Estimation of overlapping sources: the problem

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AstroStat seminar

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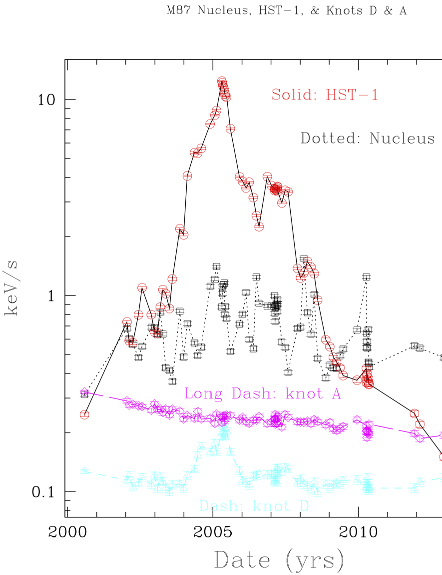
Problem Background

- Optical light curves measured by telescopes with insufficient resolution;
- Possibility of multiple overlapping sources that need to be distinguished.

Problem Background



Data

Every pixel supplies a pair of time series:

$$(X(t_i), t_i) : i = 1, ..., N$$

where

- t_i : time of observation (unevenly spaced)
- $X(t_i)$: (log) flux measured at time t_i.

Current approaches: single source

Variations in quasar luminosity can be modeled by a Continuous AR(1) process (otherwise known as the O-U process):

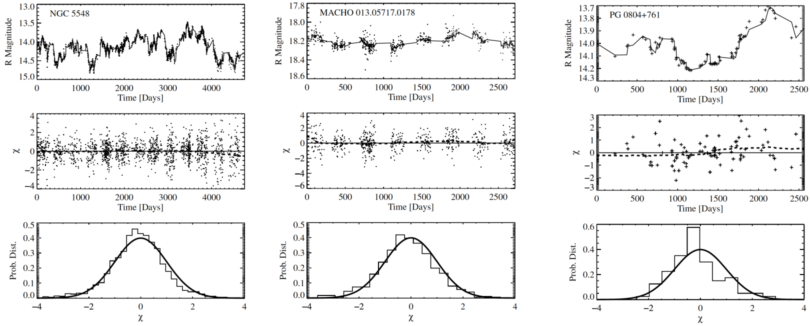


Figure: Kelly et al., 2006

Current approaches: single source

CAR(1) process:

- Parameters: $\boldsymbol{\theta} = \left(\mu, \sigma^2, \tau\right)$
  - μ: overall mean
  - σ: short-term variability
  - τ: relaxation/reversion time
- SDE representation:

$$dX(t) = -\frac{1}{\tau}\left(X(t) - \mu\right) dt + \sigma dB(t)$$

Current approaches: single source

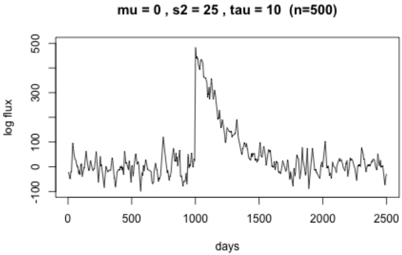
CAR(1) process:

- conditional law representation:

$$
\begin{aligned}
X(t_1) \mid \boldsymbol{\theta} &\sim N\left(\mu, \frac{\tau\sigma^2}{2}\right) \\
X(t_j) \mid X(t_{j-1}), \boldsymbol{\theta} &\sim N\left(\mu + a_j \left(X(t_{j-1}) - \mu\right), \frac{\tau\sigma^2}{2}\left(1 - a_j^2\right)\right)
\end{aligned}
$$

  where $a_j \equiv exp\left(-\left(t_j - t_{j-1}\right)/\tau\right)$
- Bayesian estimation (Kelly et al., 2009; Tak et al. 2016);
- Extensions: CARMA (Kelly et al., 2014)

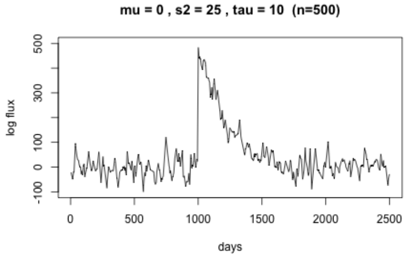
Overlapping sources: the case of flare



Questions:

- Did a flare get convoluted into the light curve?
- If so, when did it start?
- If there is one...is there a second one?

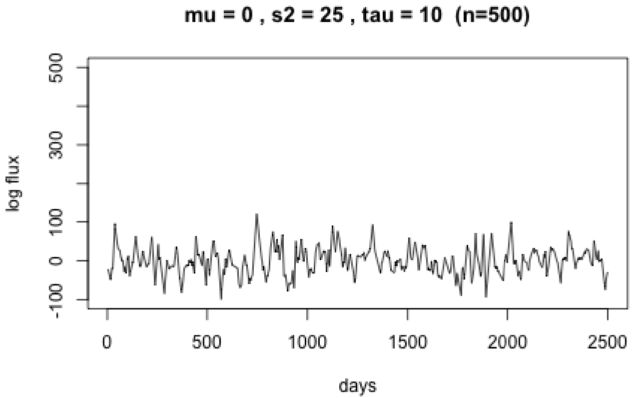
Overlapping sources: the case of flare



Possible ways to model:

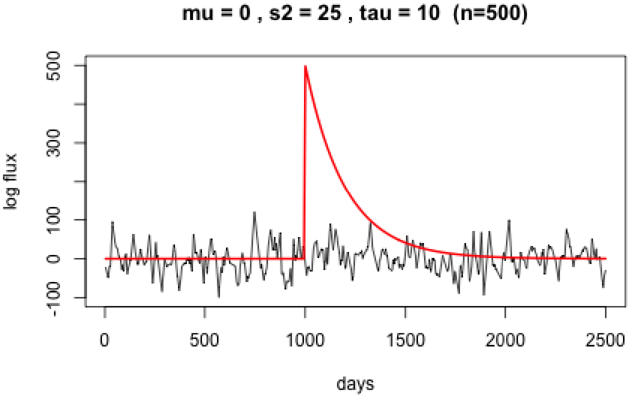
- Spline regression with unknown knot location;
- Hidden Markov-type models;
- ...?

Overlapping sources: the case of flare



$$\left(X\left(t_i\right), t_i\right)$$

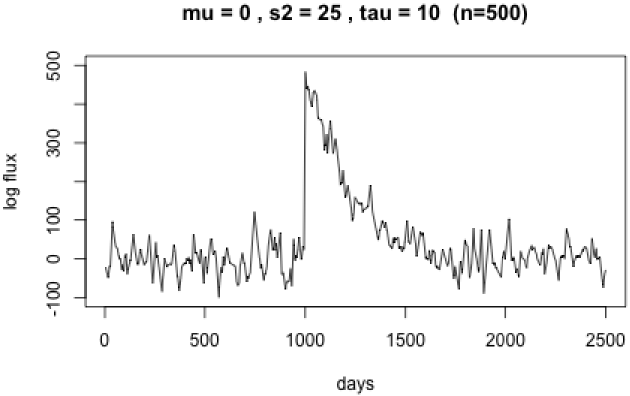
Overlapping sources: the case of flare



$$\left(X\left(t_i\right) + \color{red}{K_\eta\left(t_i\right)}, t_i\right)$$

$$K_\eta\left(t_i\right) = \eta_1 \cdot \exp\left(-\left(t_i - \eta_2\right)/\eta_3\right) \cdot \mathbf{1}\left(t_i > \eta_2\right)$$

Overlapping sources: the case of flare



$$\left(X'\left(t_i\right) \equiv X\left(t_i\right) + K_{\boldsymbol{\eta}}\left(t_i\right), t_i\right)$$

$$K_{\boldsymbol{\eta}}\left(t_i\right) = \eta_1 \cdot \exp\left(-\left(t_i - \eta_2\right)/\eta_3\right) \cdot \mathbf{1}\left(t_i > \eta_2\right)$$