Measuring the size of the BLR in quasars with *Microlensing-aided reverberation mapping*

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with Malte Tewes (AIfA – Bonn - DE)

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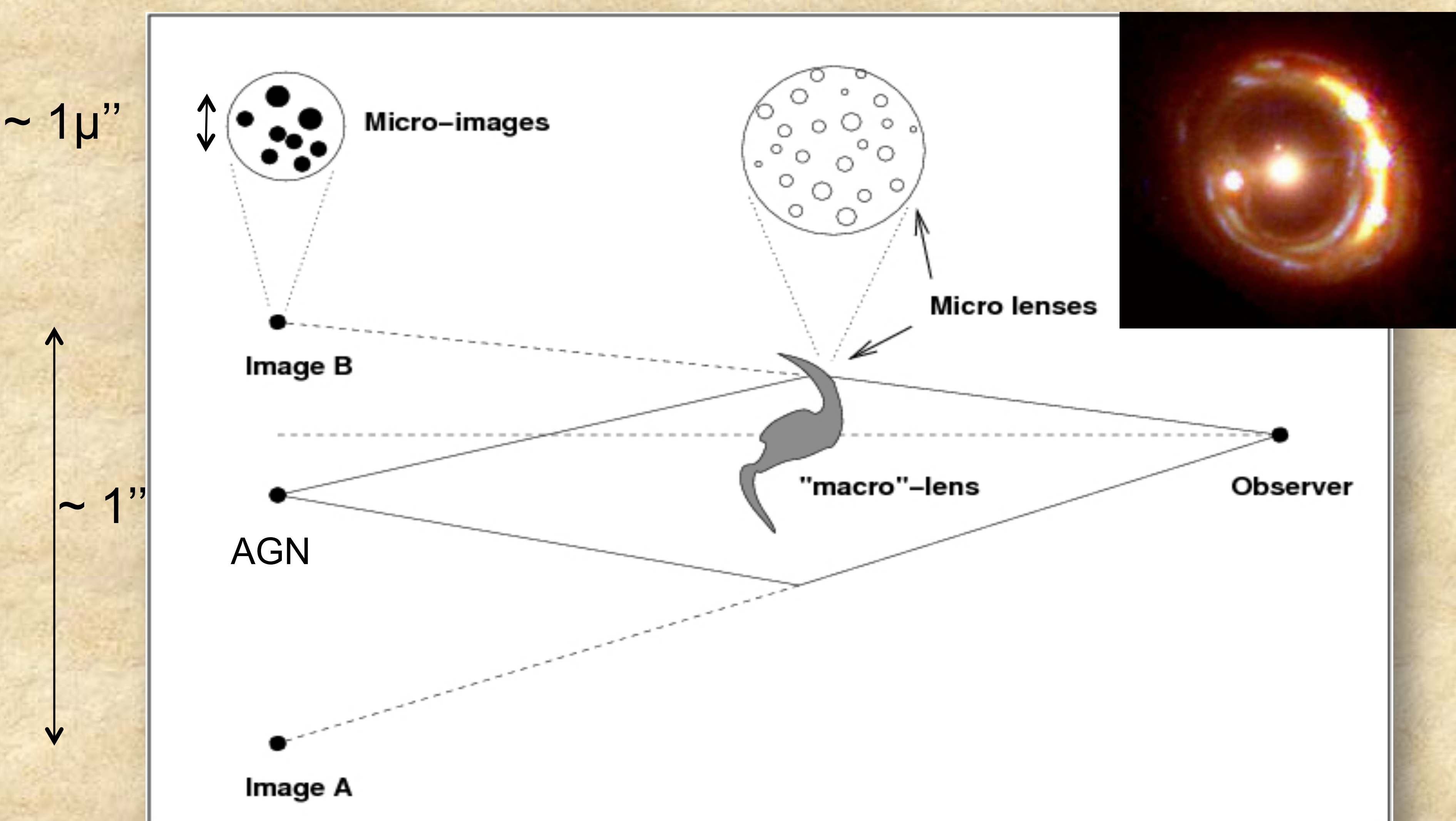
Introduction



(Credit: Courbin, Saha, Schechter 2003; Claeskens+ 2006)

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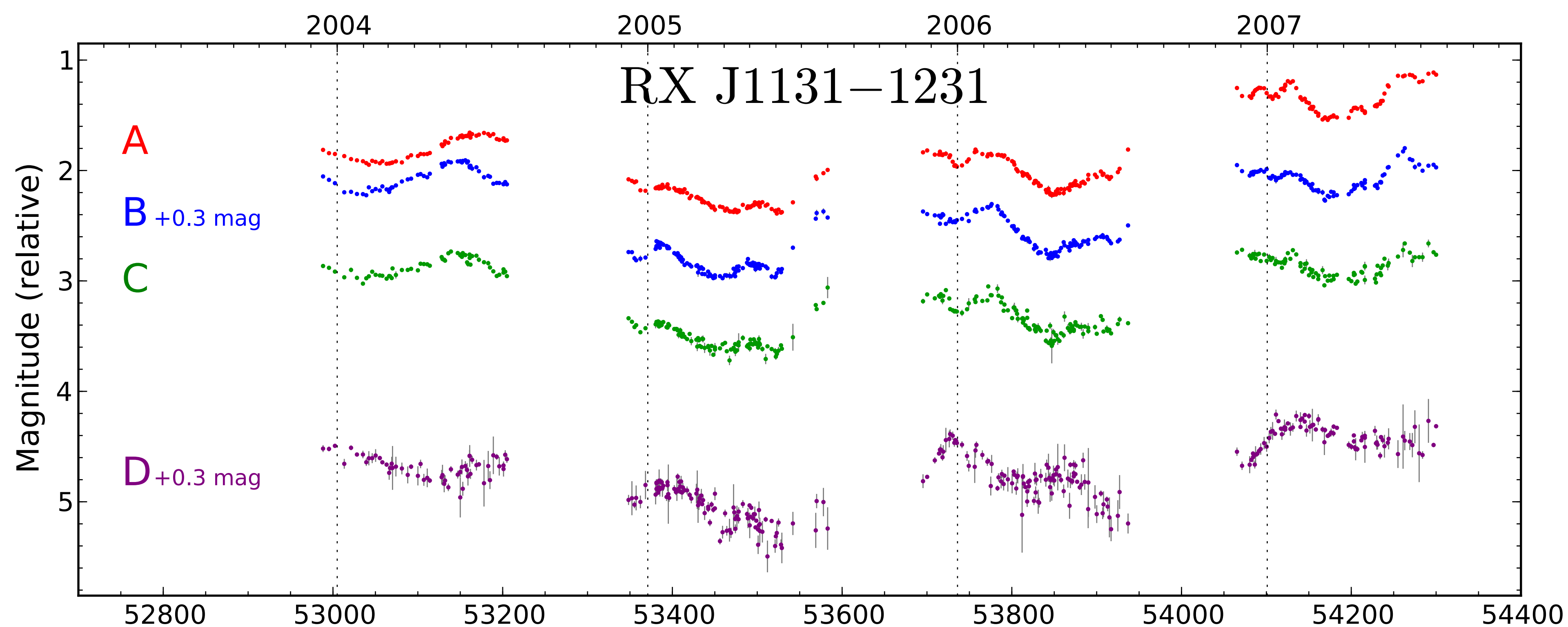
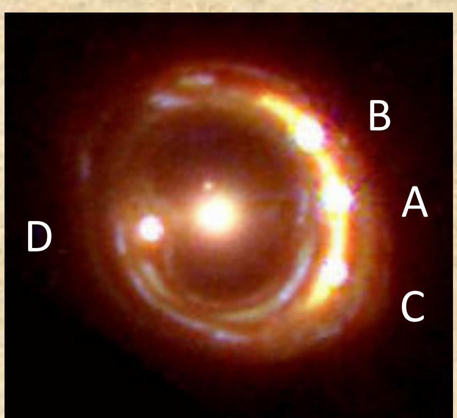


COSMOGRAIL lightcurve



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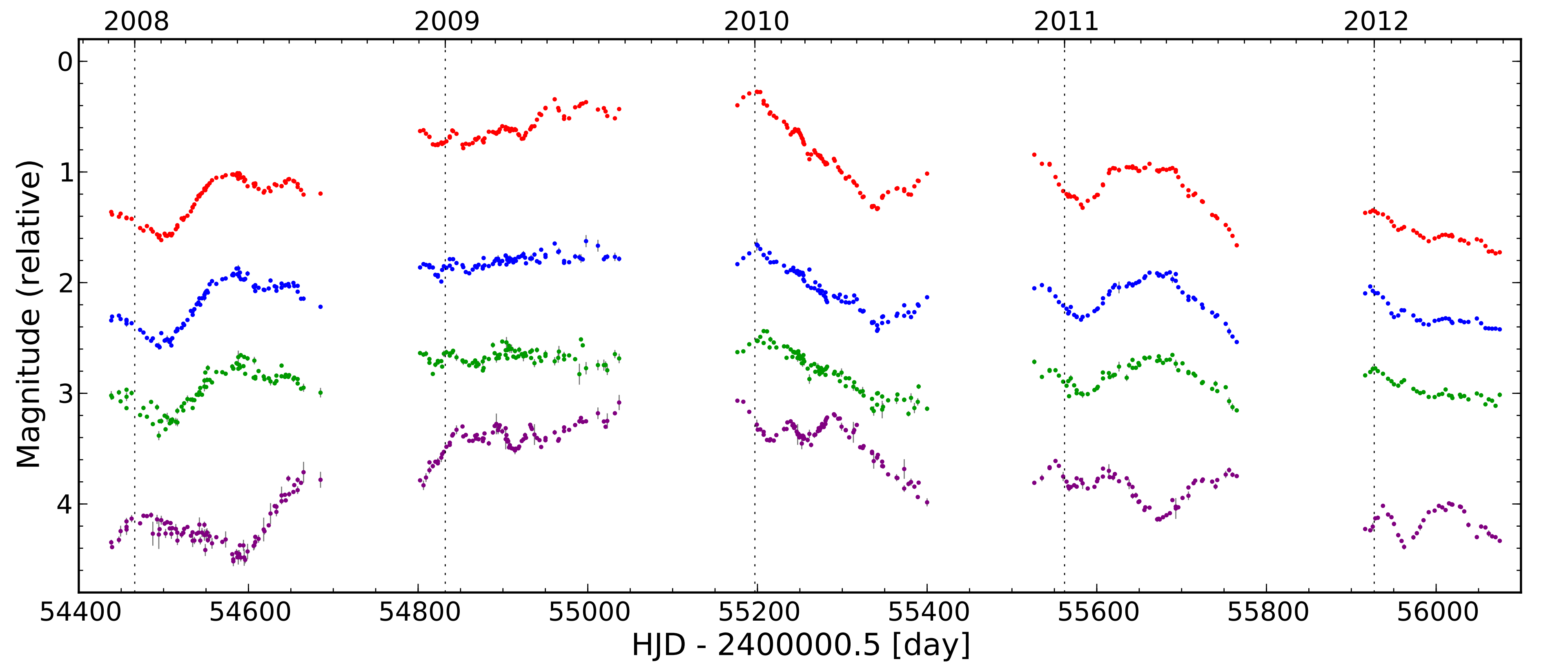

Tewes et al. 2013, A&A, 556, A22

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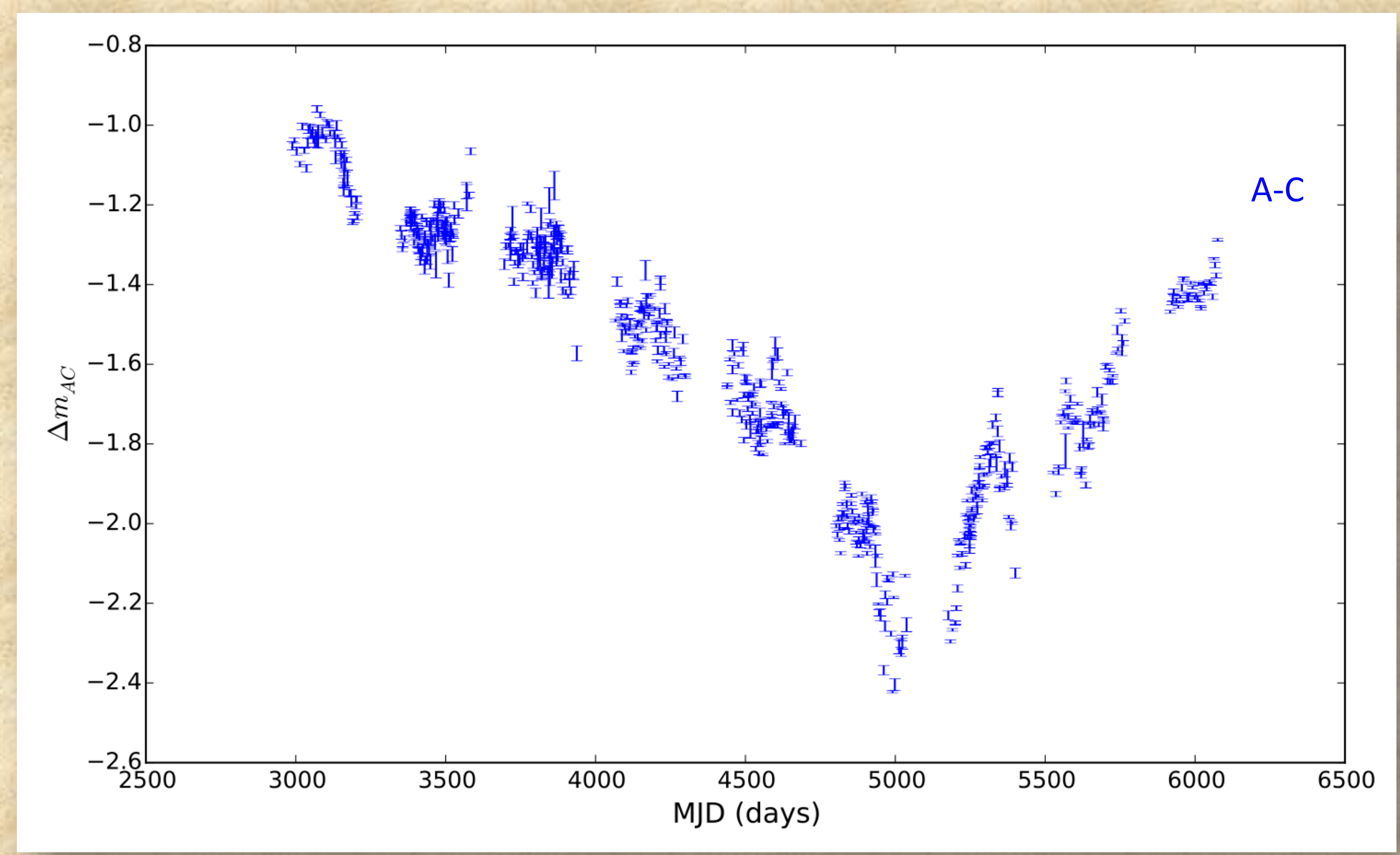

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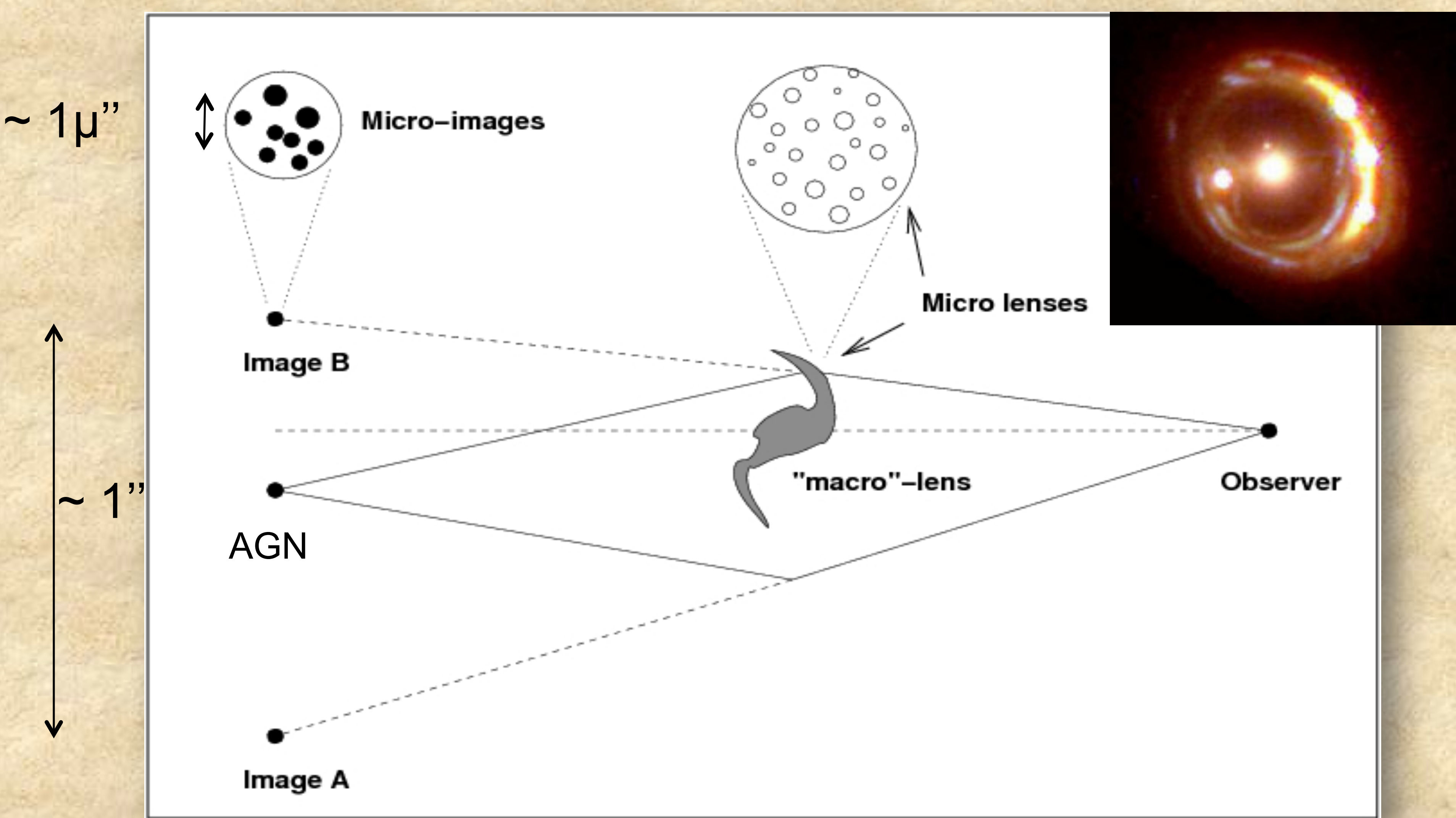

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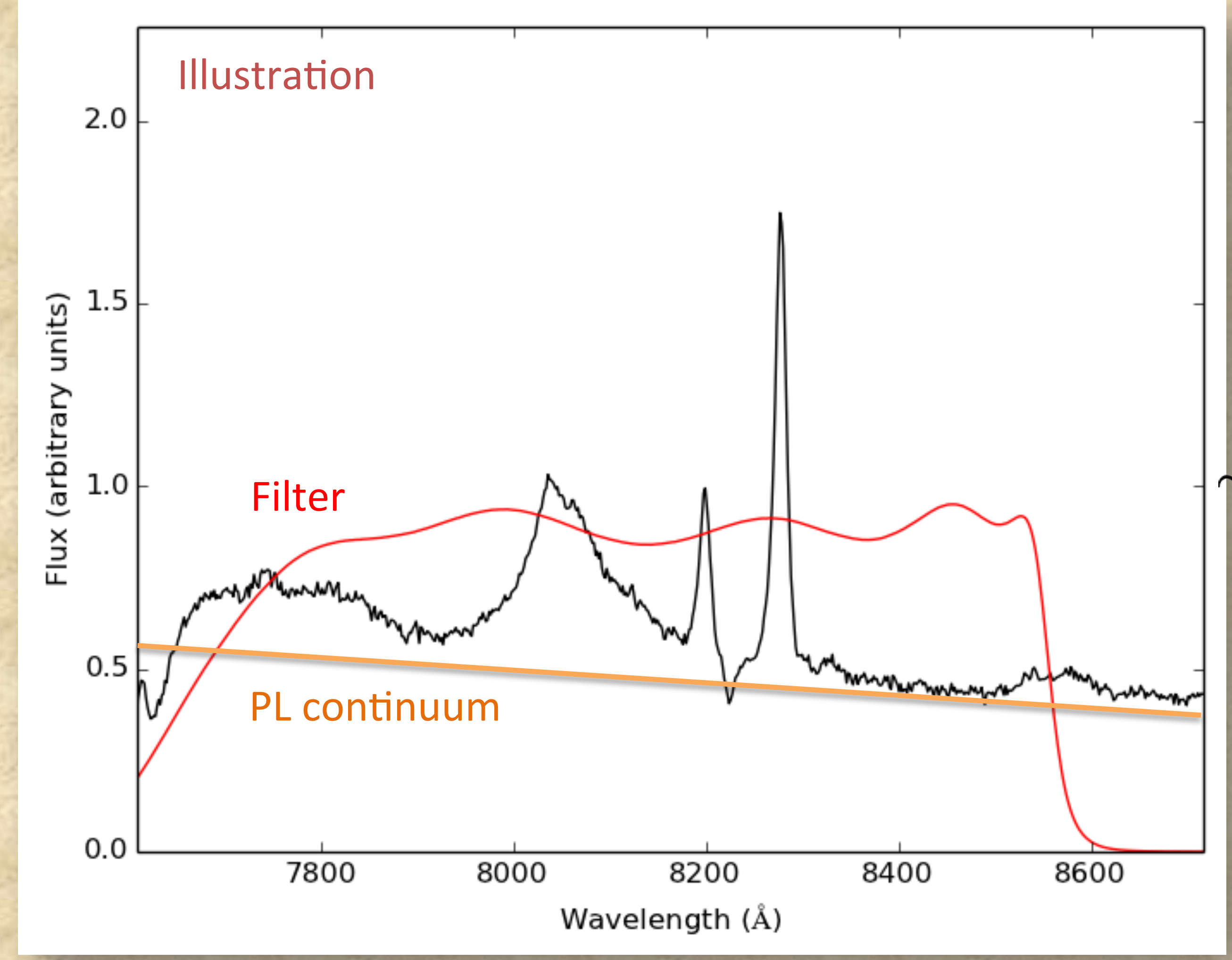
Microlensing and broad band filters

Monitoring data are BROAD band: mix several emission components



η_0 = micro-lens Einstein radius

$$\eta_0 = \sqrt{\frac{4G<M>}{c^2}\frac{D_{\rm os}D_{\rm ls}}{D_{\rm ol}}}$$

$$\sim 2.03 \times 10^{16} \sqrt{\frac{<M>}{0.3\,M_\odot}}\ {\rm cm}$$

Continuum ~ 0.2 η_0

BLR ≥ 1 η_0

NLR > 10 η_0

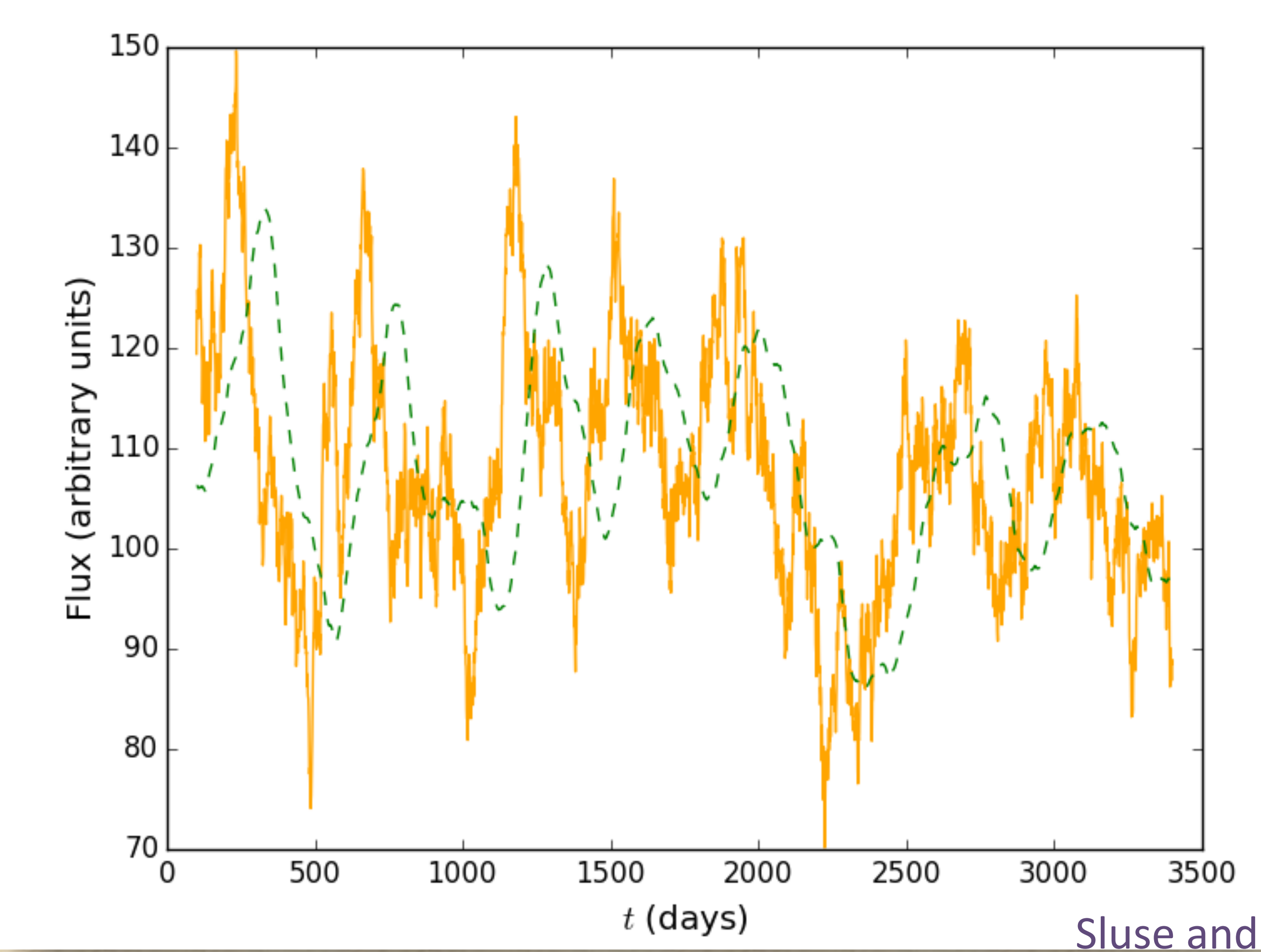
Simulating lightcurves

$F_1(\lambda, t) = M\, F_M + M\, \mu(t)\, F_{M\mu}$

$F_M = f_{BLR} * l(t)$, $F_{M\mu} = c(t)$

$$c(t) = \mathcal{GP}\{\bar{c}, \kappa(t, t')\}$$

$$l(t) = \int \Psi(t - t')c(t)\,\mathrm{d}t'.$$



$\tau = 100$ days

$f_{BLR} = 0.2$

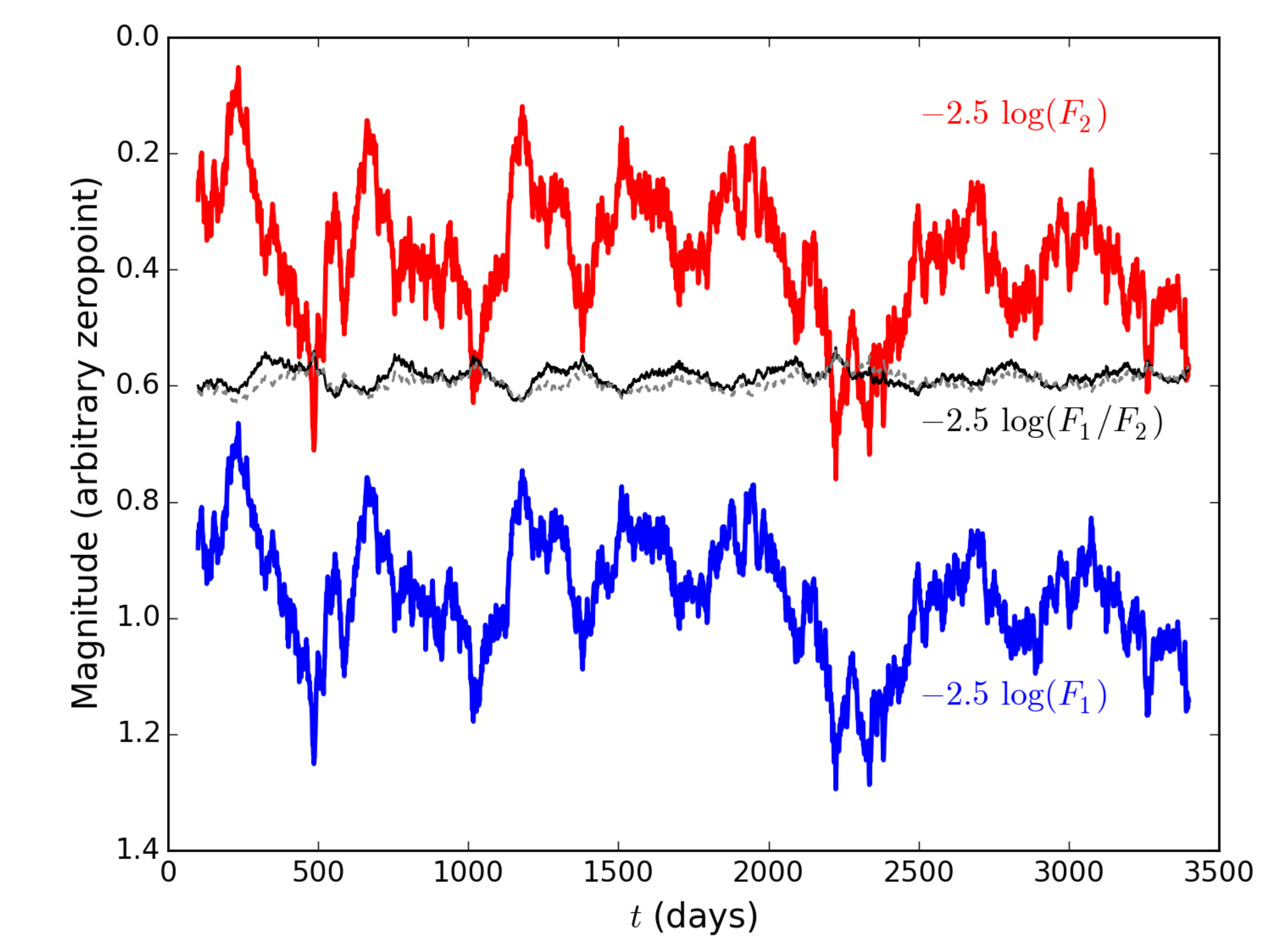
$\mu = 0.5$

Sluse and Tewes 2014, A&A, 576, A60

Simulating lightcurves

$F_1(\lambda, t) = M\,F_M + M\,\mu\,F_{M\mu}$ $F_2(\lambda, t) = F_M + F_{M\mu}$

$M=1$, $\mu = 0.5$, $F_M = f_{BLR} * l(t)$, $F_{M\mu} = c(t)$



τ = 100 days

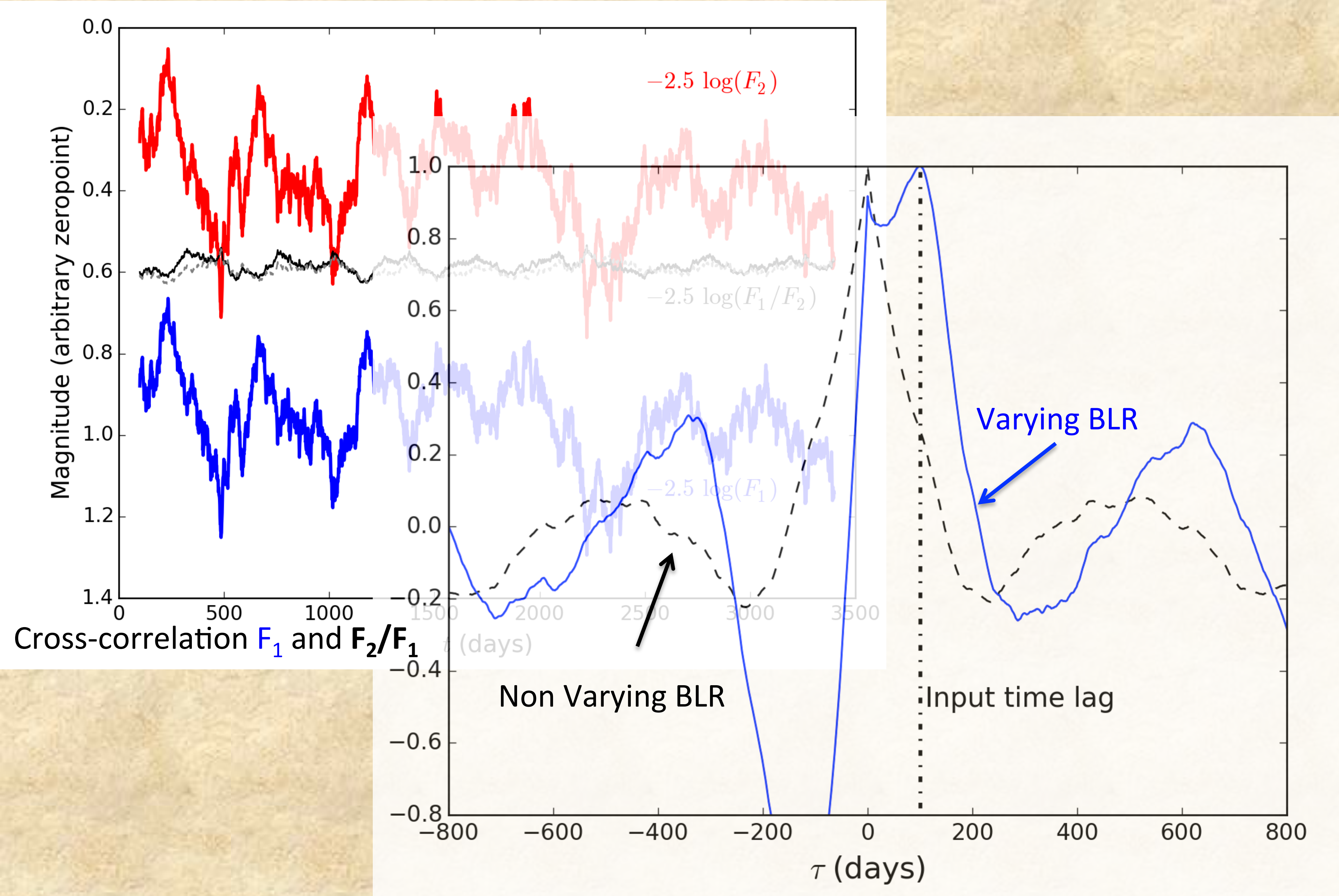
f_{BLR} = 0.2

Constant μL:

μ = 0.5

M = macro-mag. (strong-lensing)

Measuring a time lag: CCF



Estimating the microlensing flux

BLR

Continuum

$$F_1(t) = M\, F_M + M\, \mu_1\, F_{M\mu}$$

$$F_2(t) = F_M + \mu_2\, F_{M\mu}$$

We can define $A(t) = \mu_1(t)/\mu_2(t) \times M = M \times \mu(t)$

Sluse and Tewes 2014, A&A, 576, A60

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$$F_M(t) = \frac{-A(t)}{A(t)-M}\left(\frac{F_1(t)}{A(t)} - F_2(t)\right)$$

$$\mu_2(t)\, F_{M\mu}(t) = \frac{M}{A(t)-M}\left(\frac{F_1(t)}{M} - F_2(t)\right)$$

Sluse and Tewes 2014, A&A, 576, A60

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Note that we have $A(t) = F_1 / F_2$ if $F_M = 0$

In practice we may use an empirical estimate of A(t):

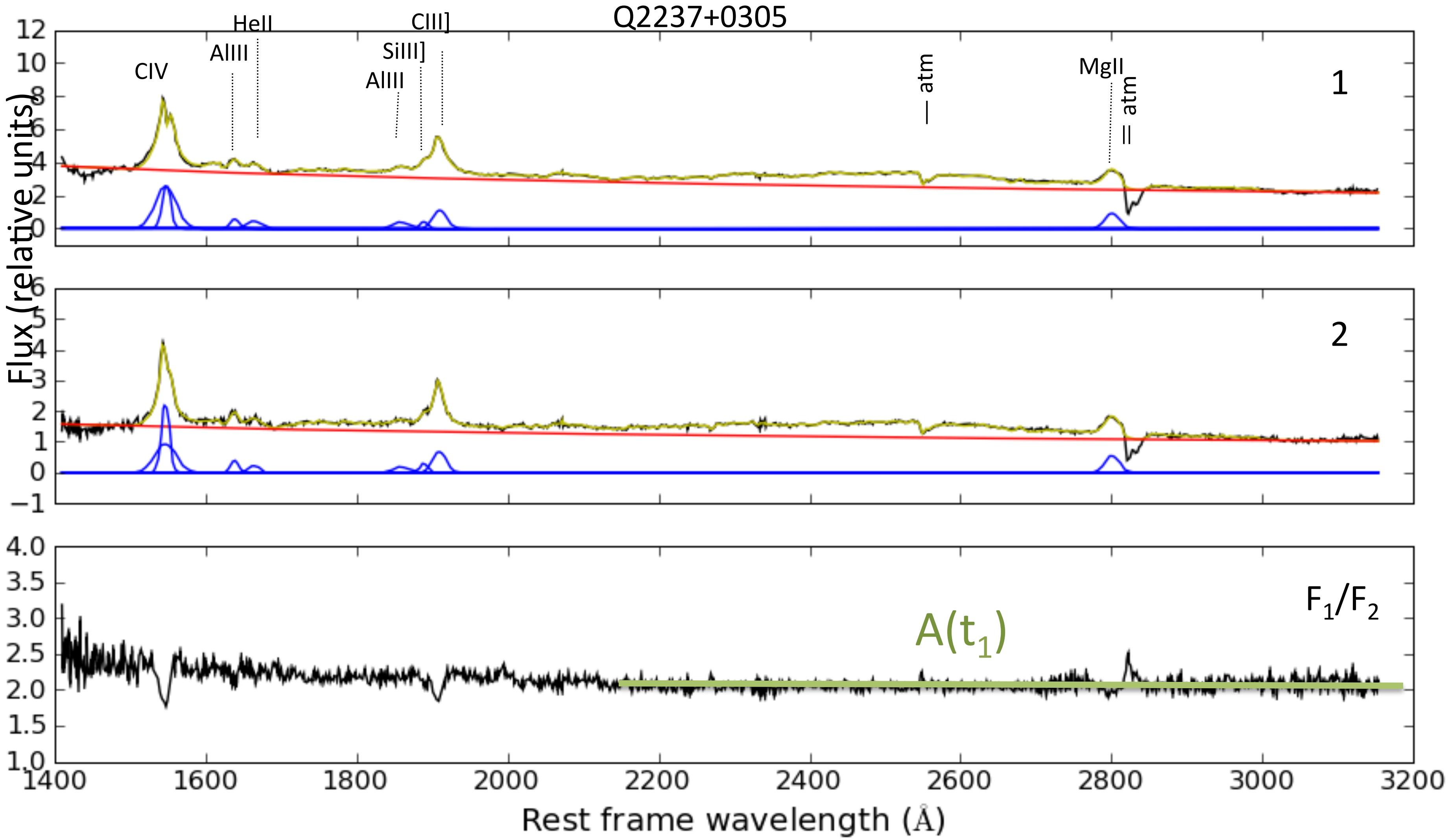
Spectrum at $t=t_1$

$$\hat{A}(t) = \frac{A(t_1)}{\hat{F}_{12}(t_1)} \hat{F}_{12}(t)$$

Model of large scale variations of F_1/F_2

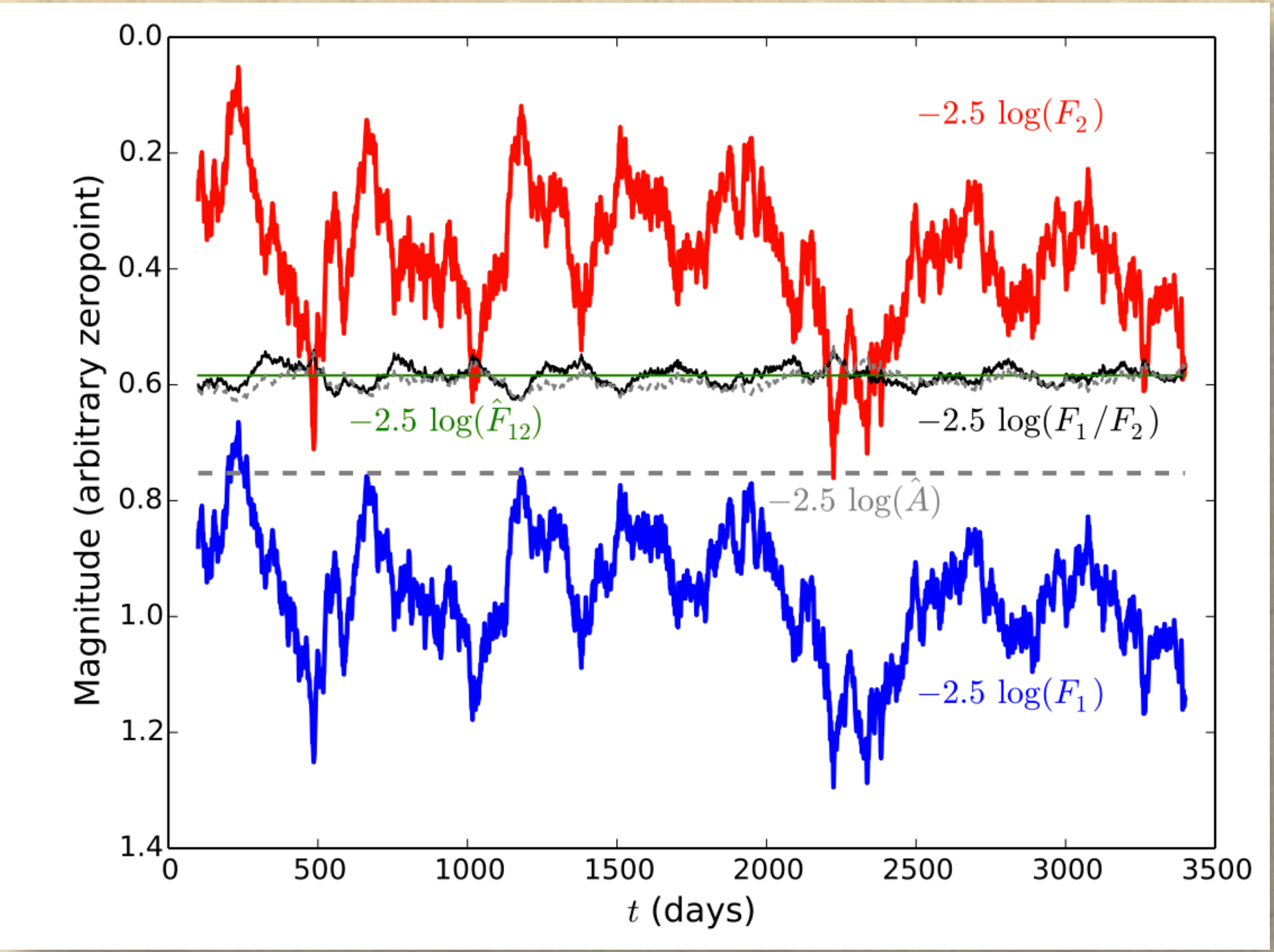
Estimating the microlensing flux

Deriving $A(t_1)$: Illustration



Estimating the microlensing flux

$$\hat{A}(t) = \frac{A(t_1)}{\hat{F}_{12}(t_1)} \hat{F}_{12}(t)$$



Estimating the microlensing flux

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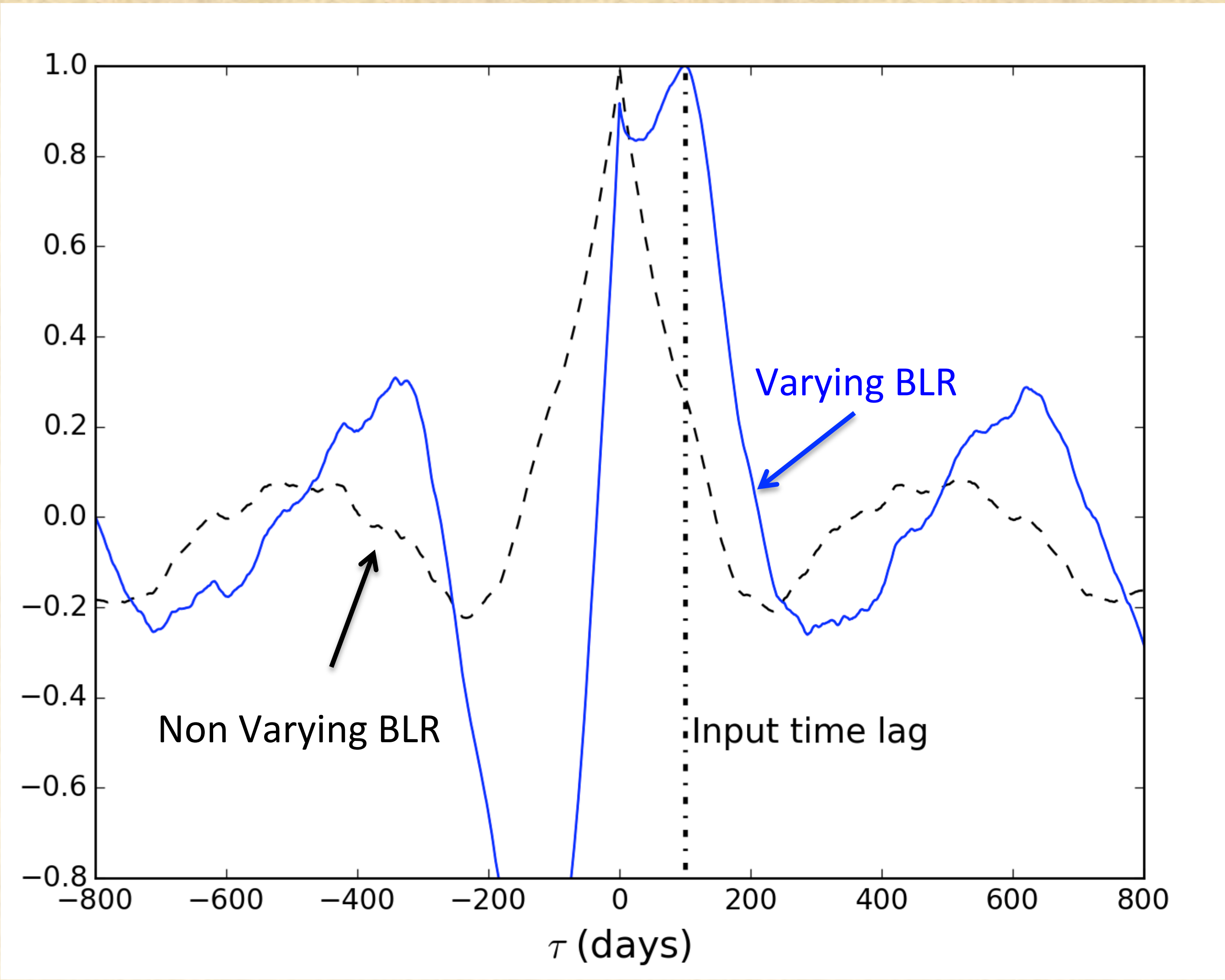
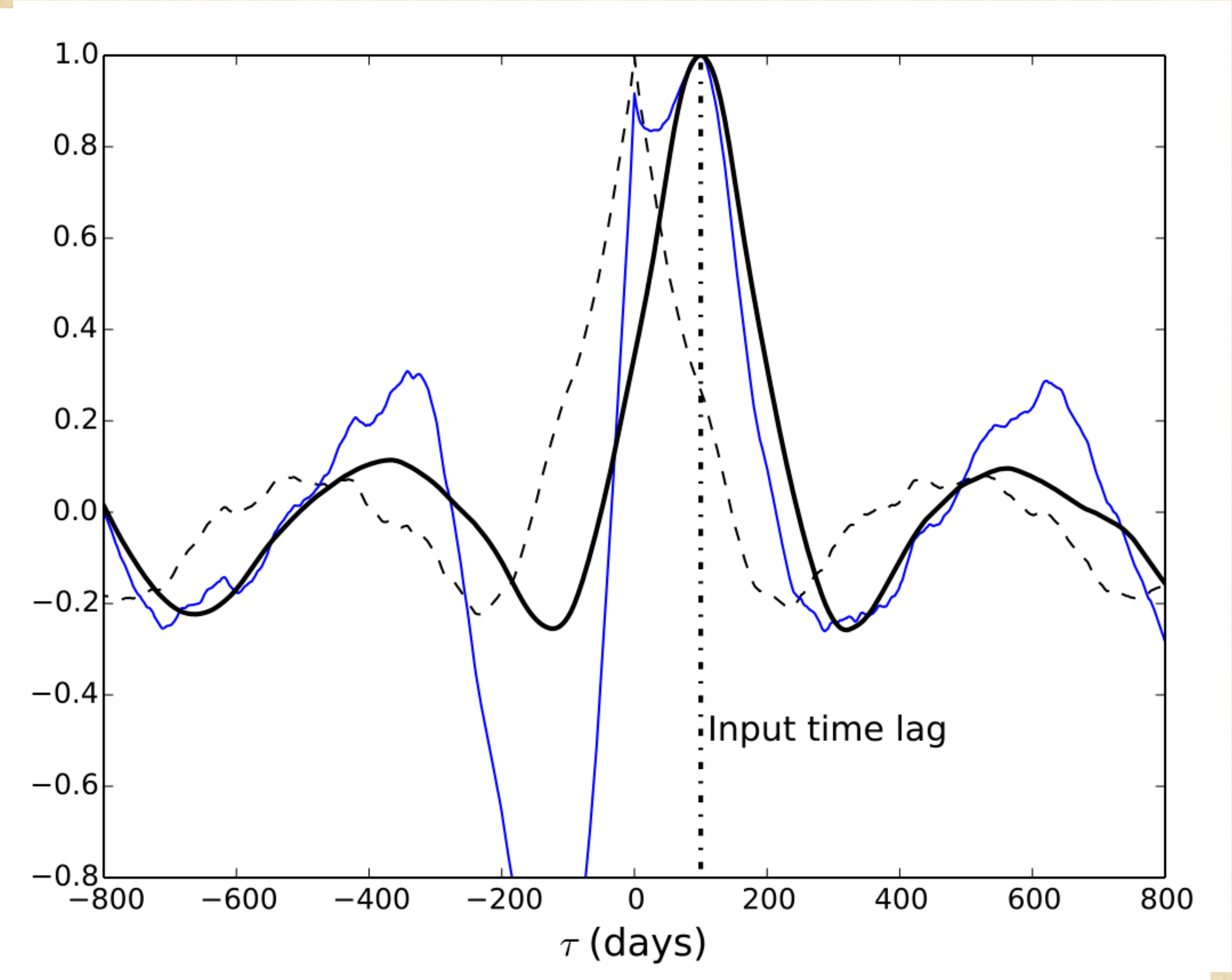
Sluse and Tewes 2014, A&A, 576, A60

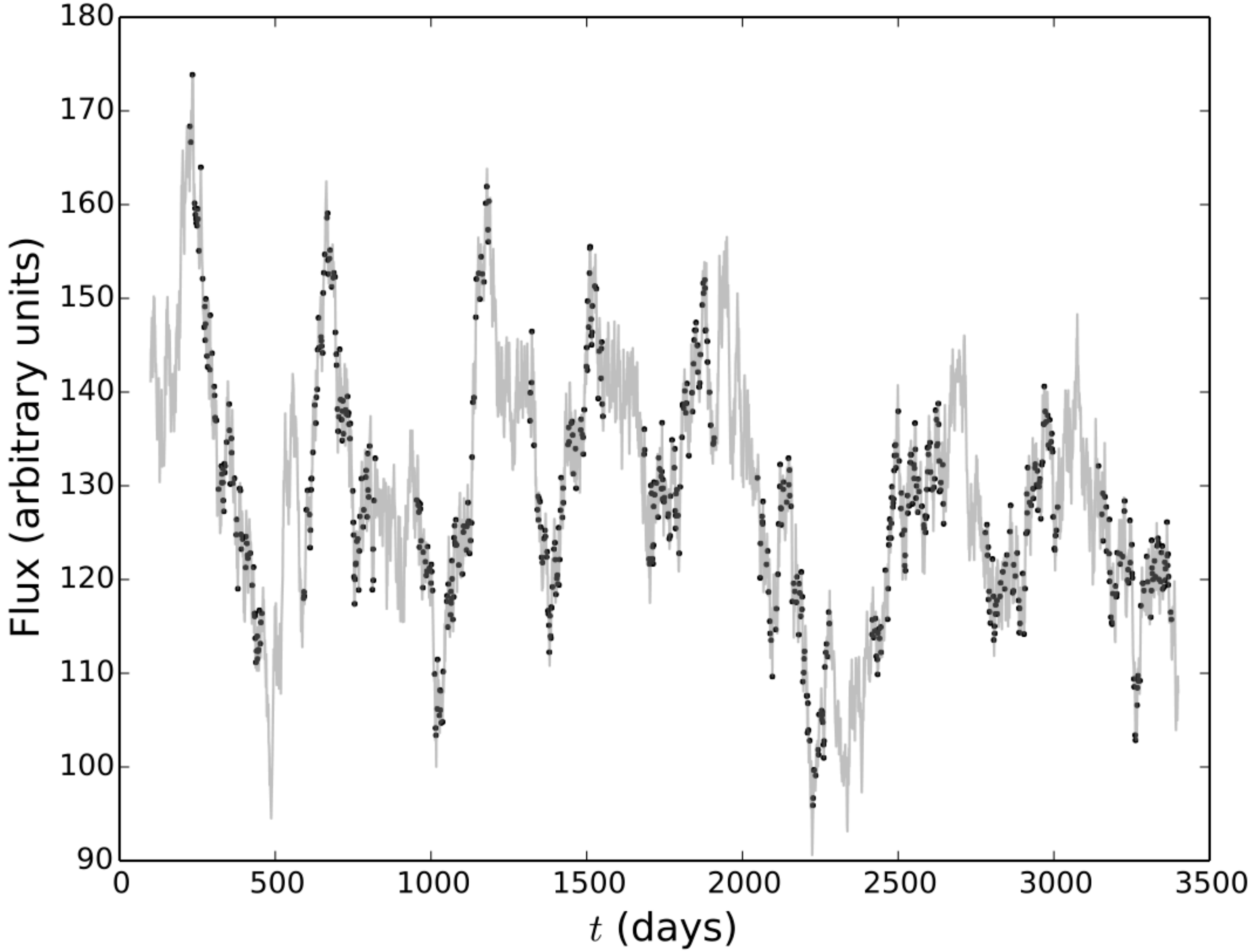
Estimating the microlensing flux



Estimating the microlensing flux



Effect of gaps and sampling



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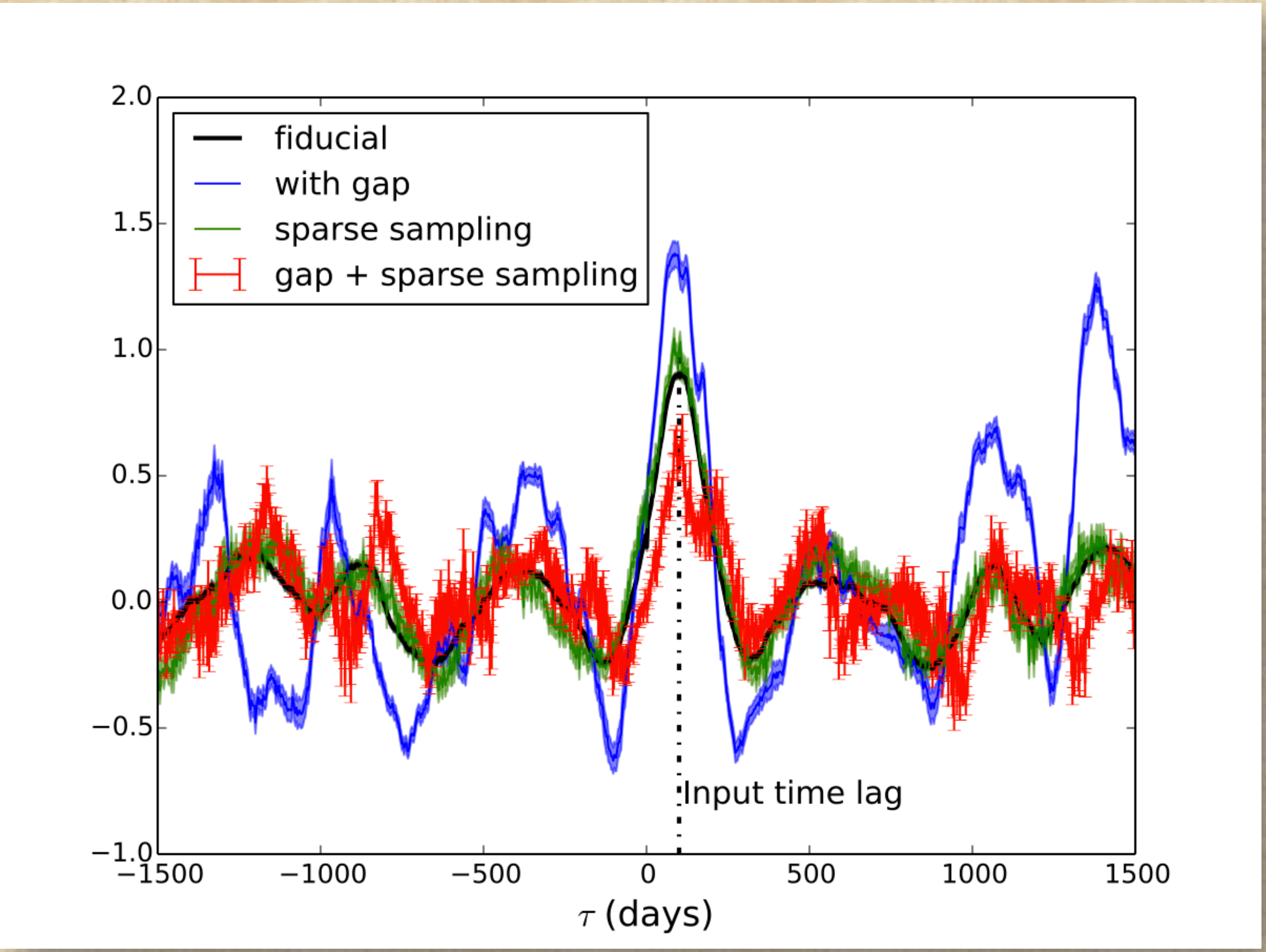
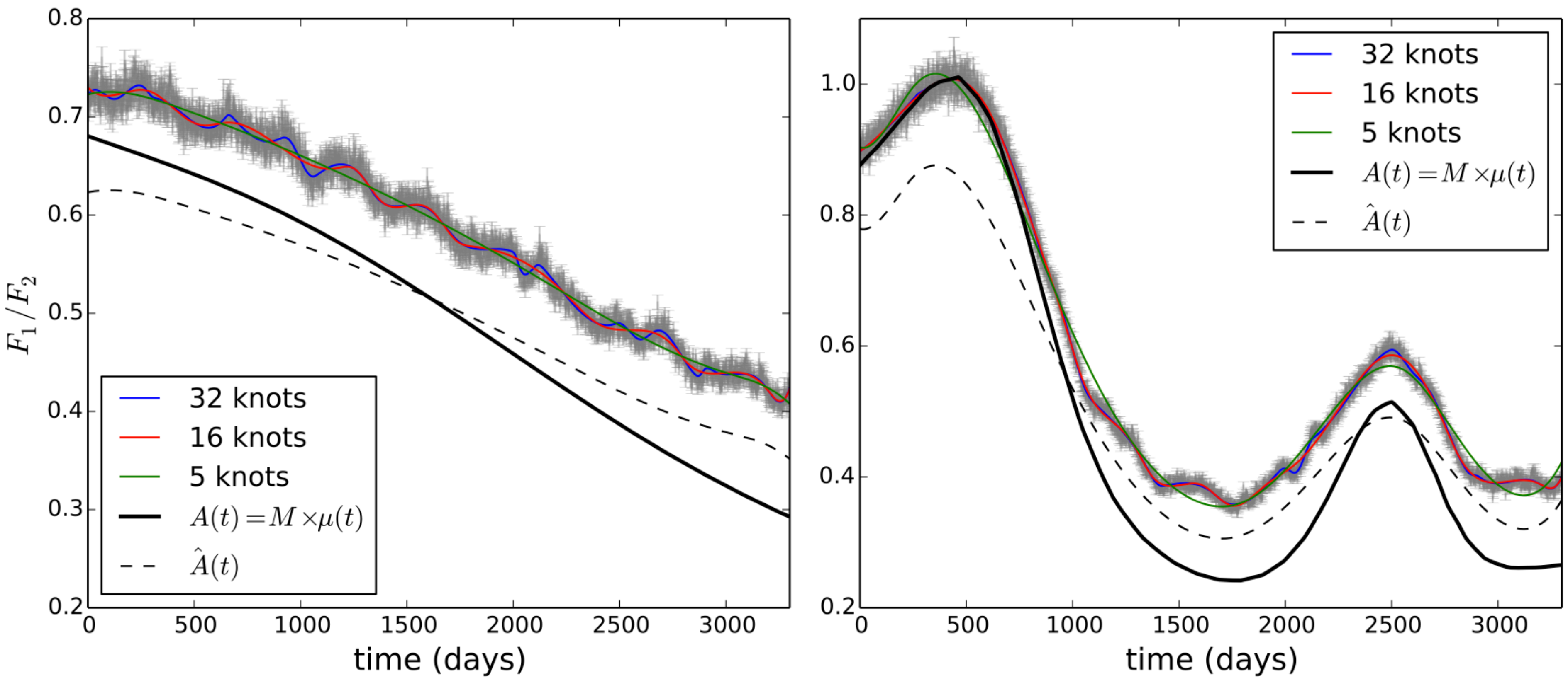


Realistic microlensing



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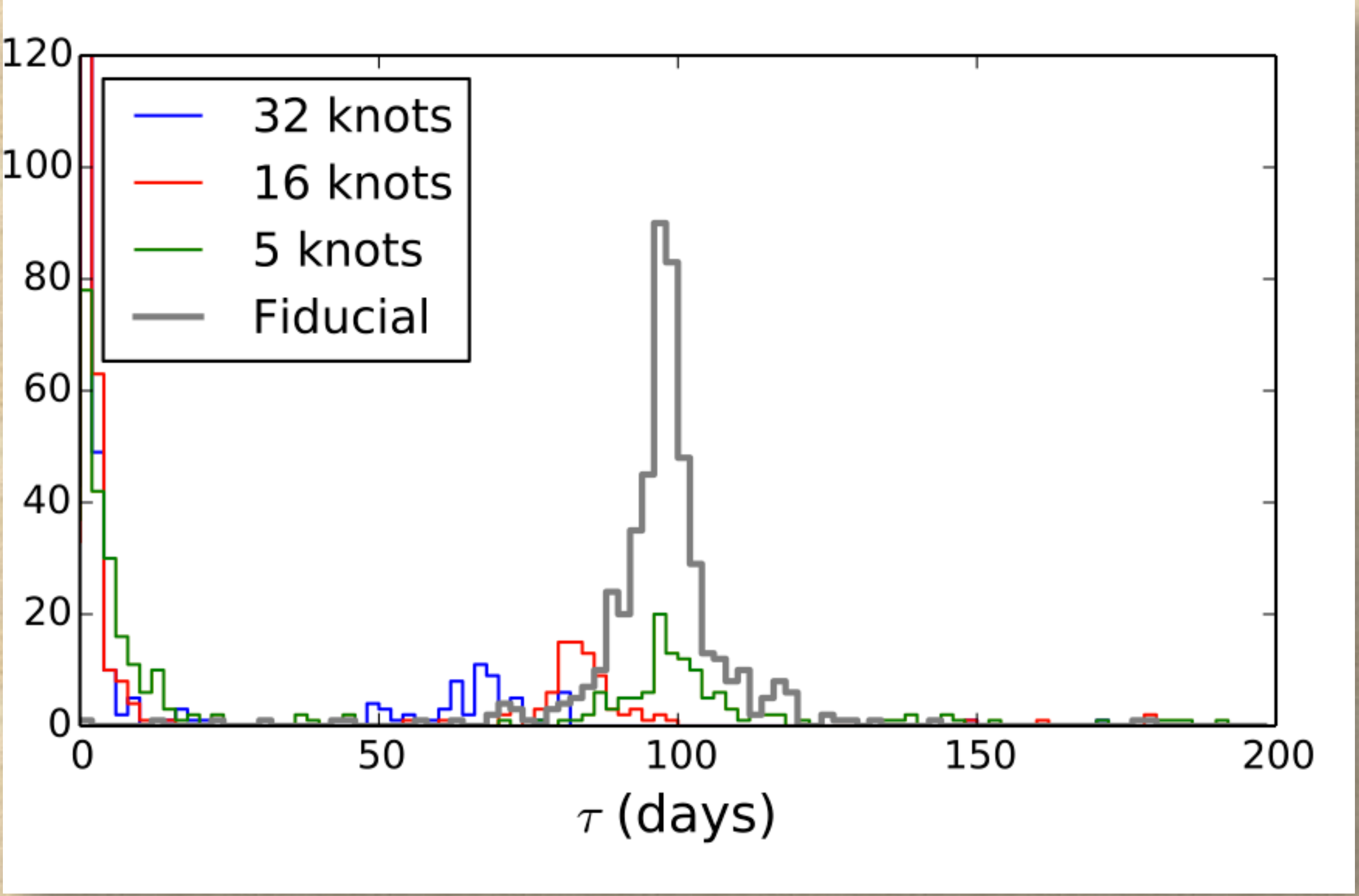
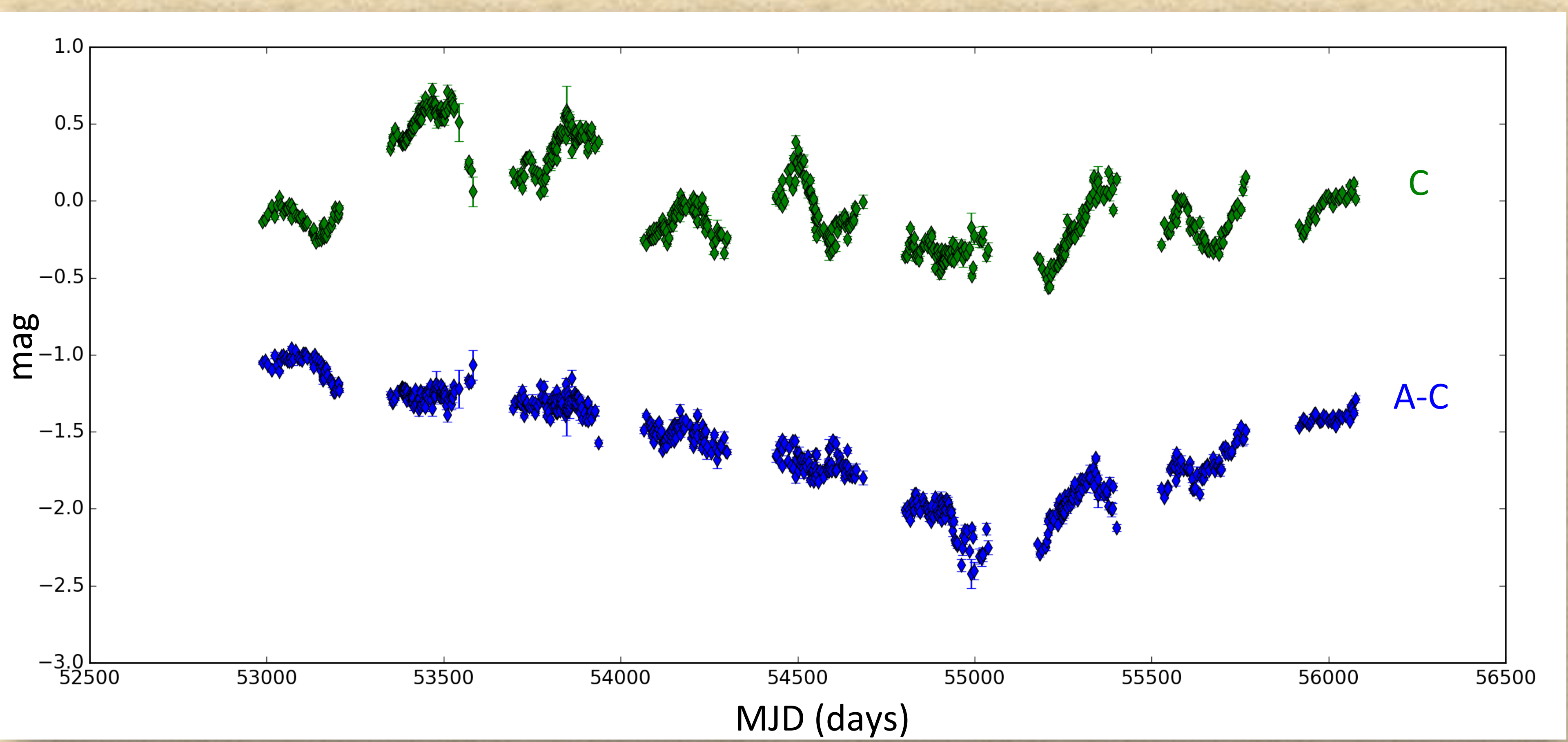
Realistic microlensing



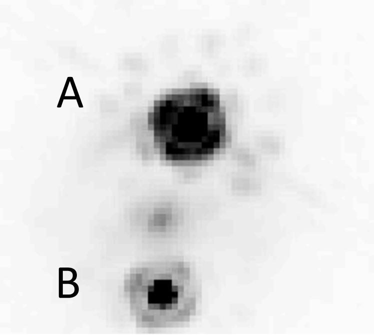
Sluse and Tewes 2014, A&A, 576, A60

Already in data ?

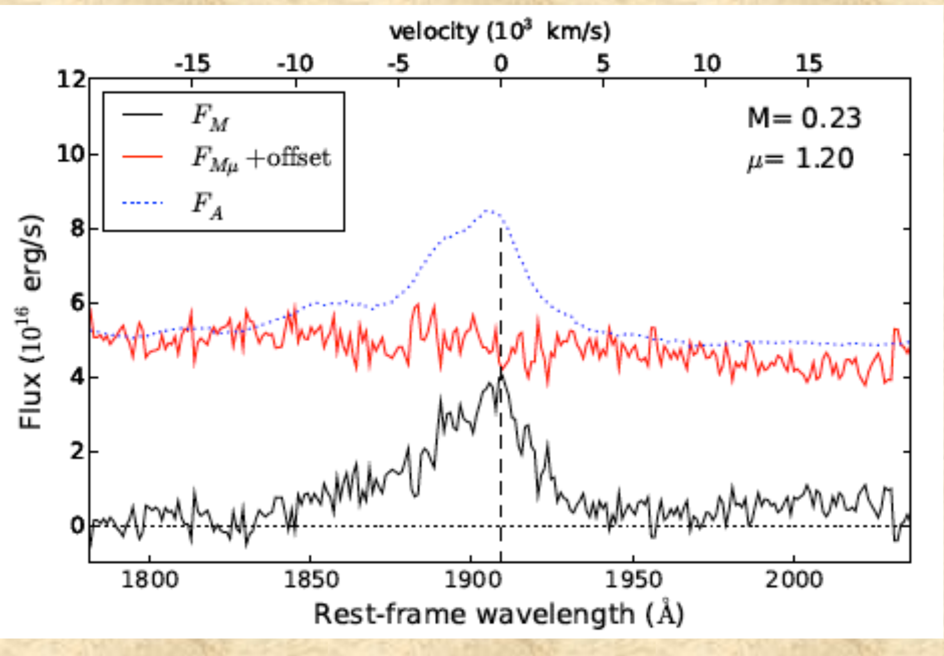


Microlensing of the BLR

Possible source of noise / additional complexity



HE 0047-1756 (A-B):



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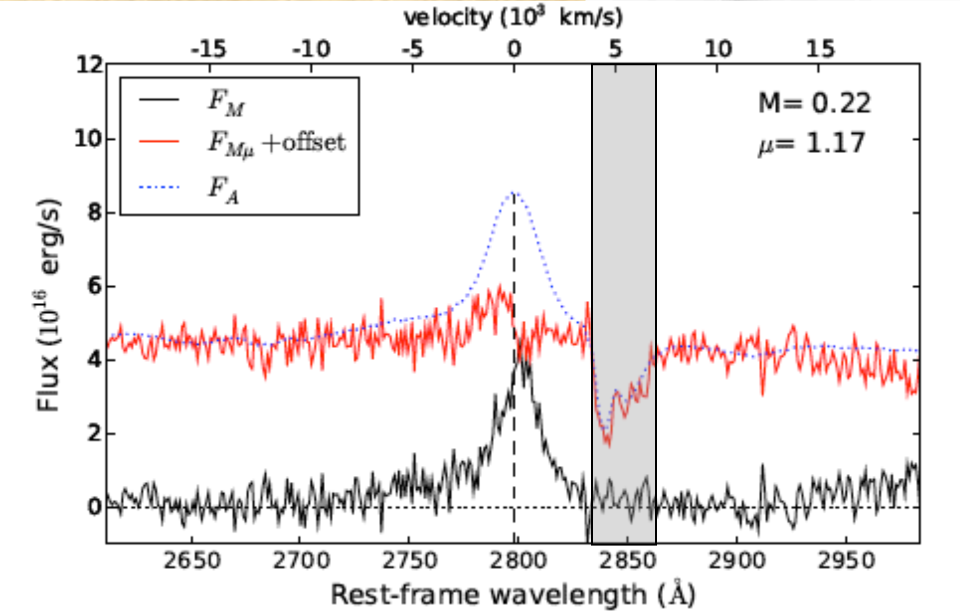

MgII

Sluse+ 2012, A&A 538, A99

Conclusions

Proof of concept that long lightcurves of gravitationally lensed quasars (such as those that will be obtained by LSST) can be used to perform photometric reverberation mapping … with single band data ! (See Sluse and Tewes 2014, A&A, 576, A60)

Signal possibly already present in existing data of gravitationally lensed quasars [STAY TUNED]

This is complementary to the use of quasar-microlensing to probe the properties of the BLR and of the accretion disc