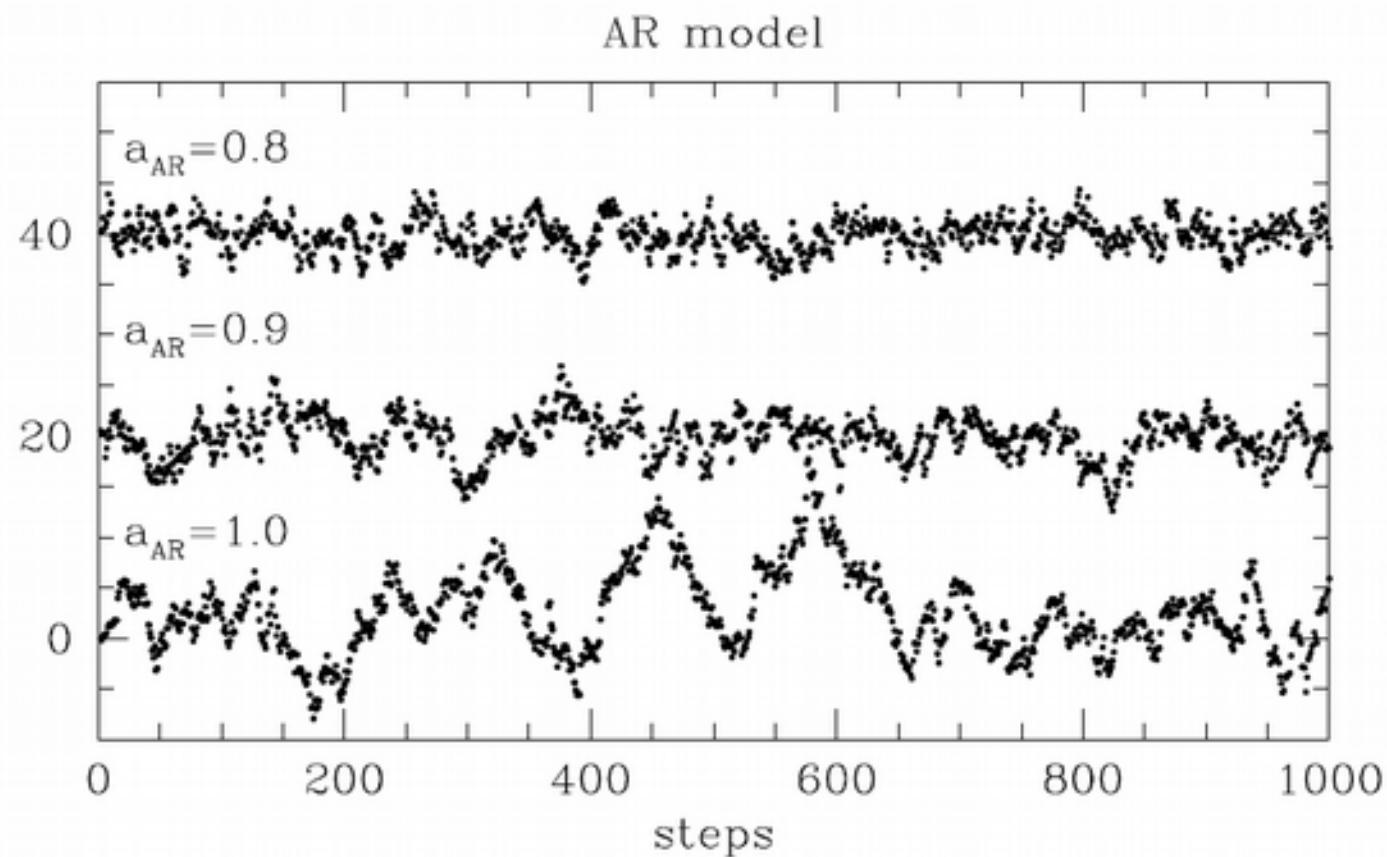
Light Curve Modeling
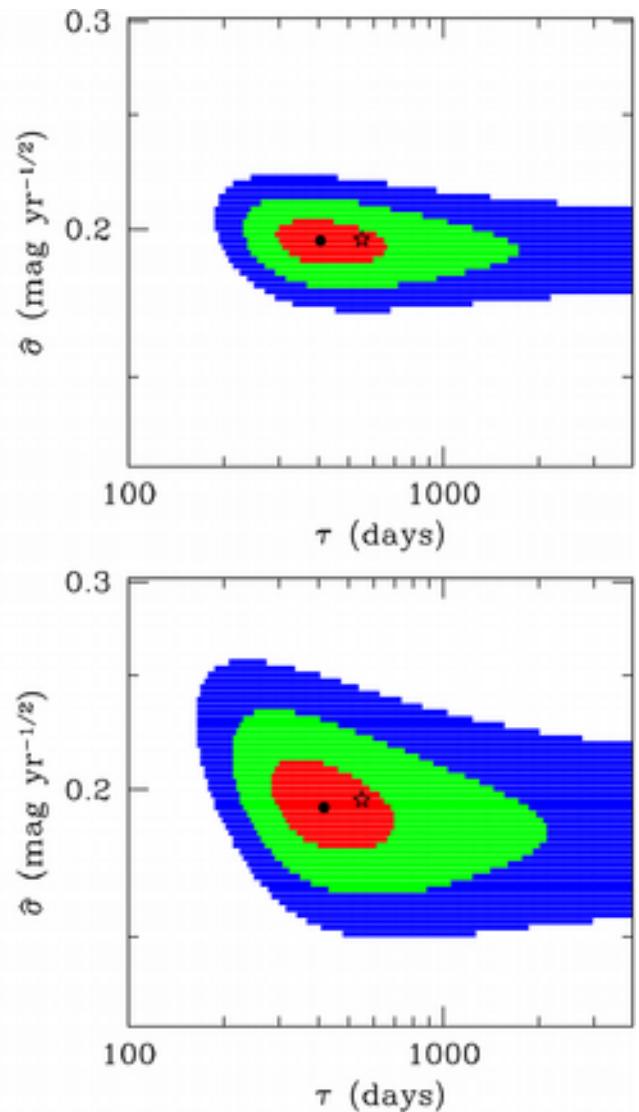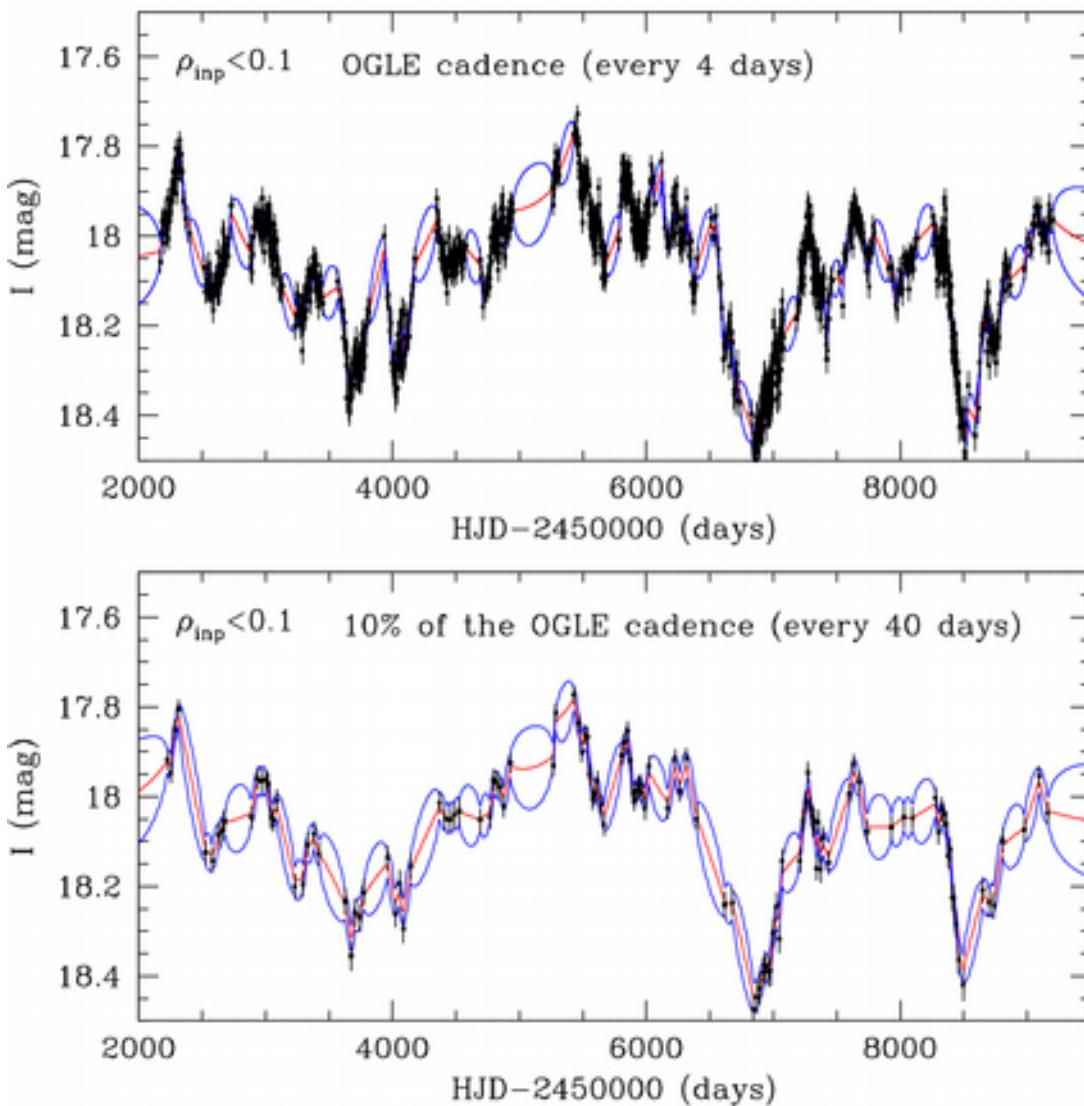
Simple Autoregressive (AR) Model

$$y_i = a_{AR} \times y_{i-1} + \epsilon_i \qquad (1)$$

AR model

Damped Random Walk (DRW)

Kozłowski 2017, A&A, 597, 128

DRW Problems

Kozłowski 2017, A&A, 597, 128

DRW Degeneracy

Kozłowski 2016, MNRAS, 459, 2787
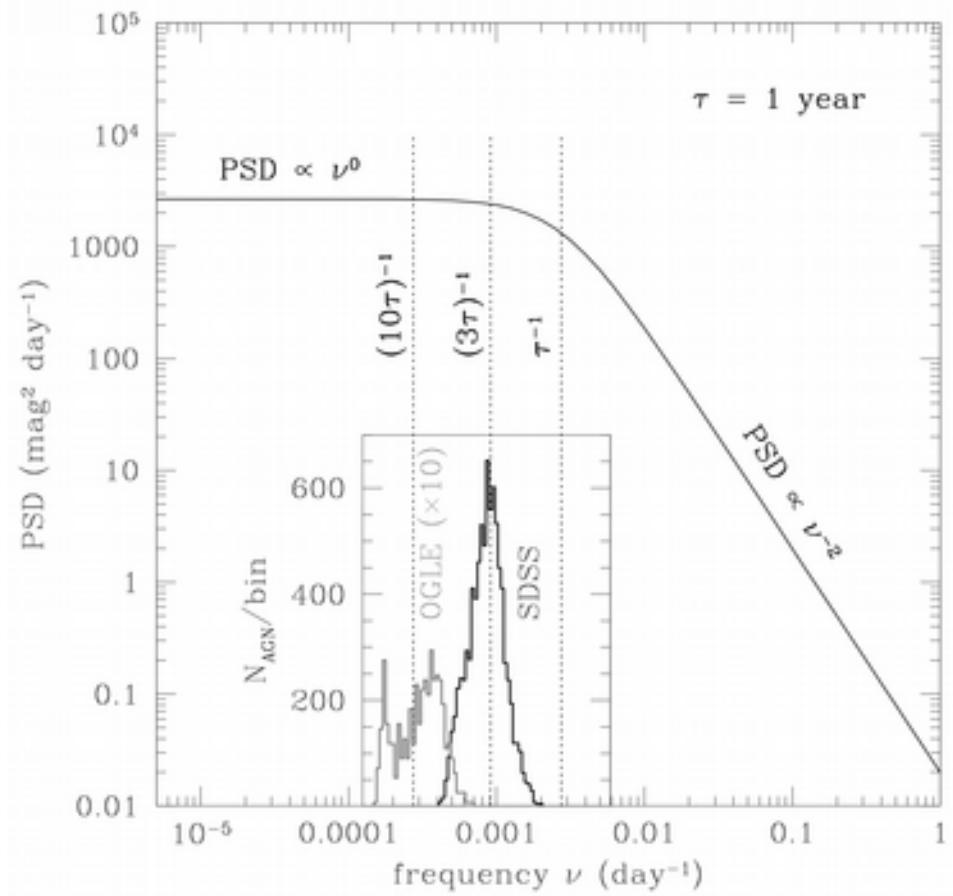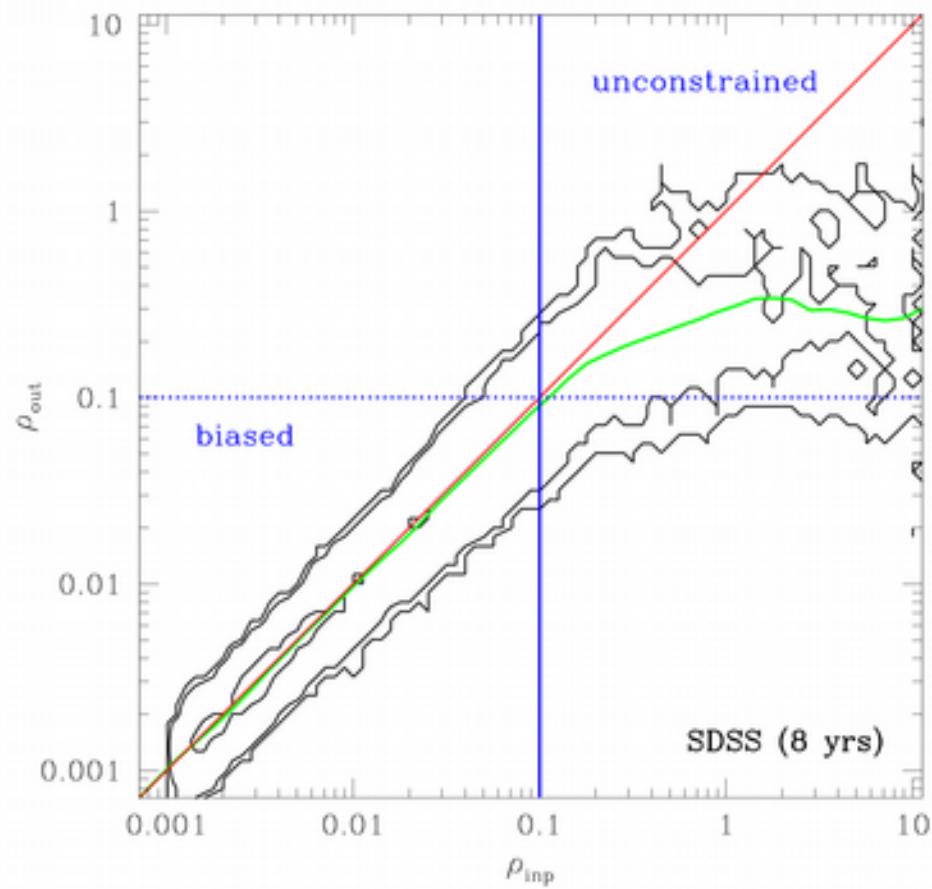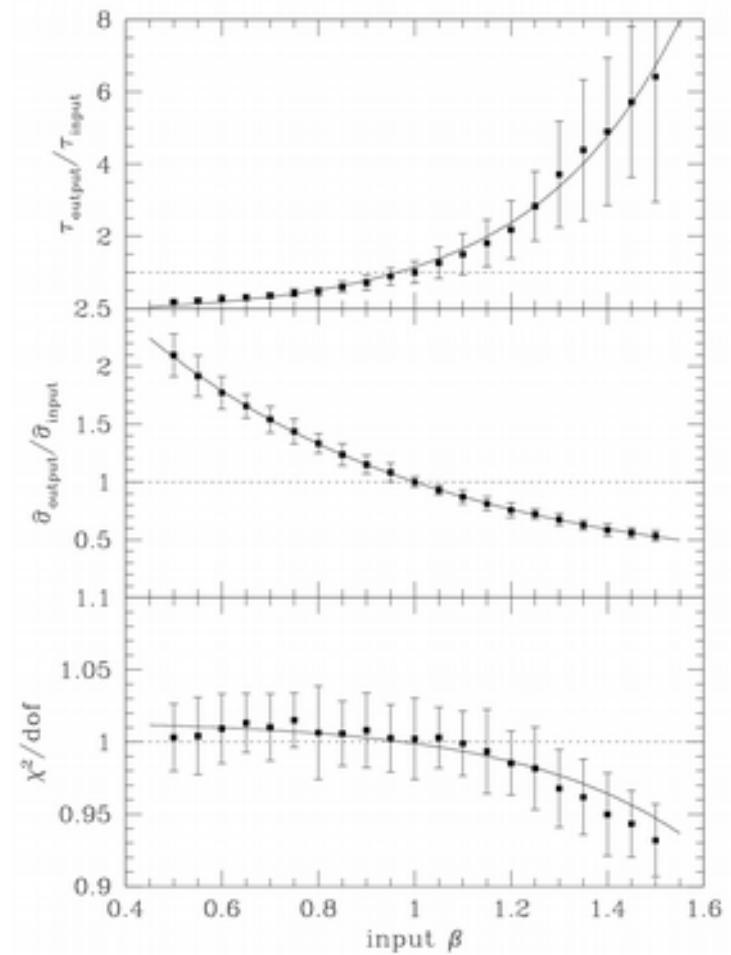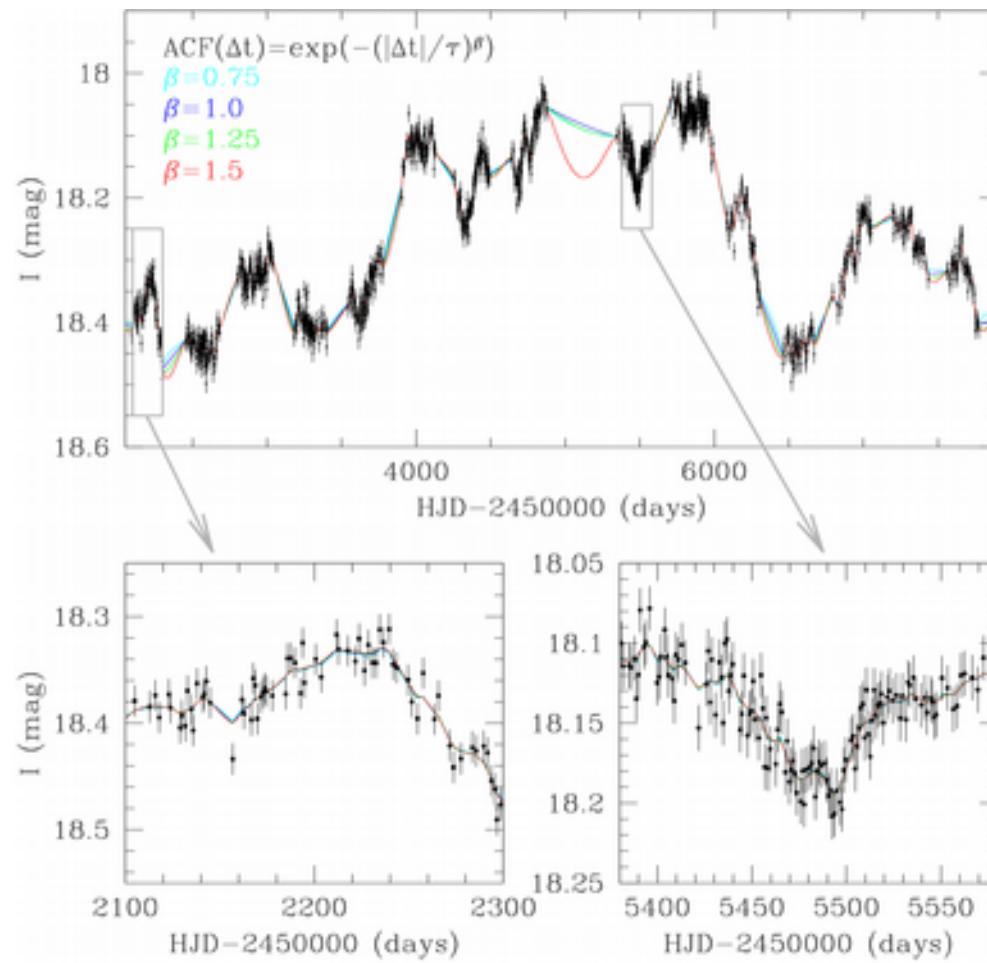
Thank you!

Revisiting Stochastic Variability of AGNs with Structure Functions
Kozłowski Szymon, 2016, The Astrophysical Journal, 826, 118

A degeneracy in DRW modelling of AGN light curves
Kozłowski Szymon, 2016, MNRAS, 459, 2787

Limitations on the recovery of the true AGN variability parameters using damped random walk modeling
Kozłowski Szymon, 2017, A&A, 597, 128

A Method to Measure the Unbiased Decorrelation Timescale of the AGN Variable Signal from Structure Functions
Kozłowski Szymon, 2017, The Astrophysical Journal, 835, 250

Structure Function

$$V(y_i, y_j) = var(y_i, y_i) - cov(y_i, y_j)$$

$$y_i = s_i + n_i$$

$$
\begin{aligned}
V(y_i, y_j) \quad = \quad & var(s_i, s_i) - cov(s_i, s_j) + \\
+ \quad & var(n_i, n_i) - \cancel{cov(n_i, n_j)}
\end{aligned}
$$

$$SF = \sqrt{2V}$$

$$SF = \sqrt{2(\sigma_s^2 + \sigma_n^2 - cov(s_i, s_j))}$$

Structure Function

$$ACF = \frac{cov(s_i, s_j)}{var(s_i, s_i)} = \frac{cov(s_i, s_j)}{\sigma_s^2}$$

$$SF = \sqrt{2\sigma_s^2 (1 - ACF) + 2\sigma_n^2}$$

$$SF = \sqrt{SF_\infty^2 (1 - ACF) + 2\sigma_n^2}$$