Imprints of the AGN structure on time delay light curves in LSST era

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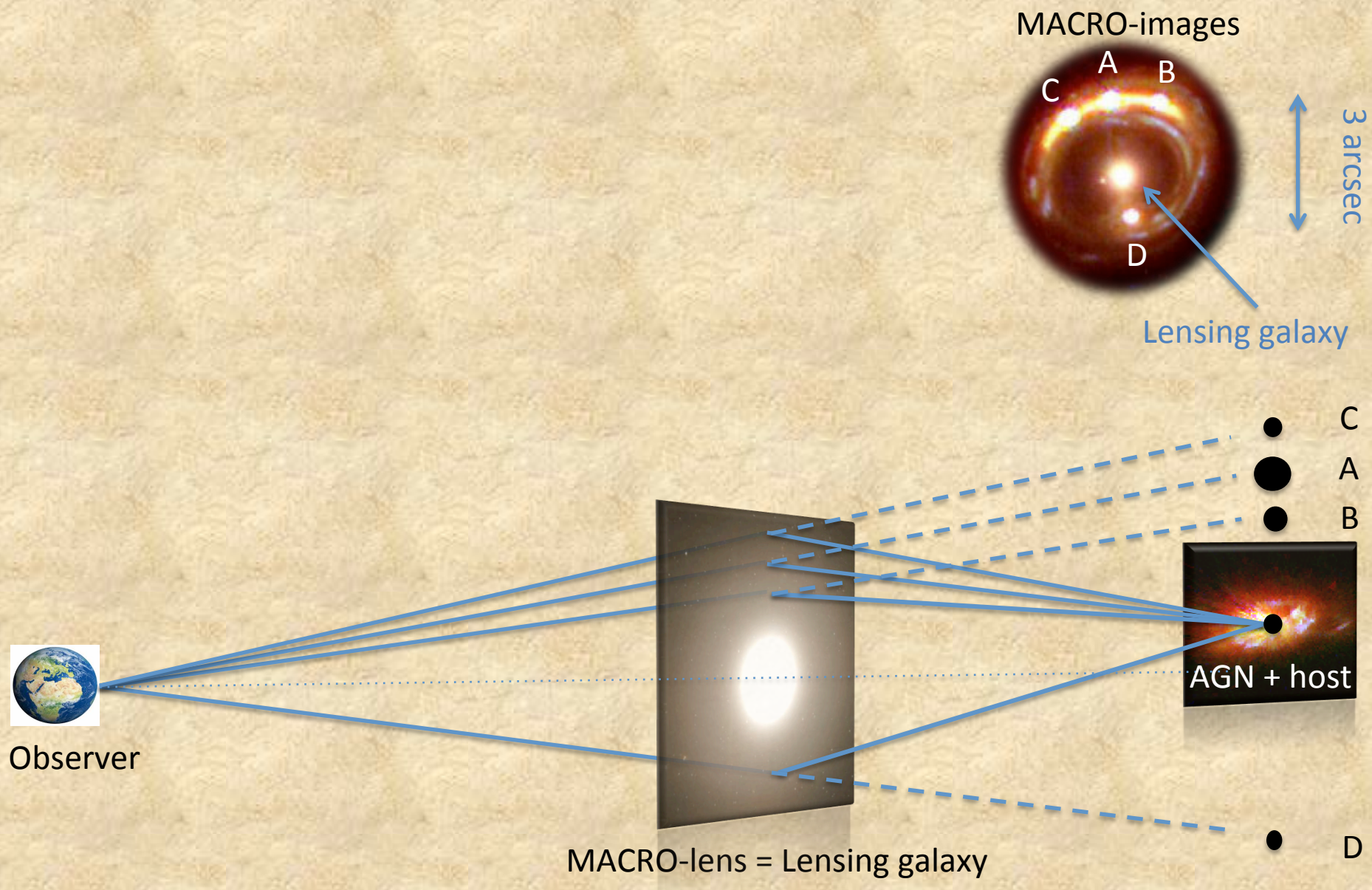
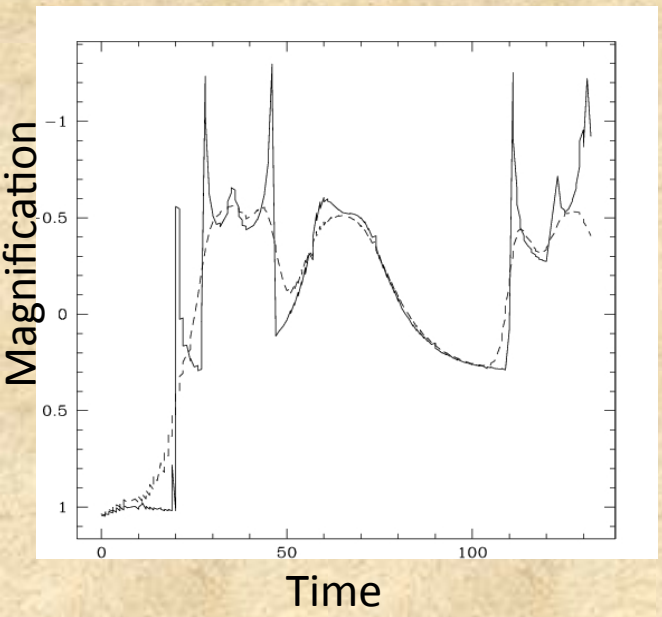
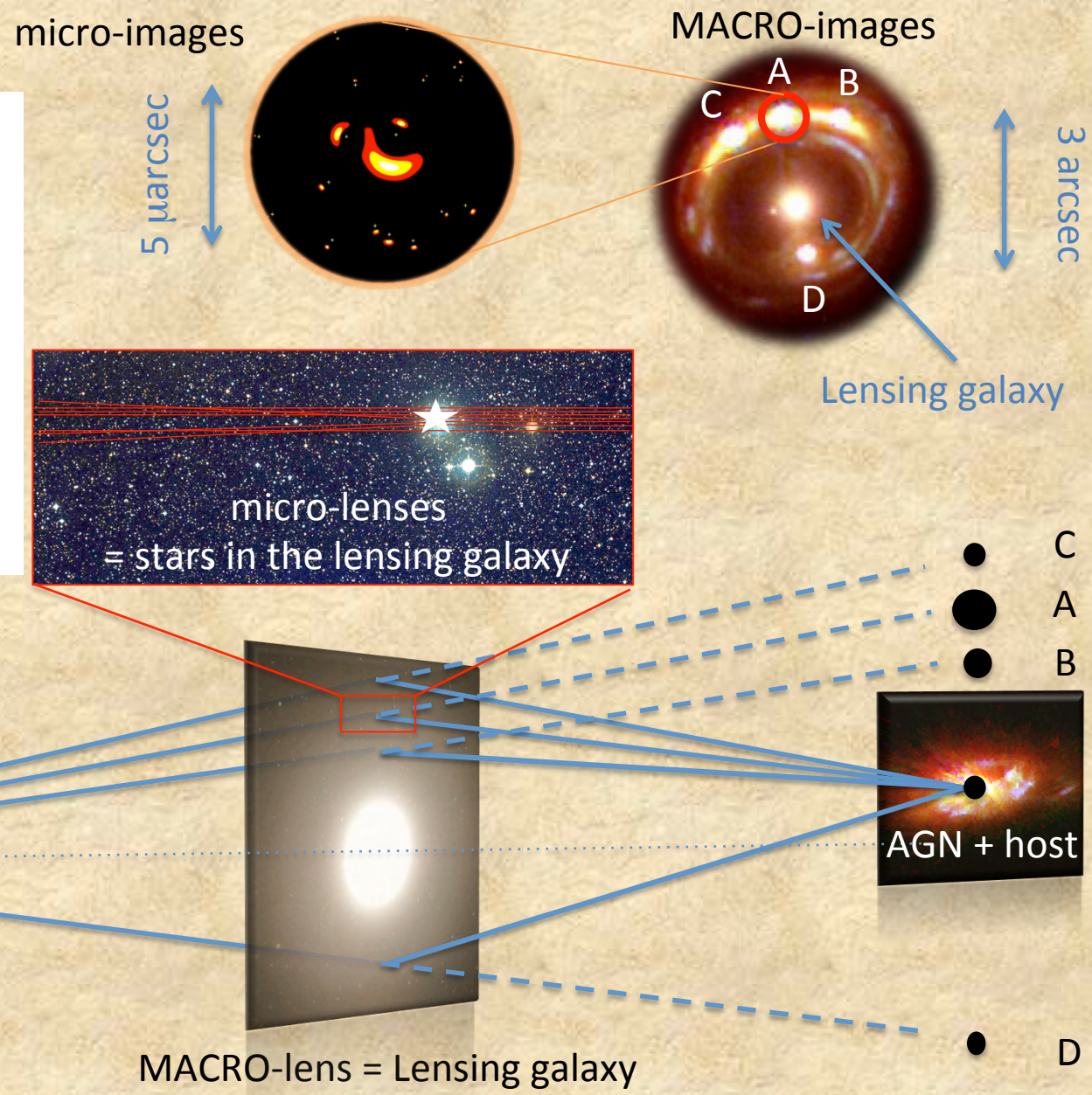
Strong Lensing in a nutshell

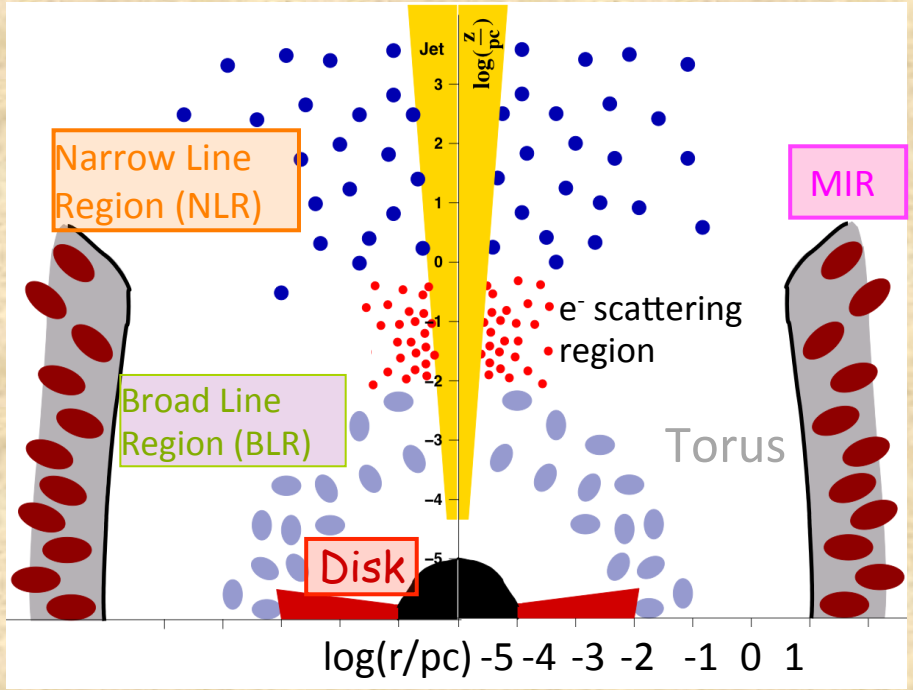


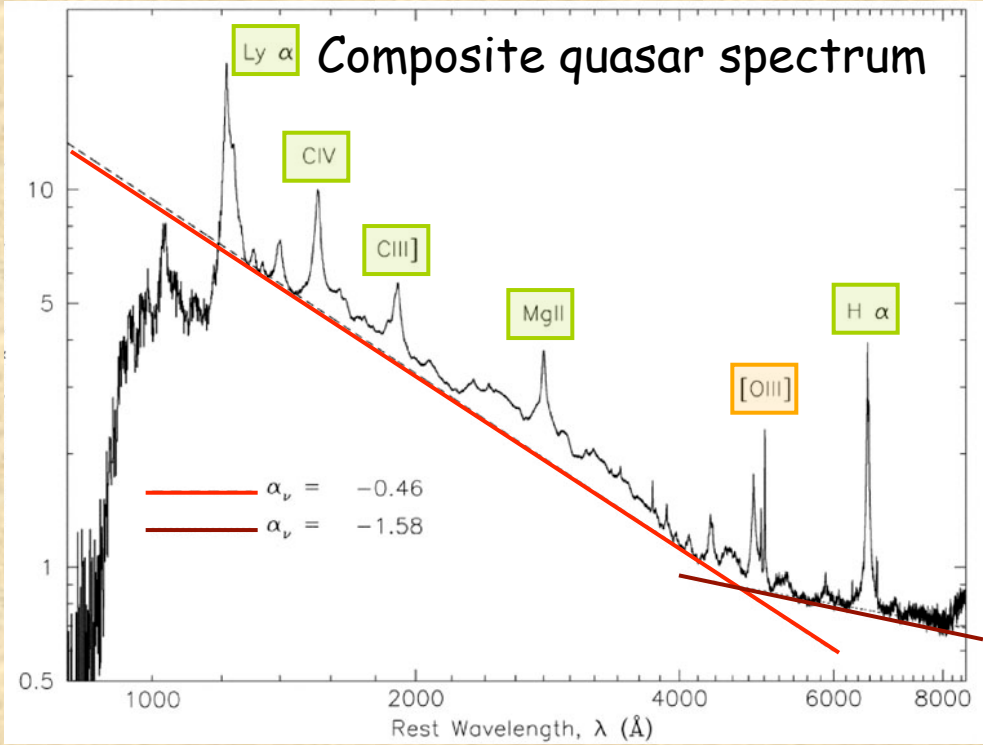
Microlensing in Strongly lensed AGNs





Which regions of AGN are microlensed ?





Vanden Berk et al. 2001, AJ, 122, 549

Today: ~ 10 mas ~ 80 pc resolution (z=3; AO)
~ 1-0.1 pc (VLTI, low z)

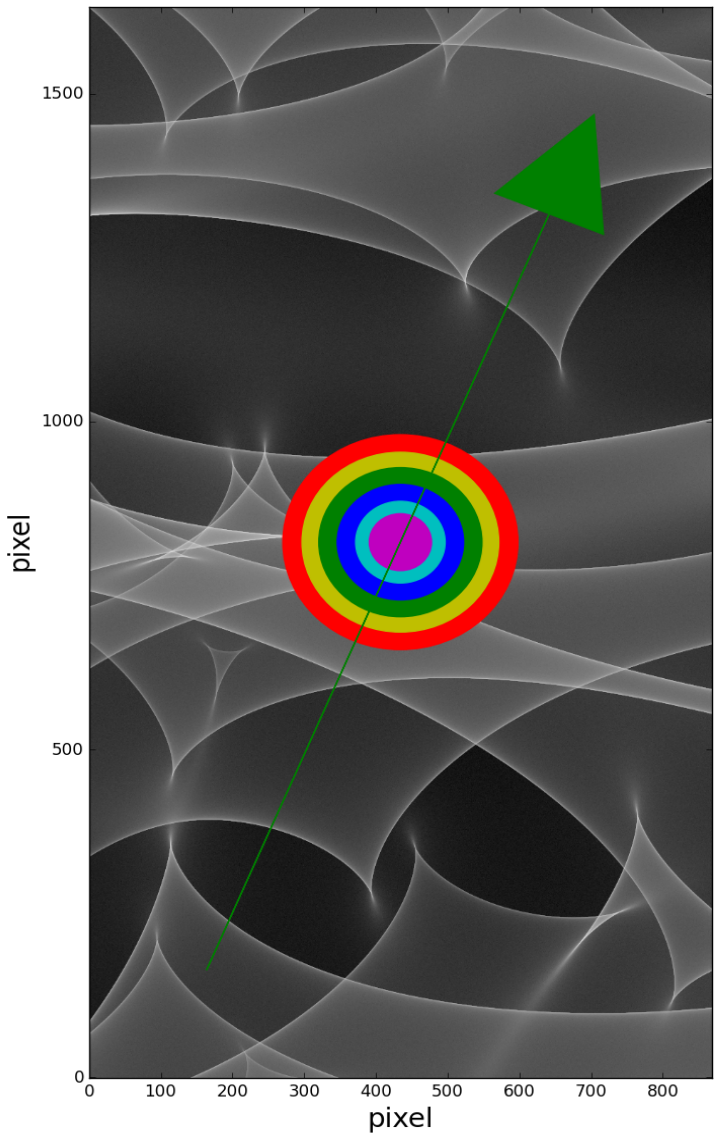
Future: 0.1 mas ~ 0.8 pc resolution (z =3)

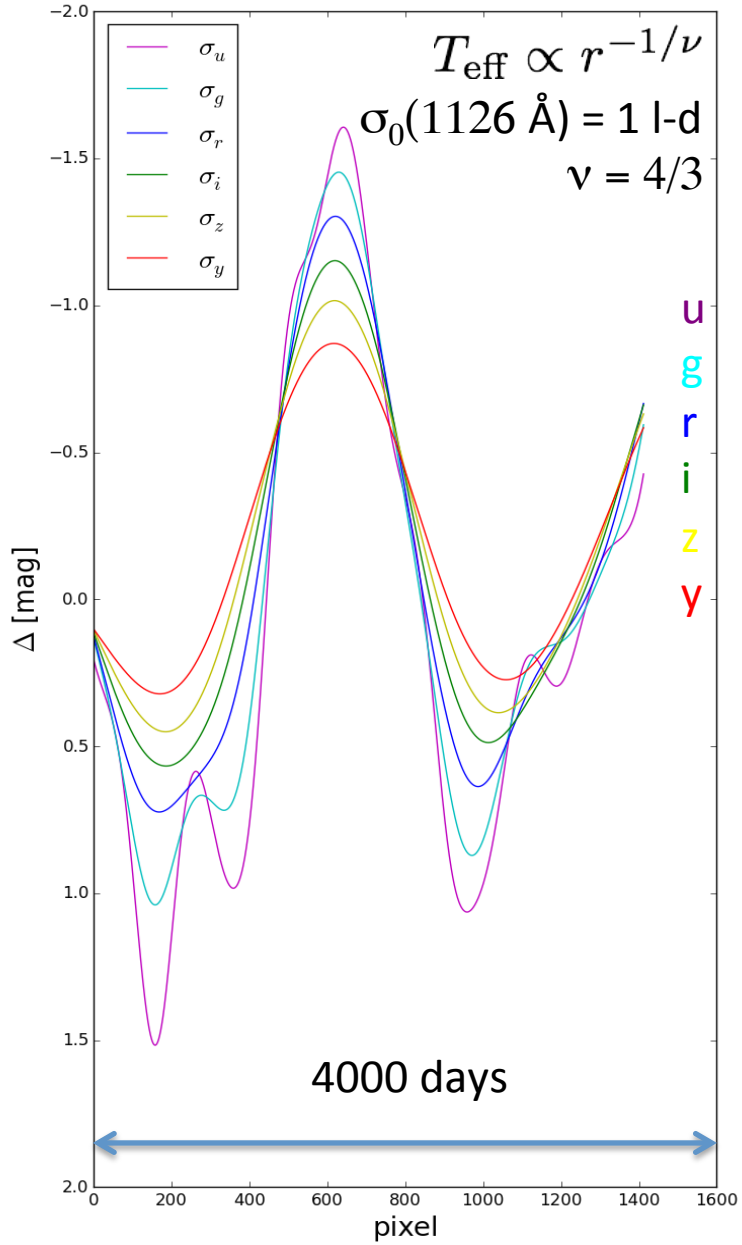
Microlensing: 0.04 pc resolution (up to z=4)

$$\eta_0 = \sqrt{\frac{4G<M>}{c^2}\frac{D_{os}D_{ls}}{D_{ol}}}$$
$$\sim 2.03 \times 10^{16} \sqrt{\frac{<M>}{0.3\,M_\odot}}\ \mathrm{cm}$$

Einstein Radius

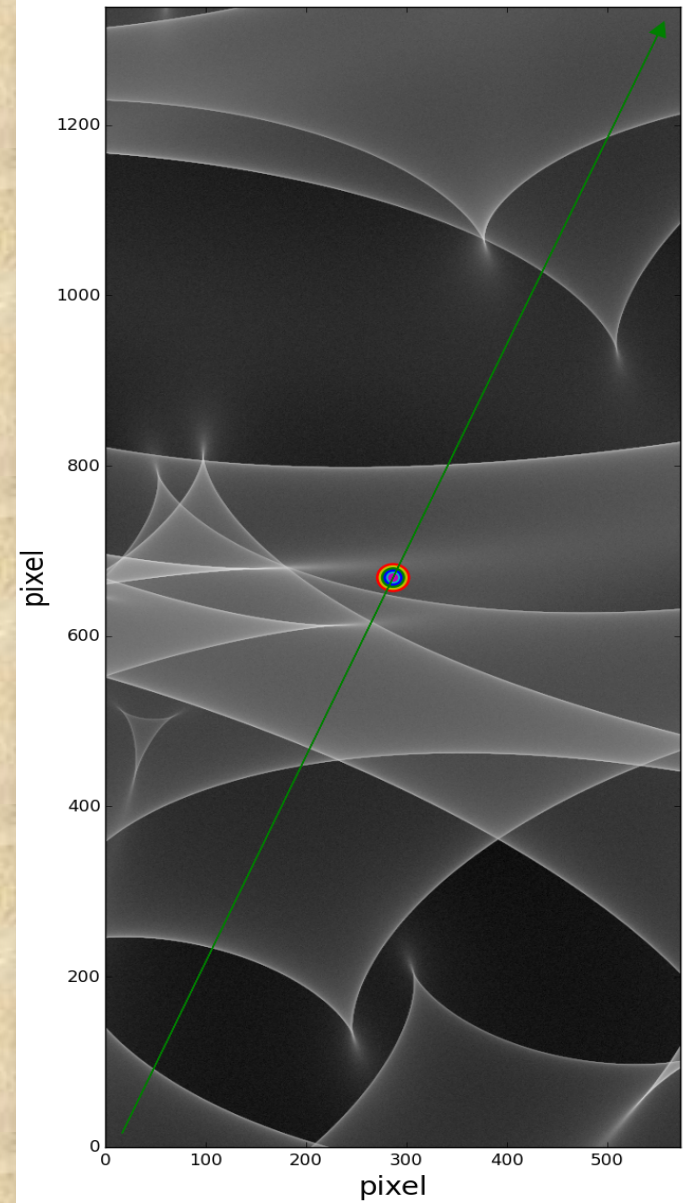
Disc size

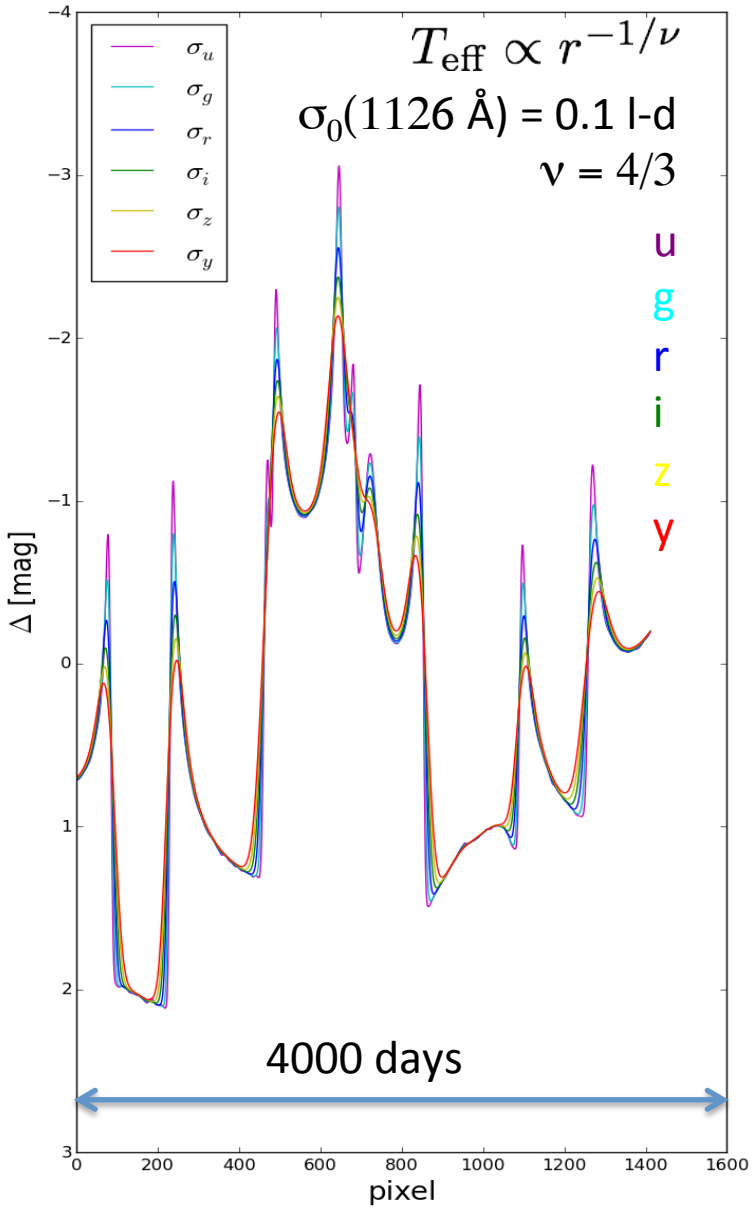




Courtesy: T. Anguita

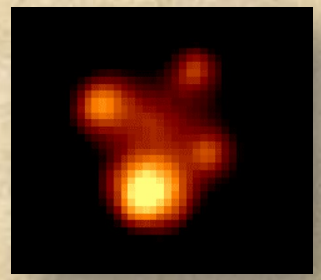
Disc size



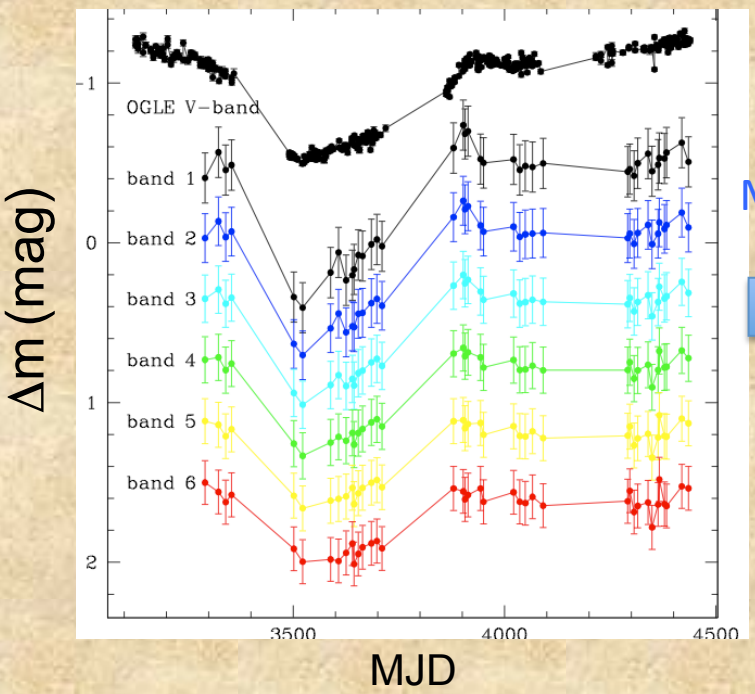


Courtesy: T. Anguita

Example on real data : Einstein Cross

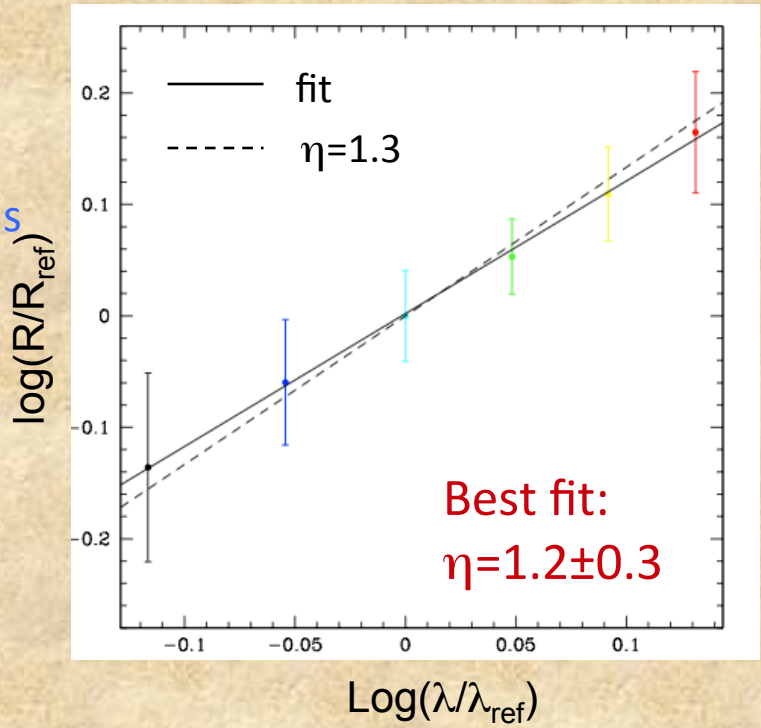


Observed micro-lensed induced chromatic variations of the continuum



ML simulations

Results of the simulation



Accretion disk model:

$$\frac{R}{R_{\mathrm{ref}}} = \left(\frac{\lambda}{\lambda_{\mathrm{ref}}}\right)^{\eta}$$

η= 1.3 (Shakura & Sunayev, 1973)
η= 1.15 (Agol & Krolik, 2000)
η= 1.75 (Gaskell 2008)

Eigenbrod et al. 2008, A&A 490, 933

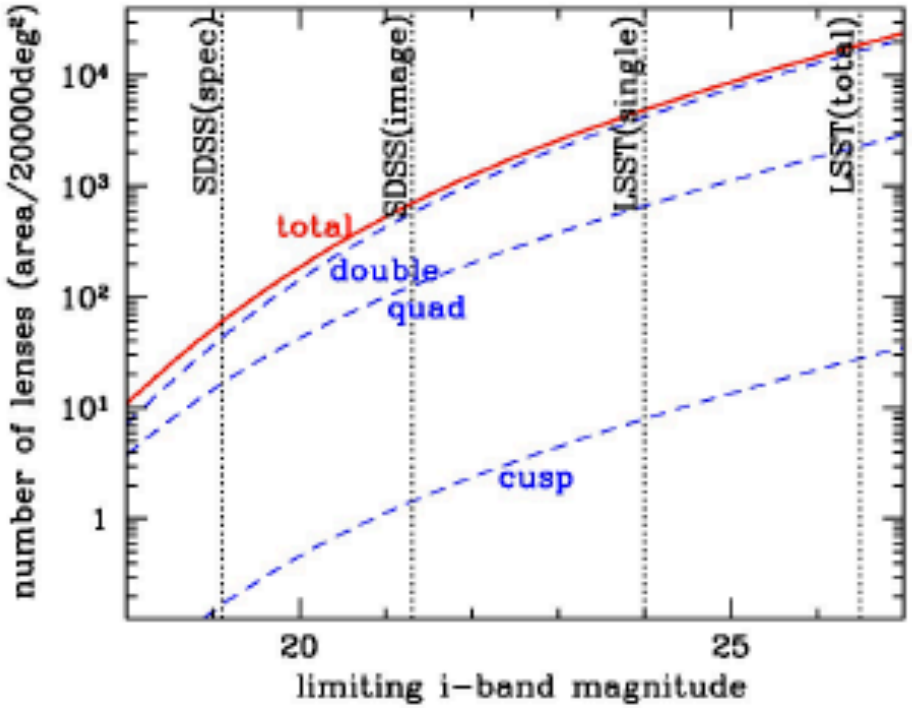
The time-domain to probe AGN structure
Current status

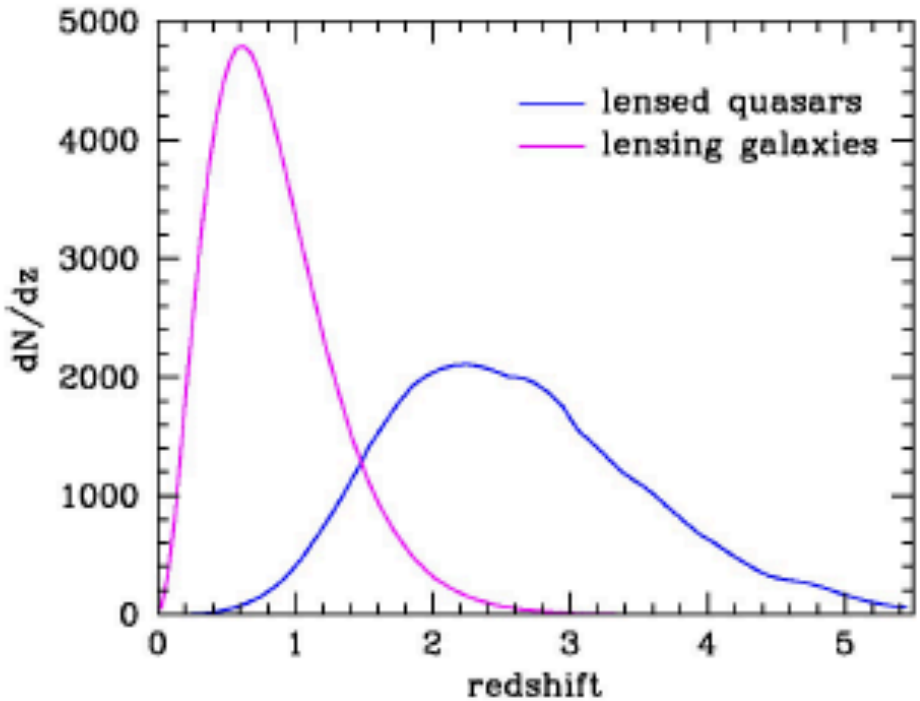
- Analysis of tens of microlensed AGN (not all with the same data quality as Einstein cross) indicate that the size of the accretion disc is larger than the standard (Shakura Sunyaev) AD size by a factor 3 to 10 (e.g. Morgan+ 2010, Blackburne+ 2011).

- "AD – reverberation mapping" of a few nearby Seyfert galaxies (Shappee+ 2014; Fausnaugh+ 2015) have confirmed this result.

- Evidence in one system for extended continuum emission (likely light scattered in the vicinity of the BH; at least 30% of AD continuum) in a BAL AGN (Sluse+ 2015)

Strongly lensed AGNs in LSST era



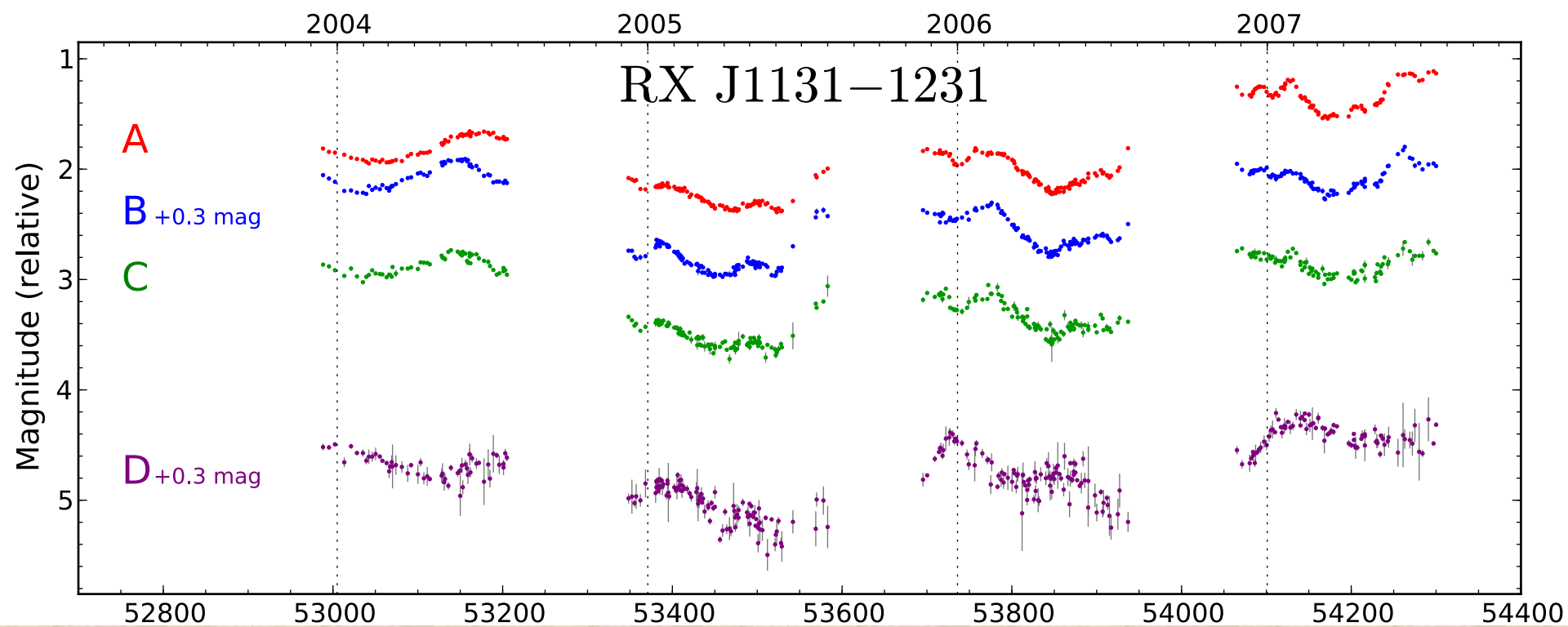


About 2000 (8000) lensed QSOs down to i_{AB} = 24 (24.9) mag

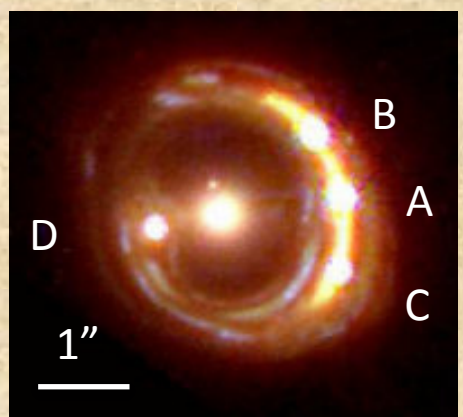
One order of magnitude more systems than currently known !

LSST science book (arxiv 0912.0201), Agnello+ 2015, MNRAS, 448, 1446

Strongly lensed AGNs in LSST era

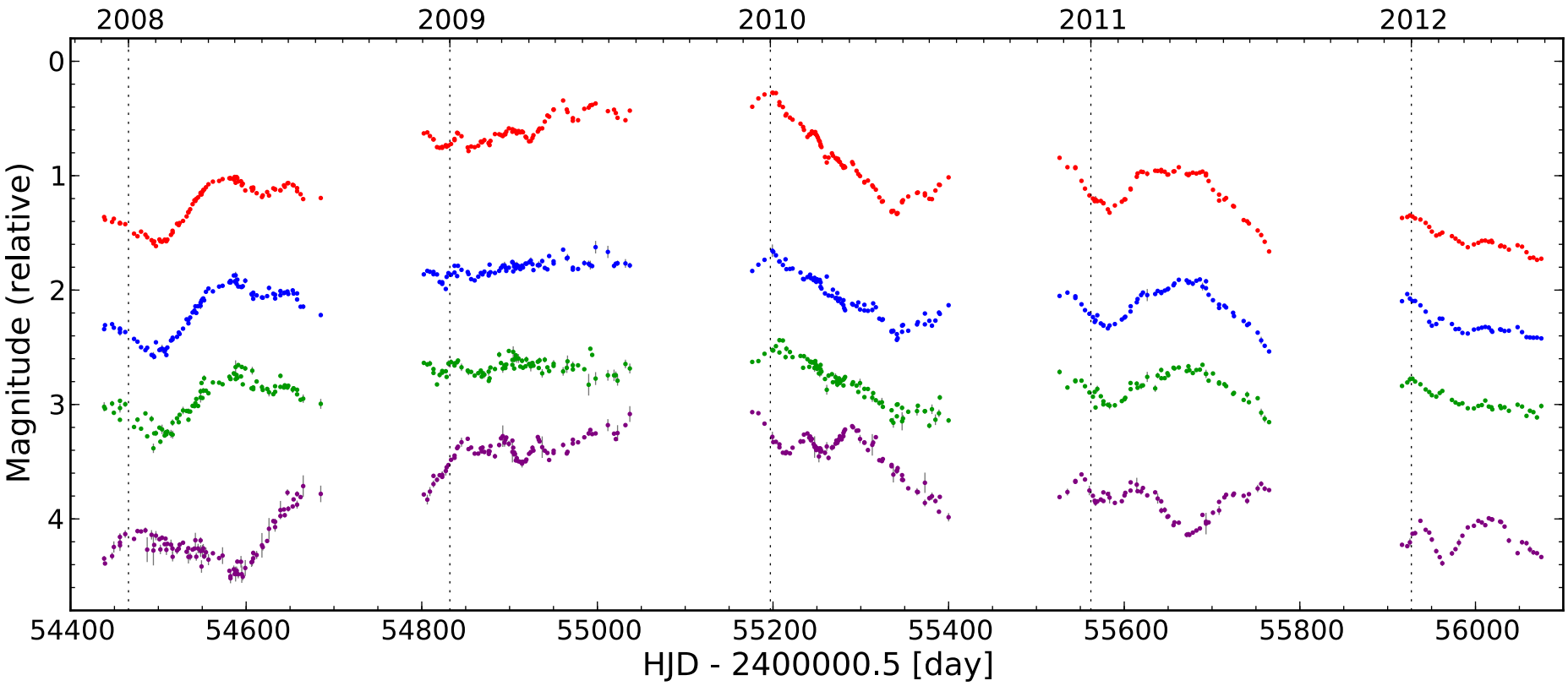


COSMOGRAIL lightcurve as a *pilot for LSST*



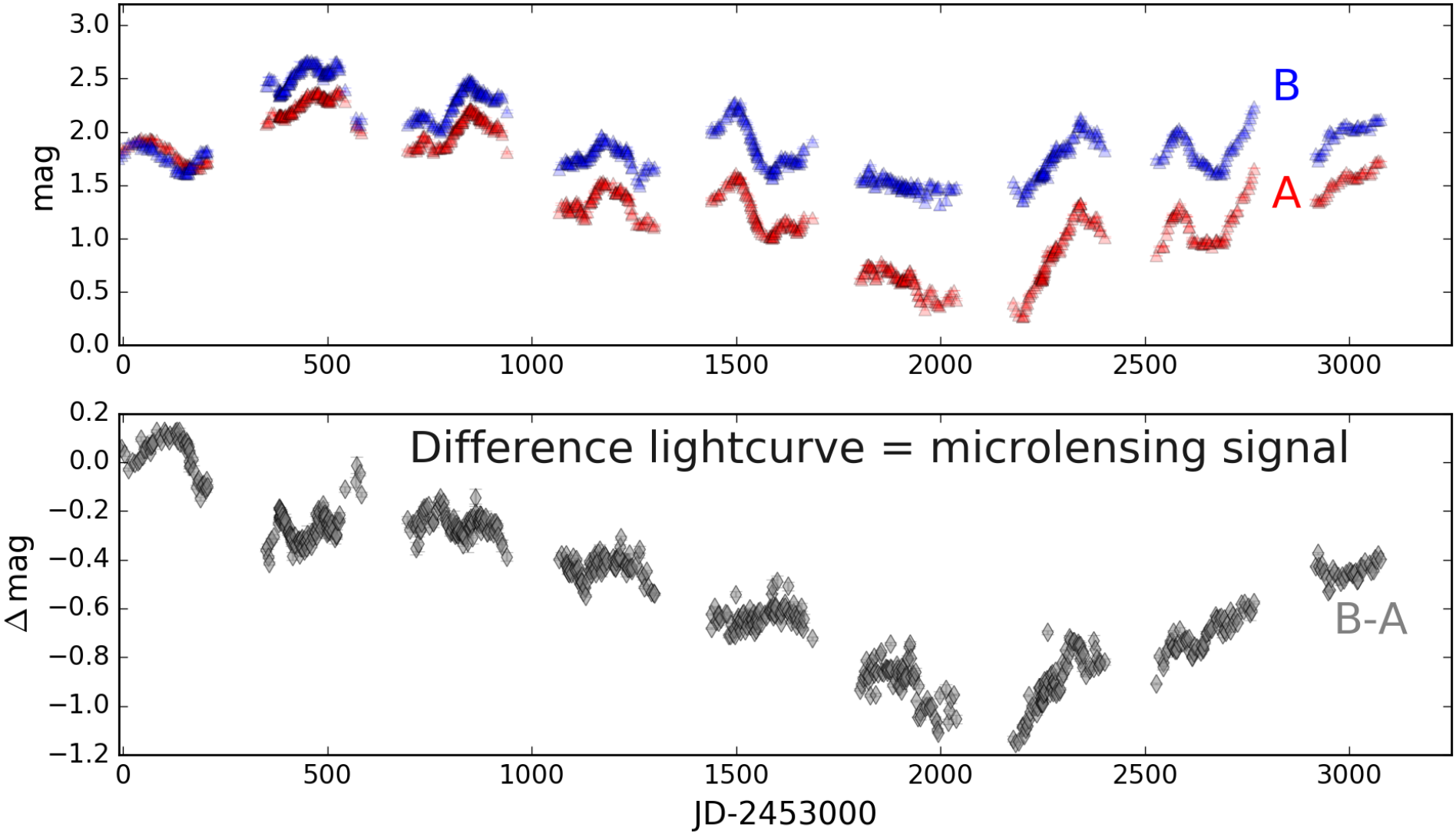
*COSMOGRAIL = Cosmological Monitoring of Gravitational lenses (PI: **F. Courbin**, EPFL)*

Strongly lensed AGNs in LSST era

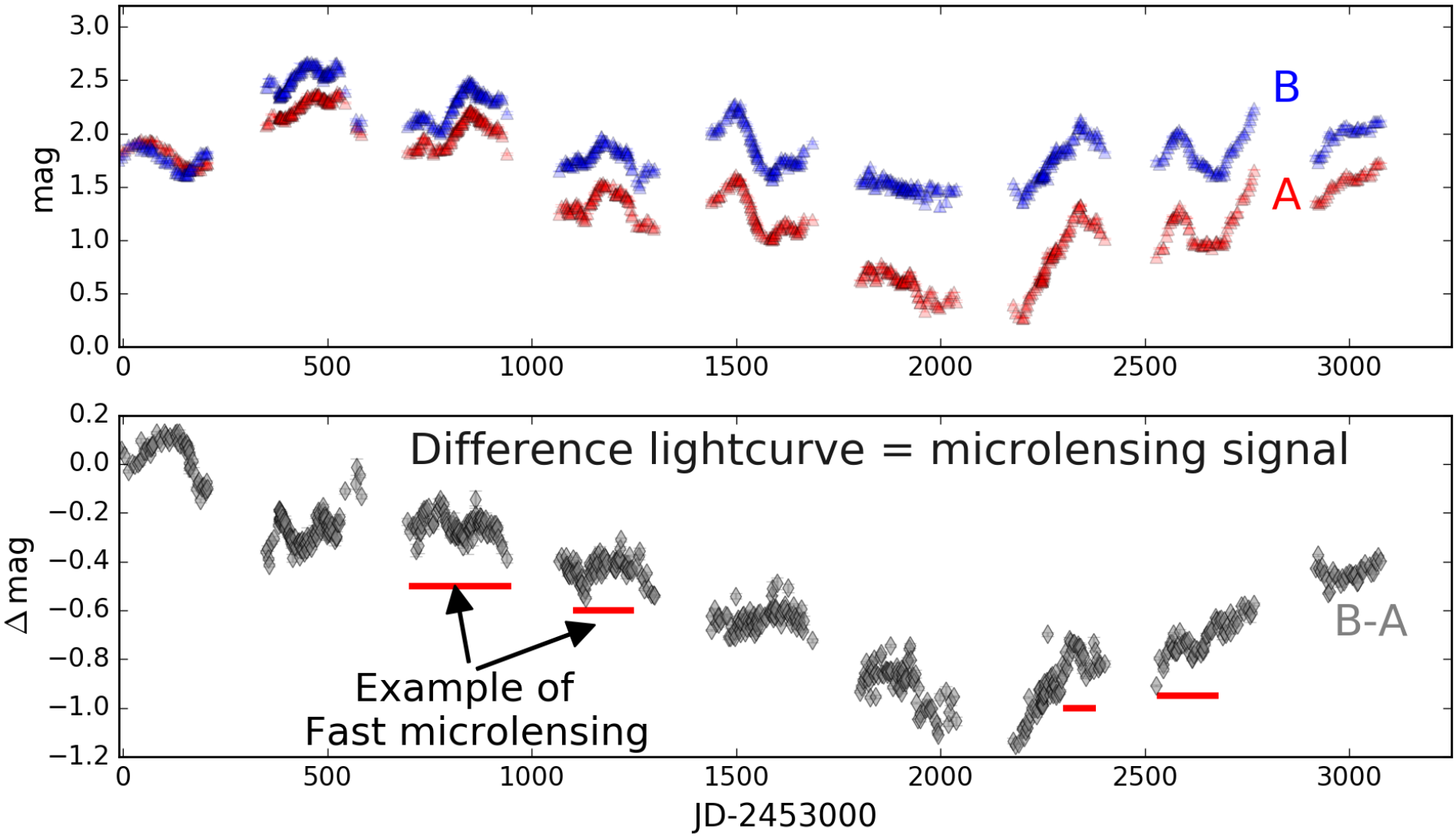


Tewes et al. 2013, A&A, 556, A22

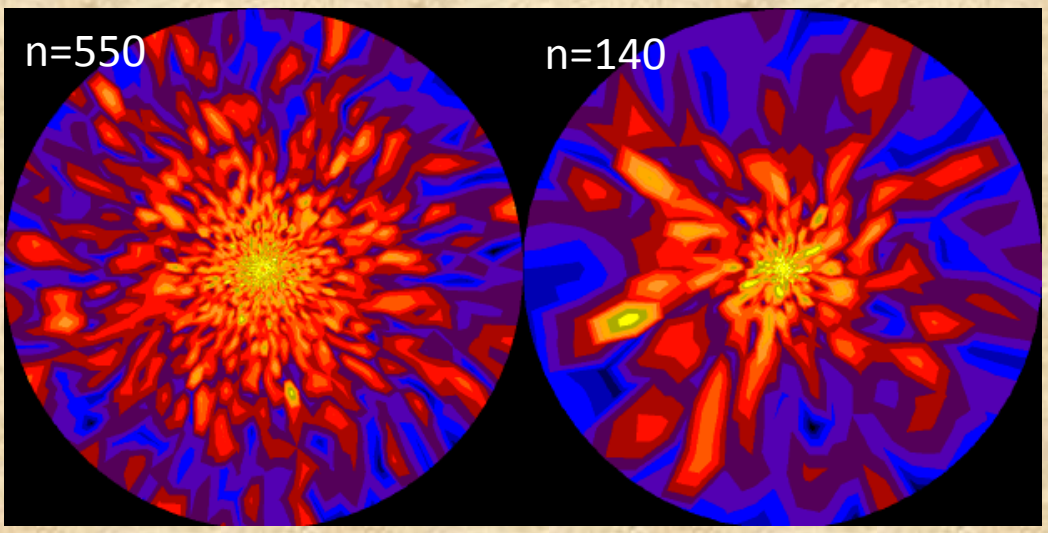
Microlensing in Strongly lensed AGNs



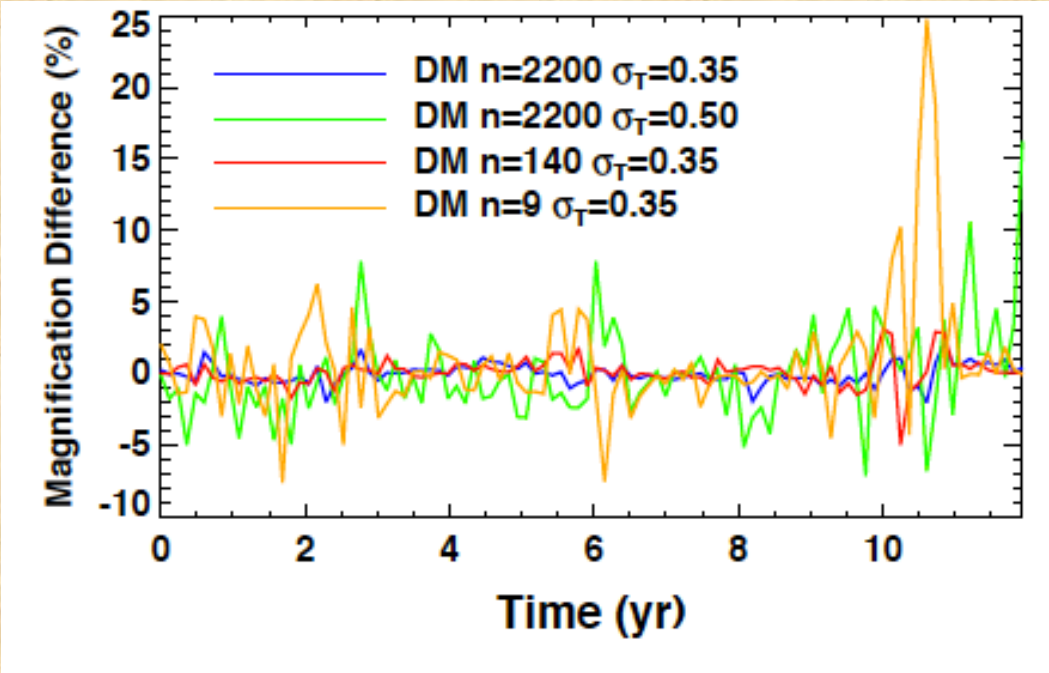
Microlensing in Strongly lensed AGNs



Test other AD models: Inhomogeneous disc

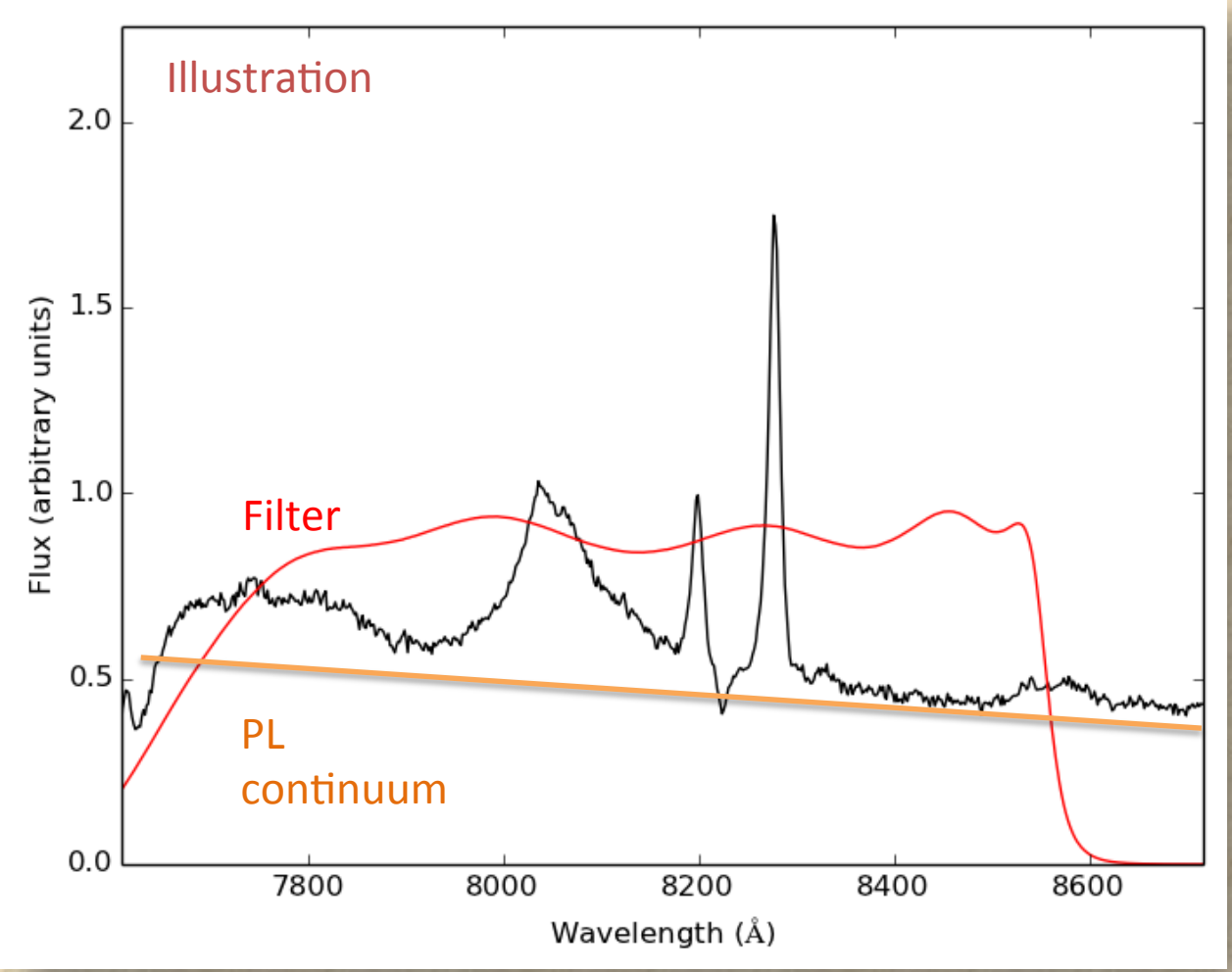


ML: difference with standard disc



Dexter & Agol 2011

Other imprints of AGN structure ?

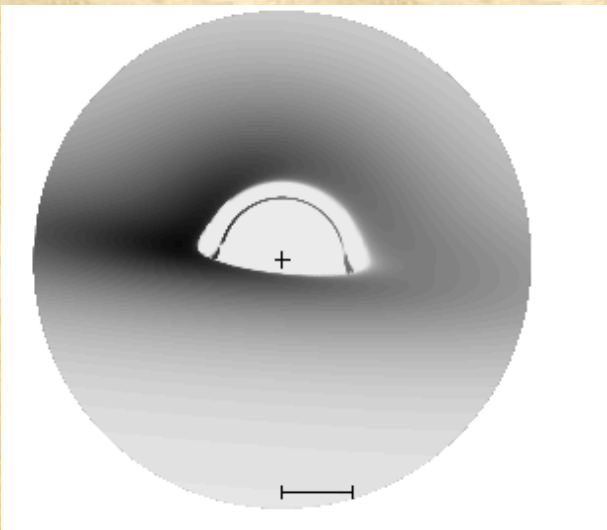


Imprint of the BLR in ML lcves (see Sluse and Tewes 2014 A&A, 571, A10)

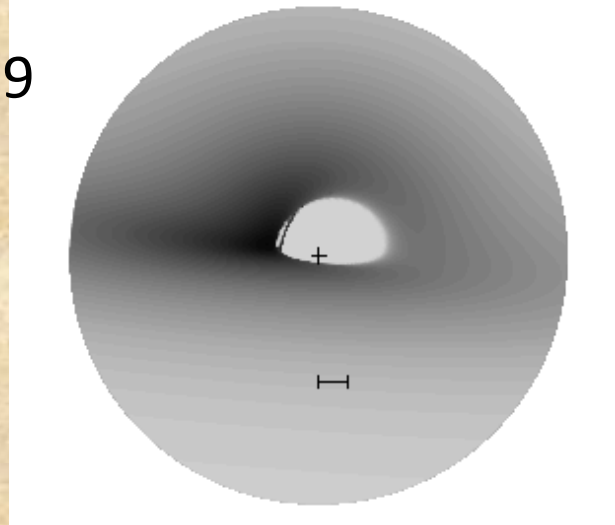
Imprints of “extended continuum” (i.e. scattered light; Sluse+ 2015 A&A 582, A109)

Test other AD models :Relativistic BH

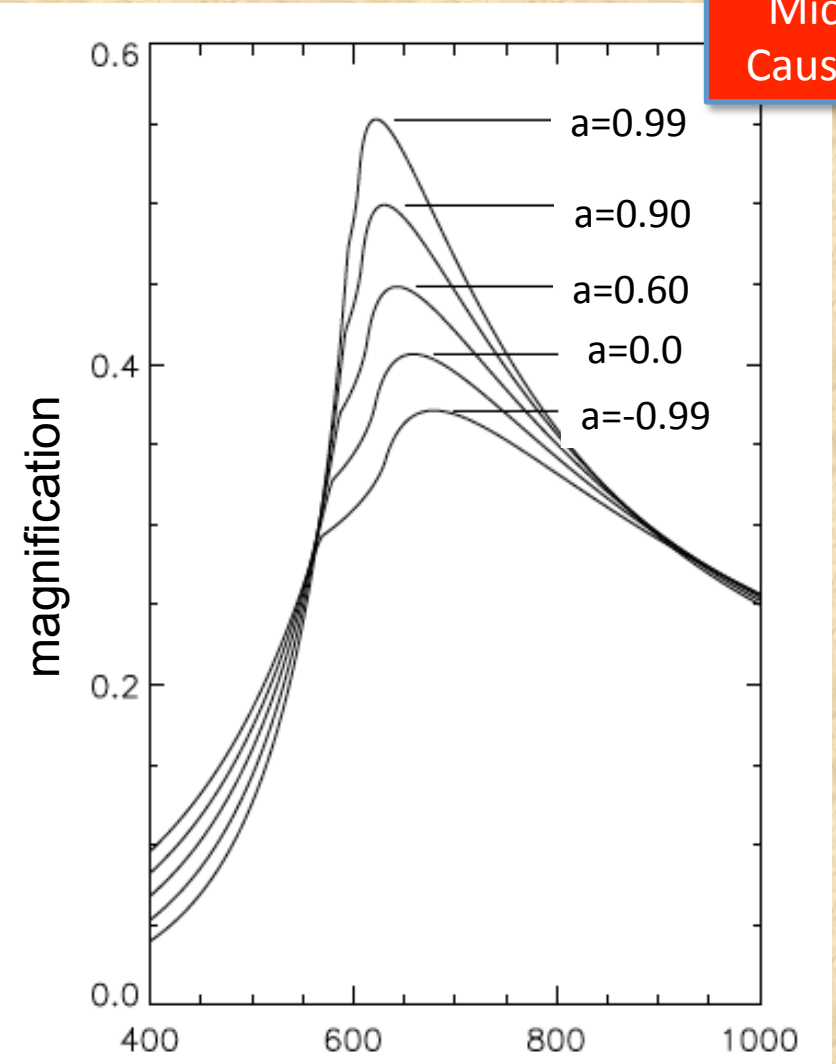
a=0



a=0.9



Microlensing: Caustic crossing



Abolmasov & Shakura 2012b

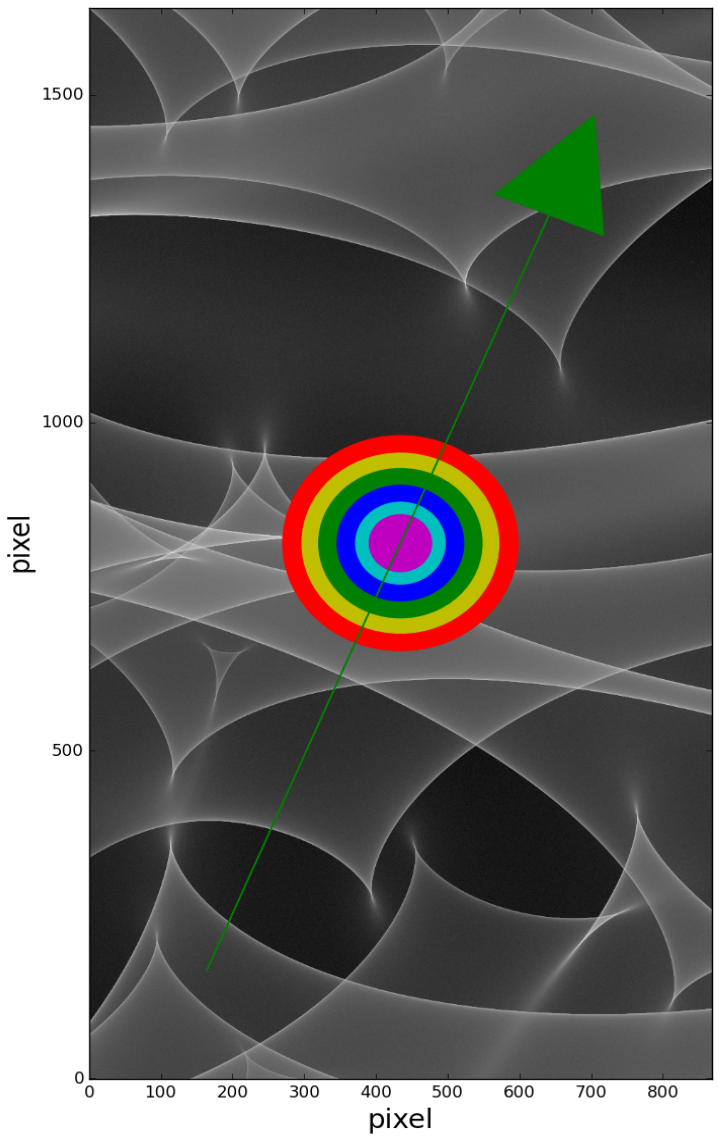
Conclusions

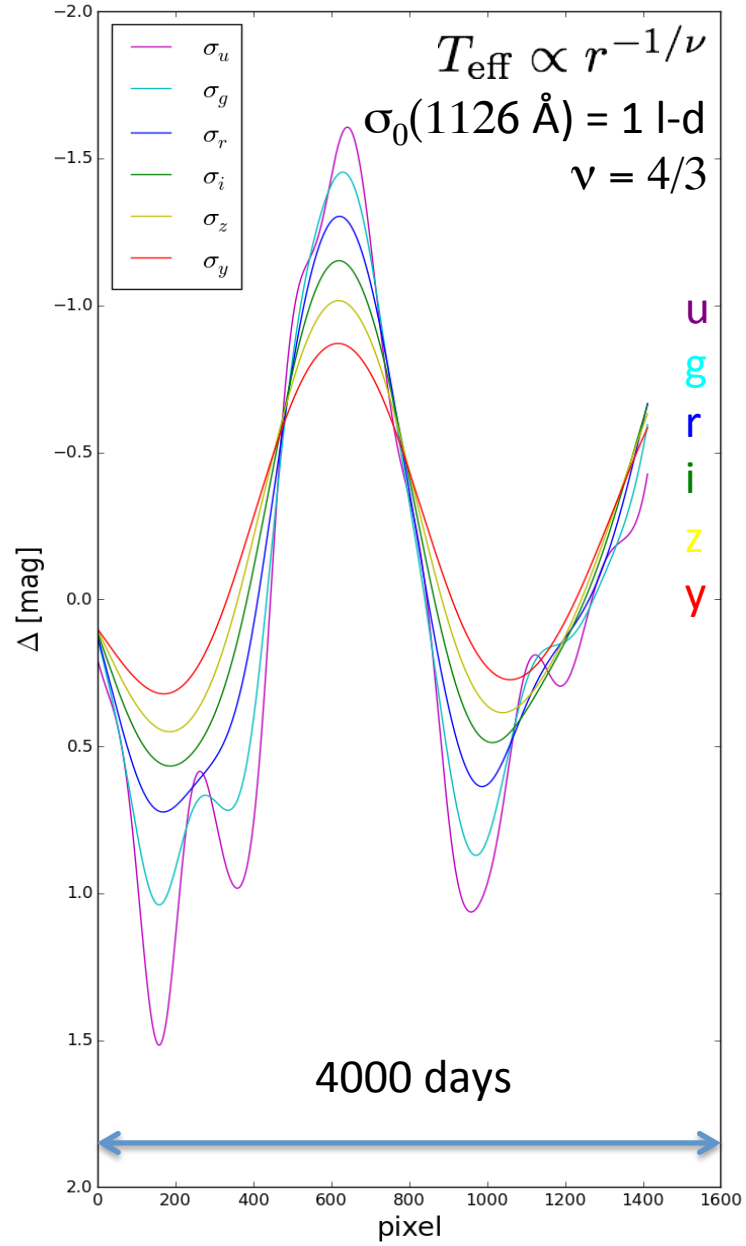
1. More than 2000 lensed AGNs to be monitored in LSST era (down to i_{AB} = 24 mag)

2. Those lightcurves provide unique insights on the structure of accretion discs in distant AGNs:
   - Disc size and temperature profile (PL Energy profile)
   - Test more advanced accretion disc models: towards a new paradigm of AD …
   - Possibly measure AD spin
   - Probe scattered continuum emission

Supplementary slides

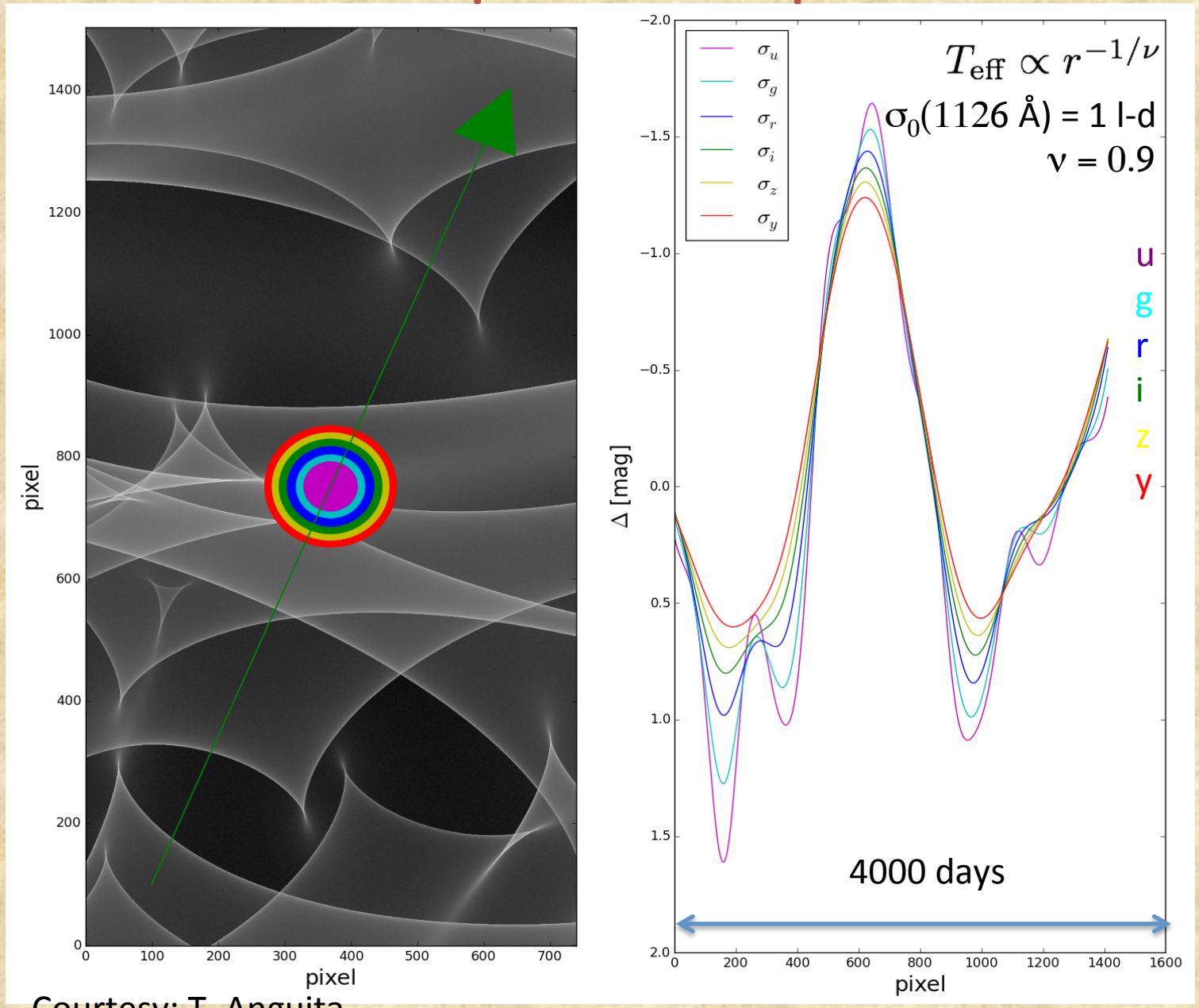
Disc temperature profile





Courtesy: T. Anguita

Disc temperature profile



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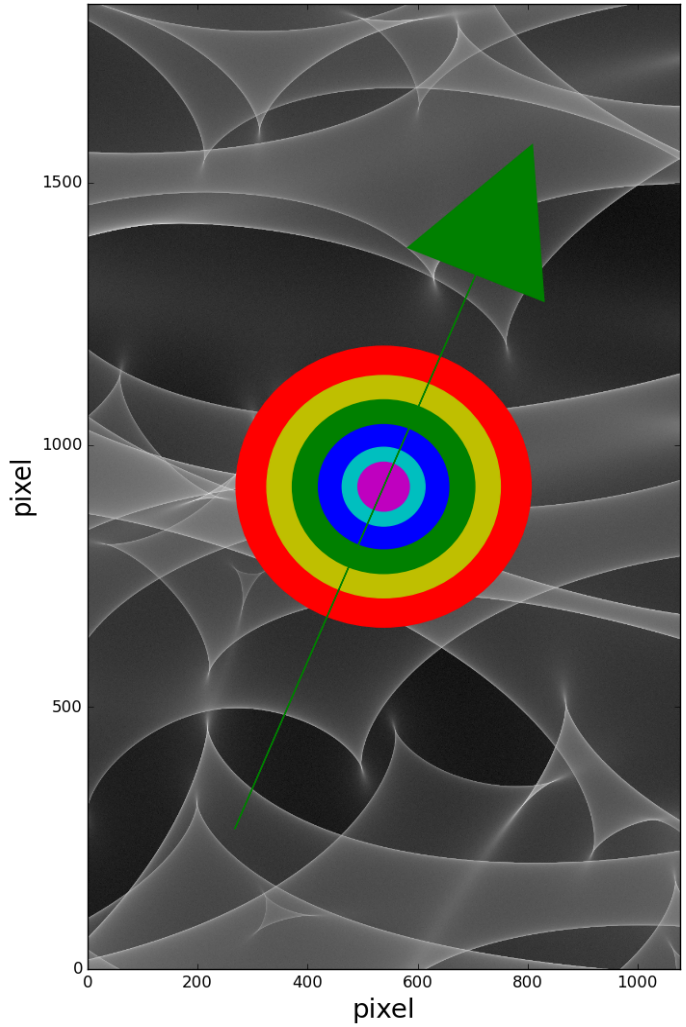
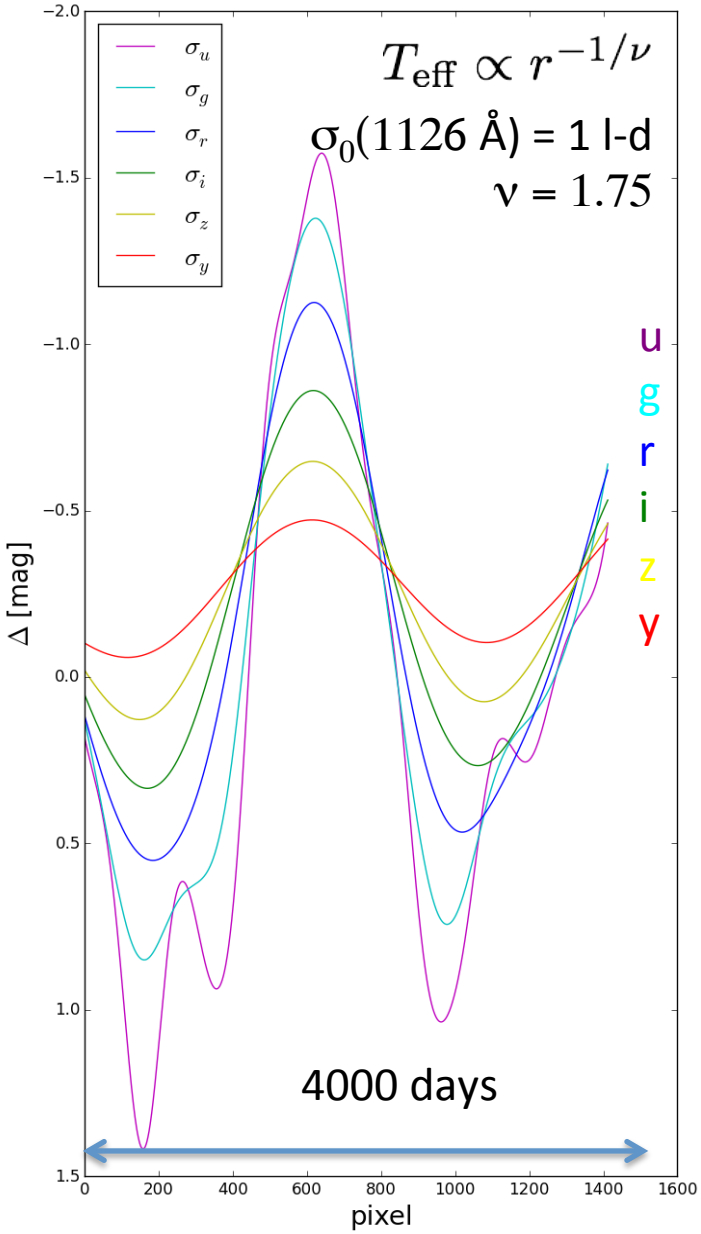
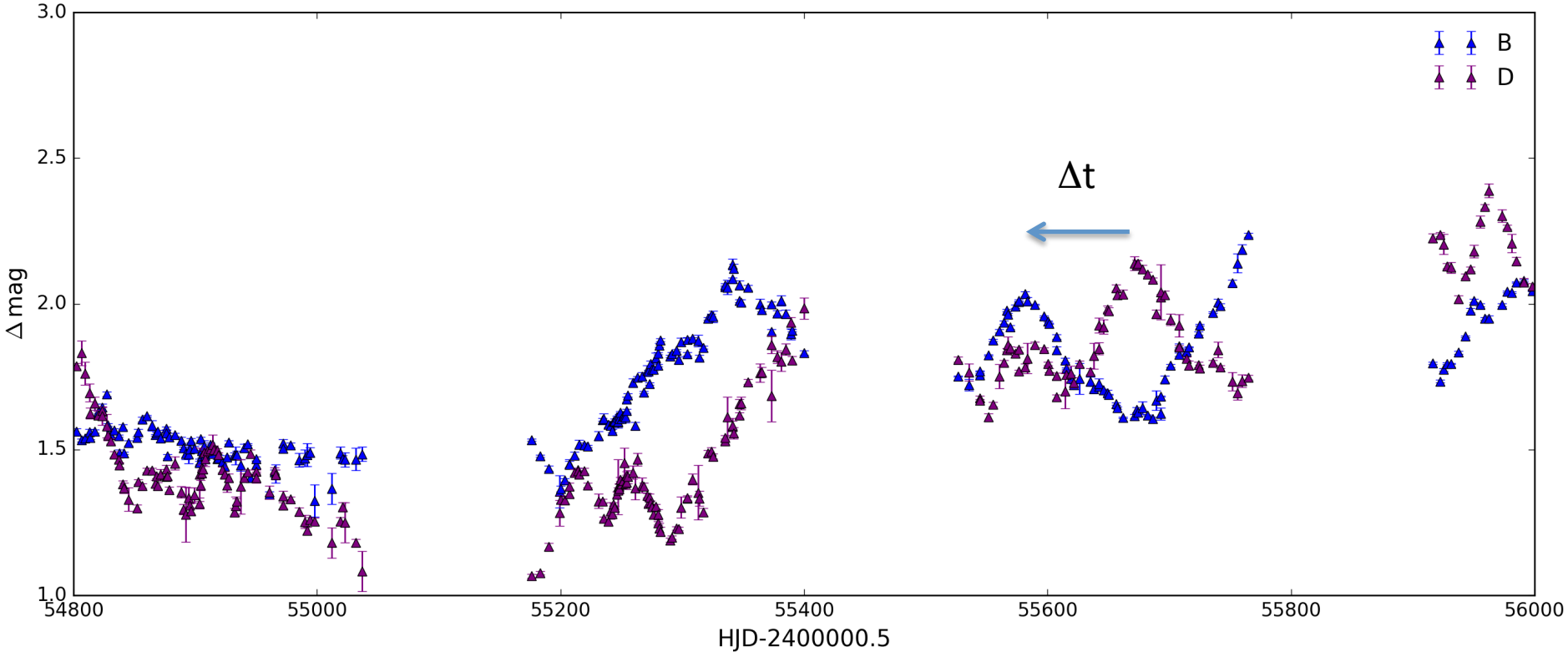


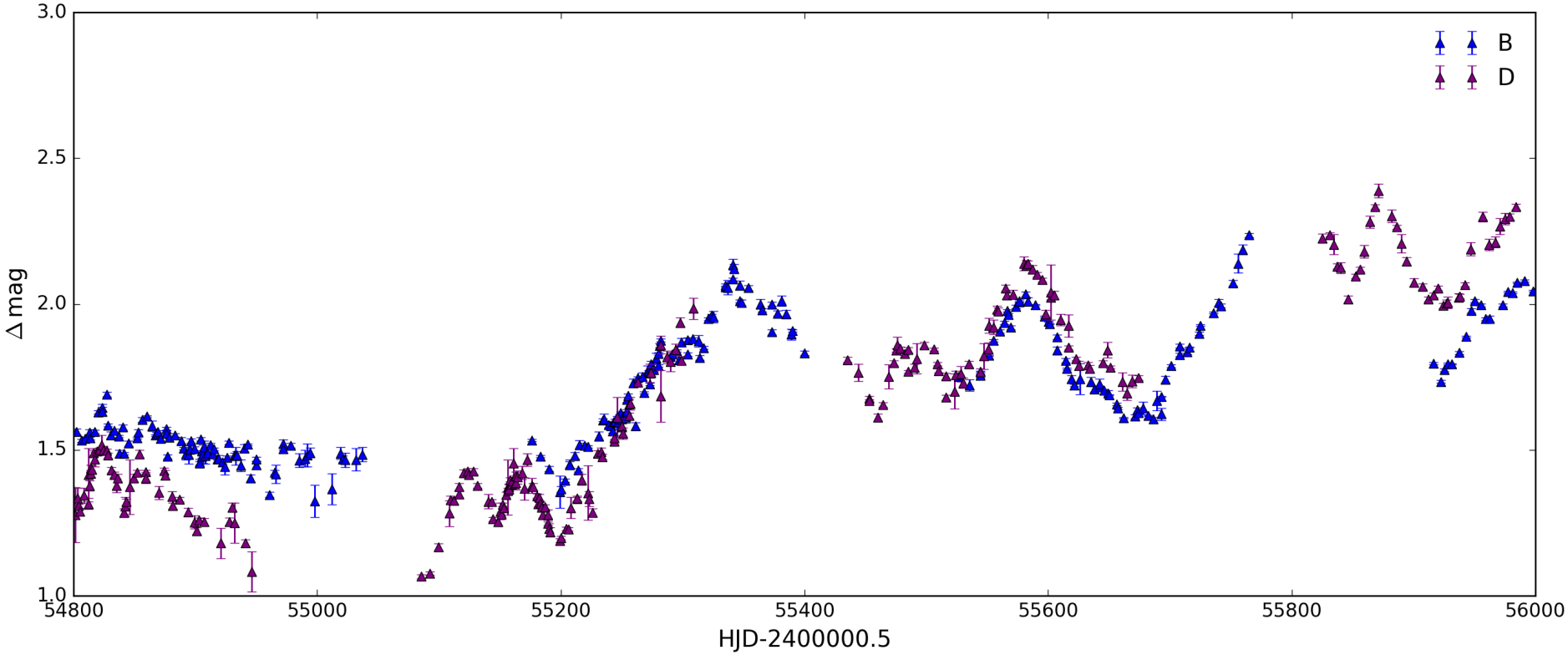


Courtesy: T. Anguita

Strongly lensed AGNs: Cosmological probes

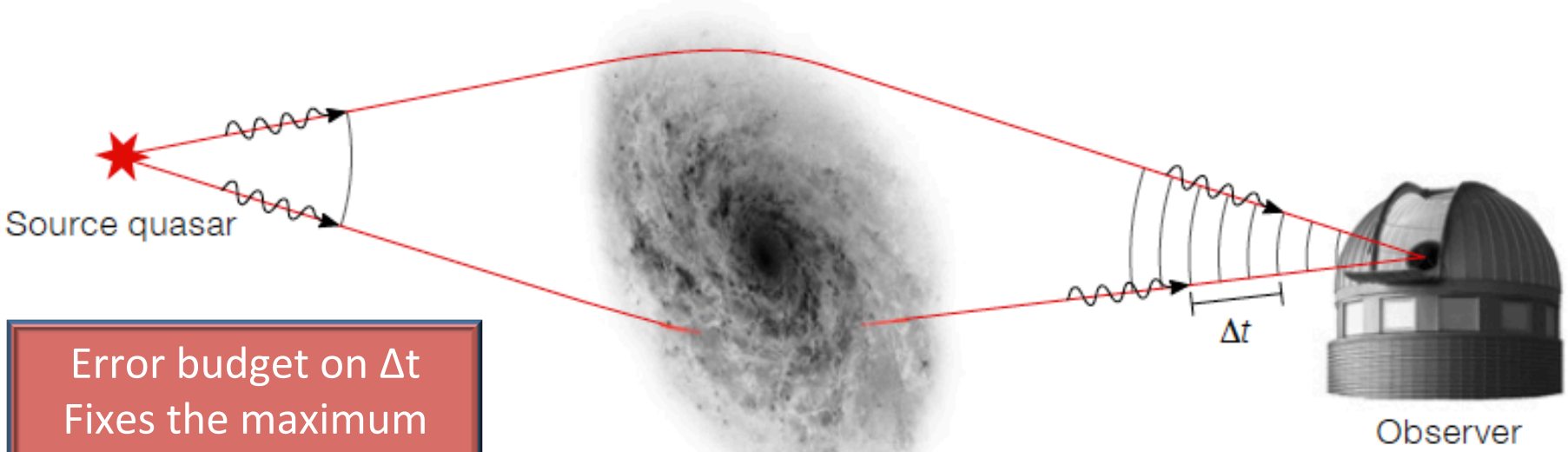


Strongly lensed AGNs: cosmological probes



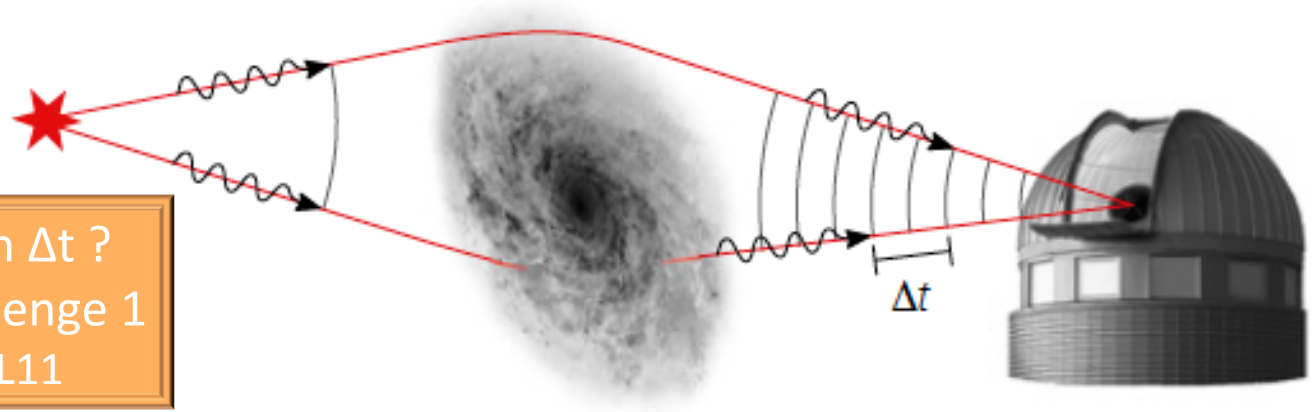
Long and high cadence lightcurves are keys to derive time-delays with a few percent accuracy

Time delays for cosmology



Error budget on Δt
Fixes the maximum
uncertainty on H_0

Large Universe, low H_0, Large time delays



Maximum accuracy on Δt ?
TDC1 – Time delay challenge 1
Liao+ 2015, ApJ, 800, L11

Small Universe, high H_0, Small time delays

Tewes+2012, Narayan & Bartelman 1996