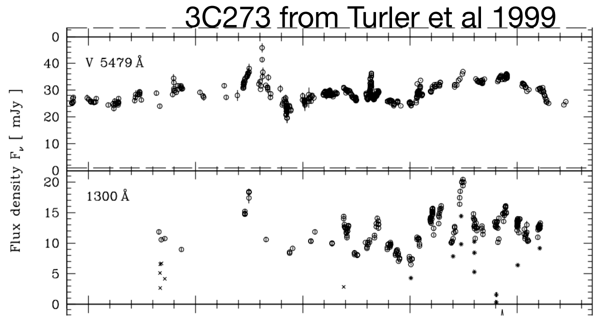
Extreme variability in AGN

Nottingham April 9th 2018

Intro

AGN all variable
Defining characteristic from earliest times
30% flickering (more in UV, realised later)
light speed: space between stars
sound speed: size of solar system

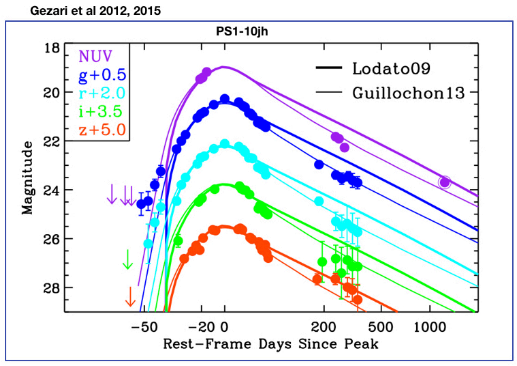
Serious physical problems - see later



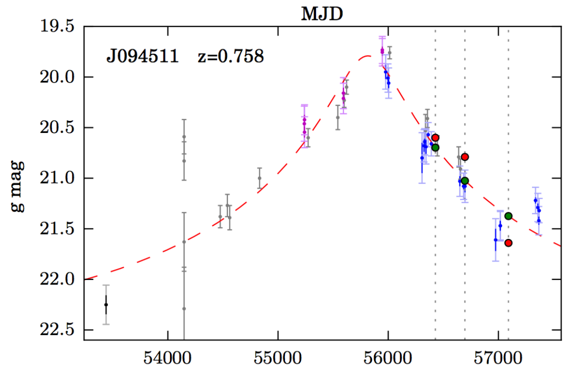
Extreme variability

* massive surveys (SDSS, PanSTARRS, CRTS)
* longer timescales: decades of coverage

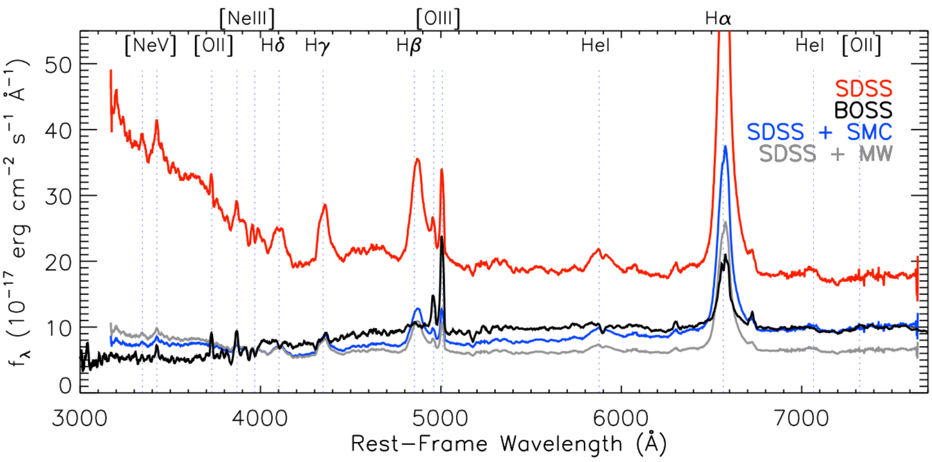
PS1-10jH: PanSTARRS
fast rise, months decay



094511 from Bruce et al 2016
SDSS vs PanSTARRS + CRTS
symmetric over decades



J1021+1645 from MacLeod et al 2016
SDSS vs BOSS collapse
"Changing Look Quasar"



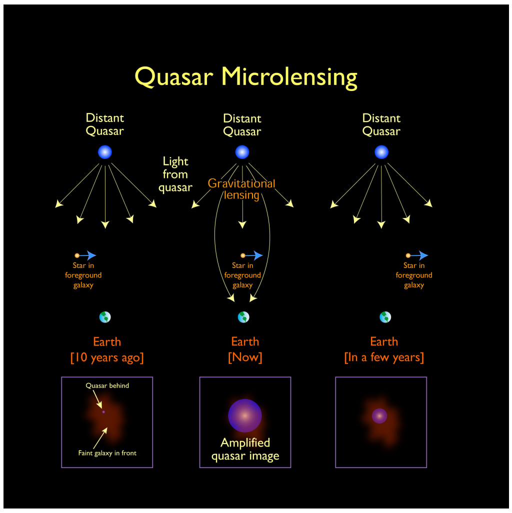
Three explanations

* accretion disc instability
* tidal disruption event
* microlensing event

Take in reverse order

Microlensing

Well known as causing differential flickering between components in strongly lensed quasars. (Claims that deduced source sizes 5xbigger than disc-theory).

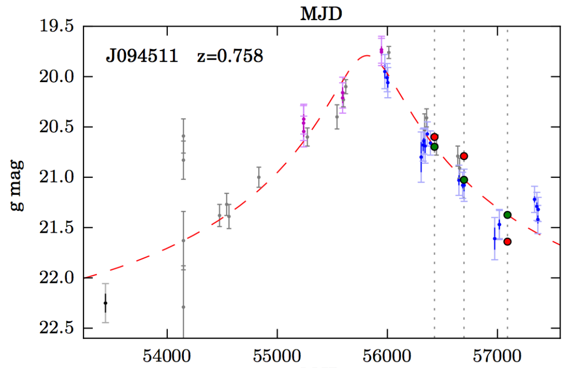


Should be occasional large amplitude flares.
L2016 found ~fifty 1.5mag flares in SDSS vs PanSTARRS
slowly changing
about right: 1/500 AGN has foreground galaxy
star passes at 0.1 theta_E every few thousand years
a few hundred on the sky at a time

Note usually will be a **dwarf galaxy** in LOS
low surface density
usually single star events
(whereas double quasars are behind big galaxies)

Typical fits:
AGN z~1 fg galaxy z~0.2 (not seen yet)
lens mass ~1 Msun

(If asked, show can make more complex light curves using CR distortions etc)

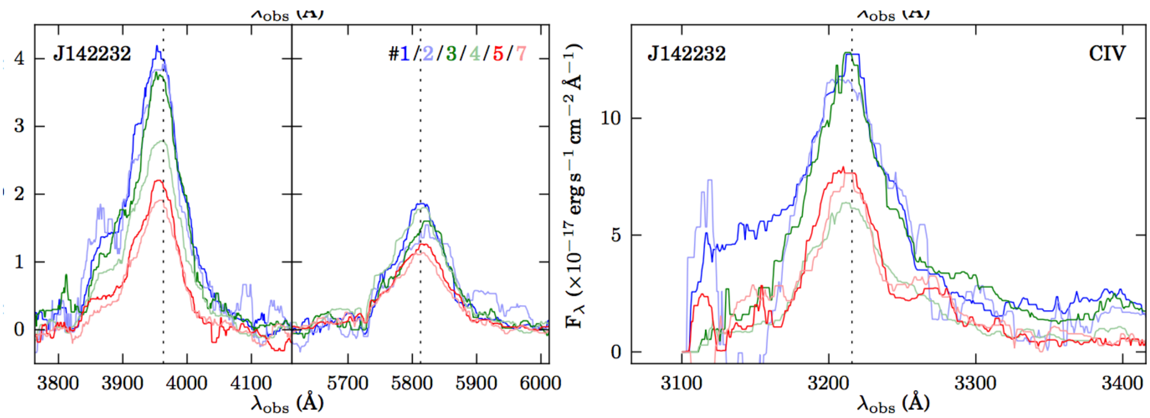


Resolution effects

theta_E ~ micro-arcsec

at lens plane: 200 AU:
cf close binary separations

at source plane: 10 lt-days
disc usually point sourc



BLR partially resolved; can measure size, potentially transverse structure. Already seeing BLR differential variability: above MgII unchanging; CIII and CIV do change; size ~lt-days

Behind M31

Sharov 21 was thought to be a nova in M31 (Sharov 1998)

Meusinger et al (2010) got spectrum and showed was quasar at z=2.109

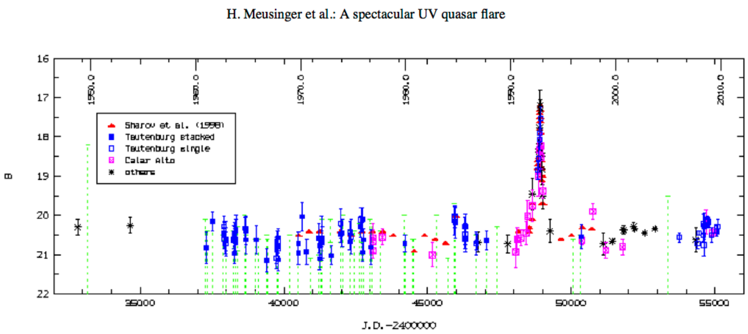
considered microlensing but dismissed as too rare.
Preferrred explanation as TDE but needs 10Msun!

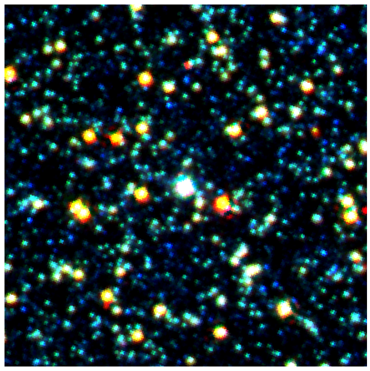
Clearly seen in PHAT survey
no recurrence

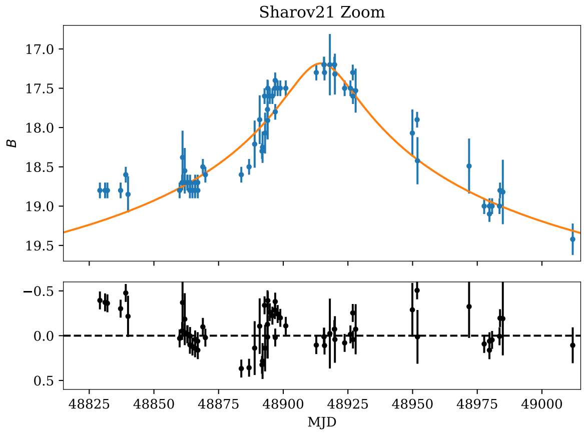
nice SED: normal

new fit: good
(Bruce et al 2018)

shoulder could be intrinsic vblty
or binary star
or neighbouring LOS star







Corner plot
zd is actually logz

distance of lensing object

0.67 (0.13 - 2.84) Mpc

cf M31 d=0.78 Mpc

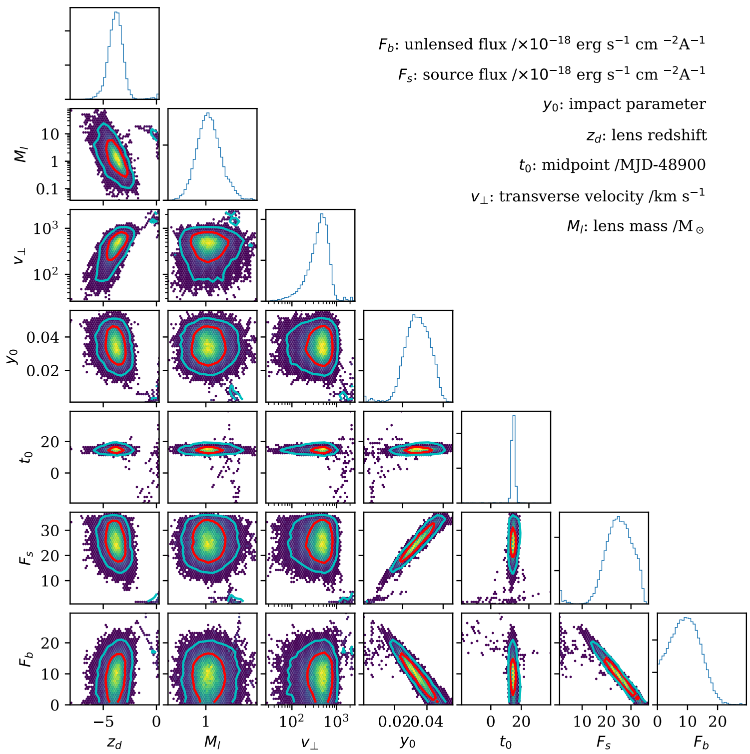
we recover the distance to M31!!
smoking gun.

More background flares?

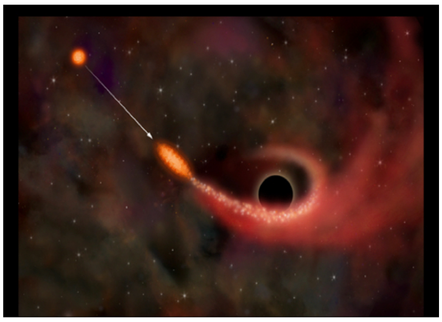
We have a few more which we are checking out..

Too many?

Can repeat the MACHO test but *through the halo of M31*

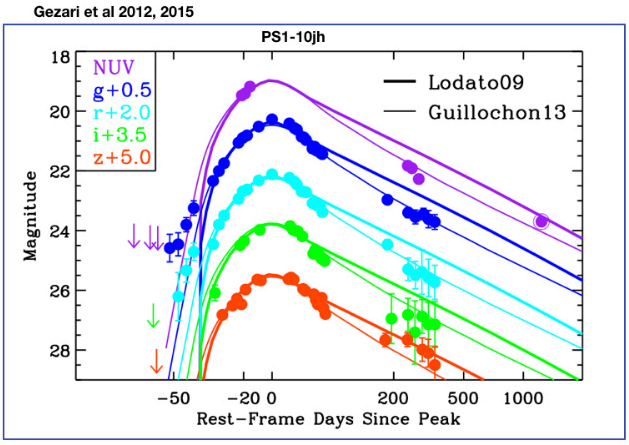


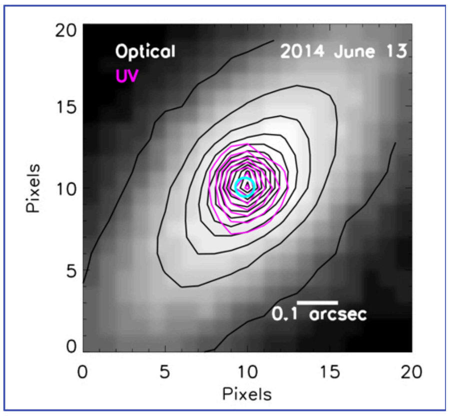
Tidal Disruption Events



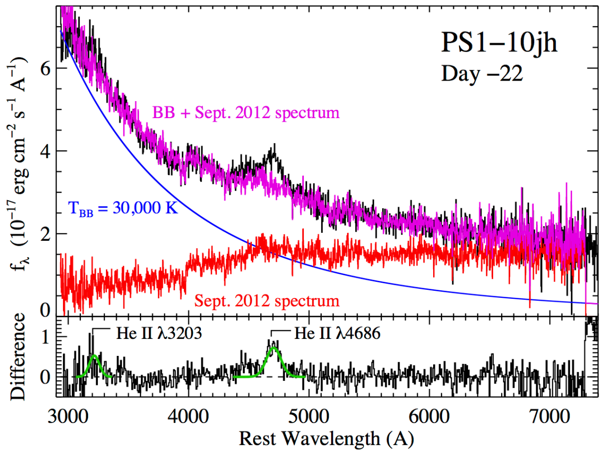
Hypothesised since the 1980s
Now very fashionable; tens of objects claimed as TDE
People are starting to refer to “the tidal disruption event xxx”
as opposed to “the TDE candidate…”
Very dangerous. We really don’t know what most of these are.

Best candidate still PS1-10jh (Gezari 2012,2015)





* huge amplitude
* late time HST right on the nucleus
  (so prob not SN or microlens)
* spectrum dominated by HeII
  (so unnusual star, not existing disc?)



BUT

E=2.1e44 J
implies Macc = 0.01 Msun   if mu=0.1

These small energies/masses typical
for other TDE candidates

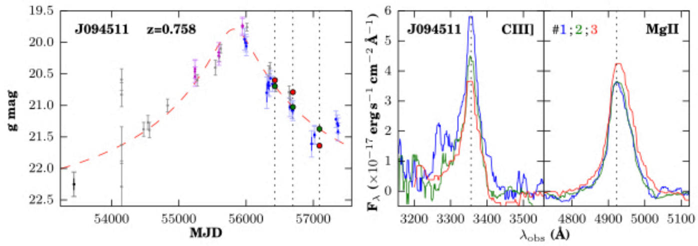
Partial disruptions? Low efficiency?
Scraps of ISM? Outbursts in existing cold discs?

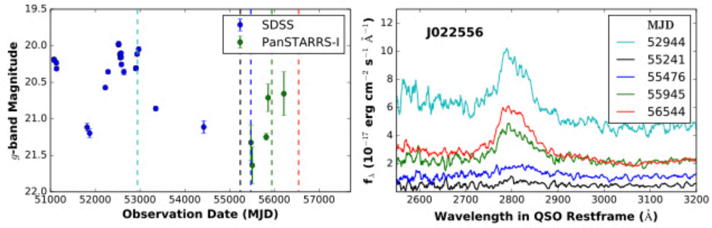
(run movie)

Simulations show very complex behaviour
TDE theorists assume accn matches fallback
But we don’t understand accretion!!
Light curves and spectra of TDE models should be
taken with a HUGE pinch of salt

So lets move on to accretion discs…

Extreme variability in regular AGN





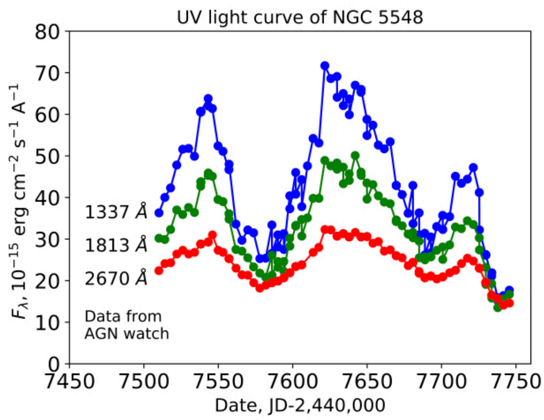
some extreme variability must be intrinsic
* pre-existing AGN
* nearby (microlens unlikely)
* erratic rather than one-off
* lines clearly respond

(these examples from Bruce et al 2017 and Homan et al in prepn)

(Line response a whole other seminar!)

Known problems in AGN variability

* simultaneous versus lambda
  (accn disc should have a propagation)
* timescale far too short



UV factor two peak-to-trough timescale
3c273: 2 years
NGC 5548 : 35 days
cf accn disc thousands of years

Saved by X-ray reprocessing
radiation has two components:

viscous heating	and	X-ray heating
slow		fast

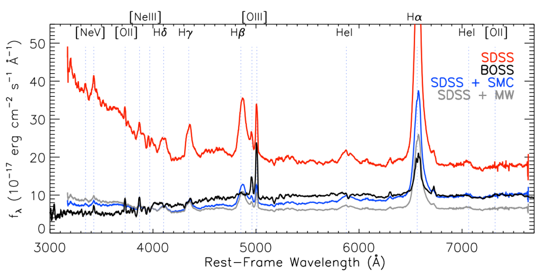
note optical change small even when UV is factor two

Why CLQs are important

specifically, collapse from normal state : Large change in *optical* not just in *X+UV*
Can't avoid conclusion that disc physically changes at large radii

Simple disc model from peak nuSnu

$$R/R_s = 4.6\ \lambda_{20}^{4/3} \left(\frac{L_E}{M_9}\right)^{1/3}$$



eg 3c273 LE=0.356 M9=0.887
100nm ==> X=29 500nm X=248

No viscous model works

what do we mean by viscosity?
classically, local transfer of momentum between layers by collisions
(particles from fast lane slip into slow lane and vice versa)
molecular viscosity too slow: need turbulence, mag fields, reconnection etc
MRI can seen as "viscous-like"

* local torques
* local heating
* local radiation

To get the luminosity need alpha ~ 0.1
(cf molecular 10^-15)

Viscous timescale

for standard disc $$t_{visc} = 12.6 \text{ yrs } \times L_E^{-3/10} M_8^{6/5} R_{30}^{5/4} \alpha_{0.1}^{-4/5} \mu_{0.1}^{3/10}$$

for 3c273 t(UV) ~ 200 yrs
t(opt) ~ 1600 yrs
cf t(obs)=2yrs

for N5548 t(UV) = 33yrs
t(opt) = 249 yrs
t(obs) = 35 days

would need alpha ~25 : feasible?

Viscous scale length

$$\alpha \sim \lambda / H$$

Rapid exchange of momentum
needs long scale length of "collisions"
Thick disc can have alpha ~1
But alpha ~25 is inconsistent with disc

("instabilities" just mean "not a viscous disk")

Route-1: non-local processes
currently assume transfer of AM, heating, radiation, all local and co-located
maybe long range torques: eg large scale magnetic fields
or dynamical infall: KE gain, thermalisation, radiation only loosely coupled

Route-2: extreme reprocessing
disc present but low viscosity and **cold**
all energy generated in very central region : heats disc
connected to obsvn that AGN are **too cool**

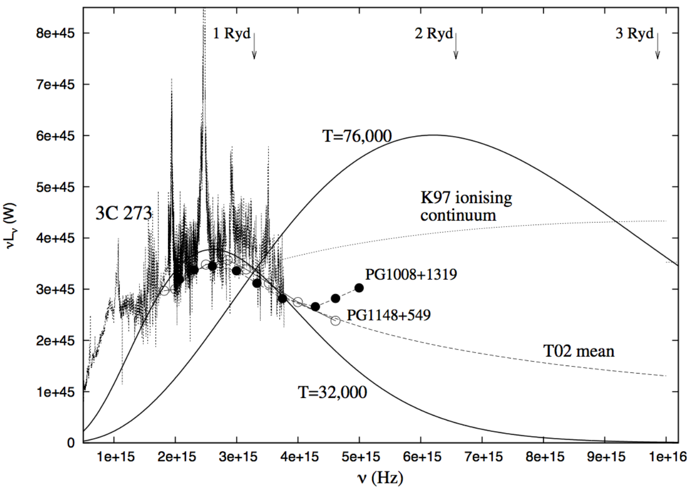
All AGN peak at ~100nm
T~30,000K cf

$$T_{ch} = 95,000 \, R_5^{-1/2} \left(\frac{L_E}{M_9} \right)^{1/4}$$

3c273: X=29
N5548: X=20

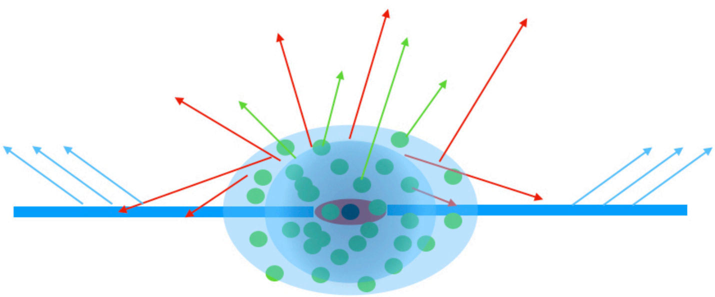
quasi-photosphere
L2016 argues is smeared line emission

dynamical timescale from
this radius is days for M8=1



Possible model

Dense clouds lifted from disc
Hard radiation scatters from clouds
partly re-processed into lines
Radiation we see has three parts



* central radiation scattered from clouds
* reprocessed radiation from clouds
* radiation from heated disc