

EXTRACTING INFORMATION FROM AGN VARIABILITY: A LSST AGN COLLABORATION PROPOSAL

LSST AGN Science Collaboration Roadmap Development Meeting Grapevine, TX

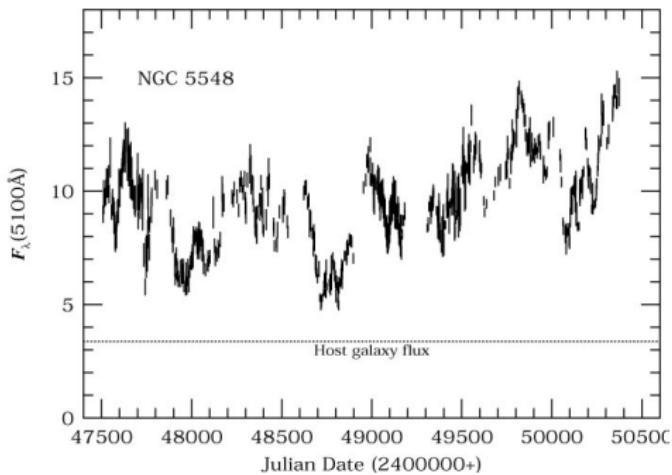
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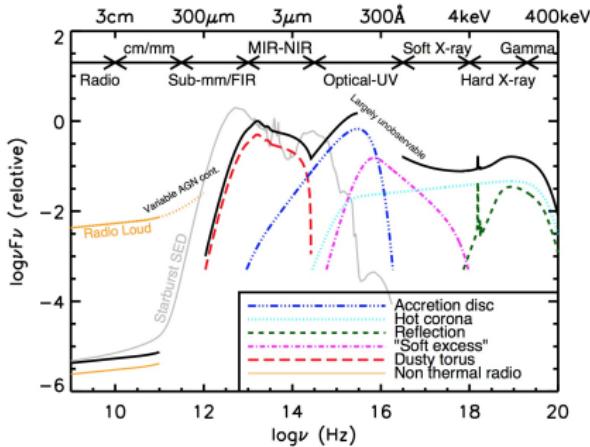
AGN Exhibit Rapid, Stochastic, Luminosity Variations (and we do not know why!)



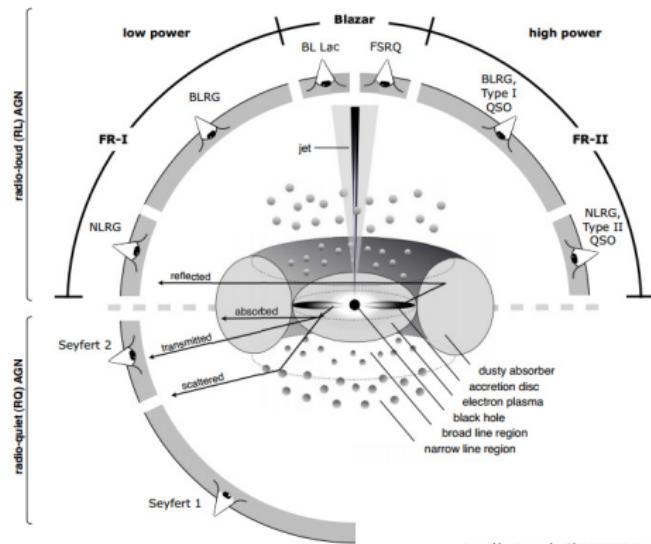
(Peterson et al. 1999)

- * ~ 90 % vary (Sesar et al. 2007)
- * Pan-spectral: shorter $\lambda \Rightarrow$ stronger variability
- * Stochastic! (Peterson 1997)
- * longer λ lag shorter λ

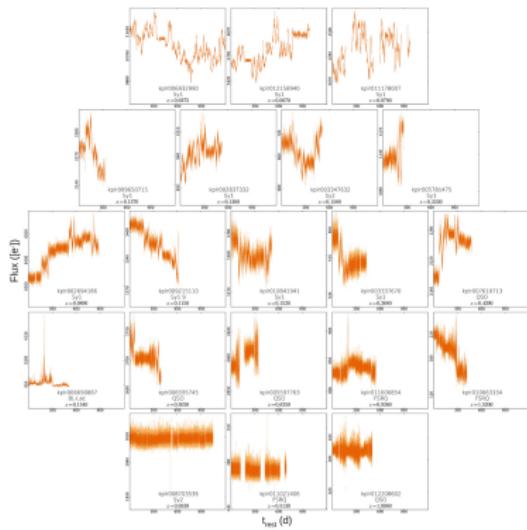
AGN Morphology: Continuum Variations → Origin in Accretion Disk



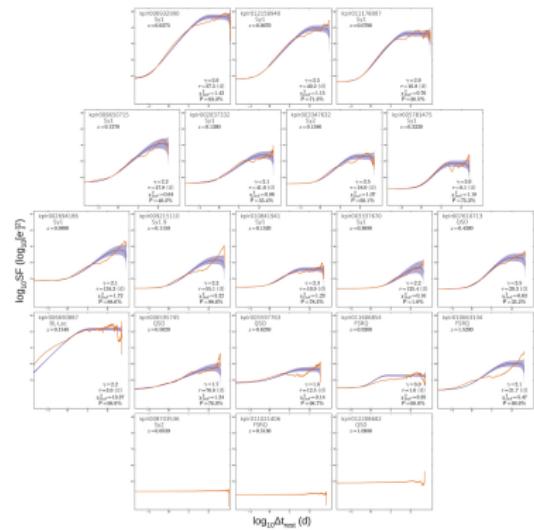
Chris Harrison

<http://arxiv.org/pdf/1302.1397v1.pdf>

AGN Show Complex Variability Behavior



- ✿ $z \sim 0.02\text{-}1.5$
- ✿ $\delta t_{\text{rest}} \sim 14\text{-}28 \text{ min}$
- ✿ $N \sim 16k\text{-}60k$



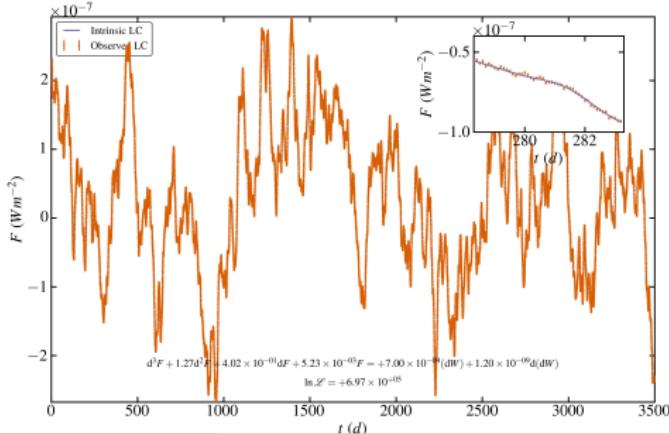
- ✿ PSD index $-1.7 \sim -3.1$
- ✿ PSD model too simple
- ✿ Onset over $\approx 1 \text{ hr}$ to $\approx 1 \text{ d}$

Continuous-time AutoRegressive Moving Average (C-ARMA) Processes

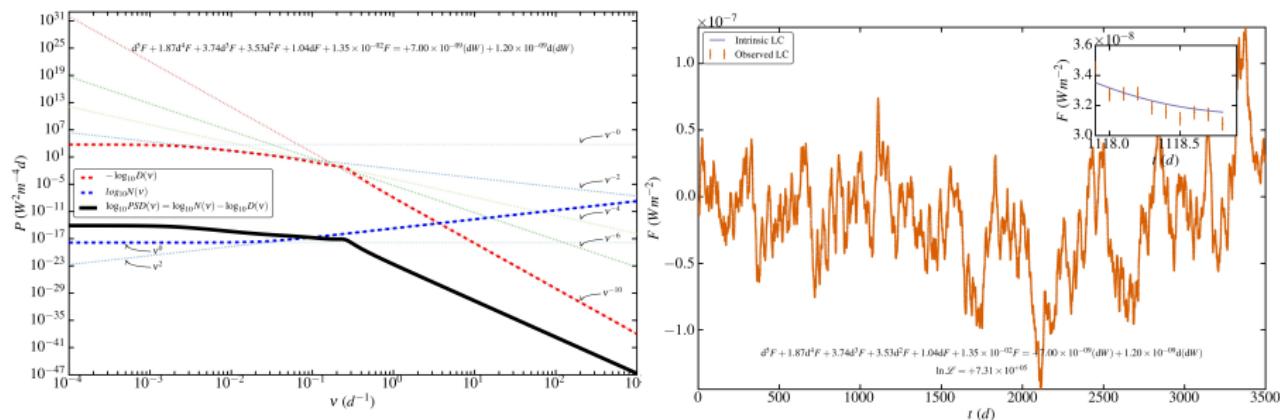
$$dW \sim \mathcal{N}(0, dt)$$

$$d^p x + \alpha_1 d^{p-1} x + \dots + \alpha_{p-1} dx + \alpha_p x = \beta_0(dW) + \dots + \beta_q d^q(dW)$$

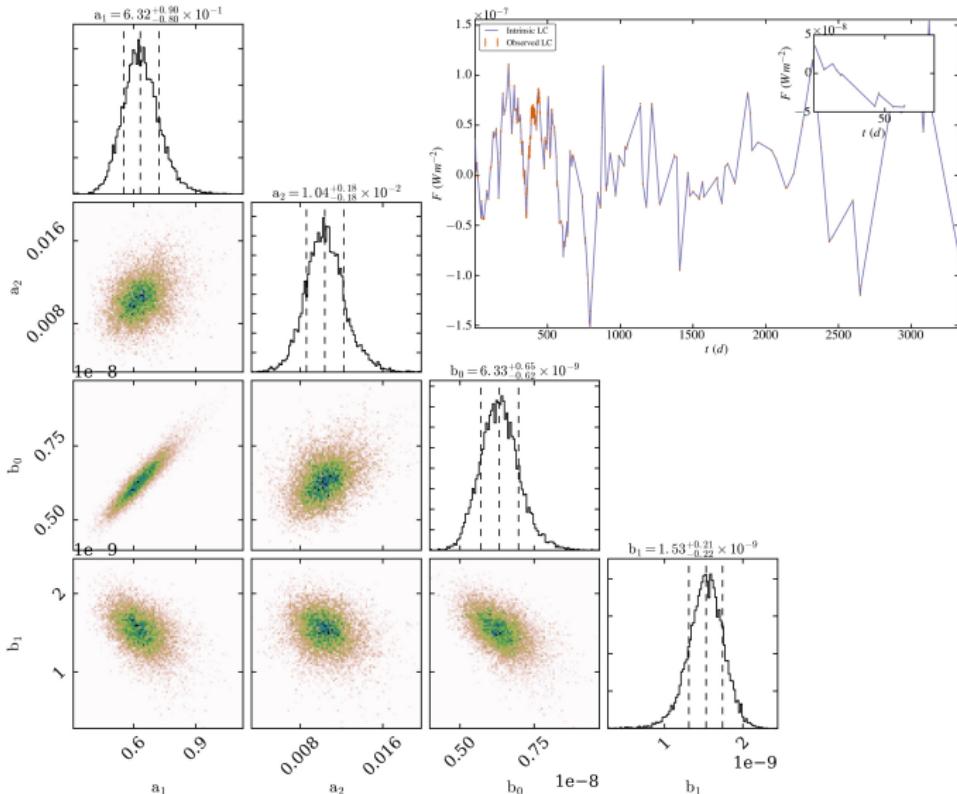
- ✿ Itō calculus Brockwell (2014); Davis (2002); Kelly et al. (2014)
- ✿ Drive linearized system with noise
- ✿ PSD is a ratio of even polynomials in frequency



Power Spectral Density Eg. C-ARMA(5,1)

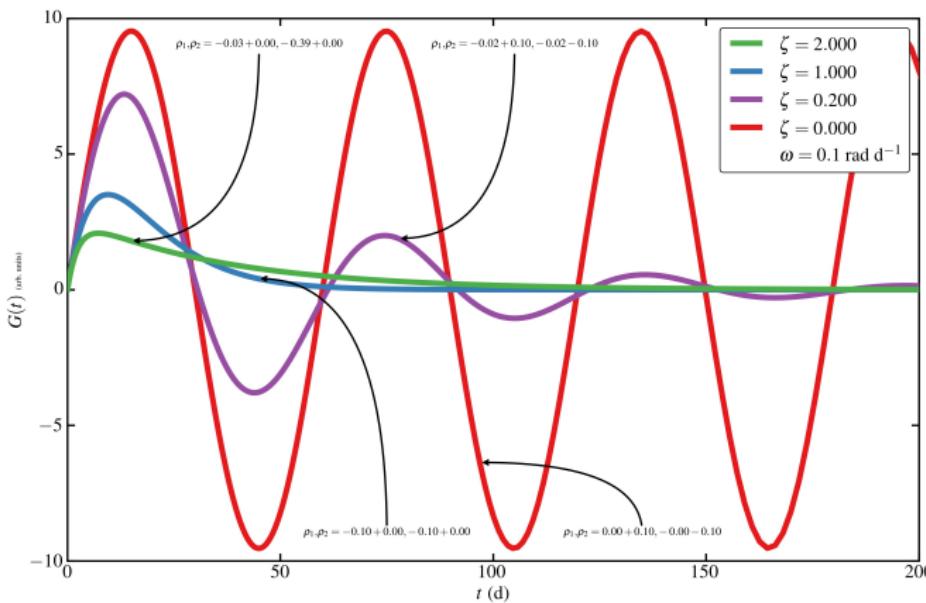


Confidence Interval Estimates

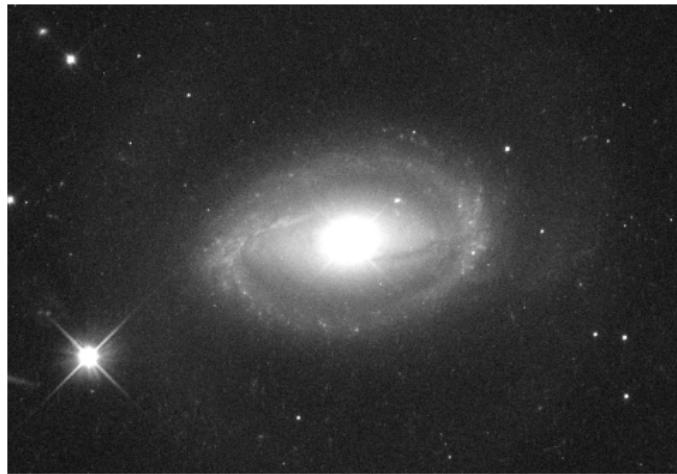


How to Interpret?: Green's Function of LHS (eg. C-ARMA(2,1)...)

$$d^2G + 2\omega\zeta dG + \omega^2 G = \delta(0)$$



Zw 229-15 (kplr006932990)



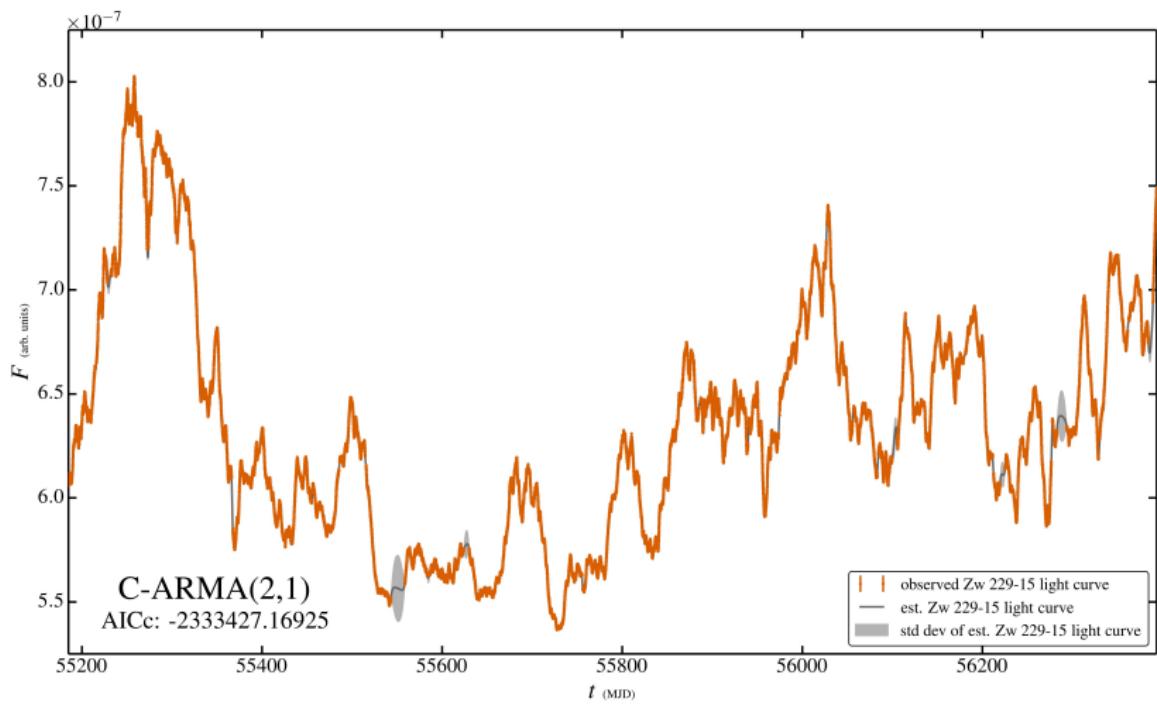
HST Image

- * Sy 1 in Lyra
- * $\Delta T_{H\beta} = 3.86^{+0.69}_{-0.90}$ d
- * mag 15.4
- * $M_{BH} = 1.00^{+0.19}_{-0.24} \times 10^7 M_\odot$

(Barth et al. 2011)

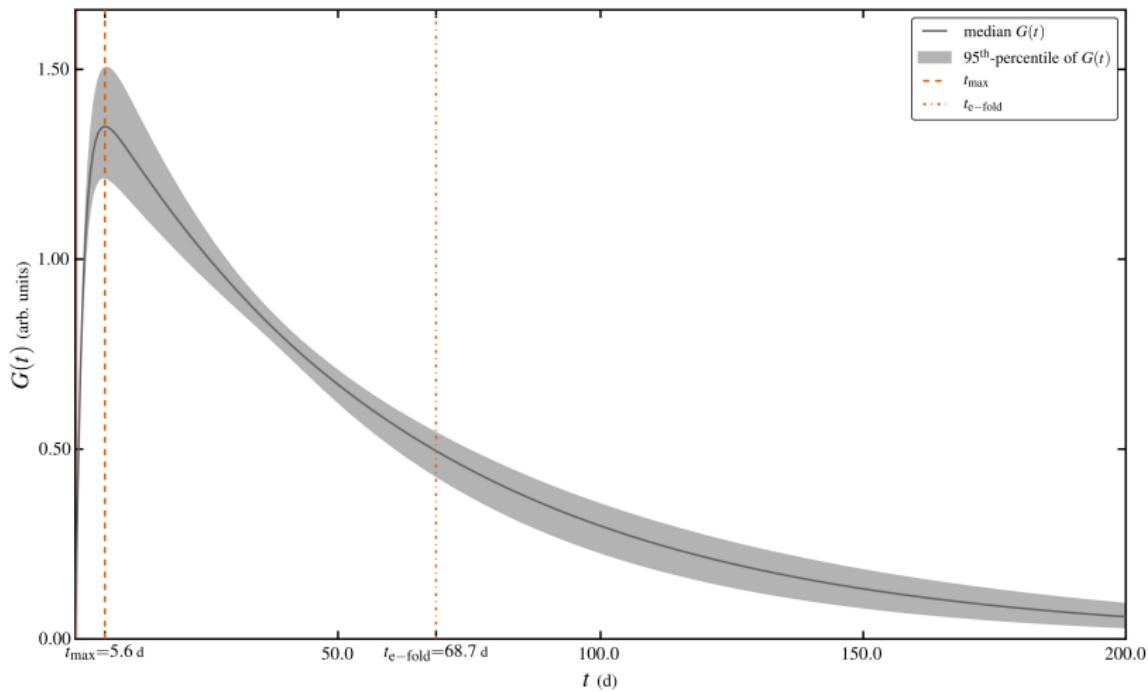
C-ARMA(2,1) model of Zw 229-15

Smoothed light curve

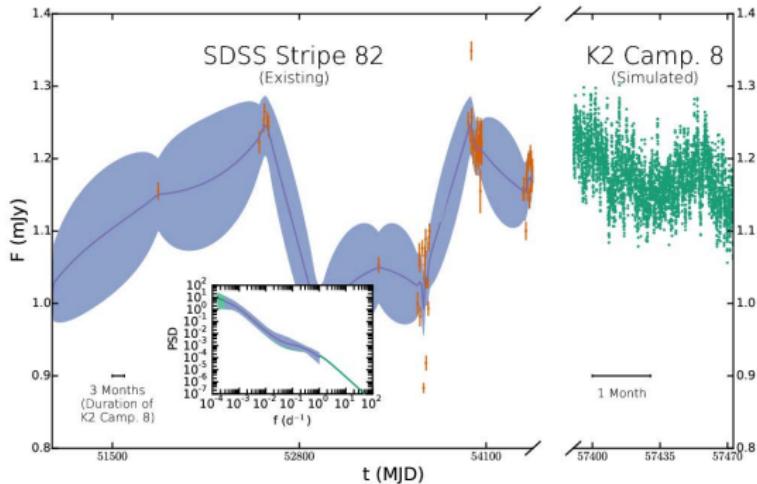


C-ARMA(2,1) model of Zw 229-15

Green's Function

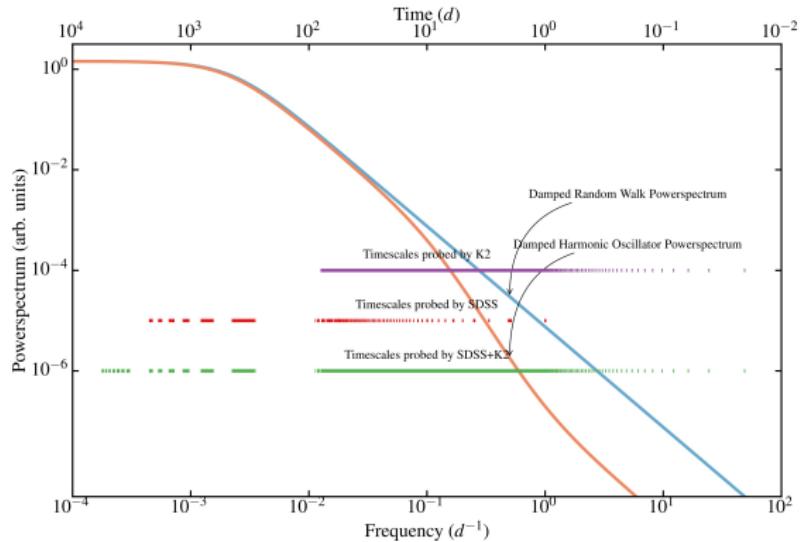


WiP: Power of SDSS+K2



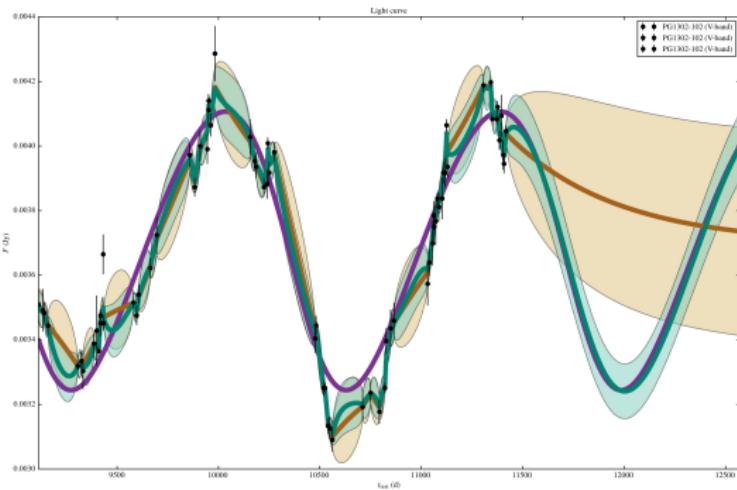
- * Spectra required for good color terms

WiP: K2 observations of Stripe 82 QSOs



- * Prototype for LSST-DDF
- * Can we use DASCH as well?

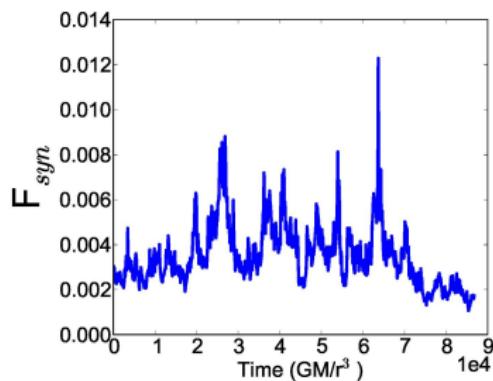
WiP: Is PG 1302-102 a Relativistically-Beamed Massive Black Hole Binary?



- ✿ $a_1 \sim 6.8 \times 10^{-3}$ pc
- ✿ $a_2 \sim 1.1 \times 10^{-2}$ pc
- ✿ $T \sim 1343$ d
- ✿ $M_{12} \sim 4.05 \times 10^9 M_\odot$
- ✿ $M_2/M_1 \sim 0.66$
- ✿ $e \sim 0.077$

Work in Progress

- ⌘ KĀLĪ package for light curve analysis
- ⌘ SDSS Stripe 82 + K2 QSO variability
 - ⌘ Connection between AGN sub-type and variability
- ⌘ Detection of binary-SMBH via variability
- ⌘ Better time series models for exotic objects (blazars)
- ⌘ Cadence and periodicity requirements of LSST
- ⌘ Multi-wavelength variability
- ⌘ Comparing simulations with observations
- ⌘ Stationarity of AGN light curves



J. Drew Hogg

LSST Prep

- ⌘ Learn as much as we can about the AGN in the DDF (we'll surely want spectra if nothing else).
- ⌘ Determine single-band LSST sampling requirements (J. Moreno).
 - ⌘ Will the WFD survey be useful?
 - ⌘ Does adding DASCH & TESS help?
- ⌘ Test applicability of C-ARMA models to large sample of AGN (J. Moreno, J. O'Brien, M. Graham & others).
 - ⌘ Can we make a strong case for tweaking the WFD survey to make it more useful?
- ⌘ Probe connections between variability properties & physical properties (J. O'Brien)
 - ⌘ Is variability a proxy for some other property?
- ⌘ Develop models for multiplicative disturbances (for blazars etc..).
- ⌘ Develop & test models for continuum-continuum variability.
 - ⌘ How much does taking data non-simultaneously hurt us?

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