Supermassive BH Science: LSST Science Expectations and Cadence Needs for Strongly Lensed AGN (or quasar microlensing with the LSST)

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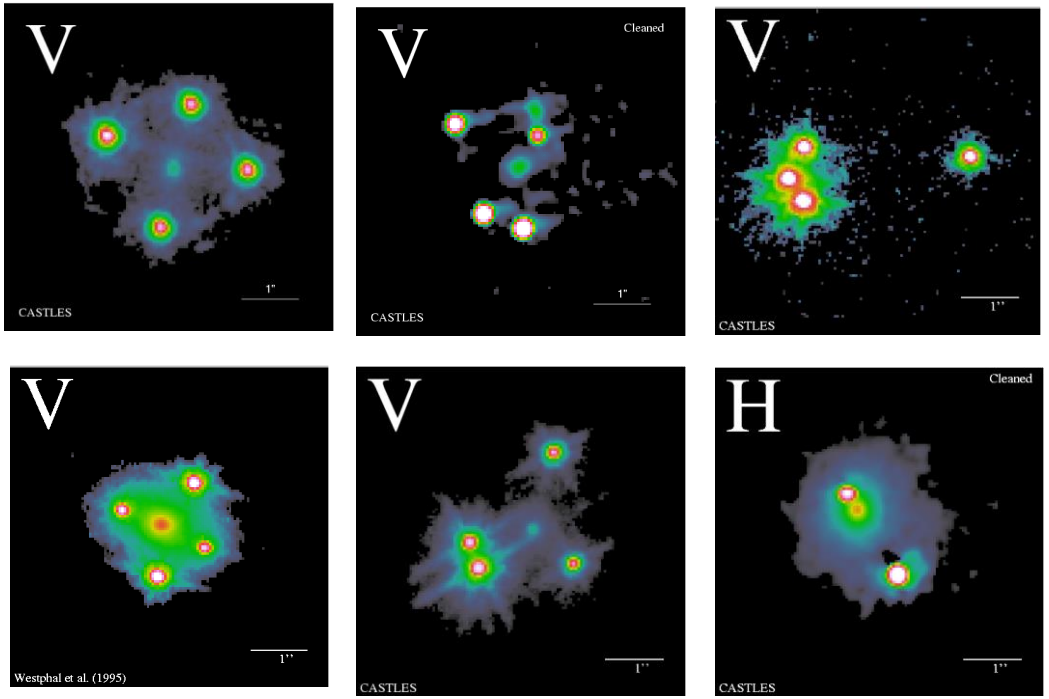
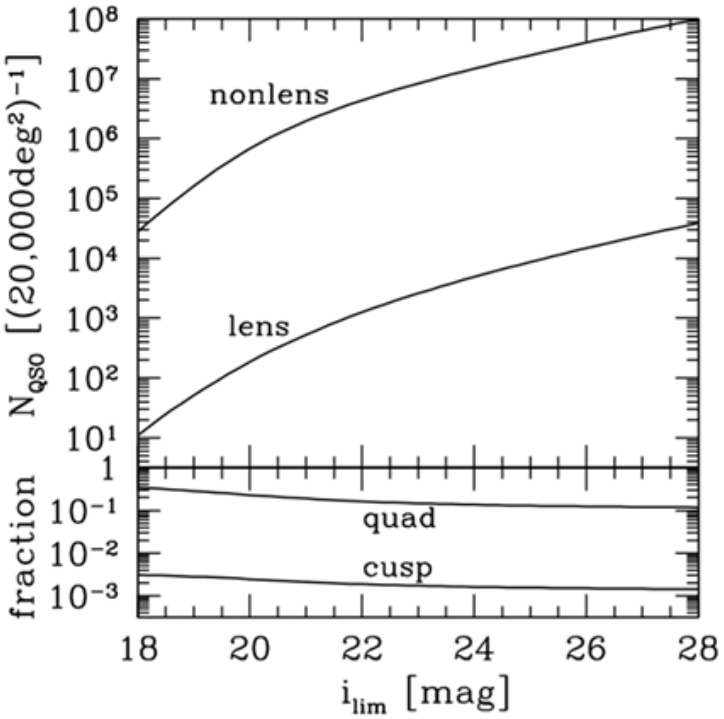
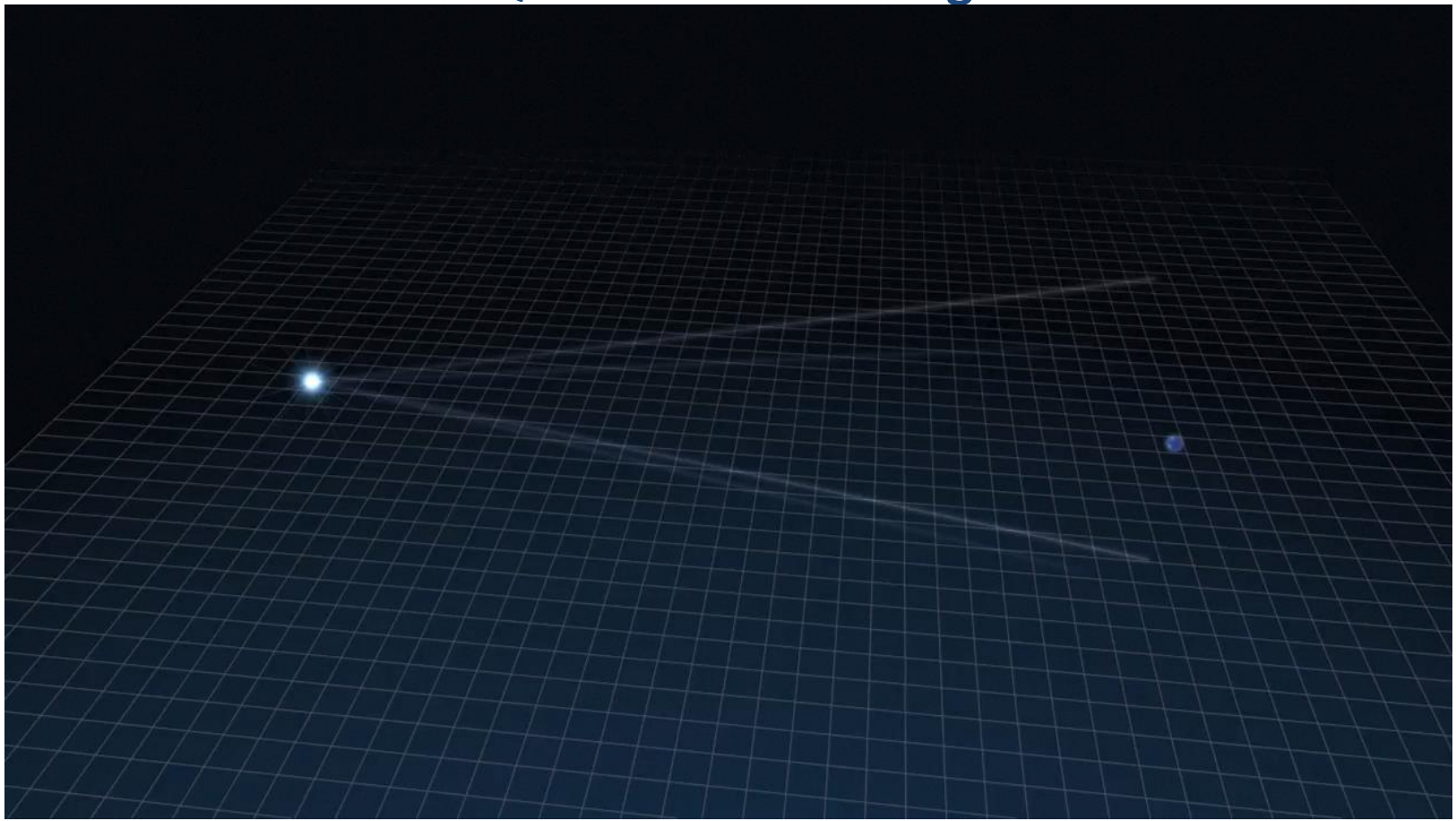
Lensed Quasars



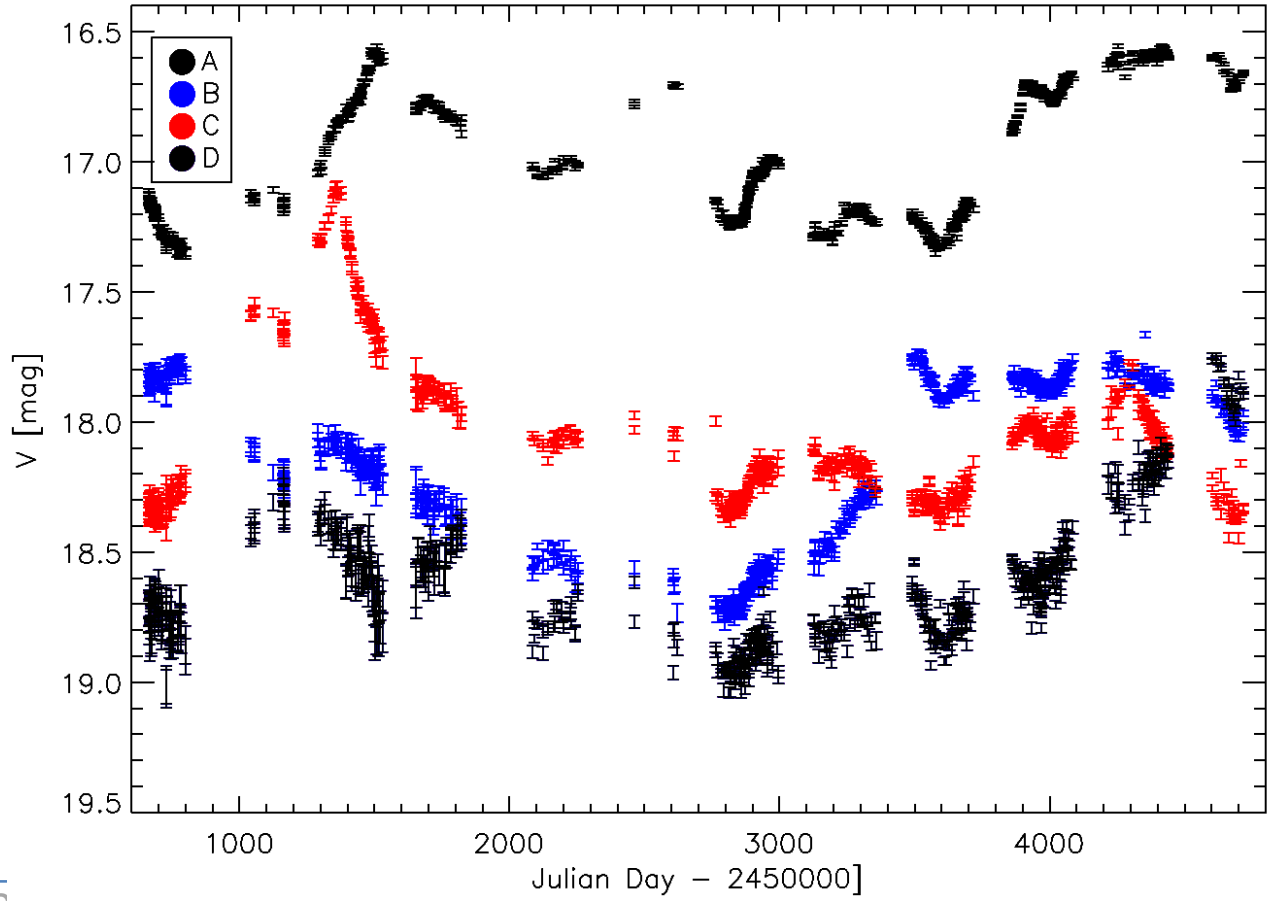
Oguri and Marshall (2010)

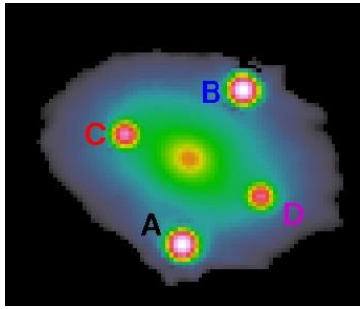


Quasar Microlensing

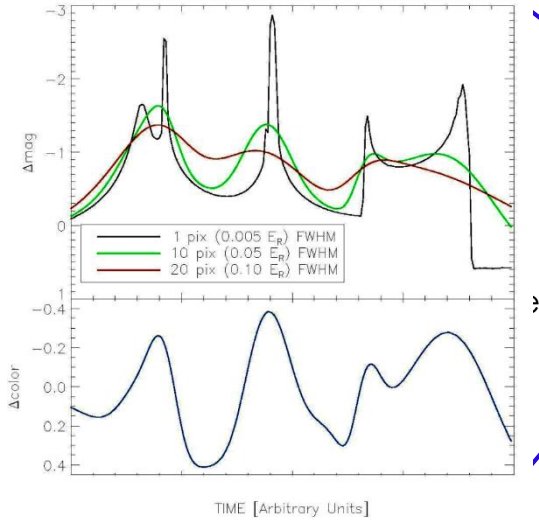


Q2237+0305 (10 years)

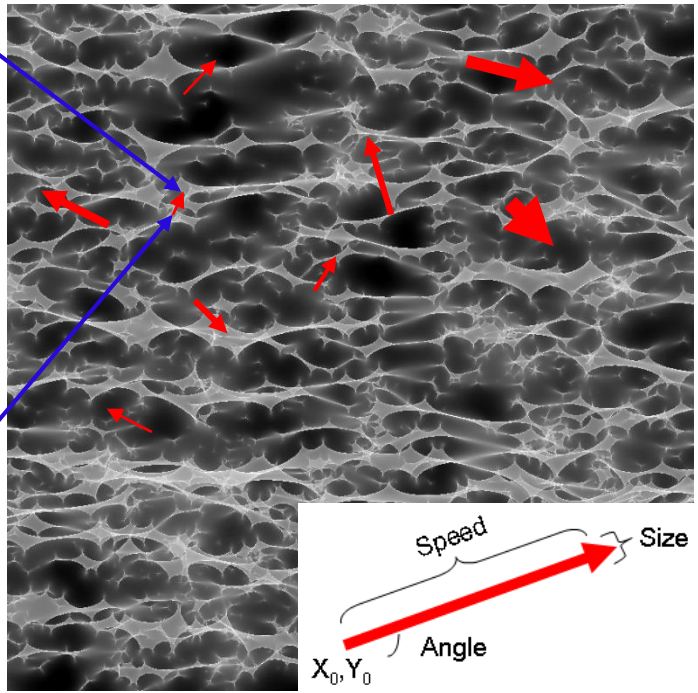




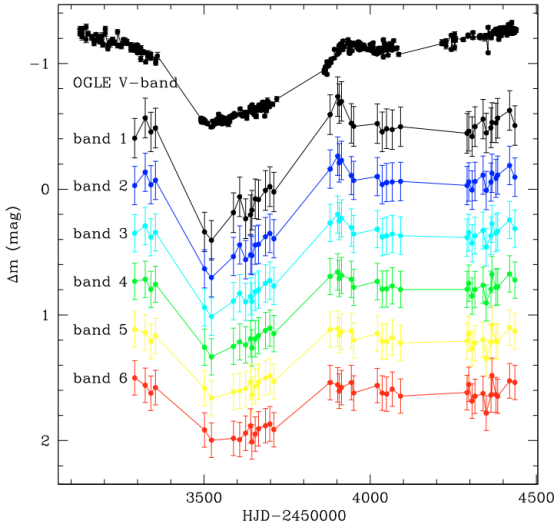
Microlensing Pattern Analysis

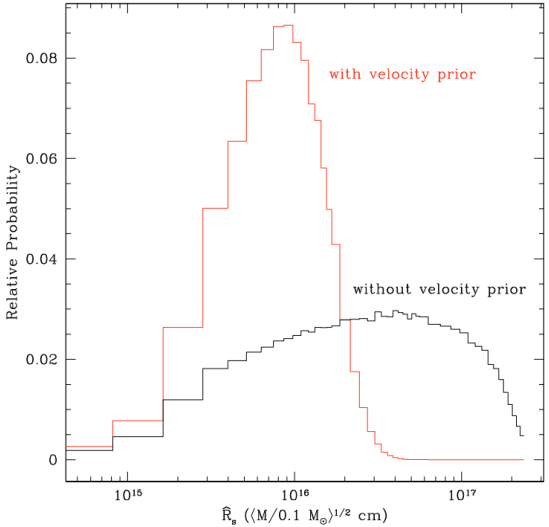


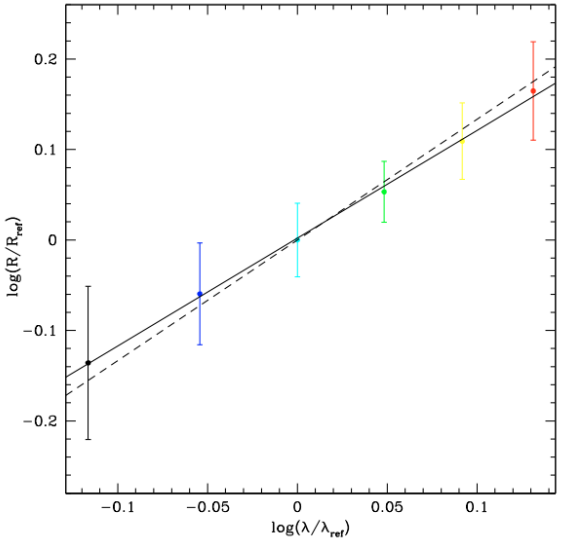
- Different source sizes show different light curves
- Difference between two shows color curve



Example: Multi-band Single High Magnification Event (Eigenbrod+2008)

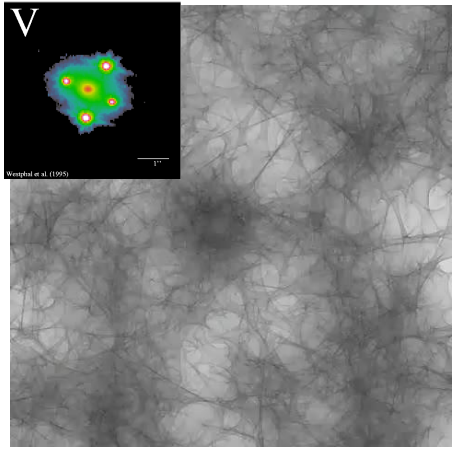


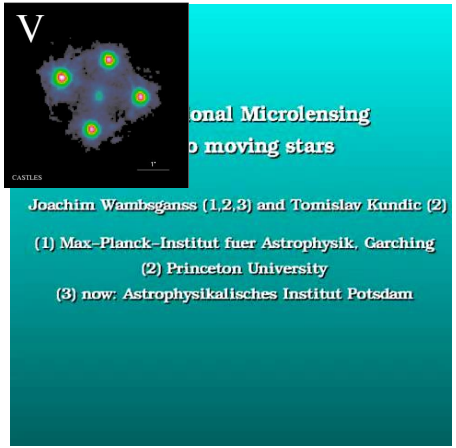


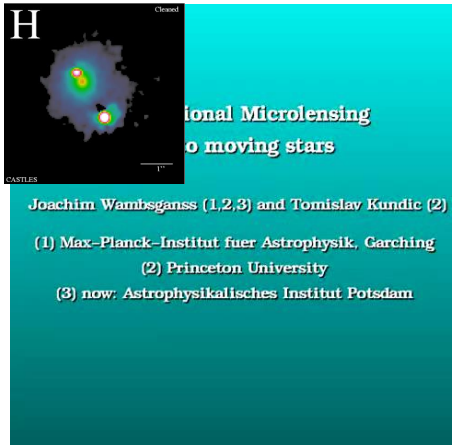


Number of microlenses

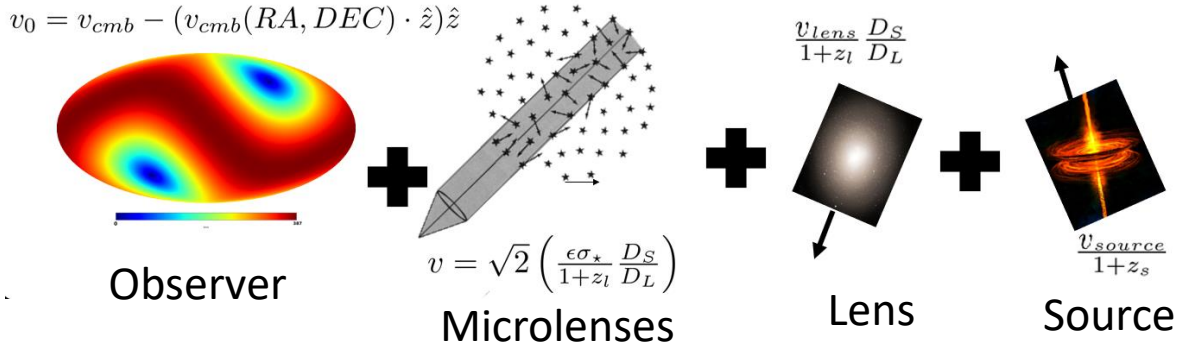
- Strong mass model in each image
  - κ, surface mass density → amount of mass
  - γ, shear → "gravitational pull"
- Further follow-up
  - s, mass in DM
  - $\kappa^*(1-s)$→amount of stars

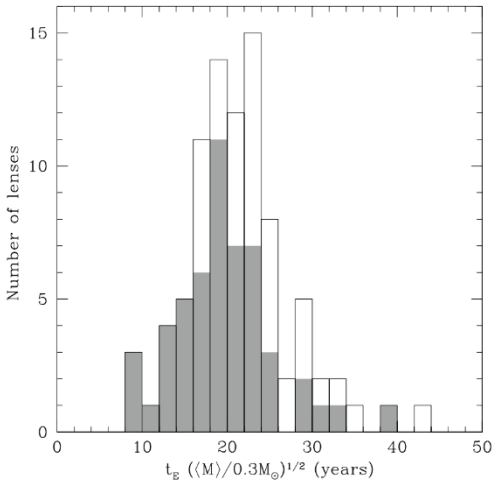


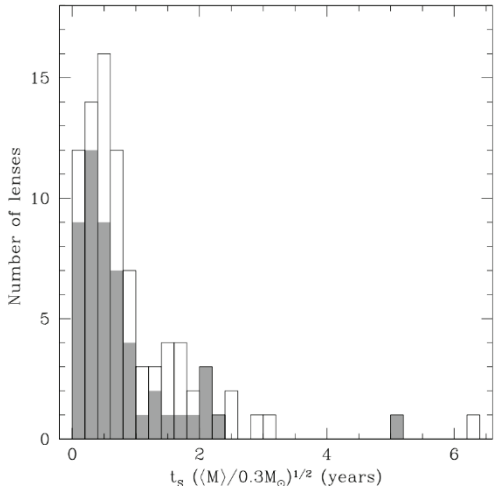




Velocities and Time-Scales



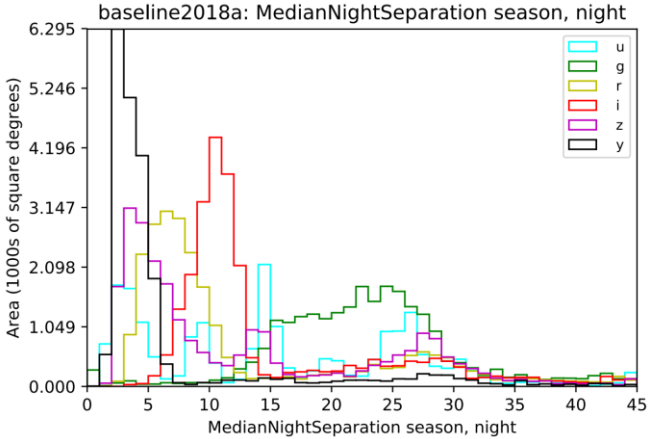


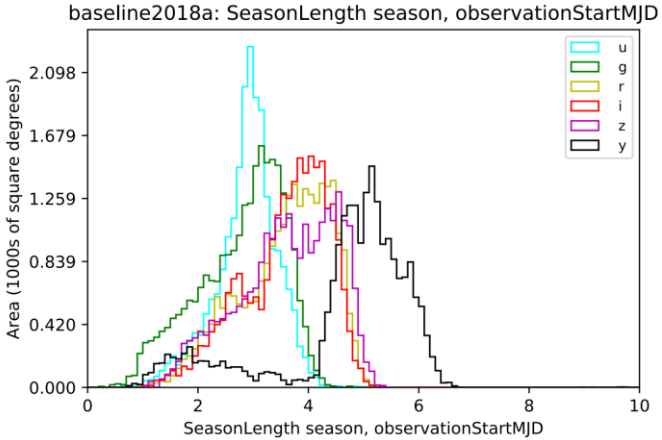


- Mosquera et al. 2011, known systems
  - t_E → Time required to cross E_R → frequency of events
  - t_s → Time for a "caustic" to cross a i-band-sized source → length of an event

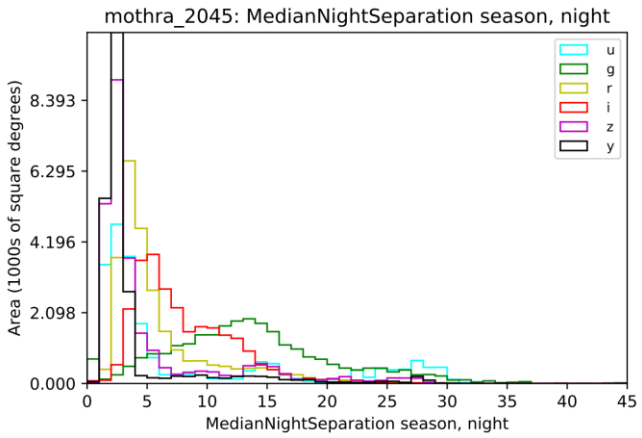
High level differences (MAF analysis)

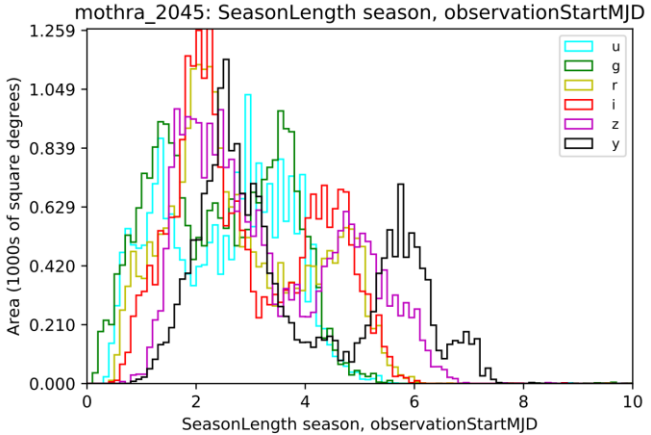
Baseline





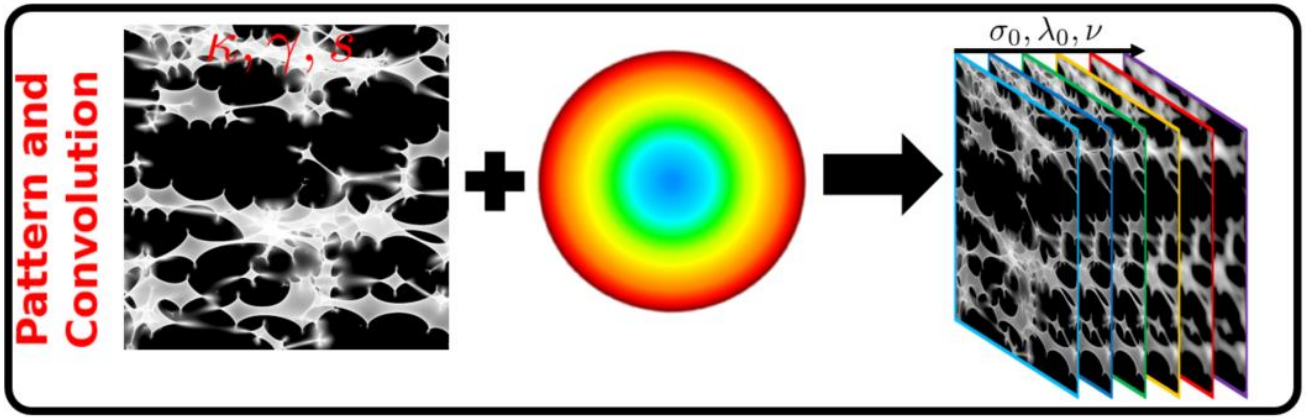
Rolling

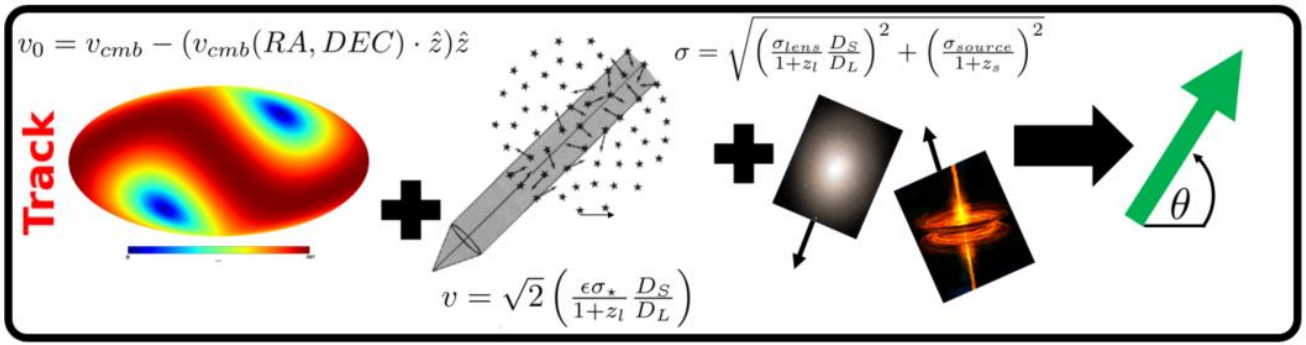


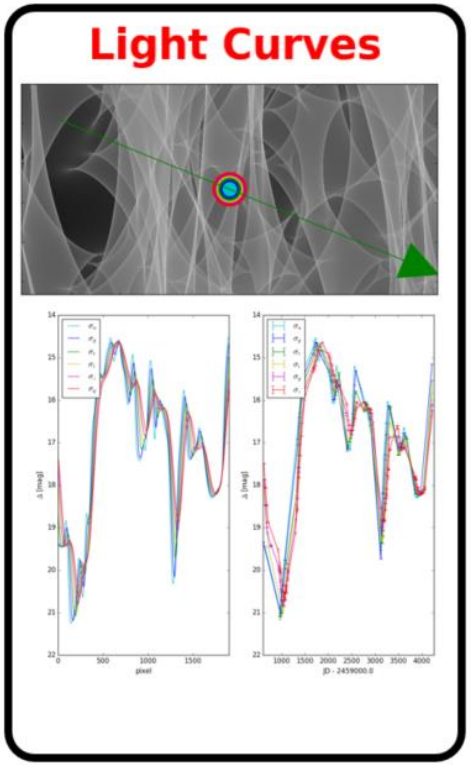


The LSST Quasar Microlensing Simulator

RECIPE

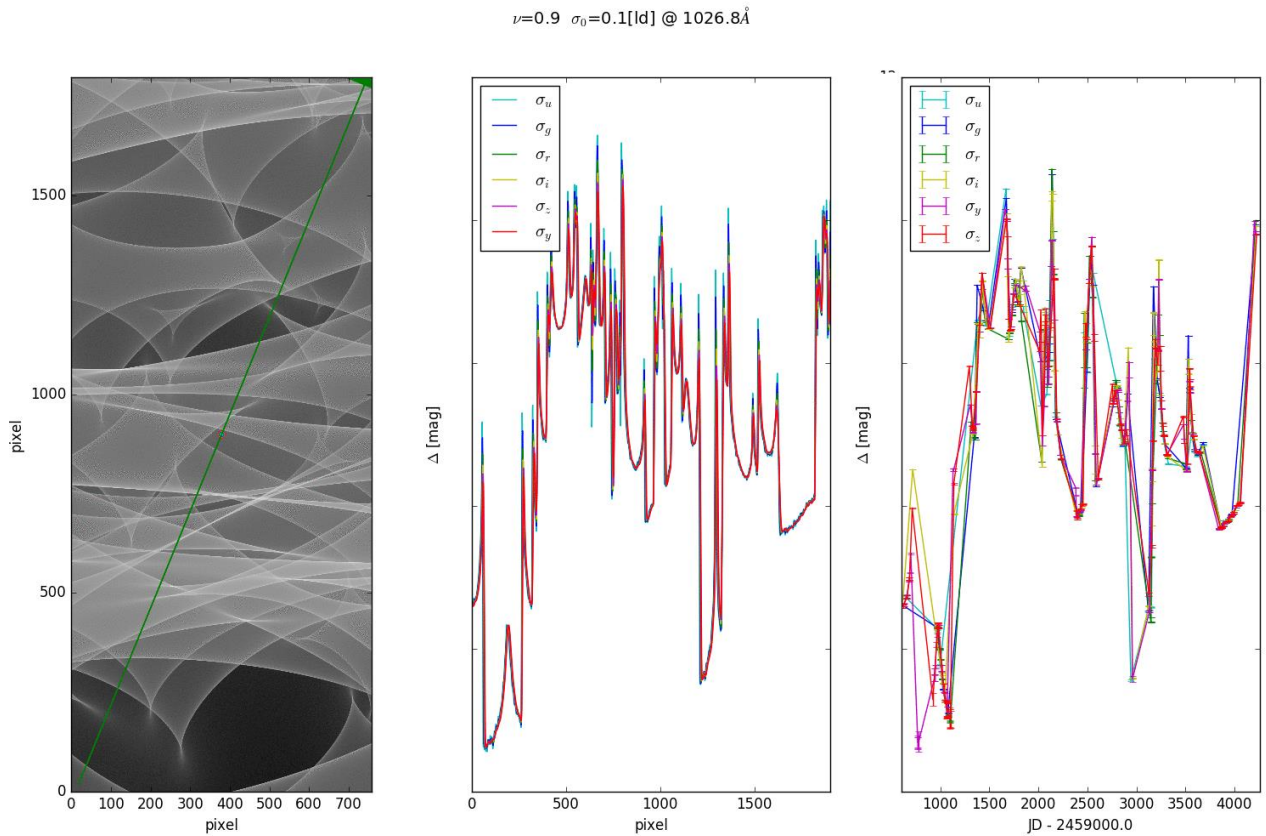




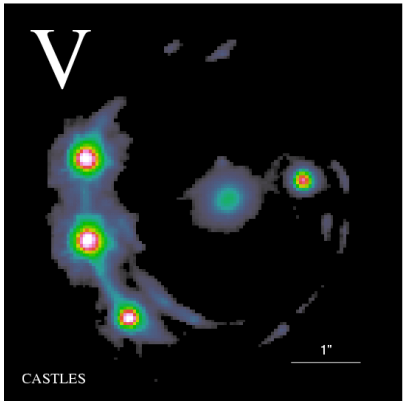


Neira, Anguita & Vernardos 2018 (in prep)

The LSST Quasar Microlensing Simulator

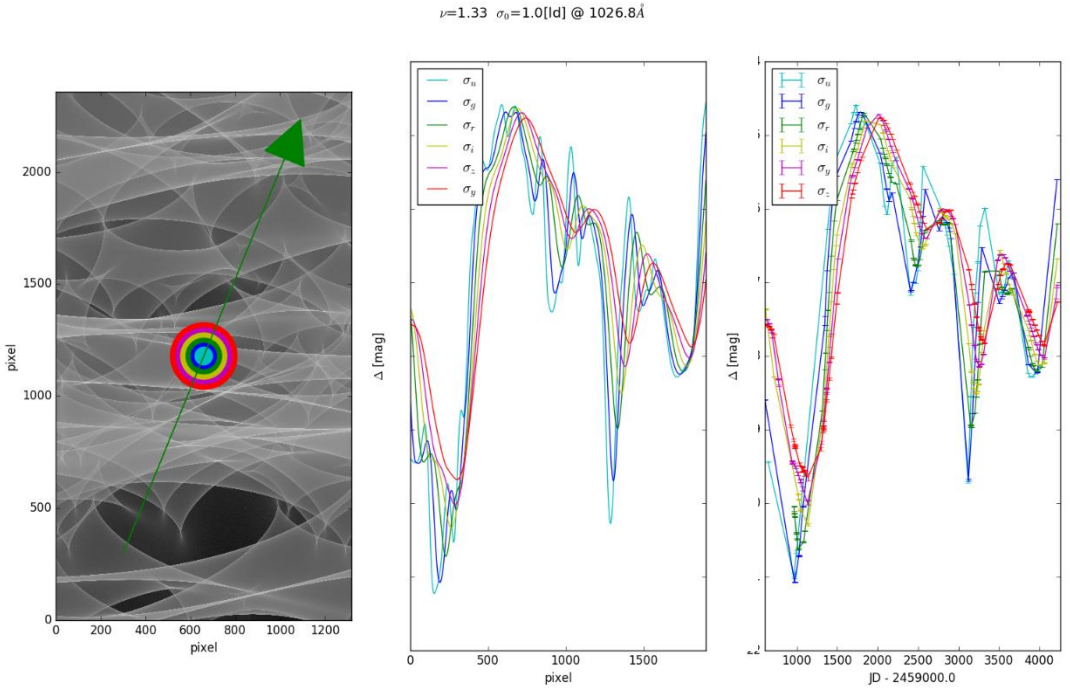


RXJ1131-1231



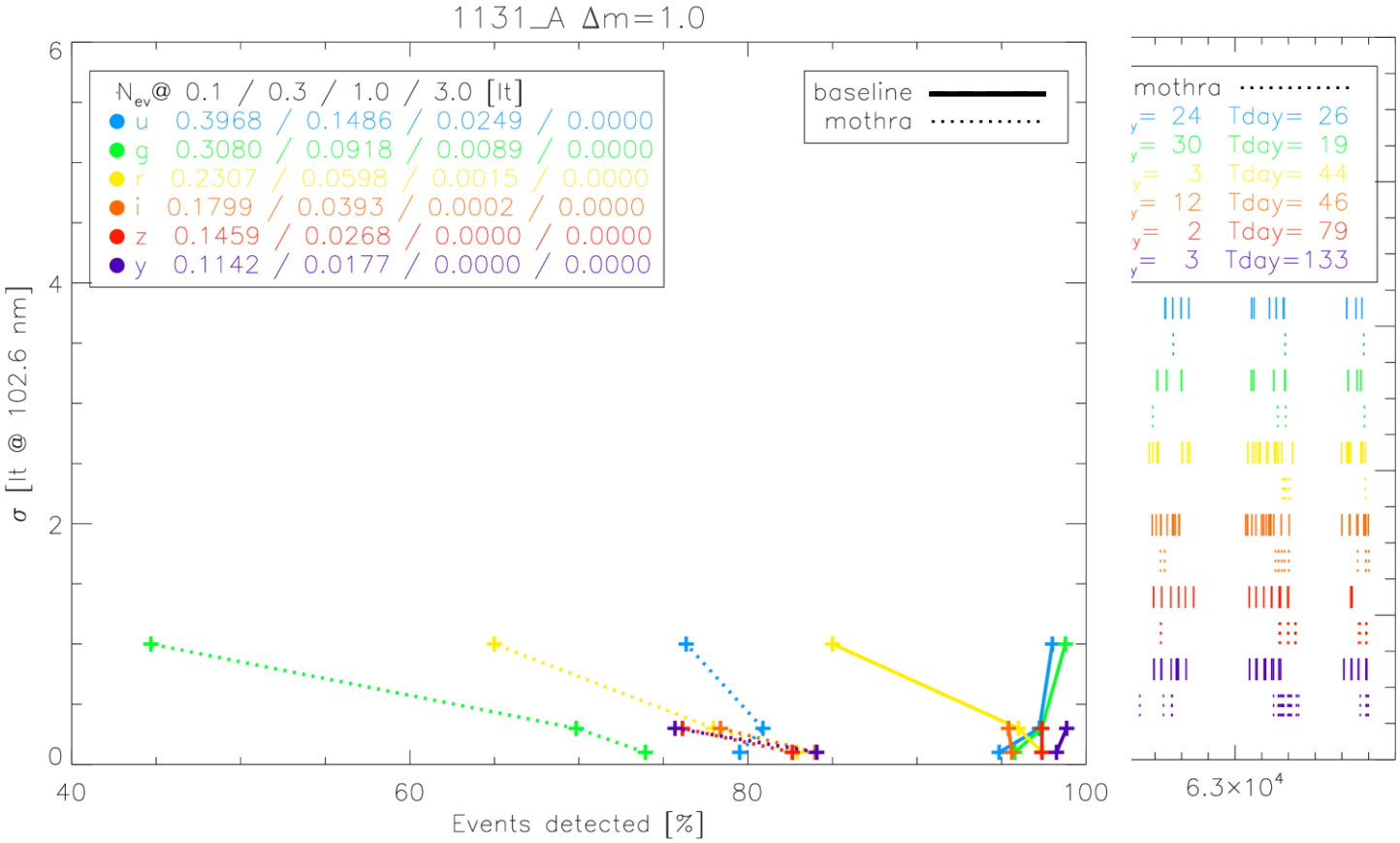
- z_l = 0.295
- z_s = 0.658
- κ = 0.494
- γ = 0.562
- s = 0.6

$v_t \tilde{\propto} D_S/D_L$ =1.6x

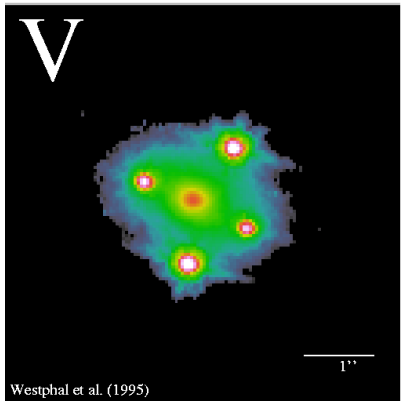


κ [amount of mass] $*$ (1–s [% of mass in DM)]) = 0.2x $\propto N_{micro}$

RXJ 1131-1231



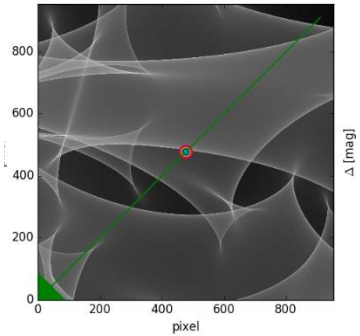
Q2237+0305

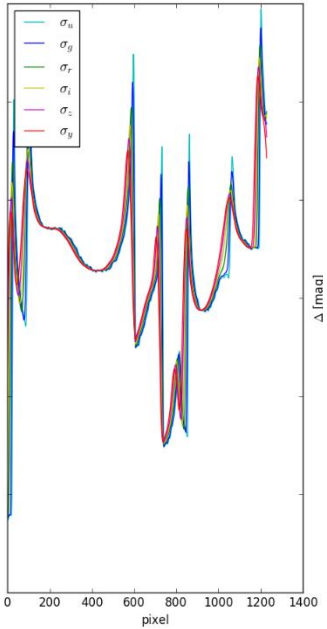


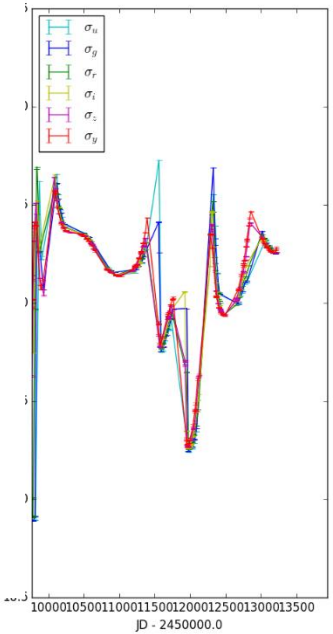
- z_l = 0.034
- z_s = 1.695
- κ = 0.394
- γ = 0.395
- s = 0.0

$v_t \widetilde{\propto} D_s/D_L$ =12.5x

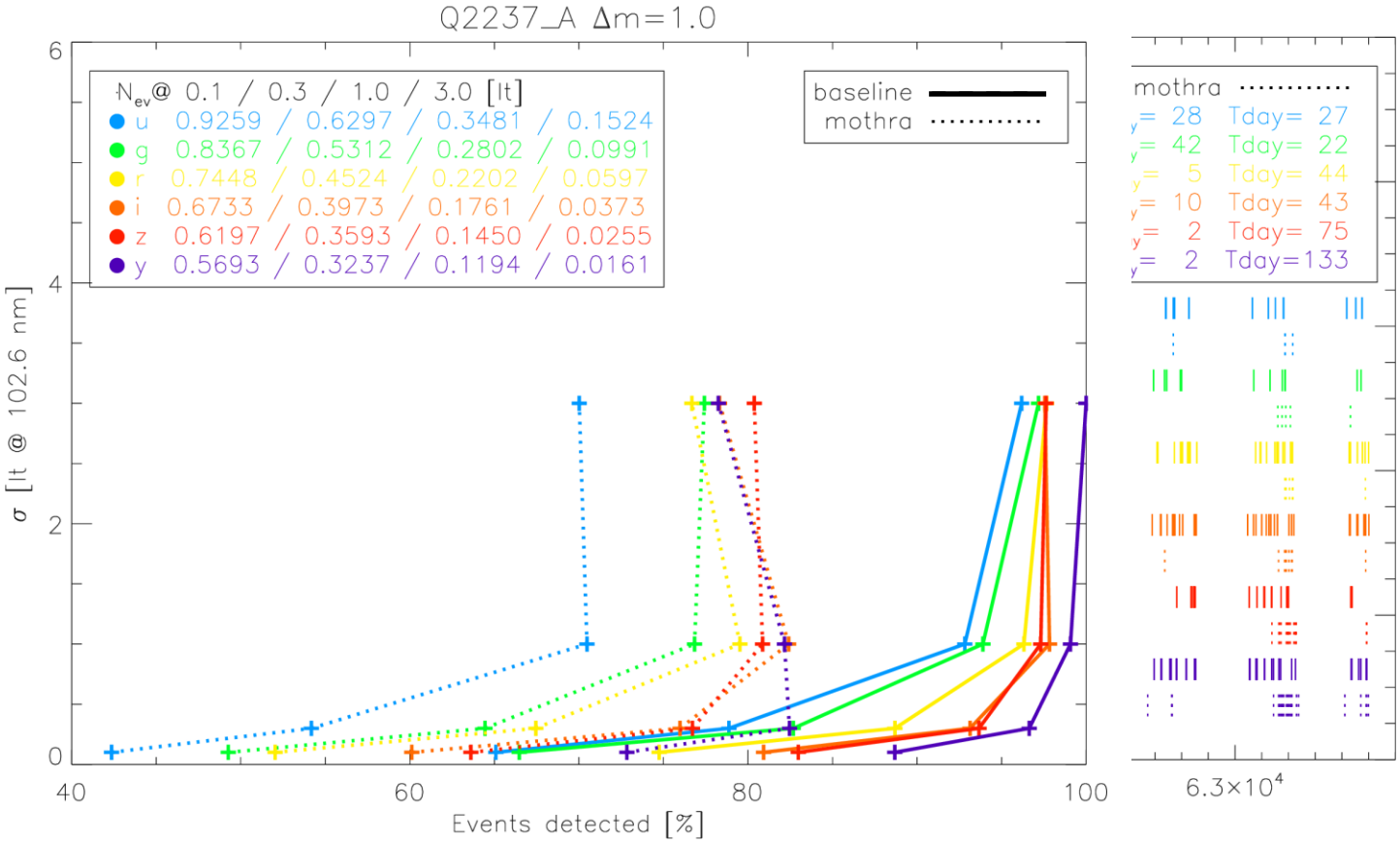
$N_{micro} \propto$ 0.394x



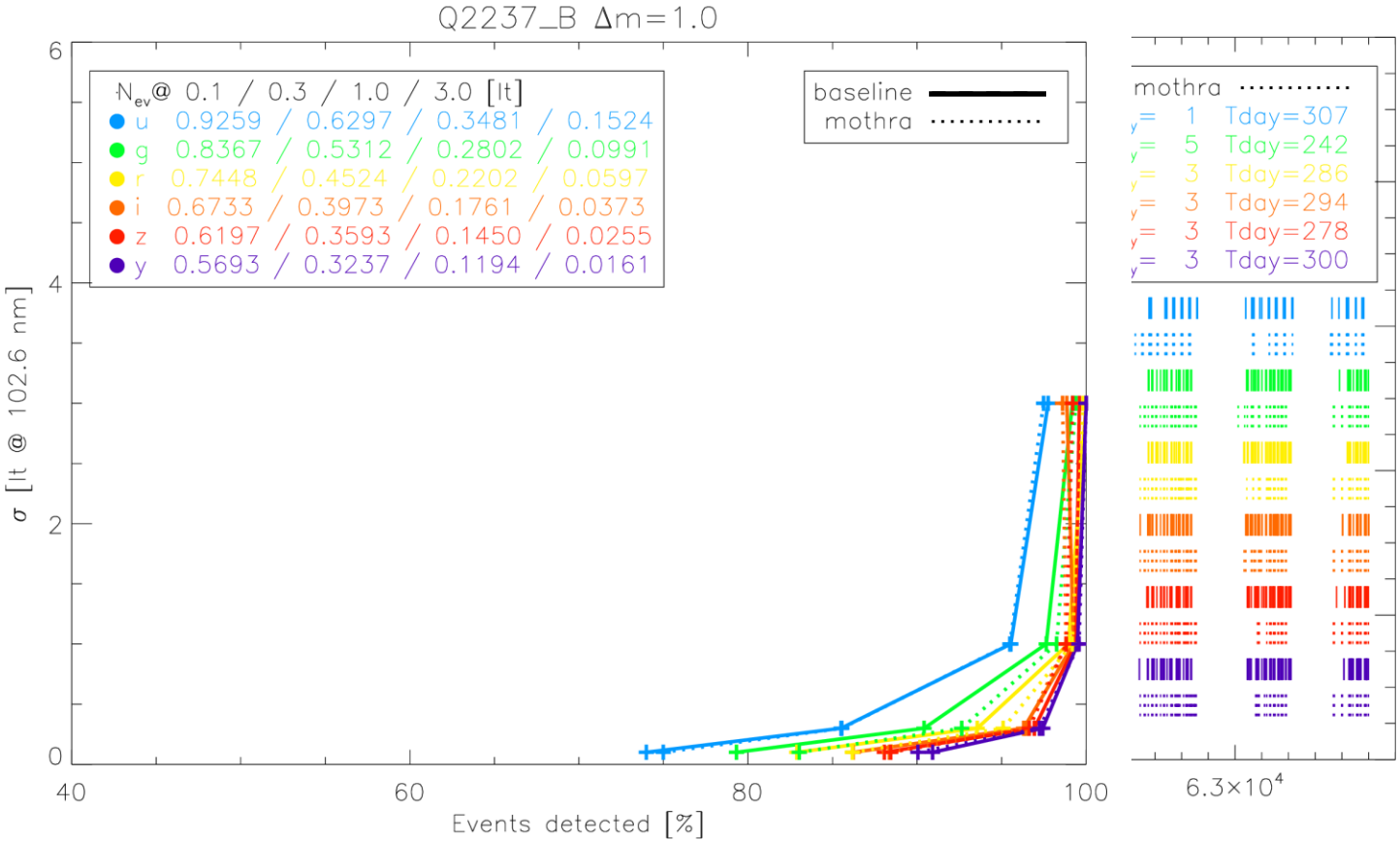




Q2237+0305

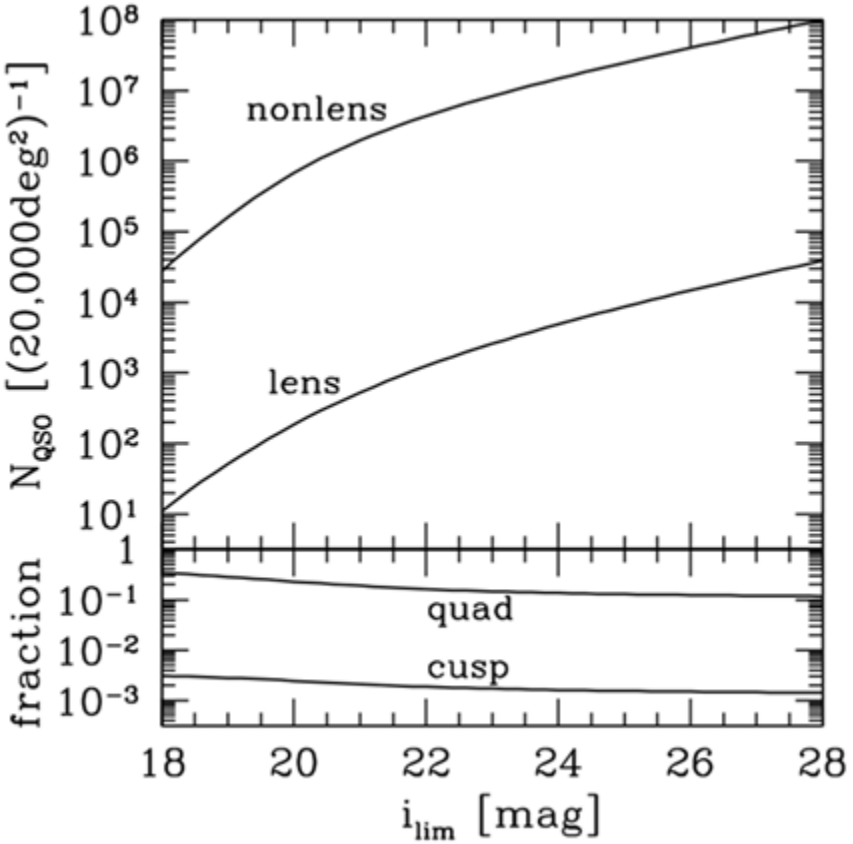

Q2237_A Δm=1.0
N_ev@ 0.1 / 0.3 / 1.0 / 3.0 [lt]
u 0.9259 / 0.6297 / 0.3481 / 0.1524
g 0.8367 / 0.5312 / 0.2802 / 0.0991
r 0.7448 / 0.4524 / 0.2202 / 0.0597
i 0.6733 / 0.3973 / 0.1761 / 0.0373
z 0.6197 / 0.3593 / 0.1450 / 0.0255
y 0.5693 / 0.3237 / 0.1194 / 0.0161
baseline
mothra
σ [lt @ 102.6 nm]
Events detected [%]
mothra
y= 28 Tday= 27
y= 42 Tday= 22
y= 5 Tday= 44
y= 10 Tday= 43
y= 2 Tday= 75
y= 2 Tday=133
6.3×10^4

Q2237+0305 in a DDF



LSST: How many microlensing "usable" lensed quasars?

- All will have microlensing→ maximize number of (bright systems)
  - Good seeing g images maximize discovery (Collet 2015)
  - Increase WFD area?
  - Minimize galactic center (in u and g)?
- Oguri and Marshall 2010
  - 8000 lensed quasars (15% quads)
  - 3000 with measured time delays
- Less uniform cadence → same number of systems, perhaps smaller fraction of time delays measured? (not entirely clear still)

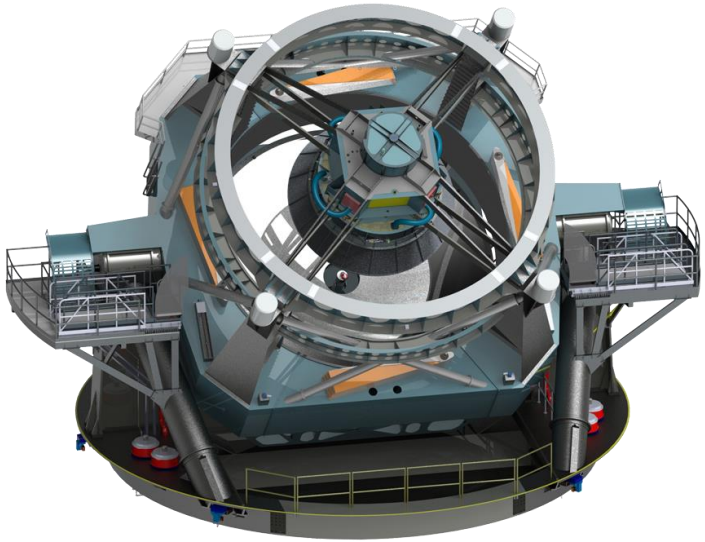


Summary

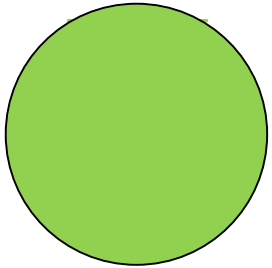
- LSST will be able to produce light curves with significant microlensing signal for thousands of quasars
- Scarcity of systems, long timescales → Ideal survey
- A rolling cadence
  - Less uniform + short seasons → Loss of some “chromatic” events, loss of bluer bands cadence
  - would reduce the microlensing signal
- But also, time delay measurements are necessary for (most) microlensing studies.

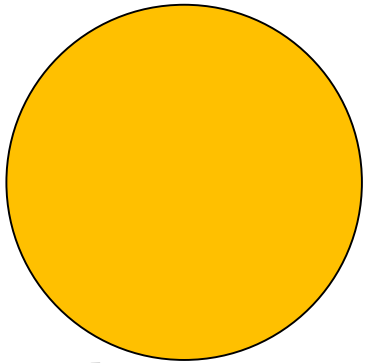
Large Synoptic Survey Telescope

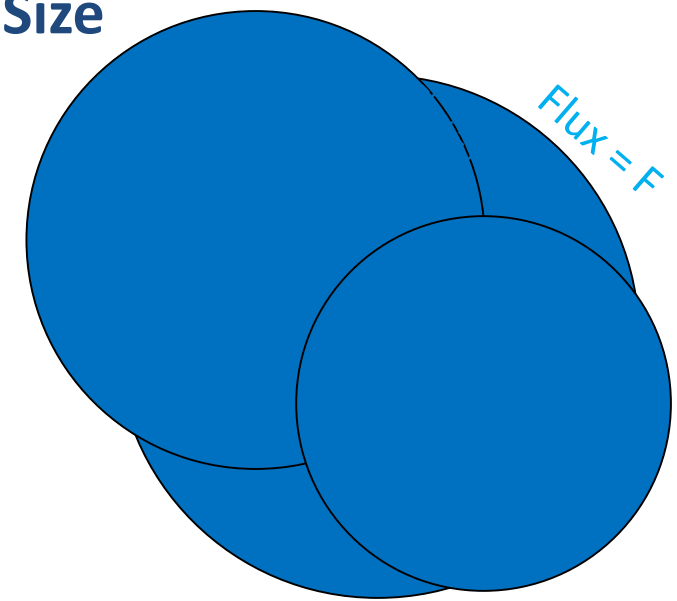
Thanks!



Magnification and Size

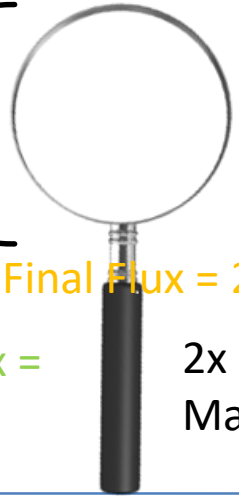






$$\theta_E = \sqrt{\frac{4GM}{c^2}\frac{D_{LS}}{D_L D_S}}$$

+



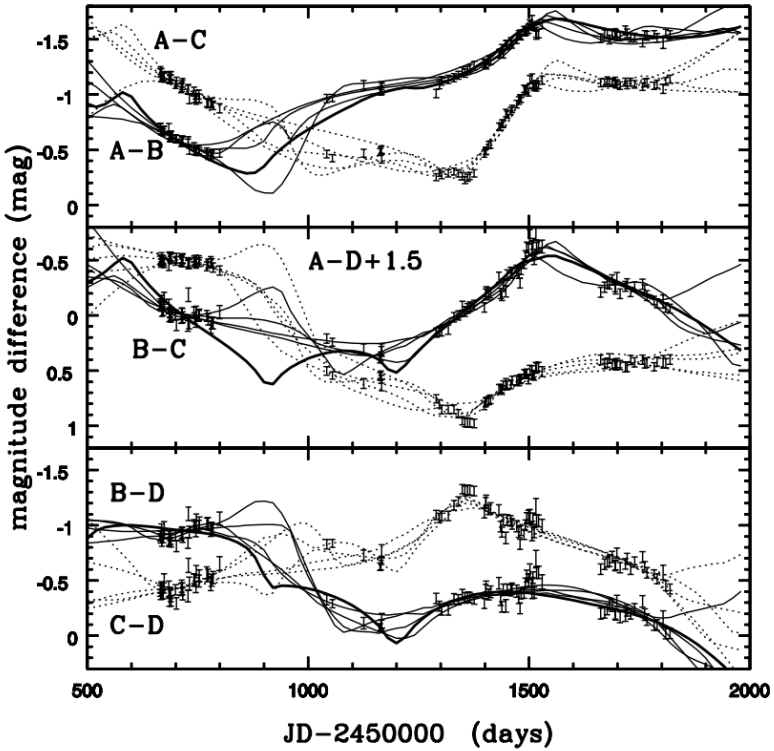
Final Flux = 2xF

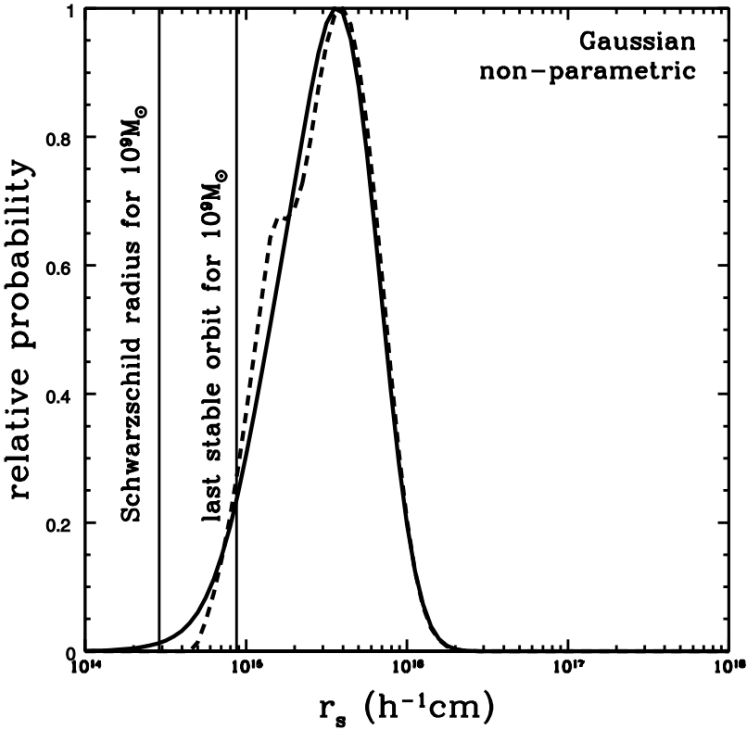
Final Flux = 2xF

2x Magnification

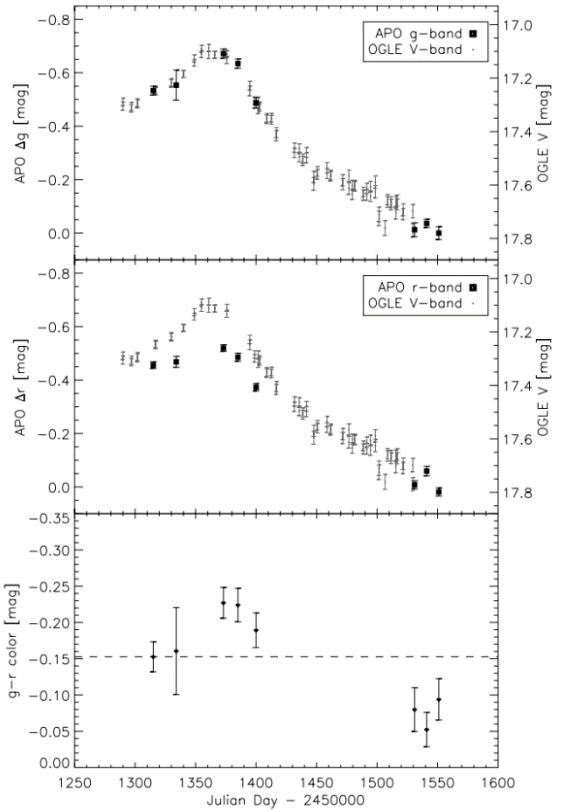
Final Flux = 2xF/4 + 3F/4 = 1.2xF

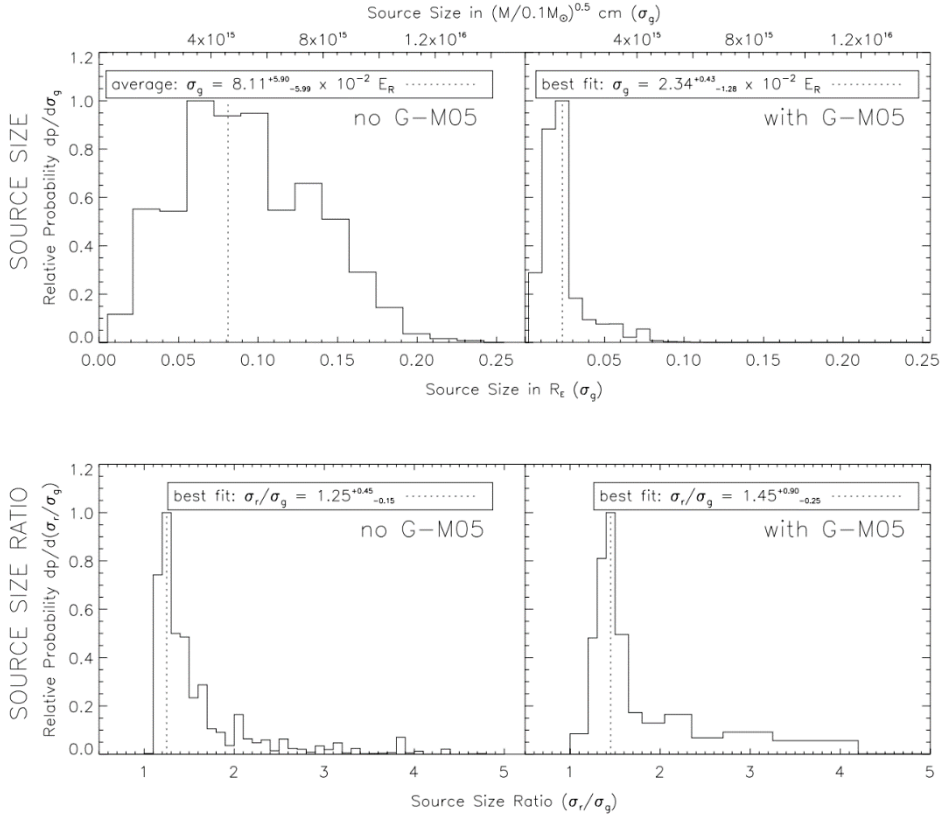
Example: Long Light Curves (Kochanek 2004)



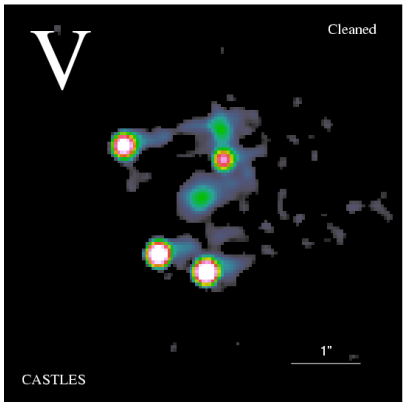


Example: Two band Single High Magnification Event (Anguita+2008)





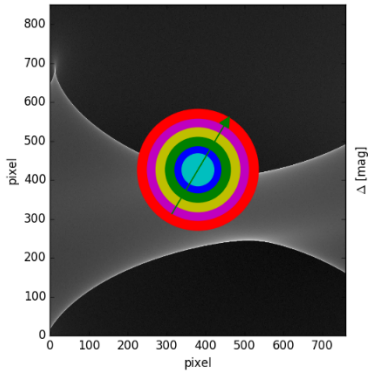
HE0230-2130

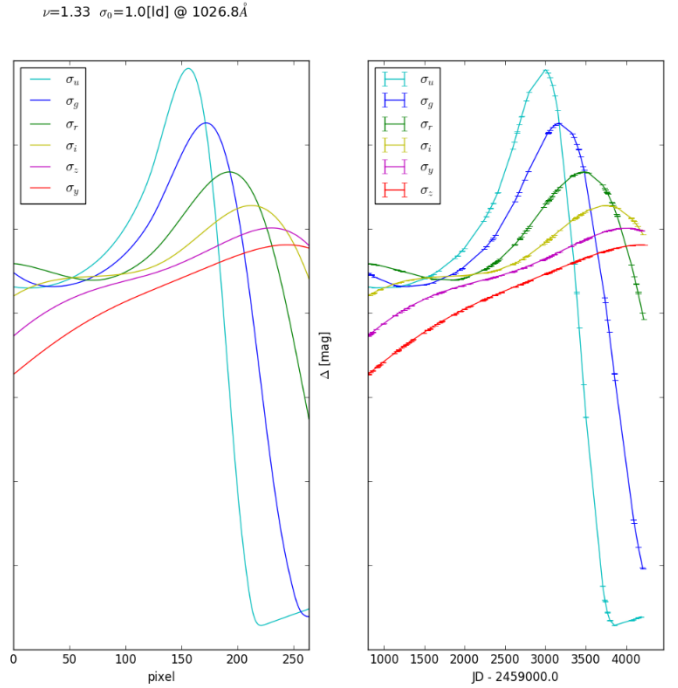


- z_s = 2.16
- κ = 0.472
- γ = 0.416
- s = 0.99

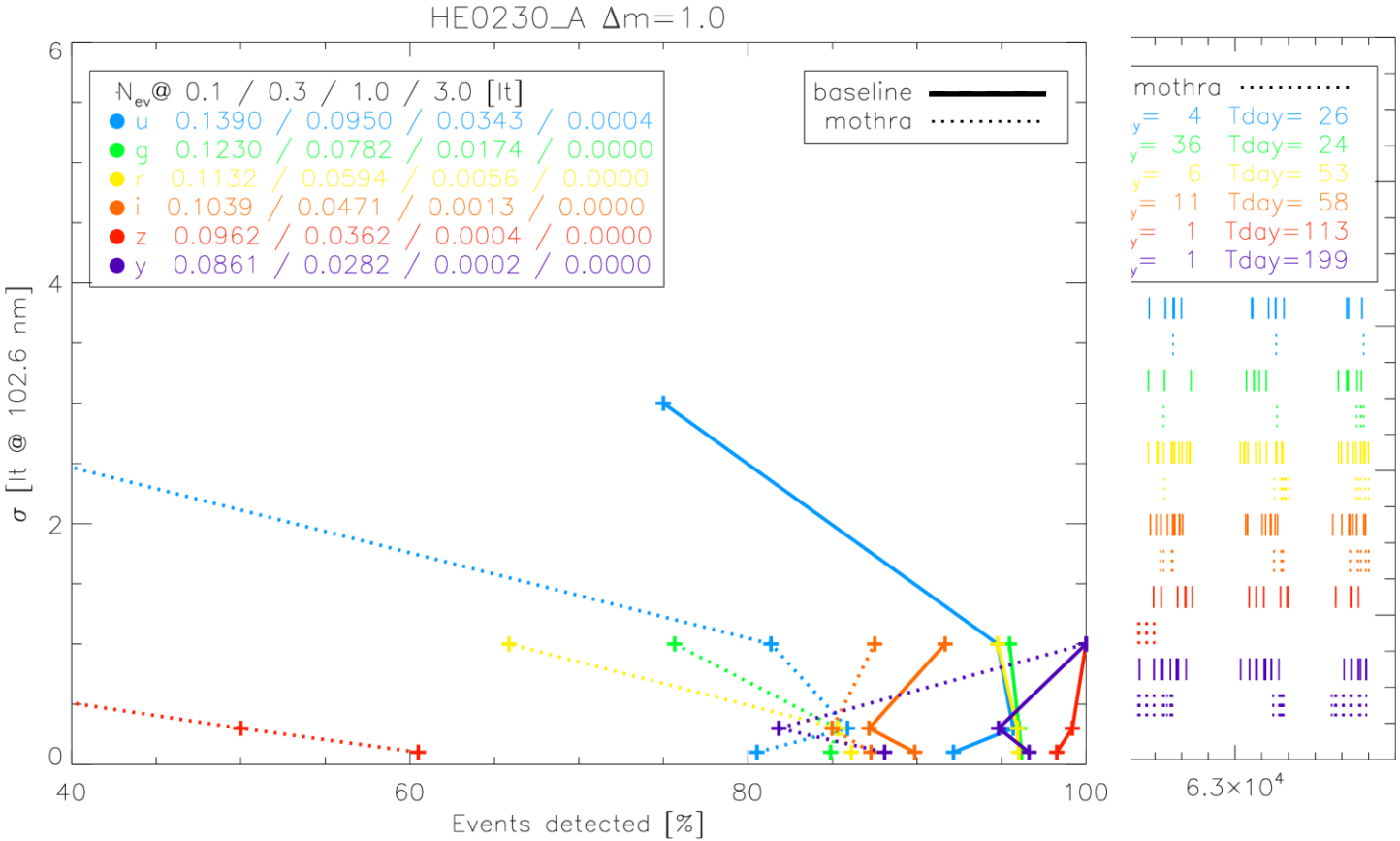
$v_t \approx D_S/D_L = 1.3$

$N_{micro} \propto 0.005$





HE 0230-2130


HE0230_A Δm=1.0
N_ev@ 0.1 / 0.3 / 1.0 / 3.0 [lt]
u 0.1390 / 0.0950 / 0.0343 / 0.0004
g 0.1230 / 0.0782 / 0.0174 / 0.0000
r 0.1132 / 0.0594 / 0.0056 / 0.0000
i 0.1039 / 0.0471 / 0.0013 / 0.0000
z 0.0962 / 0.0362 / 0.0004 / 0.0000
y 0.0861 / 0.0282 / 0.0002 / 0.0000
baseline
mothra
σ [lt @ 102.6 nm]
Events detected [%]
mothra
Tday= 26
Tday= 24
Tday= 53
Tday= 58
Tday=113
Tday=199
6.3×10^4