Extracting AGN variable component properties with long-term optical photometry

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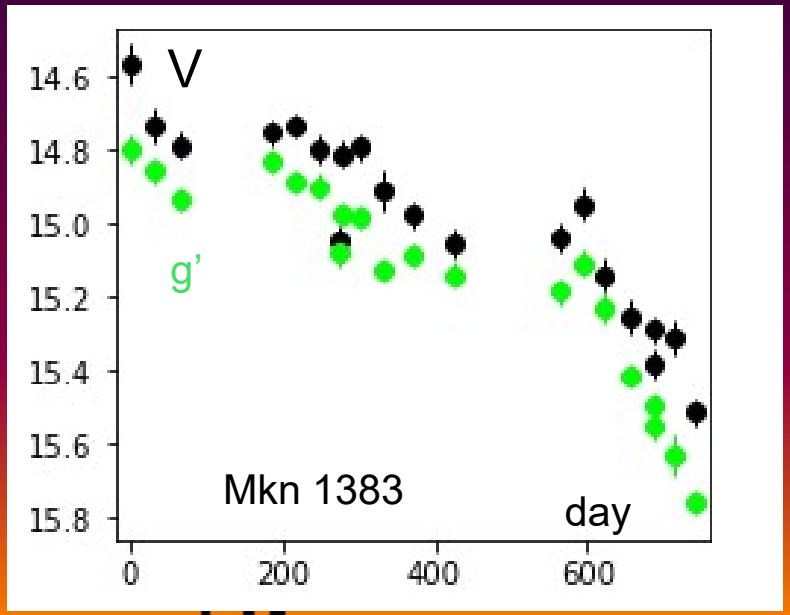
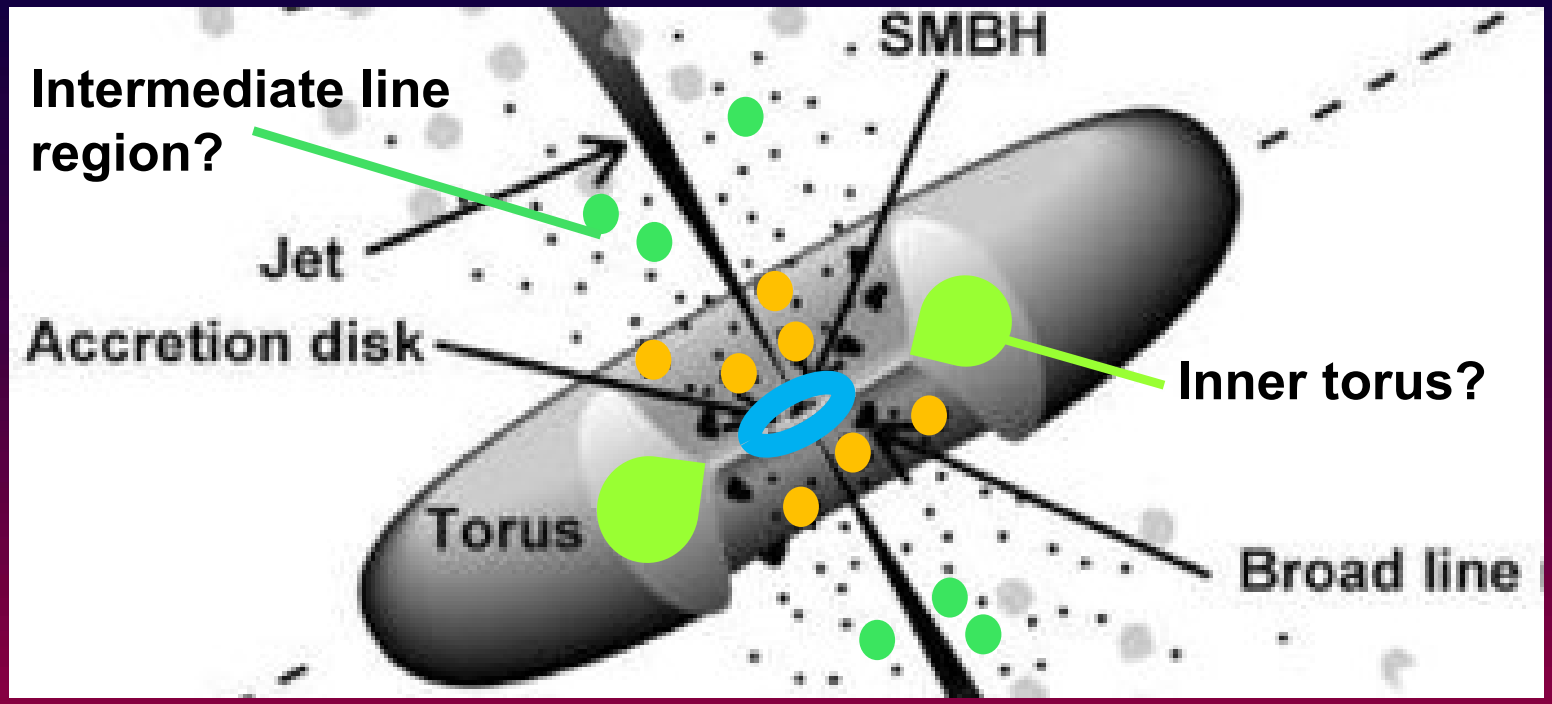
"The restless nature of AGN"
Napoli
27 June 2023



Conference theme: Variability as a probe of the central engine and its surroundings

Numerous components contribute to the (optical) nuclear luminosity – how do these all vary?



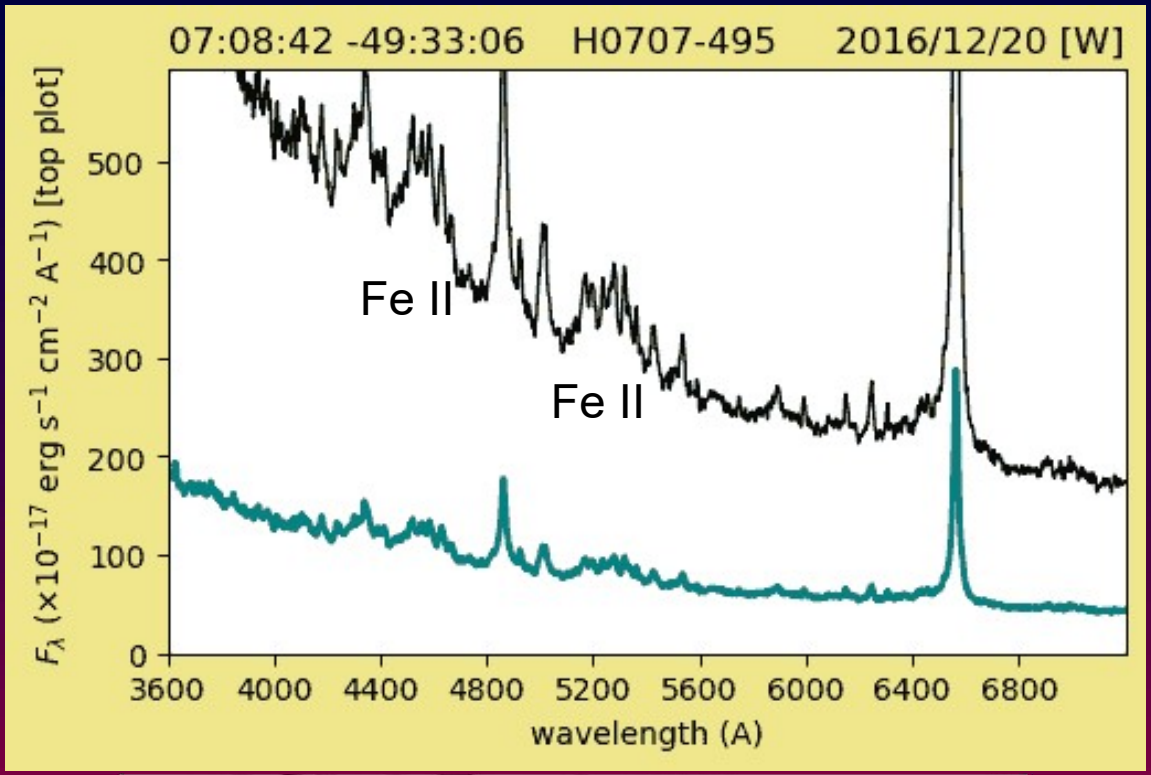
from fermi.gsfc.nasa.gov

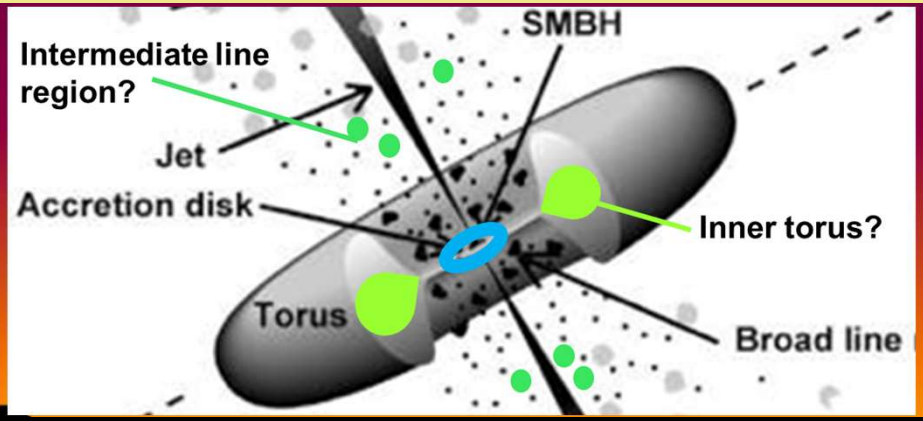
These potential nuclear components are not equally represented in all AGN. Some components are particularly strong in specific subclasses

Narrow line Seyfert 1 galaxies (with strong Fe II emission – prototype: I Zw 1)

While traditional broad and narrow-line spectra are present, such AGN display rich emission features of intermediate width, especially Fe II – not yet clear where this region is located

Extreme X-ray variability has often been reported – not nearly as dramatic in optical

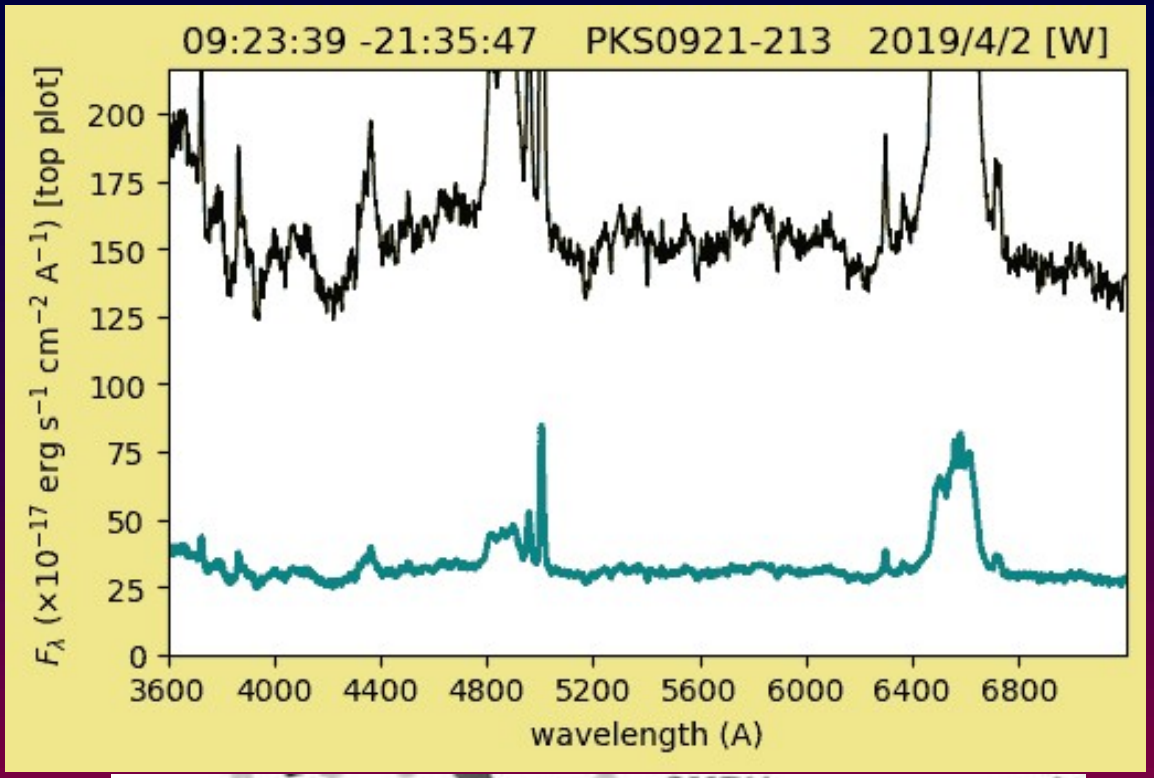


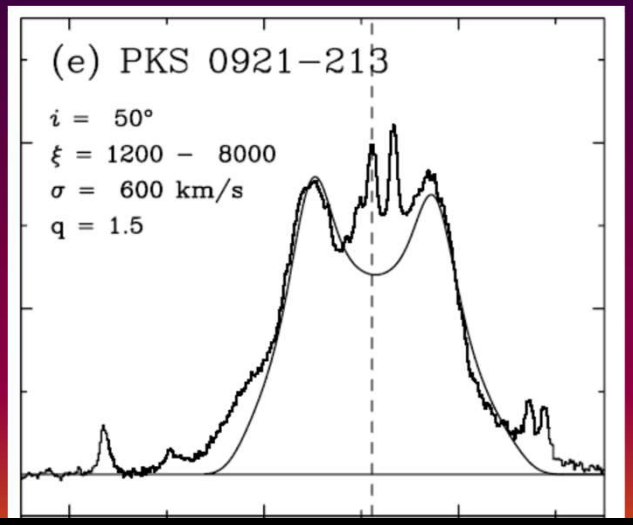


Keplerian rotators – double-peaked broad line profiles

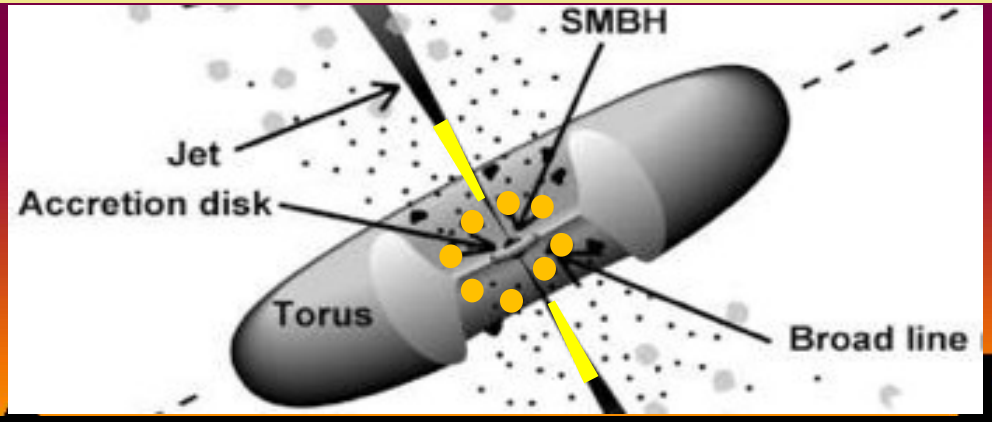
Shown to arise from Keplerian orbiting of broad line region

Similar profiles also generated by in- or outflow





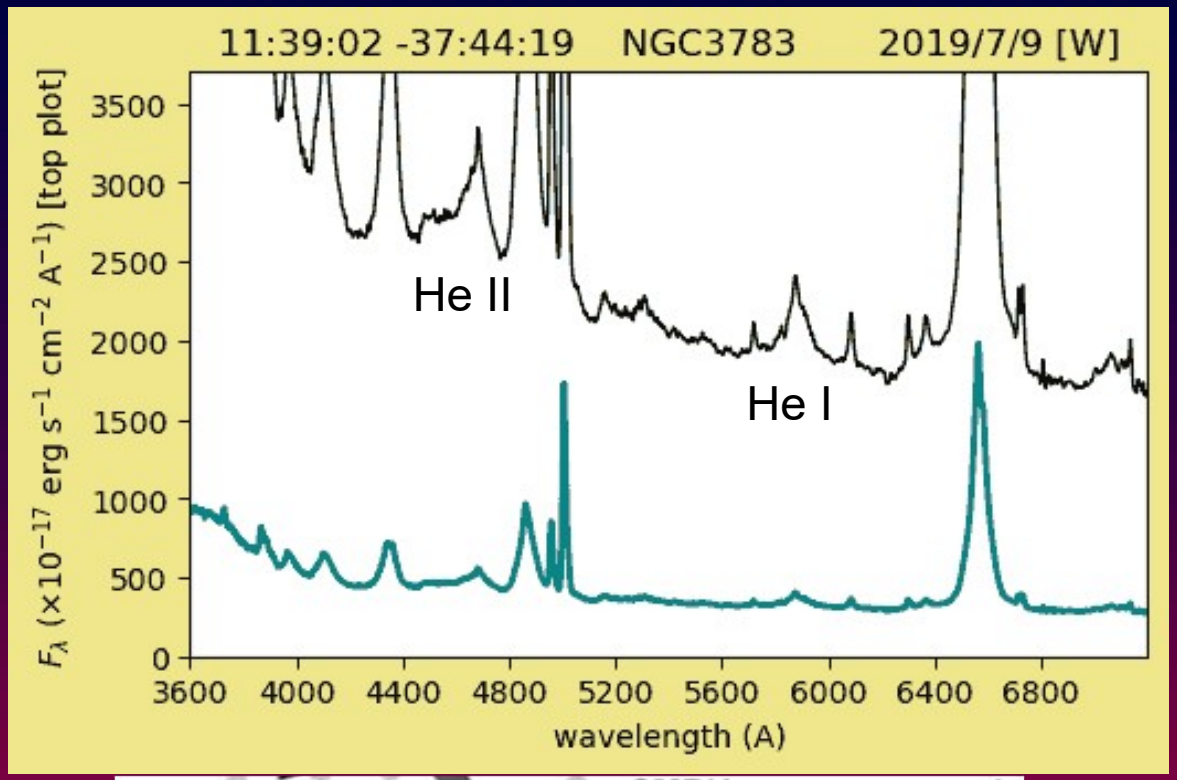
Spectrum and fit from Eracleous & Halpern (2003)

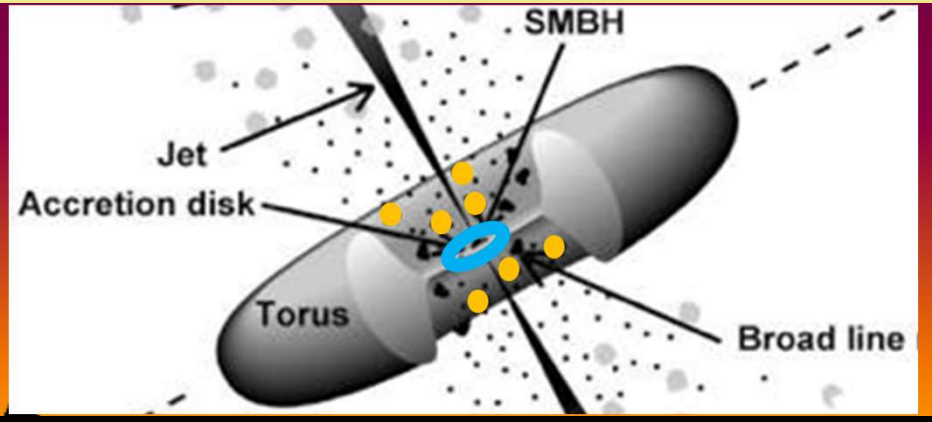


Seyfert 1 galaxies with strong broad He emission

He II (also He I) is more prominent in some AGN than others (not previously singled out as a sub class of AGN?)

He lines often wider and more variable than the Balmer lines, consistent with being formed particularly close to the black hole



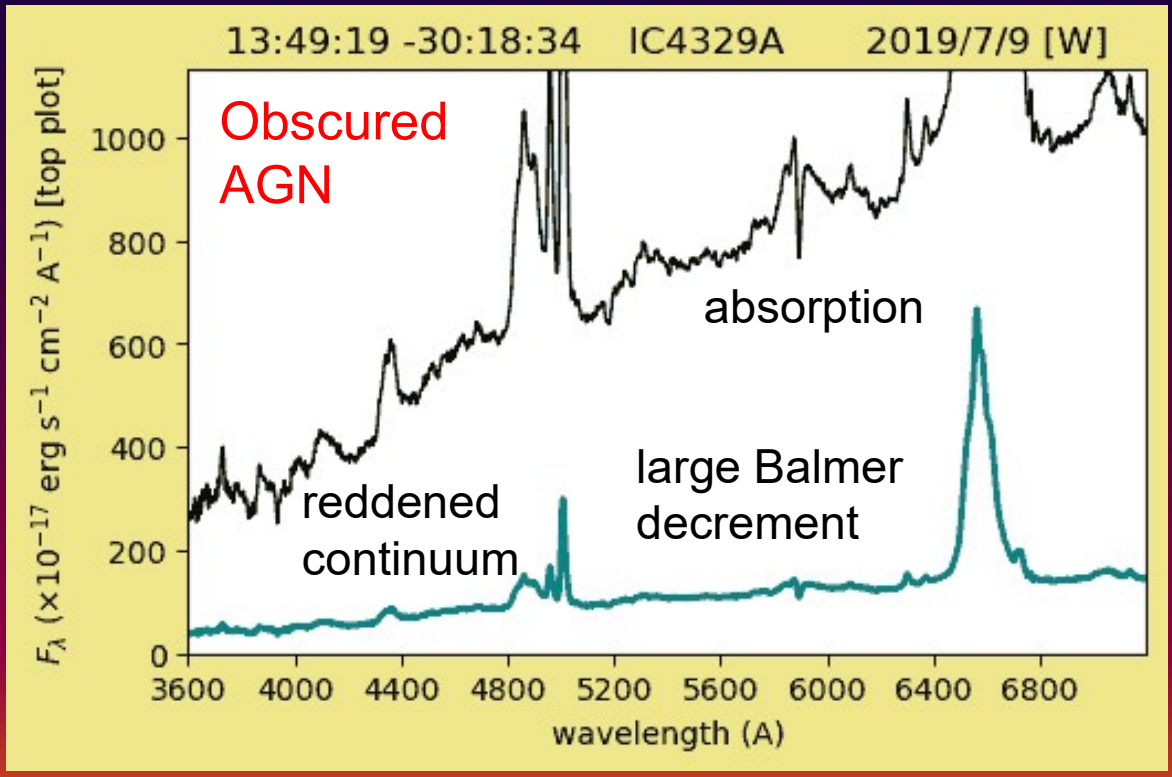


Obscured AGN, Changing Look AGN and blazars

Variations in obscured AGN are very difficult to measure, but offer an opportunity to study any link between brightness variations and potential changes in obscuration

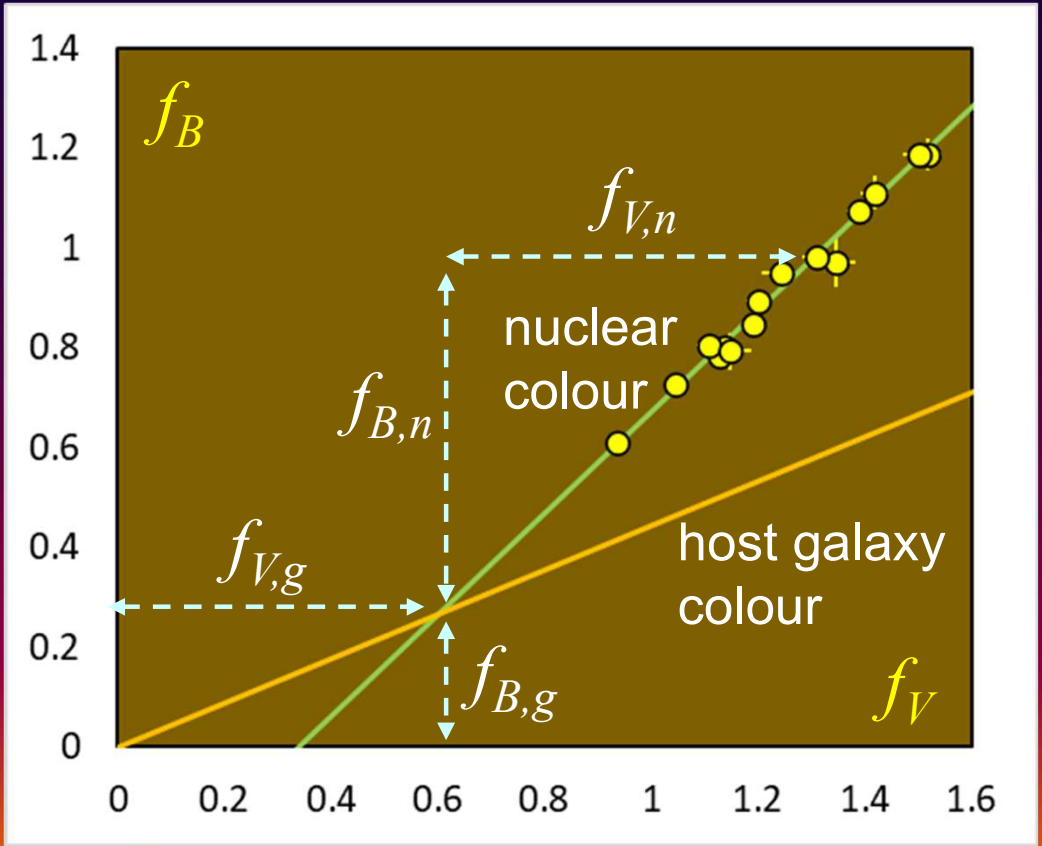
Changing Look AGN: what happens during changing look events; do the nuclear colours change?

Blazars: association with jets and their alignment; how significant is jet variability?



Extracting the nuclear component and nuclear extinction using the flux variation gradient method

As in other AGN, plotting flux vs flux in different filters yields a tight linear relationship showing a varying but constant colour nucleus superimposed on a constant host galaxy



(Choloniewski, 1981, Winkler et al, 1992, Winkler, 1997)

Yields:

- nuclear colour (i.e. flux distribution)
- nuclear flux fraction
- nuclear extinction (if unreddened colours are known)
- intrinsic luminosity

Las Cumbres Observatory (LCO) robotic telescope network

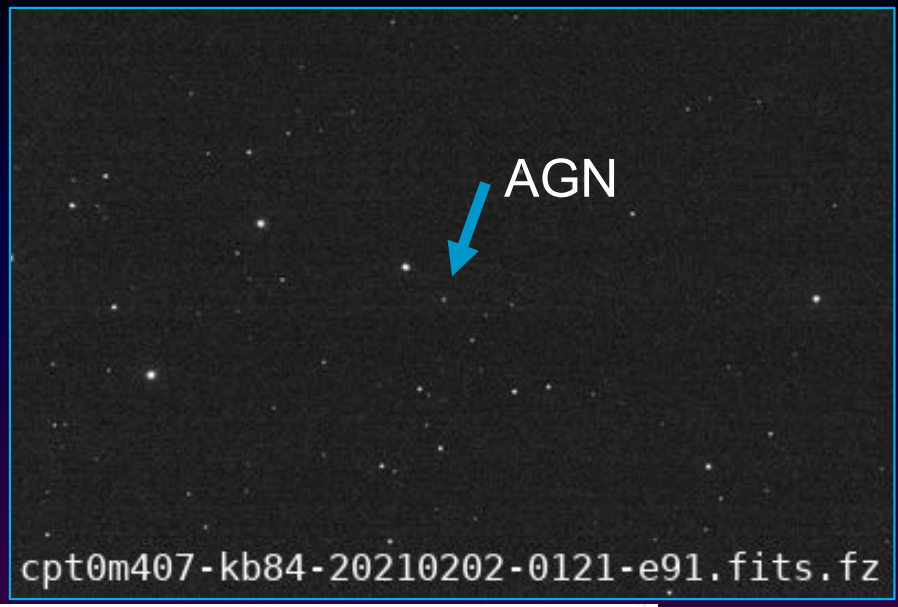
Photometry with LCO

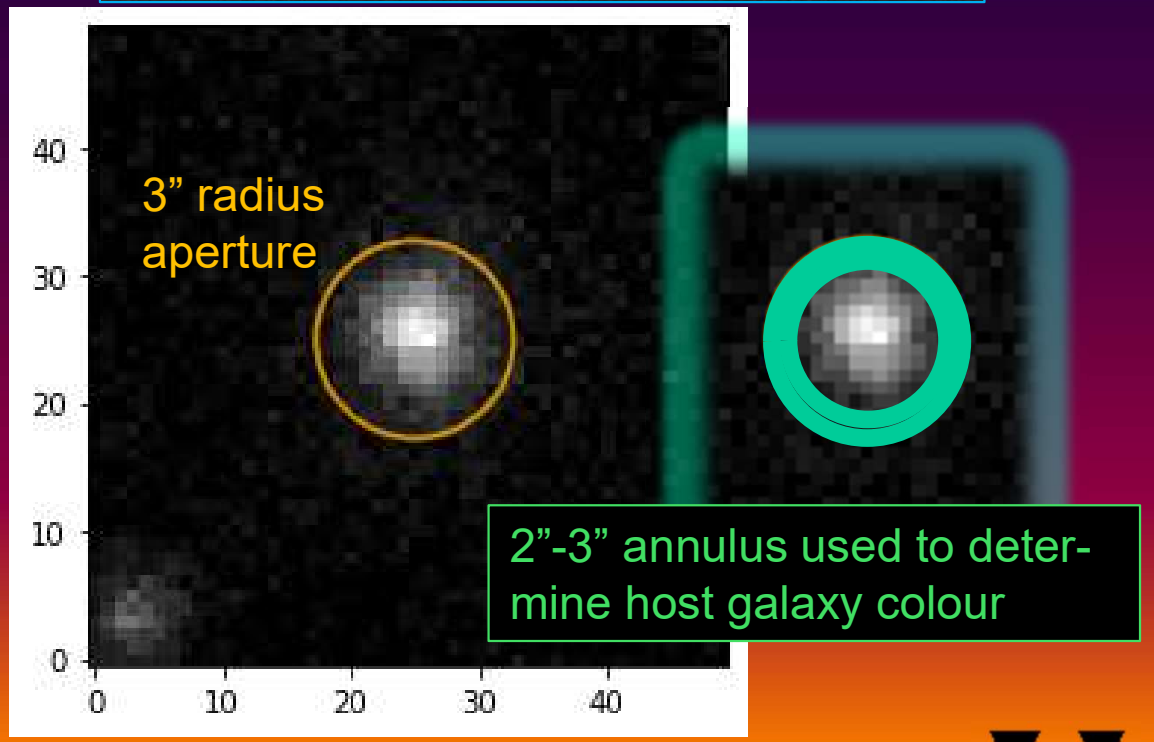
(U)BV(u')g'r' filters
2x images in each filter

Observations carried out at roughly monthly intervals

3 arcsec radius aperture

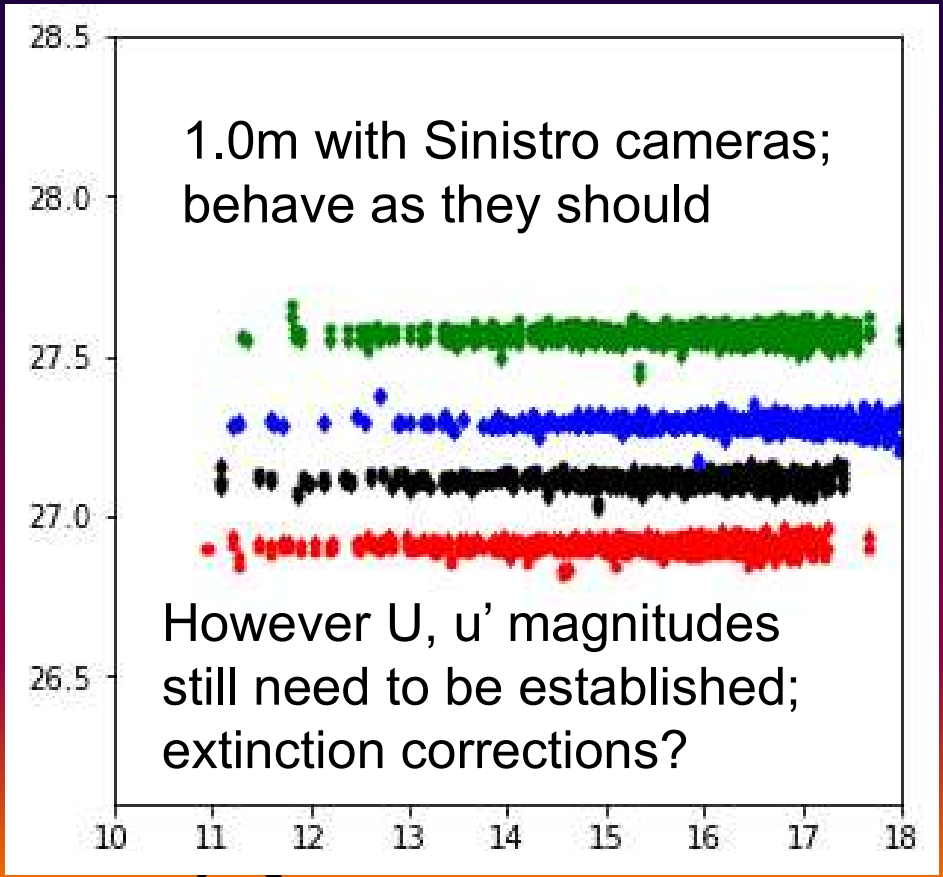
Photometric calibration using the multitude of stars in each image that have magnitudes in the APASS database (NB: doesn't have U, u' mags)

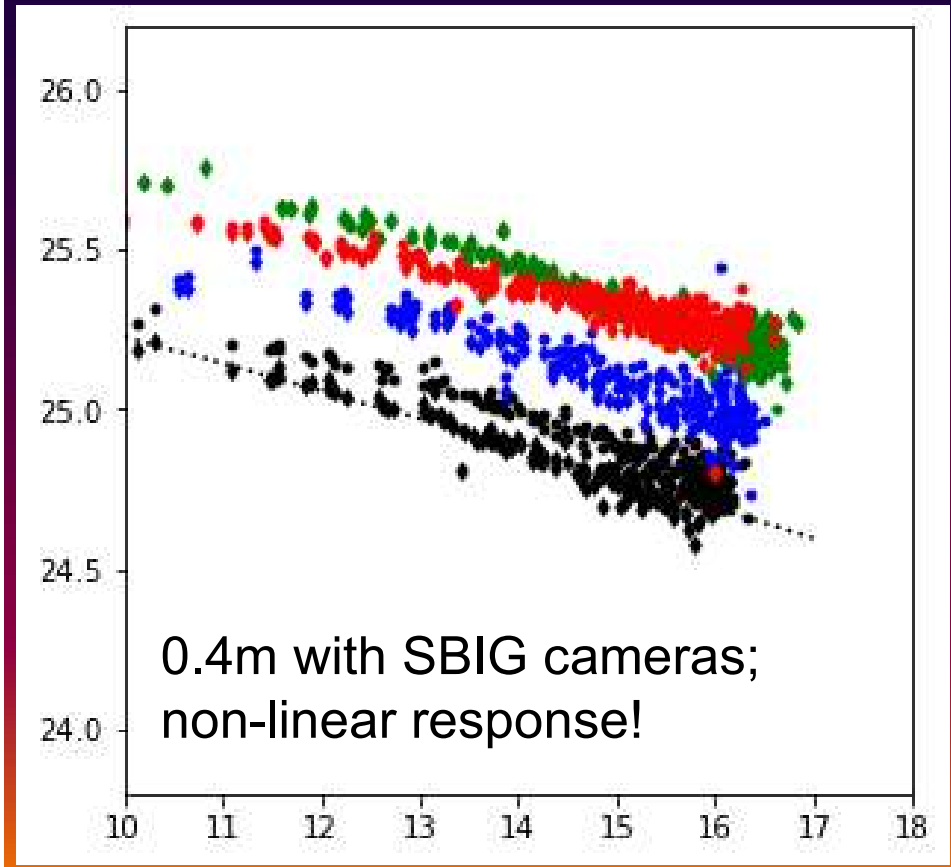




AGN photometry with the LCO network

The biggest source of uncertainty in this study is not the photon statistics associated with the AGN, but rather the uncertainty in the photometric calibration!



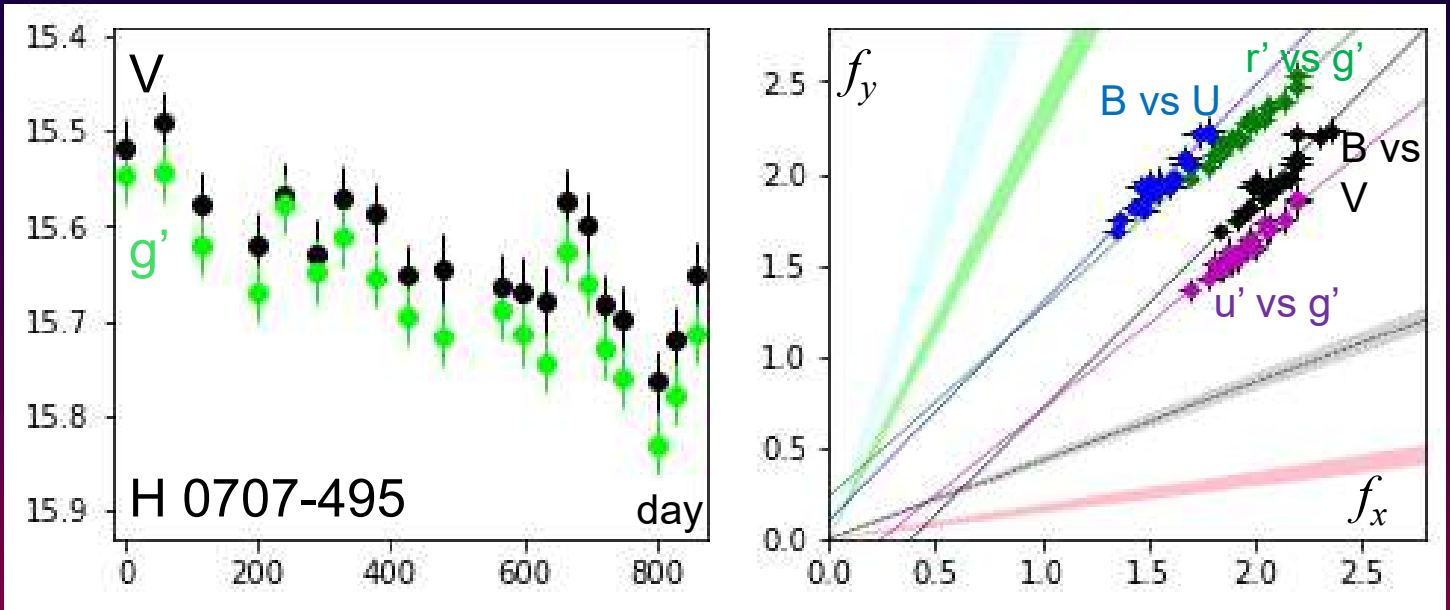


The sample and observing programme

- Programme started in August 2020, ongoing
- To date there have been ~280 h of observations with the 1.0m network and ~510 h with the 0.4m network
- 86 AGN have been observed photometrically between 3 times (for newly added objects) and ~30 times. Of these:
  - 17 were NLSy1 with strong Fe II
  - 16 were AGN with double-peaked broad lines
  - 8 were strong broad He line emitters
  - 8 Changing Look AGN; 4 obscured AGN & 10 blazars
  - The rest were ordinary Seyfert 1 galaxies, sometimes chosen to better enable photometric calibration

NLSy1 with strong Fe II emission

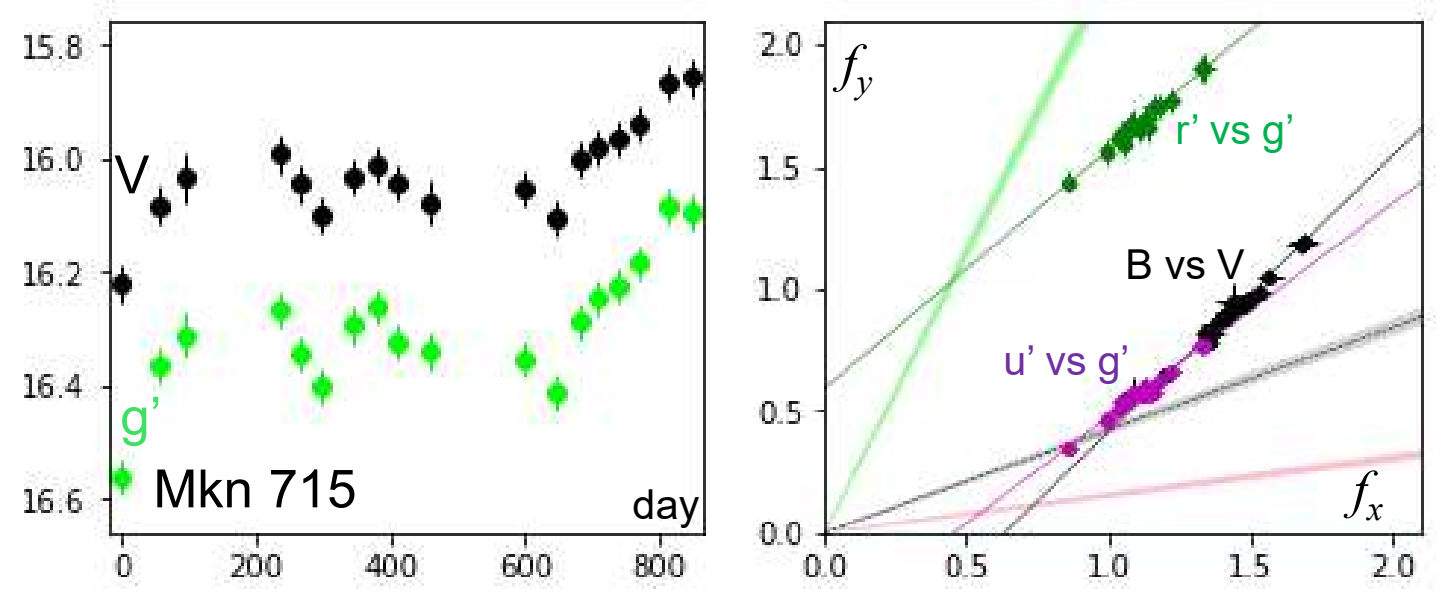
Note that very dramatic X-ray variability has been reported in many AGN falling under this class. In the optical however it is a different story …



Out of the 12 targets in this class observed for ~2 years, 4 only have statistically insignificant variability to date, while for most of the remaining targets the fractional range of variations is clearly smaller than for 'average' Seyferts

AGN with Keplerian rotator line profiles

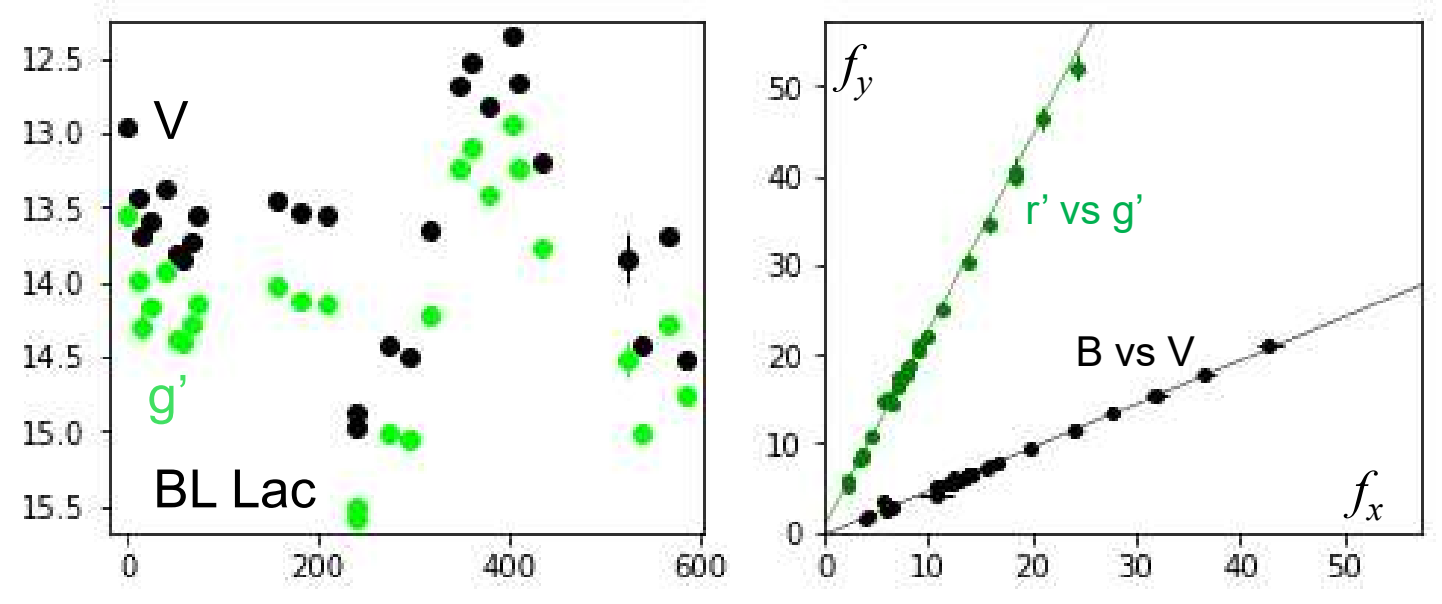
While substantial variations were recorded in some targets, variability was moderate or unconfirmed in most cases



There is a suggestion that double peaked profiles are only properly visible in low-luminosity phases (good example: Mkn 926)

Strong broad He, Changing Look, blazars

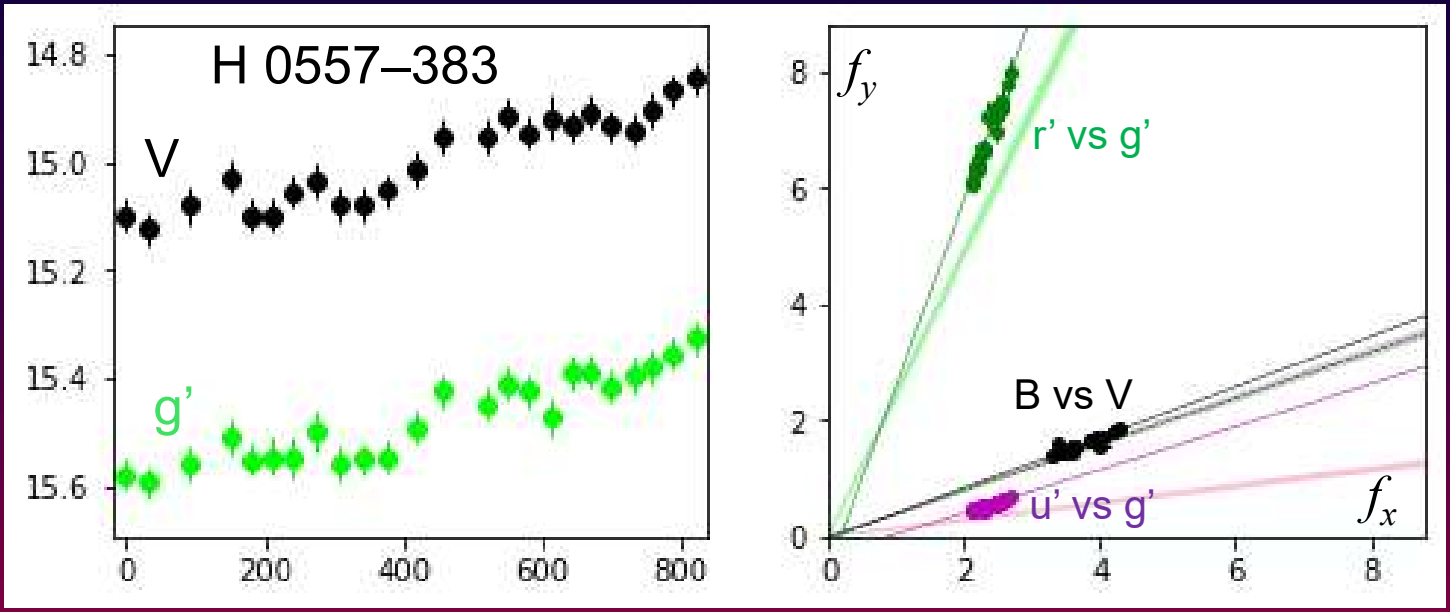
i) Too few He-strong have thus far yielded accurate nuclear colours, and these do not appear different to average Seyfert colours
ii) Only 0.4m data is available for blazars. Still … (e.g. BL Lac)



iii) No changing look events have been witnessed in AGN previously known to exhibit such behaviour. Most have been in a faint state, when the FVG technique is less effective

Highly obscured AGN – investigating the interstellar medium is an AGN host galaxy

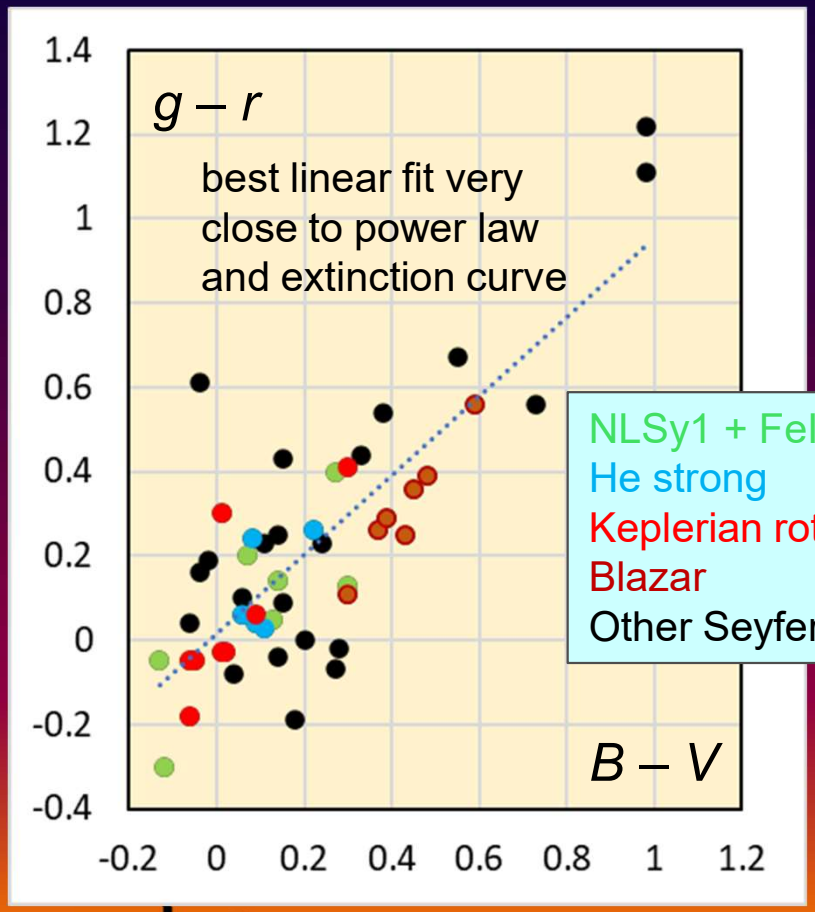
The obscuration will result in reddening of the variable component - but what extinction law determines the reddening?



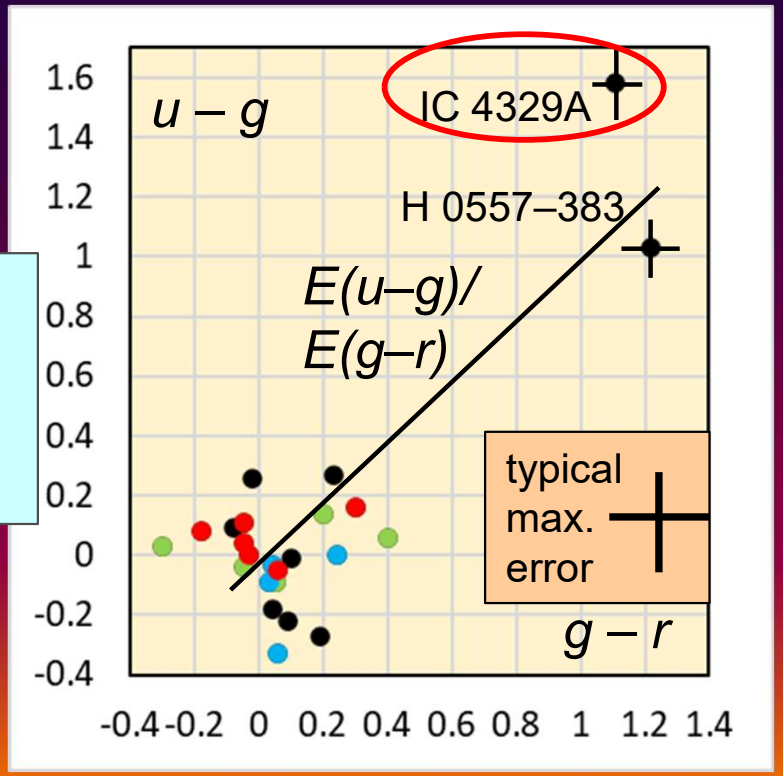
These observations are more challenging, as the nuclear component will be (i) fainter and (ii) its colours are now similar to the host galaxy. Only two of the Seyferts investigated have thus far allowed accurate analysis: IC 4329A and H 0557–383

Variable component colour plots

Virtually the entire sample has been found to have nuclear colours consistent with theoretical accretion disk colours at different degrees of obscuration. Also consistent with blazar power law distributions



No other immediately evident differences between sub-classes



Summary – preliminary findings of study

- NLSy1 with strong Fe II emission have lower variability ranges. Have substantial nuclear component that is only weakly variable
- Previously bright AGN now in a much fainter state (often linked to "Changing Look" category) are now stuck there for a long time, and optical variability during these faint phases appears limited
- Keplerian rotator profiles appear more prominent during optically weak phases, and these components are only mildly variable
- No immediately evident differences between the optical nuclear colours and variability characteristics of most sub-classes studied
- The IC 4329A nucleus appears to have non-standard interstellar reddening in the host galaxy – not sure yet how common this is in other heavily obscured nuclei
- Many investigated sources have displayed some of the brightest (BL Lac) or faintest (Mkn 1383) phases recorded to date

Thanks to: i) The conference organisers; ii) SAAO for allocating telescope time; iii) LCO for use of their robotic telescope network and technical support; iv) SA-GAMMA collaboration for funding this conference trip