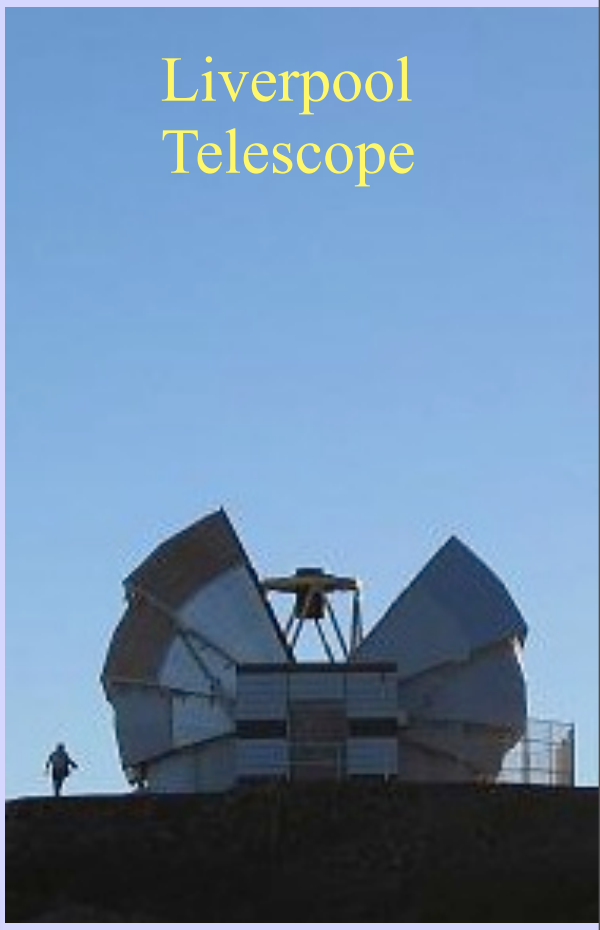


Bright nuclear transients
- what are they ?

June 2012 Andy Lawrence ESAC TDE conference

with Suvi Gezari, Martin Elvis, Martin Ward, Tim Heckman and

the Harvard and Belfast transient pipeline teams
(especially Stephen Smartt, Ken Smith, Darryl Wright)
the PS1 project team
the PS1 transients WG

PanSTARRS-1 3π survey

- 1.8m / 7 sq.deg / *g r i z y*
- 30,000 sq.deg, 2 month cadence, g=22-ish

- Pipeline in Maui
- Transient pipelines in Harvard and Belfast

- 3 year survey started Jan 2011
- ~3500 "good" transients so far
- ~150 confirmed SNe

- ~tens of good nuclear candidates ? TDEs ?

Programme

- bright transients triggered by 3Pi *vs* SDSS difference
- choose those
  - coinciding with SDSS object=galaxy
  - with distance <0.5"

- follow up on Liverpool Telescope at *u g r*
  - weekly at first then monthly
  - simple 2arcsec photometry for now

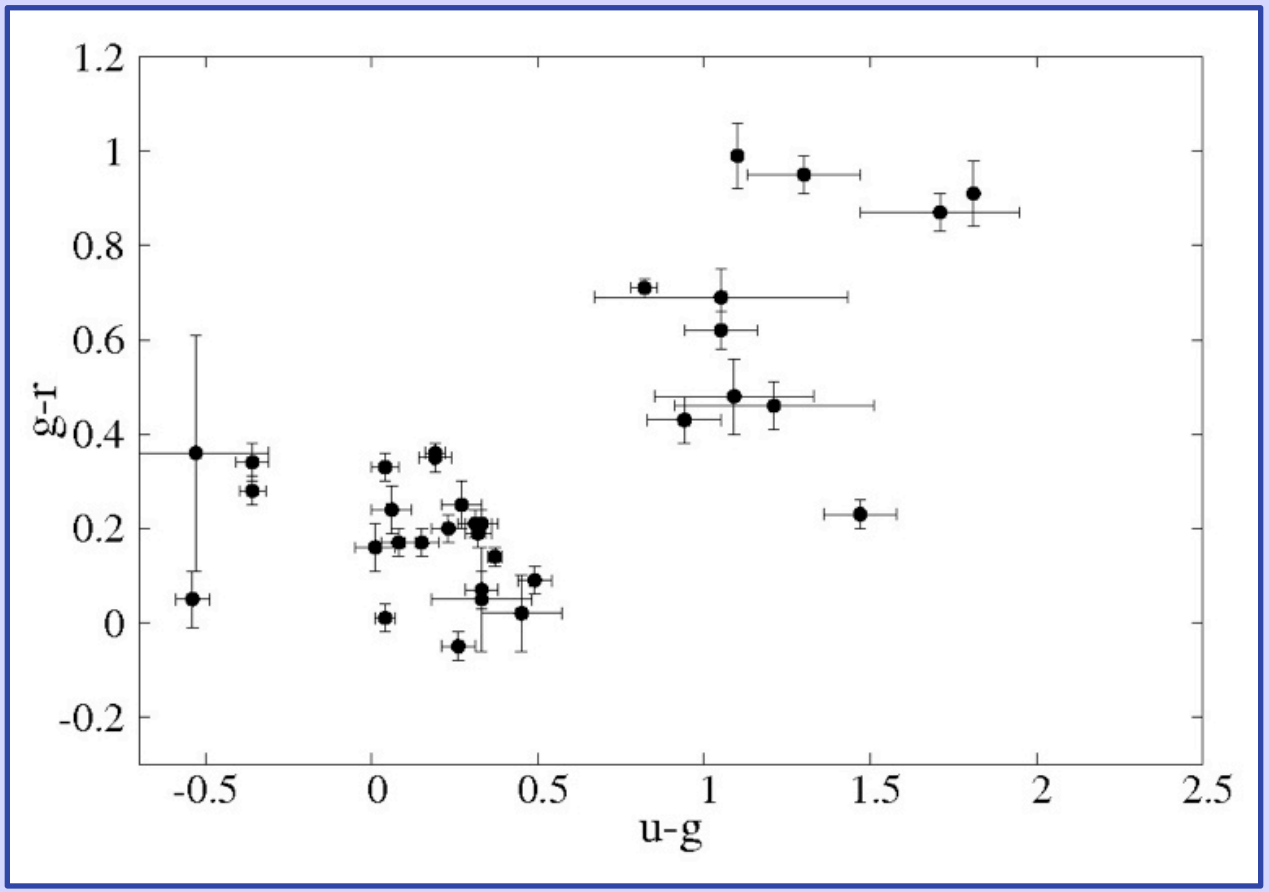
- 49 targets followed since October 2011

- typically

g(gal) = 21-22 z_{phot} ~0.2-0.3ish
g(transient) = 19-20

colours

three colour groups



colours

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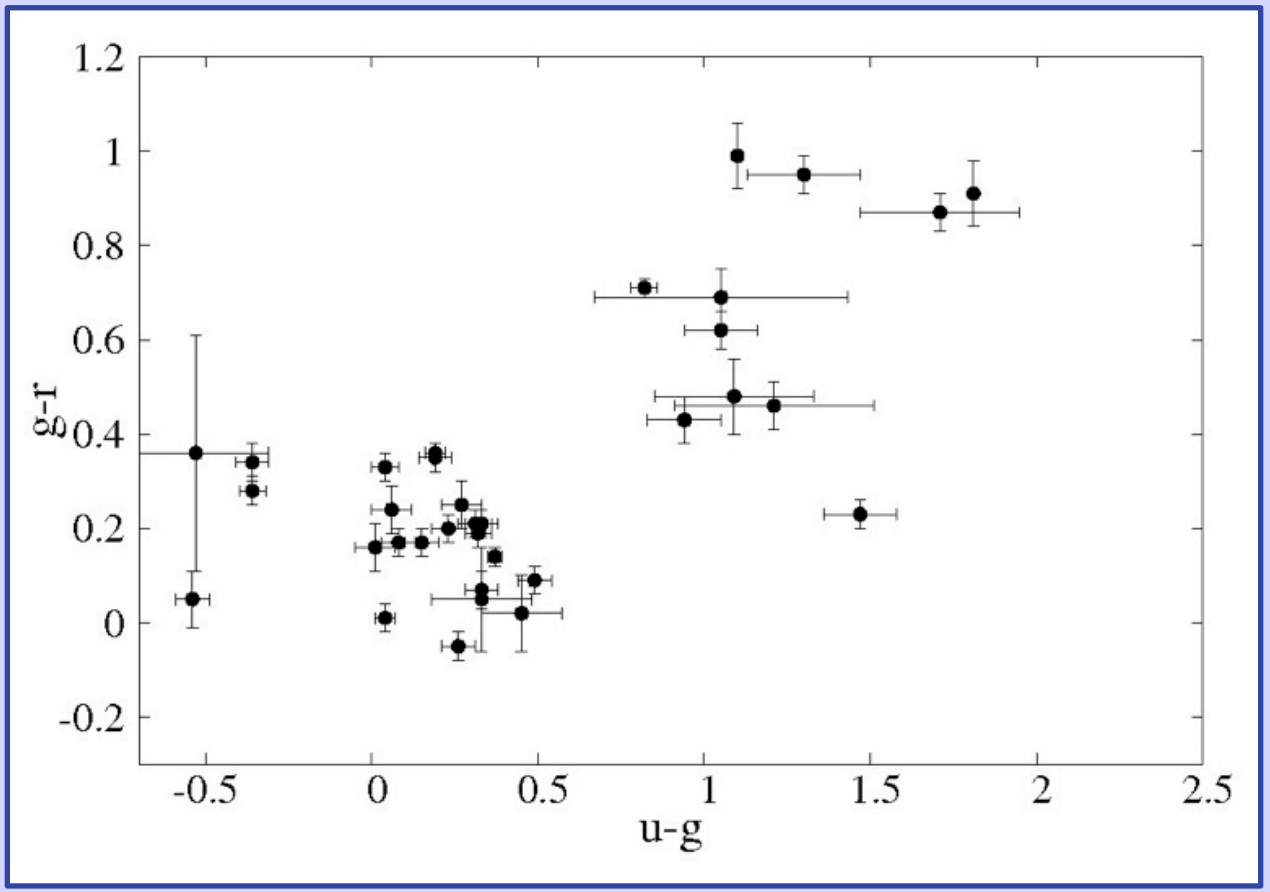
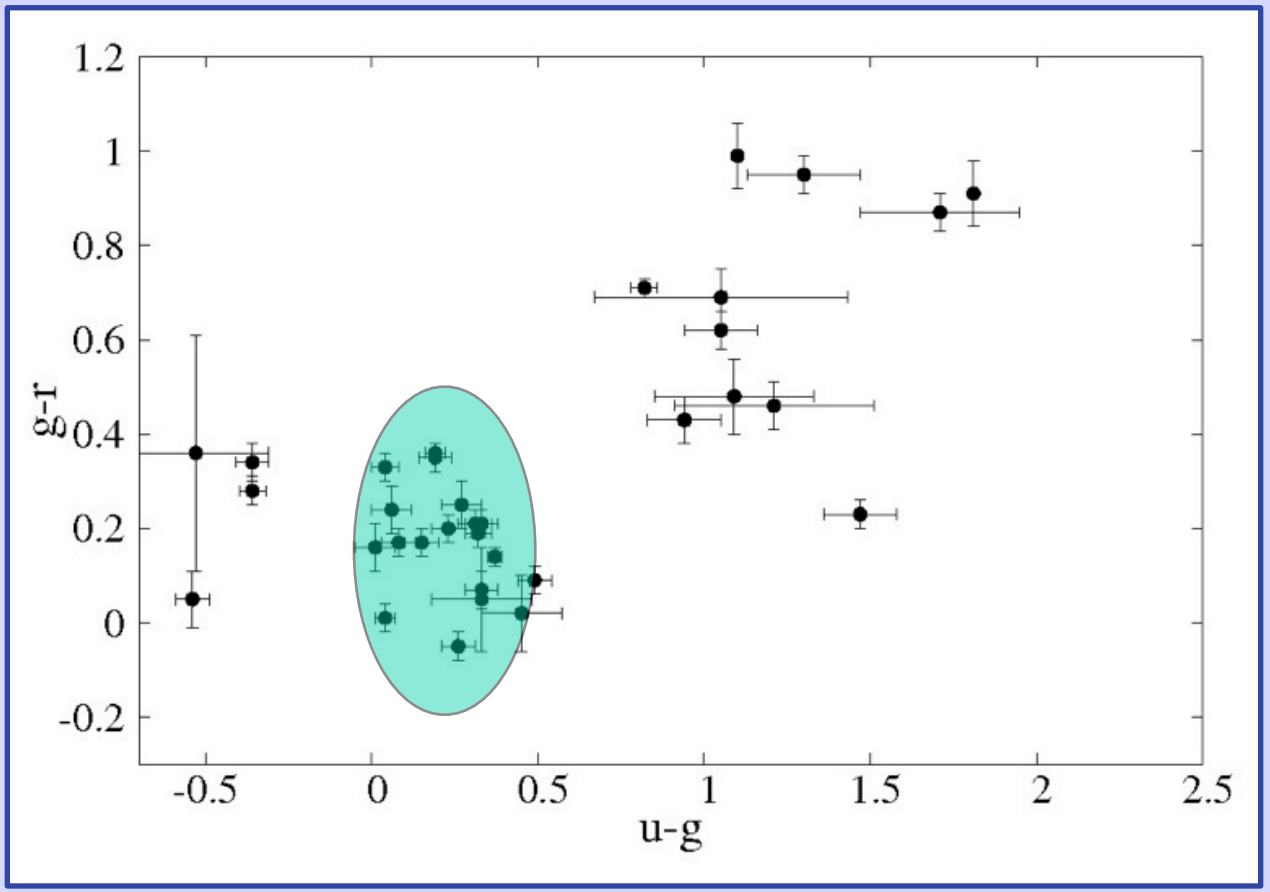


blue objects
typical of
quasar colours

colours

three colour groups



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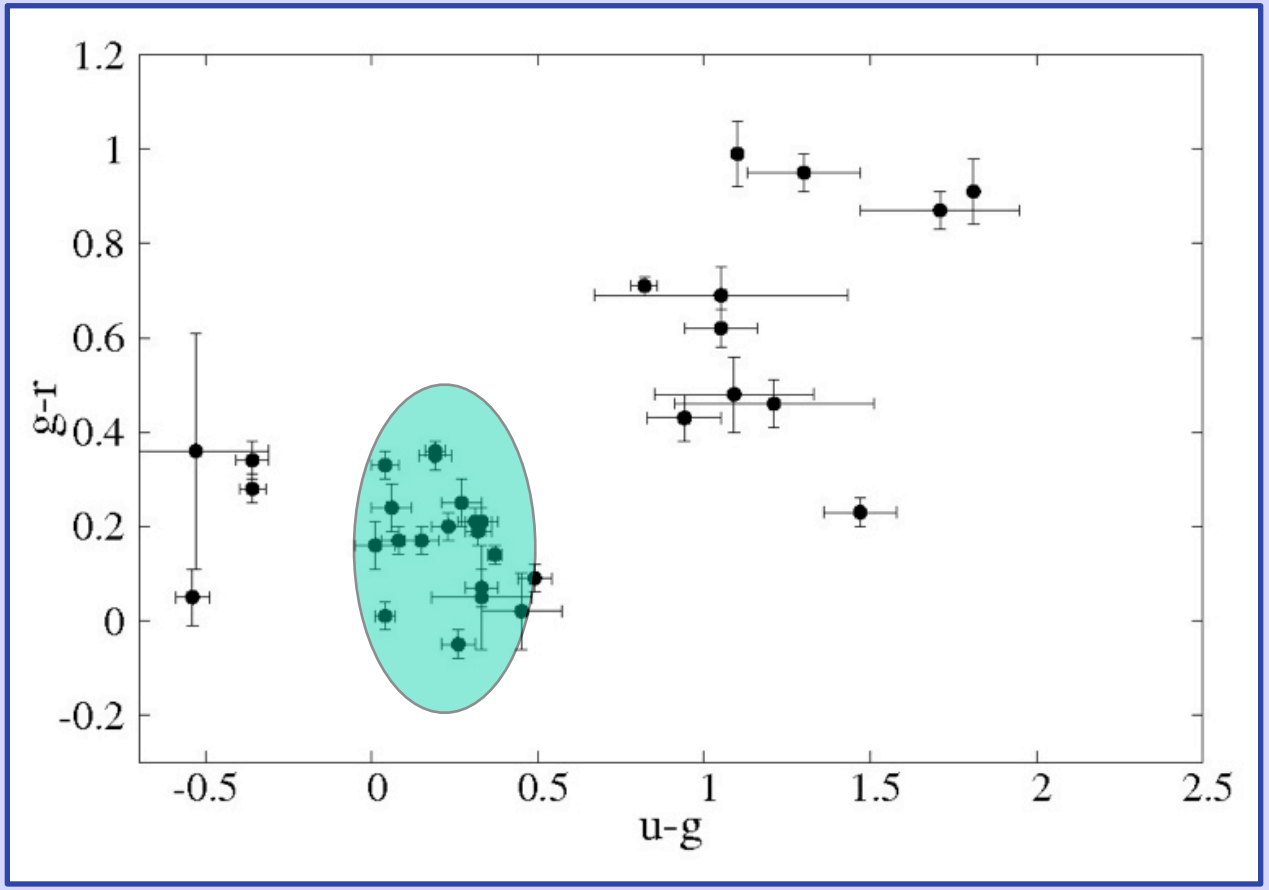
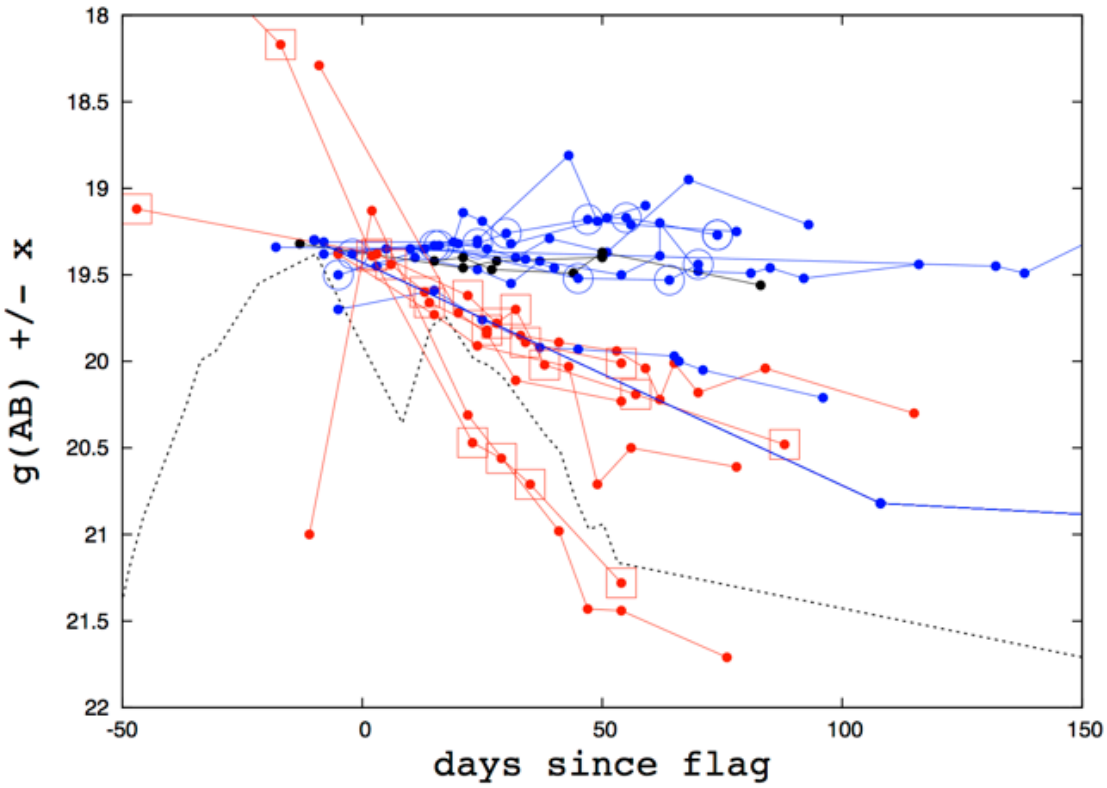


some ultra-blue objects much bluer than normal quasars

blue objects typical of quasar colours

combined light curves



red = fast
($t_{1/2}$ ~ month)

most blue = slow
($t_{1/2}$ ~ 1-3 years)
some seen rising

Much slower than predicted for TDEs

PS1-10jh stands out as different

open symbols
= spectral type

circle=AGN
square=SN

spectral summary

Spectra collected and analysed by the Belfast team

OBJECT	light curve	type	redshift	galaxy mag
090119	red/fast	SN IIN	z=0.11	g=21.50
094612	red/fast	SN Ic	z=0.175	g=22.12
120921	red/fast	SN 1a	z=0.058	g=22.24
122417	red/fast	SN II ?	??	g=19.67
031240	blue/slow	AGN	z=0.886	g=21.49
081916	blue/slow	AGN	z=0.43	g=21.49
092635	blue/rising	noisy	??	g=21.43
104556	blue/rising	AGN	z=0.995	g=21.40
141056	blue/rising	AGN	z=1.68	g=20.62
160928	rise and fall	TDE	z=0.17	g=21.95
OR		AGN	z=0.996	

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Proposal : most of the blue transients are background AGN amplified by **stellar microlensing** in the foreground galaxy

cf known microlensing

Lensed Quasars :

- differential flickering in multiple components (Irwin et al 1989)
- massive galaxy ==> strong macrolensing
  significant lensing optical depth
  continual low level amplification

PS1 transients :

- smaller galaxy ==> little macrolensing
  small optical depth
  rare high amplification single star events

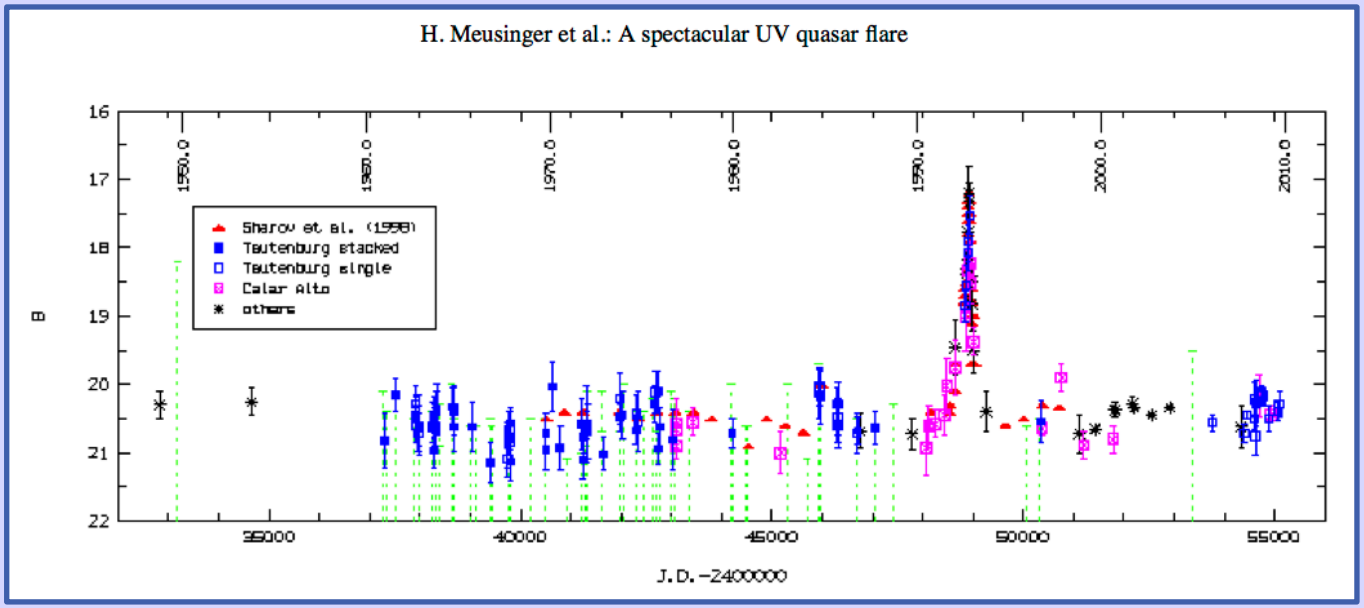
- AGN not seen before event
- Seyfert-like rather than quasar ($L \sim 10^{43\text{-}44}$ erg/s)

The Sharov 21 flare

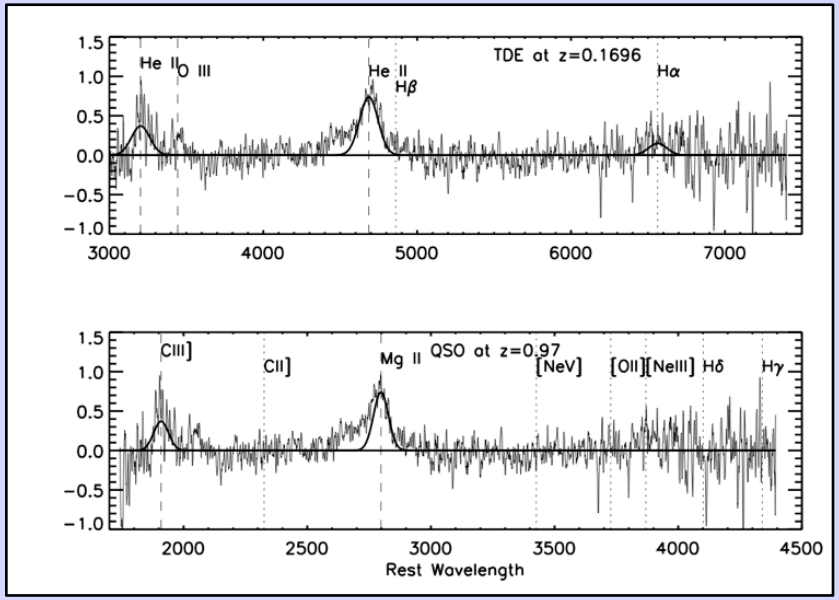
Meusinger et al 2010 show that a flaring object in M31 is actually at z=2 background quasar

They discuss two possibilities

microlensing by a star in M31
tidal disruption of a star in the quasar



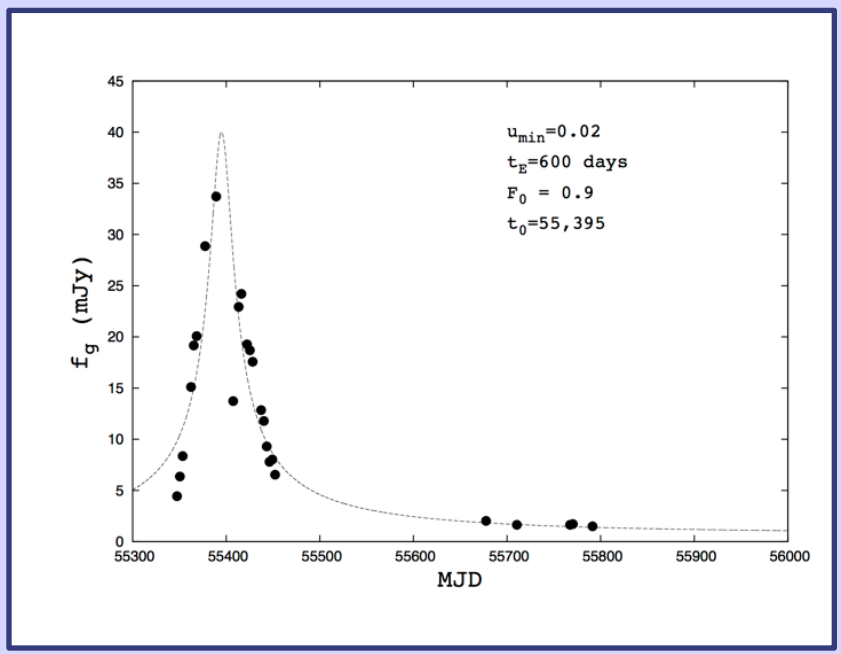
PS1-10jh ?



z=0.17 HeII explanation

z=0.97 MgII+CIII explanation

... but $z_{host} = z_{HeII}$

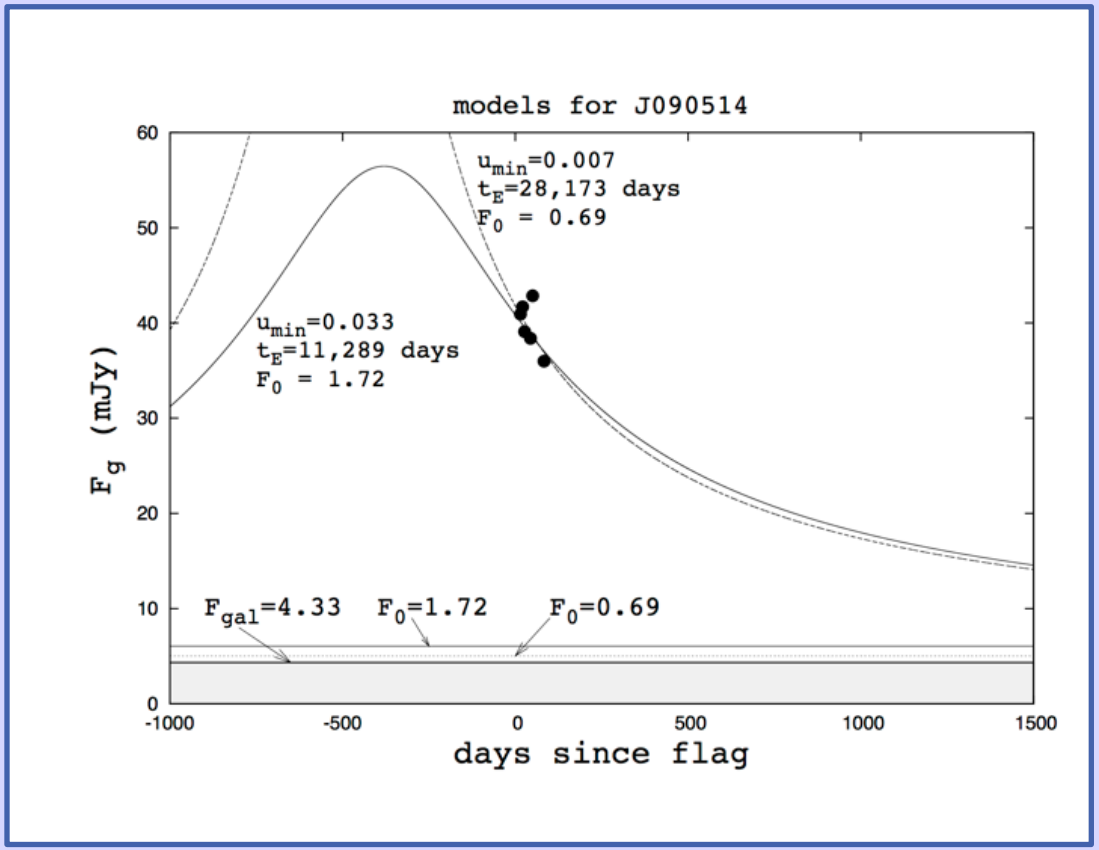


optical light curve can be modelled by microlensing ...

... but BLR should not be amplified (see later)

TDE still preferred model for this unnusual object

fits to more typical transient



Model with F_0 1 mag below galaxy :
u_{min} = 0.033, A = 30
t_E = 11,289 days = 31 years

Fit parameters
base level F_0
impact param. $u_{min} = \theta_{min}/\theta_E$
crossing time t_E

note $t_{1/2} \approx 2\ u_{min}\ t_E$
and amp $\approx 1/u_{min}$

$t_{1/2}$ reasonably measured
but F_0 poorly known

==> range of possible
t_E/u_{min} values

but small u_{min} events
less likely

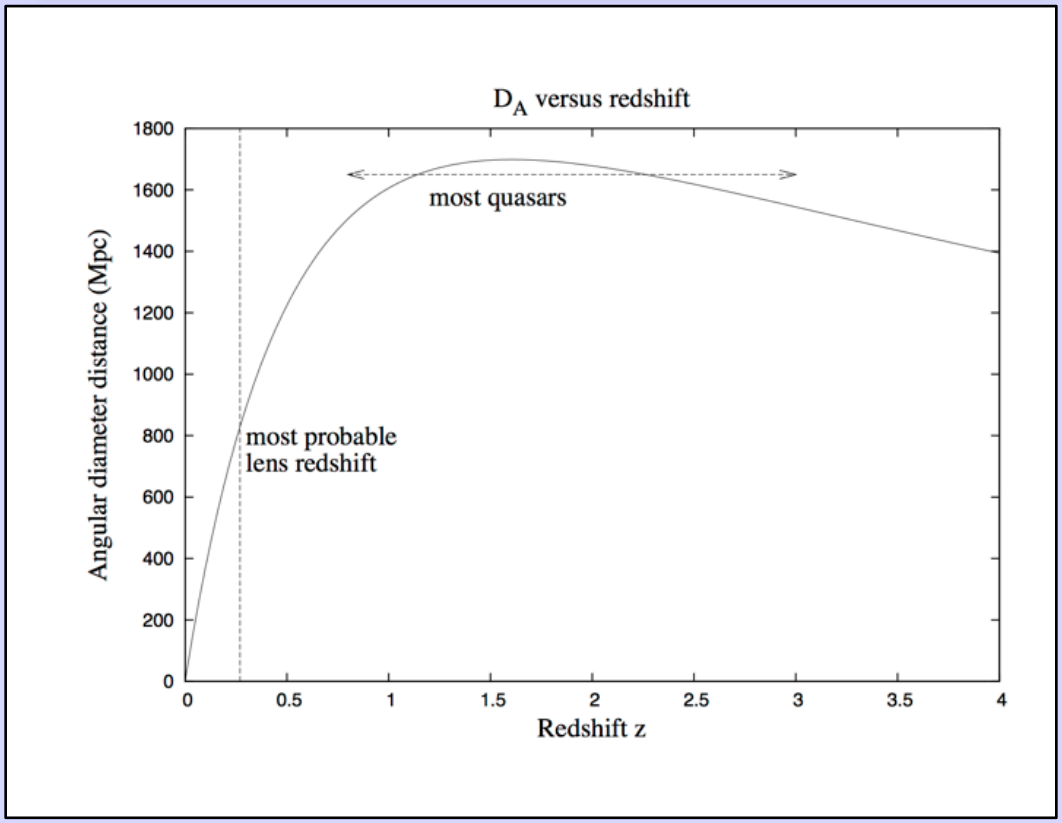
does this make sense ?

we observe :

- AGN at z~1
- hosts at z~0.3
- amplification ~30
- rise/decay timescales 1-3 years ==> t_E~30-100 years
- ~100 in outburst at any one time

how does this compare to what we might expect ?

distances and angles



most AGN at z=1-3
all at the same D_A ...

maximum lensing area
per dz shell at z~0.27

....consistent with
observed hosts

but more distant AGN
are fainter - so most of
what we see will be z~1

Use typical z_s=1 z_l=0.25 z_{ls}=0.6 which for a solar mass lens gives

$$\theta_E = 2.91 \mu\mathrm{as}\,(M/M_\odot)^{1/2}$$

event timescale

at lens plane θ_E corresponds to

$$r_E = 3.48 \times 10^{14}\mathrm{m}\,(M/M_\odot)^{1/2} = 2326\mathrm{AU} = 0.011\mathrm{pc}$$

Relative motion mostly due to relative galaxy motions - use 300 km/s

$$t_E = r_E/v = 36.8\ \mathrm{years}\,(M/M_\odot)^{1/2}\,(v/300)^{-1}$$

Observed timescale depends on amplification / impact parameter :

$$t_{1/2} = 893\ \mathrm{days}\,(M/M_\odot)^{1/2}\,(v/300)^{-1}\,(u_{min}/0.033)$$

event rate

for Milky Way like gal at z_l=0.25 :

covering factor at θ_E is f~0.1
covering factor at u=0.033 is f~10^{-4}
so repeat timescale is

$$t_{rpt} \sim 6000 \text{ years } (M/M_\odot)^{1/2} \, (v/300)^{-1} \, (u_{min}/0.033)^{-1}$$

Outburst duty cycle ~ 6 x 10^{-4}
Surface density of distant AGN ~ 1 arcmin^{-2}
==> 0.03% of foreground galaxies have a background AGN
and 0.06% are in outburst at any one time

Number of g=22ish galaxies ~ 10^8
==> expect 20 to be currently in outburst ...

resolution effects

Scale to $M_{BH}=10^8$; accretion disc ~10 R_S ; BLR ~1000 R_S

At z=1 D_A=1650 Mpc

$\theta_{disc} = 12 R_{10} M_8$ nas c.f. $\theta_{\rm lens} = 291\,(u_{\rm min}/0.1)$ nas

	A=10 lens 291 nas	**A=100 lens 29nas**
disc 12nas	pt srce	significant resoln effects
BLR 1200 nas	amplified less	amplified very little

what we can learn from microlensing events

accretion disc structure	$A(\lambda)$
BLR size and geometry	rise vs decay
cosmological geometry	distbn of lens redshifts

separating microlensing and TDEs ?

ultra blues ?
blue but fast ?

Could also be high amplification lensing events

Optical spectra

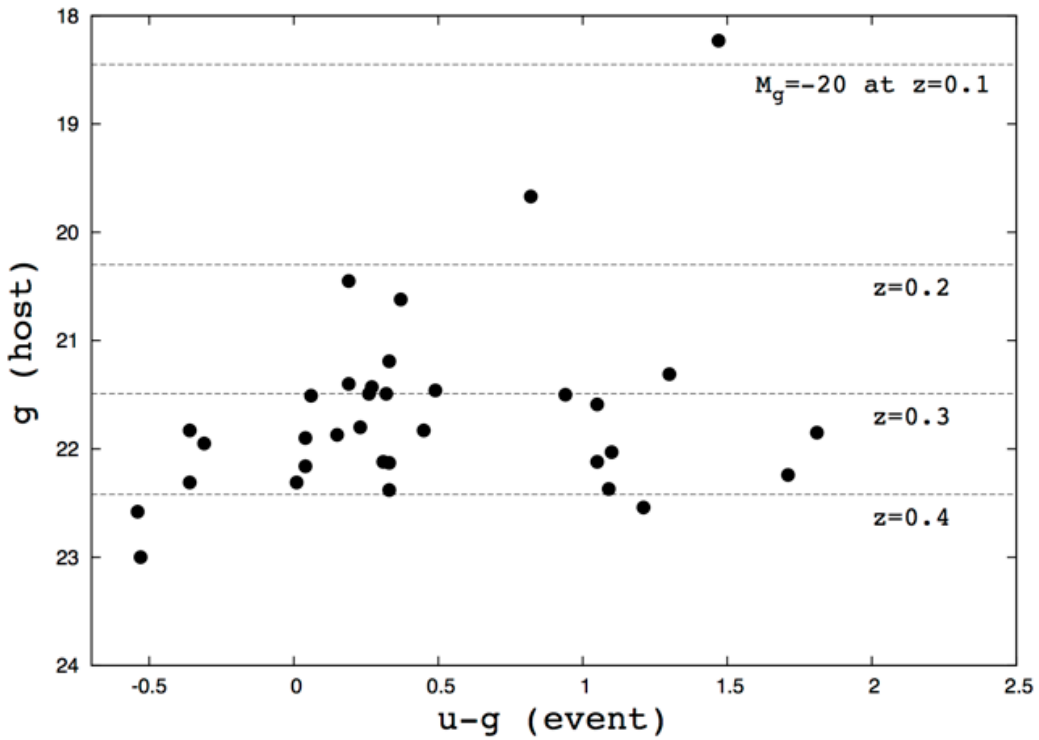
need $z_{em} = z_{absn}$

what **is** the signature of a TDE ?
- $T=10^5$ K ?
- broad lines ?
- coronal lines ?
- no lines ?
- jet ?

FIN

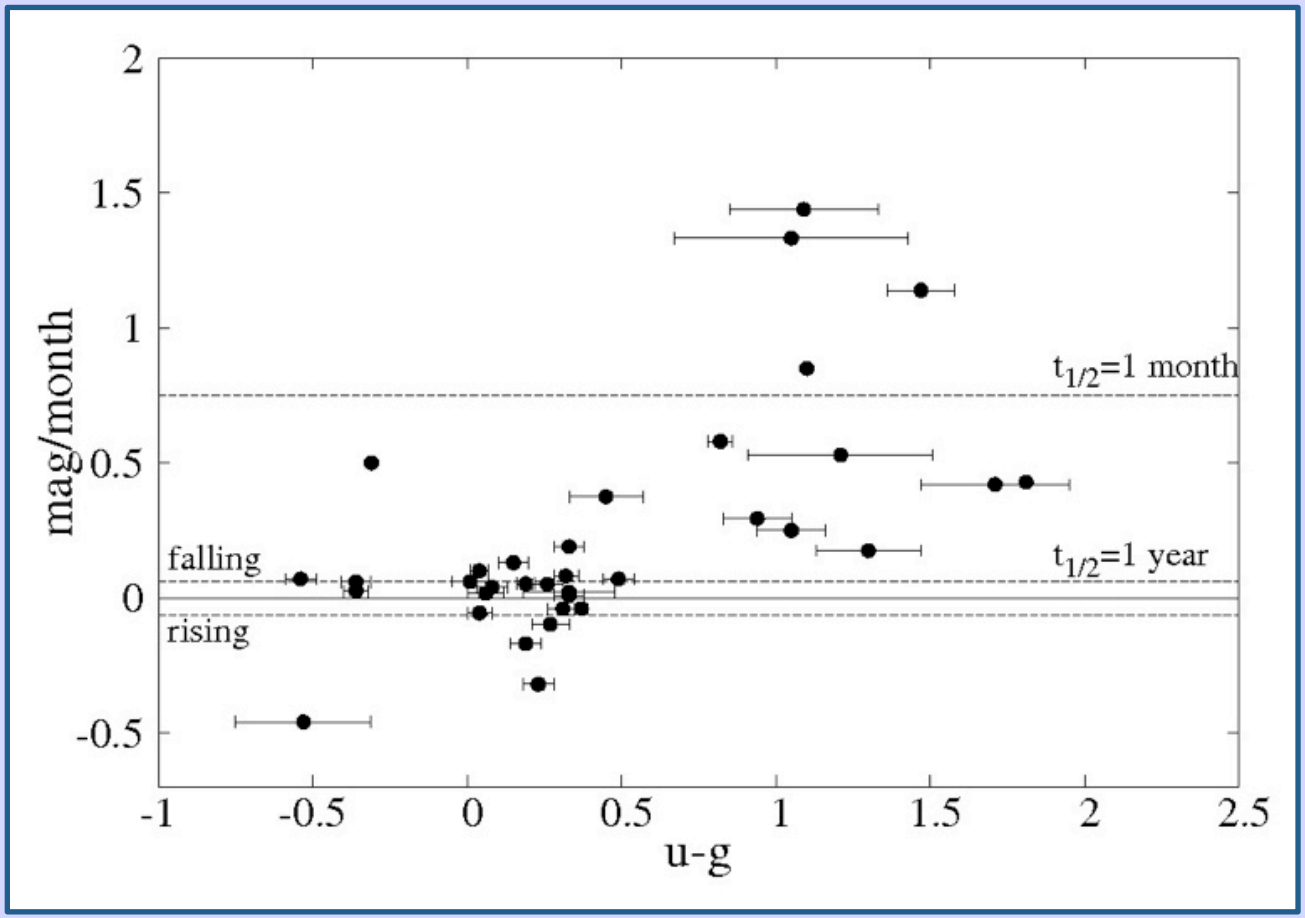
spares

host mags



hosts consistent with normal gals z~0.3ish

colour vs decay rate

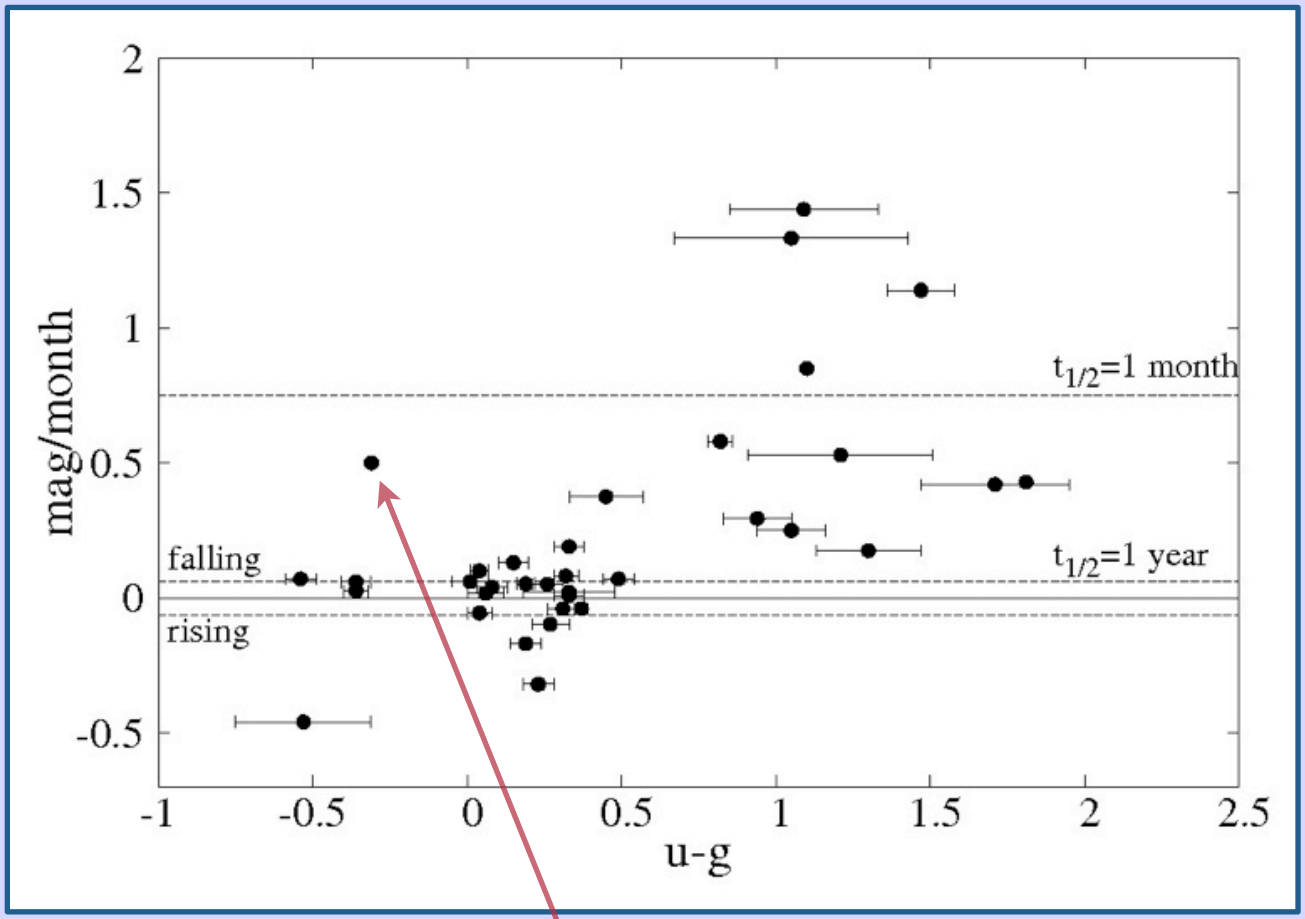


in general

red=fast (month)

blue=slow (year)

colour vs decay rate



PS1-10jh

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red=fast (month)

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PanSTARRS-1

- 1.8m telescope on Hawaii with FOV 7 sq.deg
- Imaging in *g r i z y*
- Medium Deep Survey : 12 fields, 3 night cadence, g=25-ish
- 3Pi Survey : 30,000 sq.deg, 2 month cadence, g=22-ish
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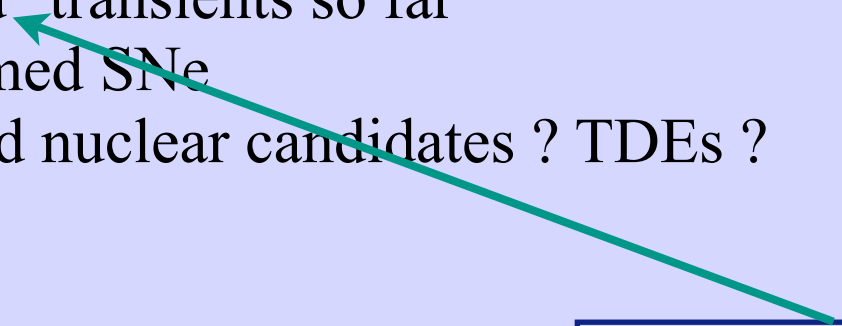
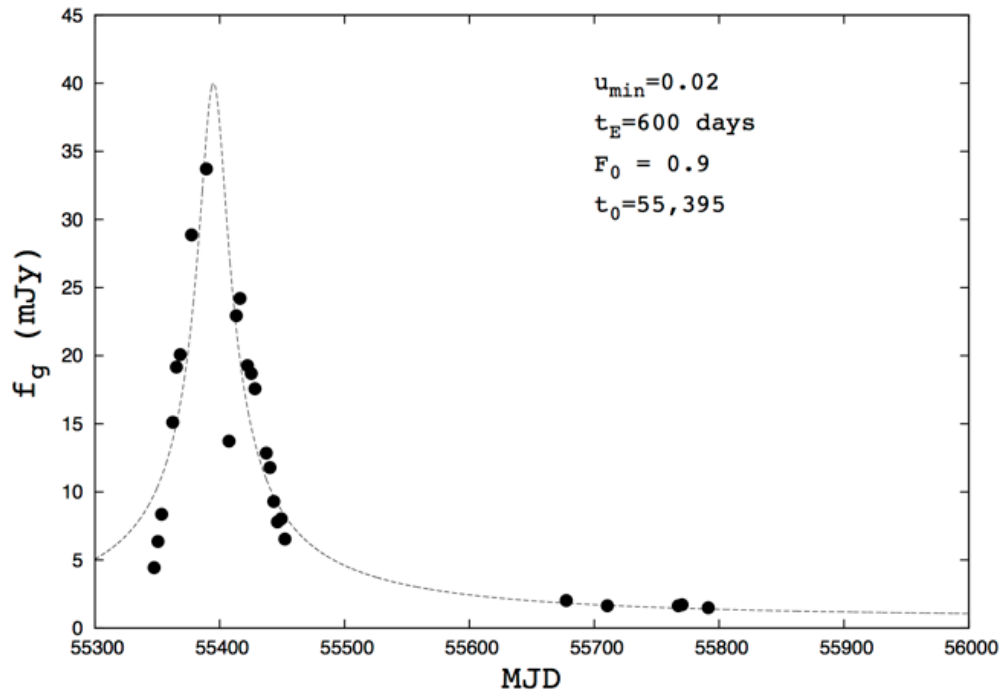


QC reduces by factor 10^3

light curve fit to PS1-10jh



simple microlens model

but NUV non-detection at earlier epochs suggest amplification ~350

much rarer and should strong colour effects and negligible BLR amplification (see later)

Microlens probably ruled out in this case
- but what about the more common slow blue transients ?