Comparing the optical variability characteristics of different subclasses of AGN

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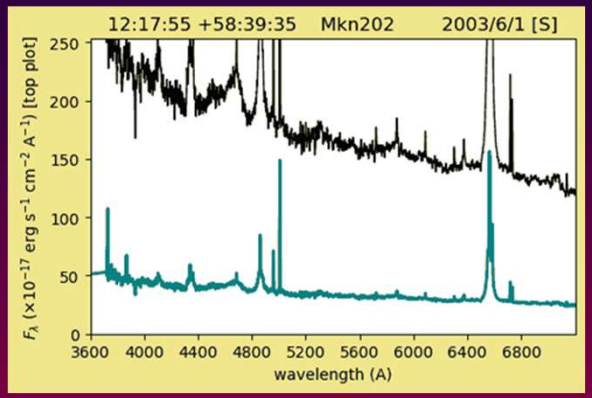
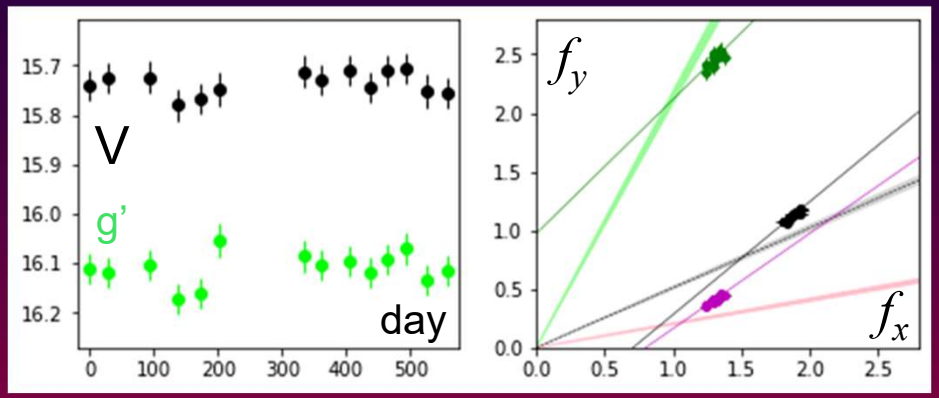
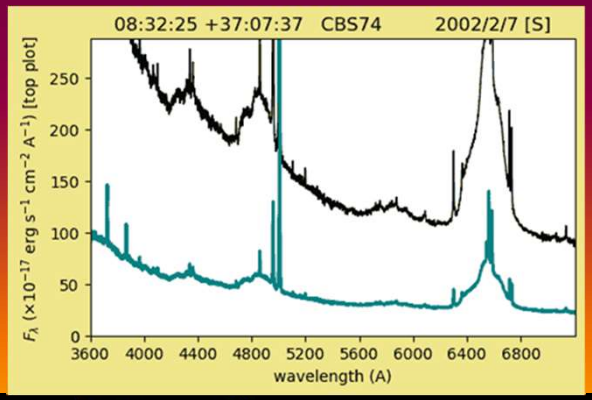
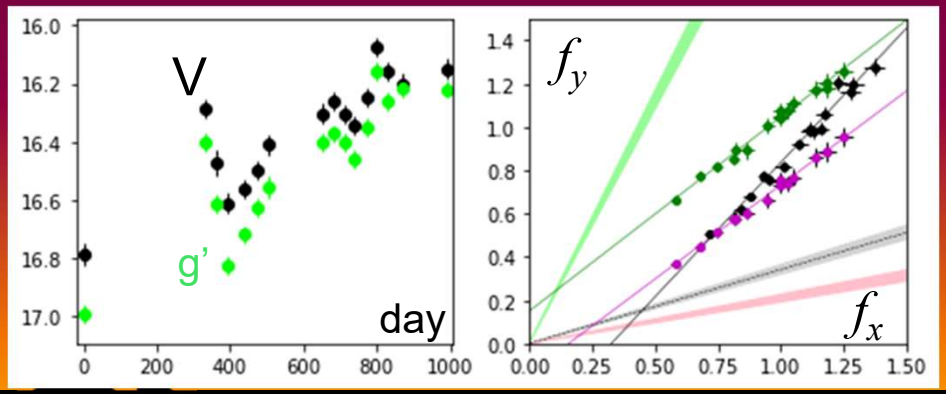


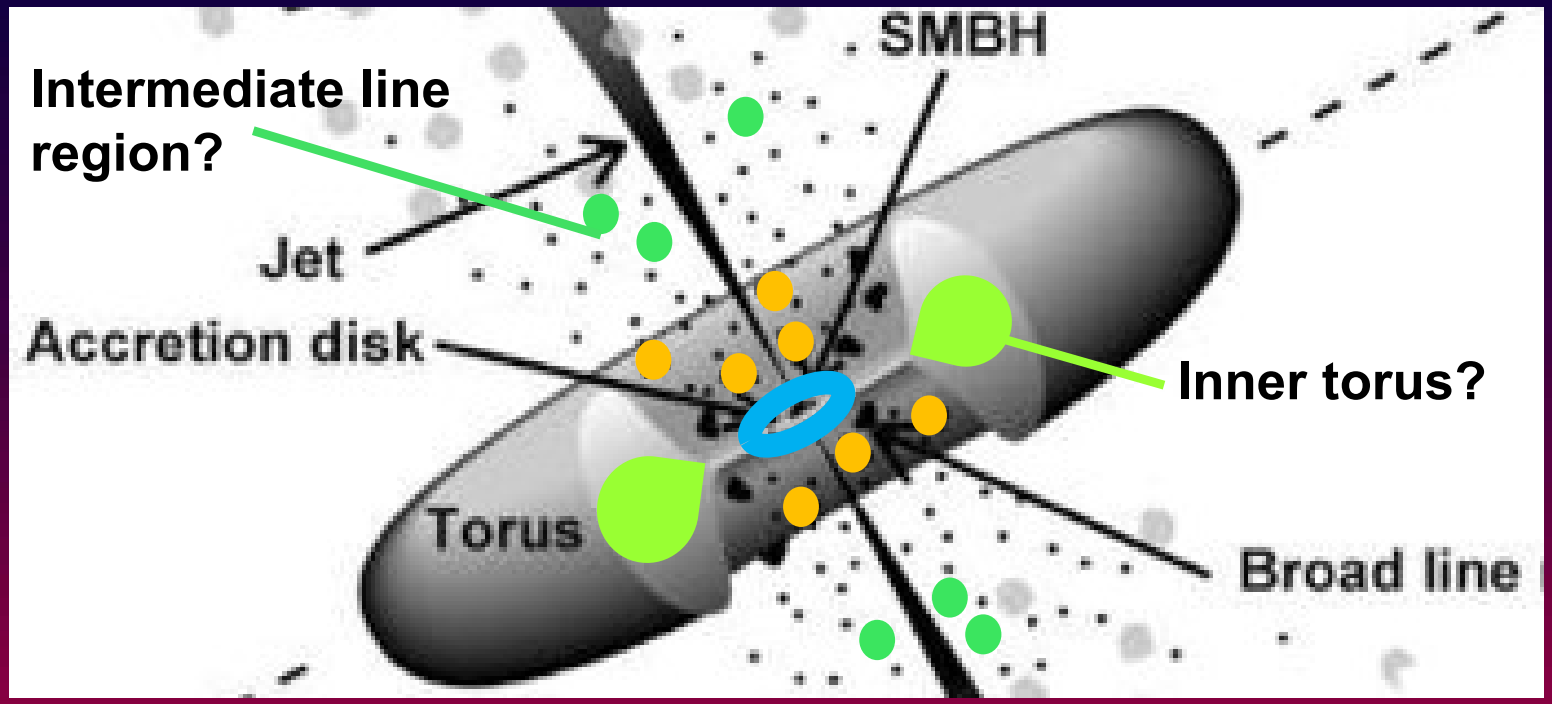






Variability as a probe of the central engine and its surroundings

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



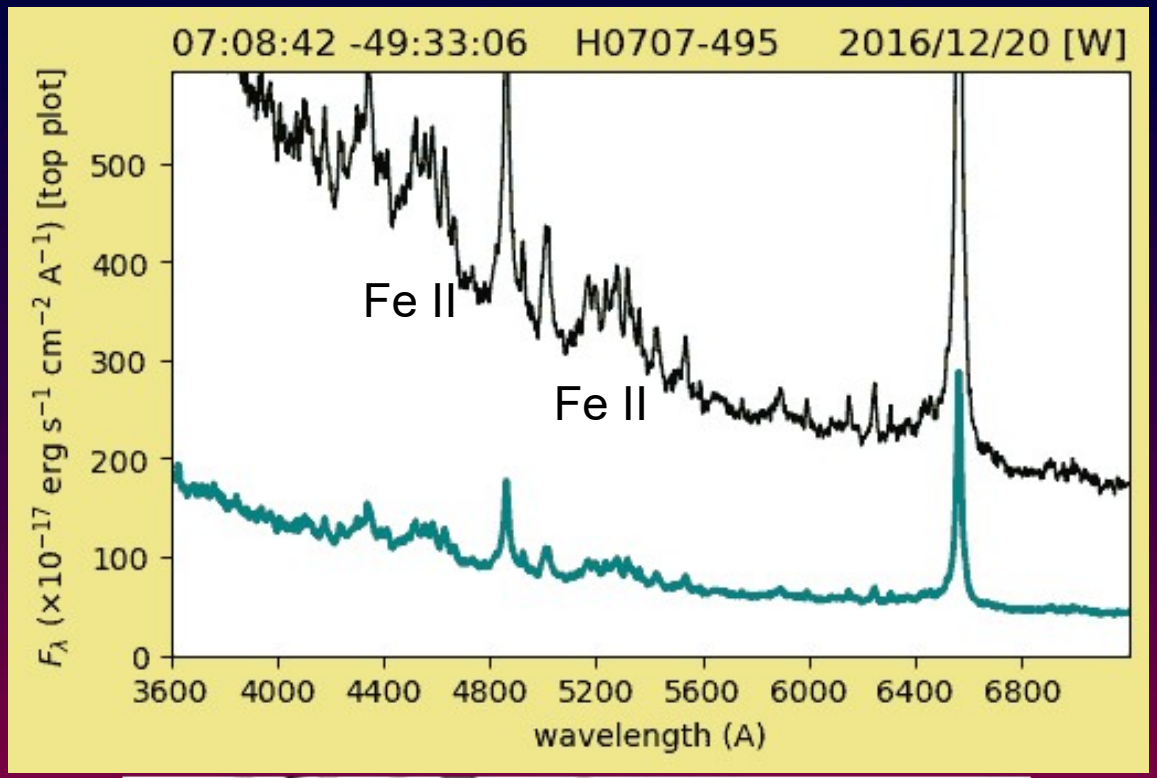
from fermi.gsfc.nasa.gov

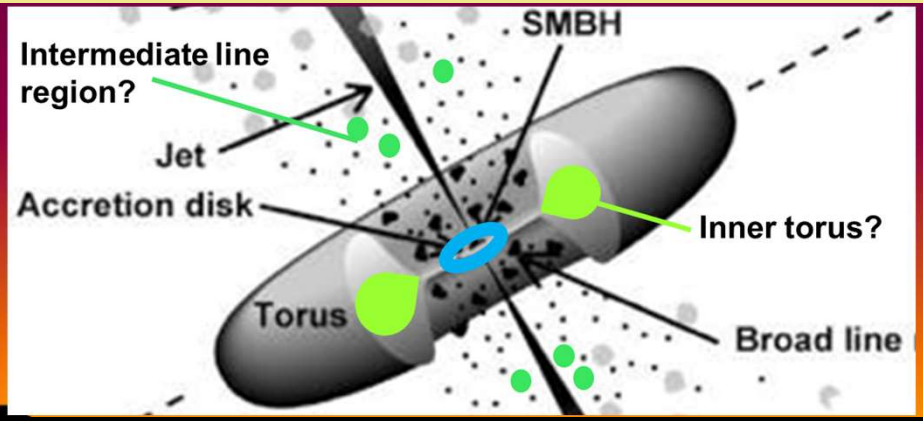
These potential nuclear components are not equally represented in all AGN. Some components are particularly strong in specific subclasses

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

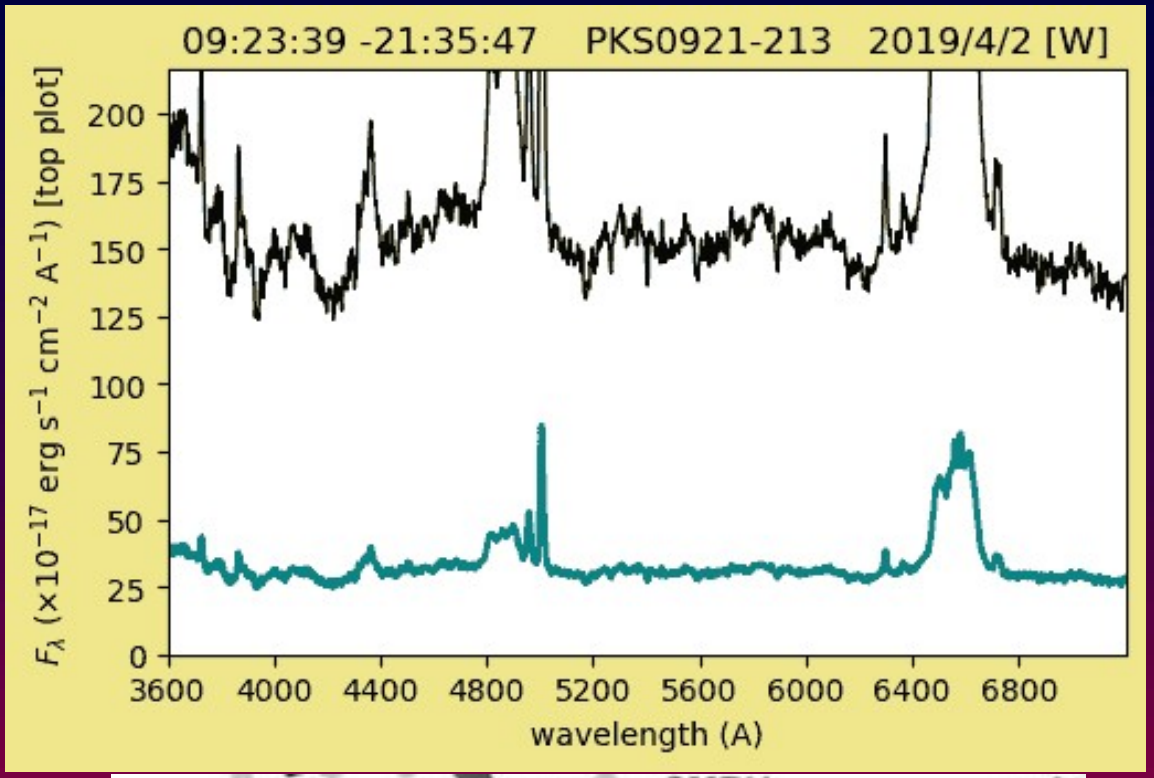


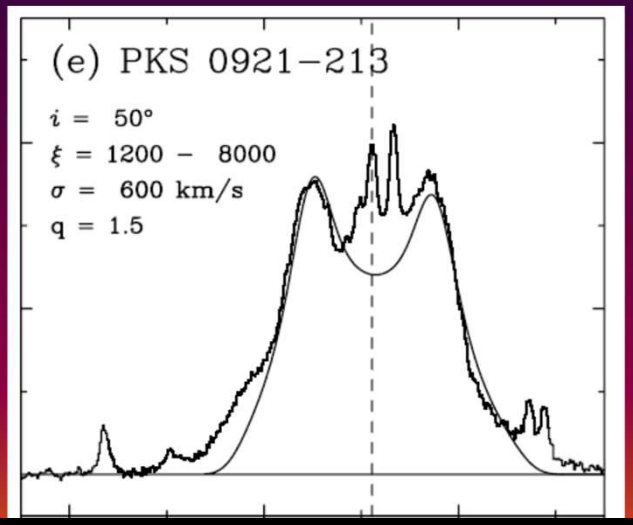


Keplerian rotators – double-peaked broad line profiles

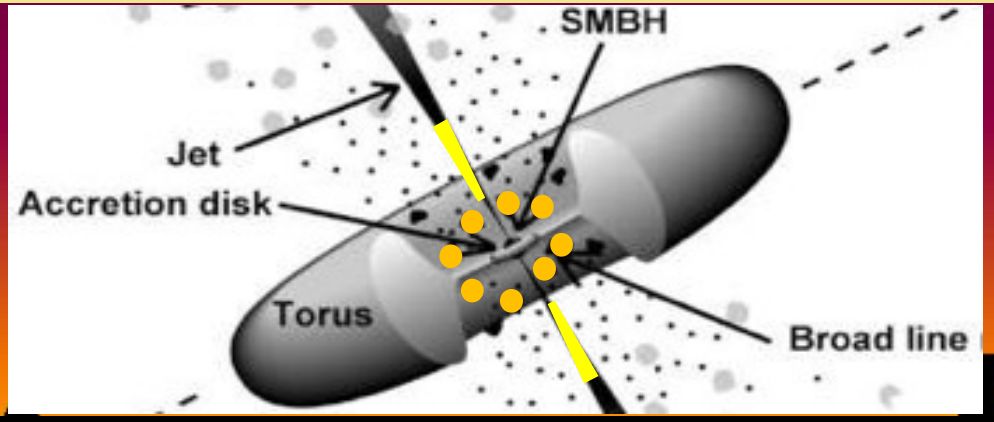
Shown to arise from Keplerian orbiting of broad line region

Similar profiles also generated by in- or outflow

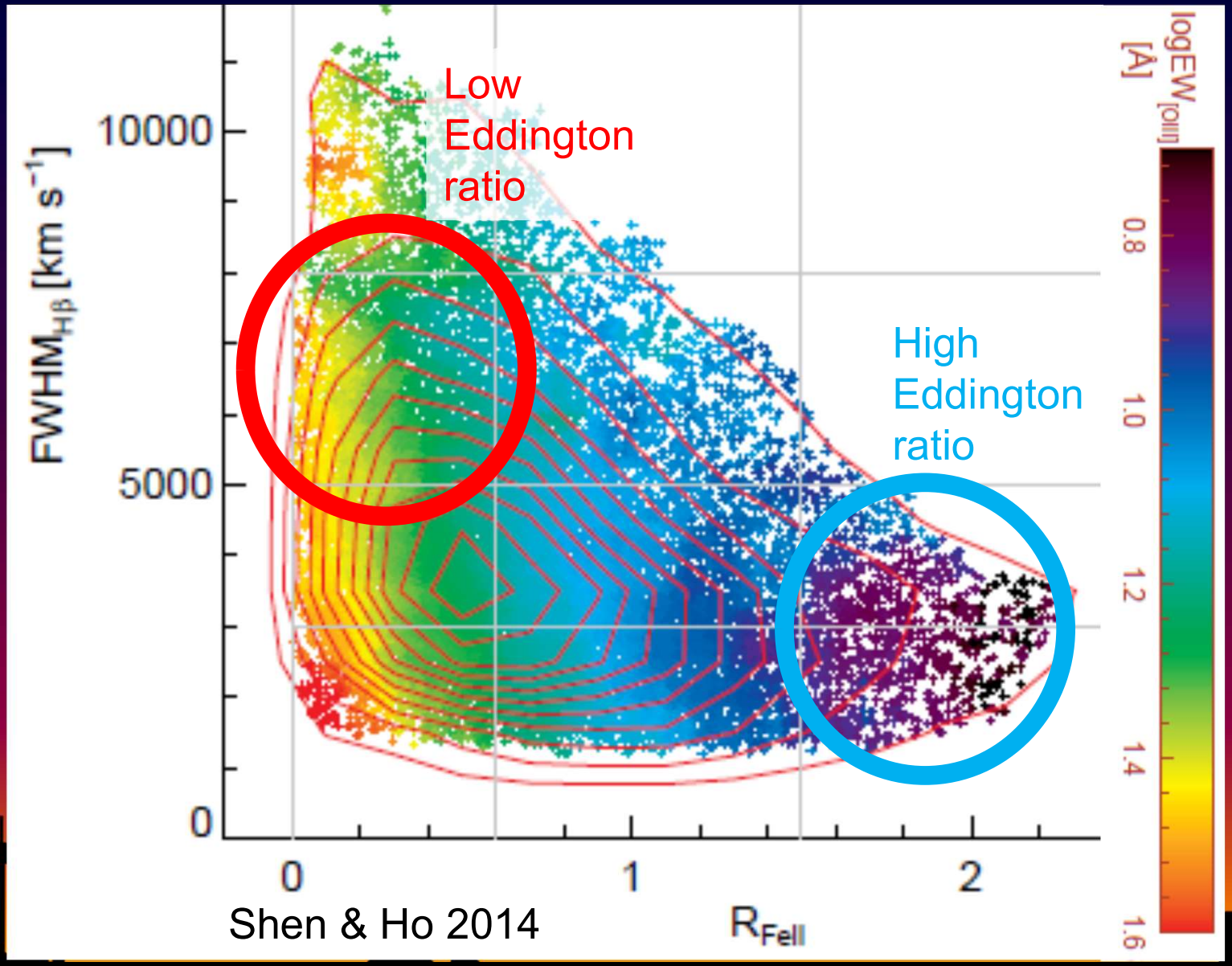




Spectrum and fit from Eracleous & Halpern (2003)



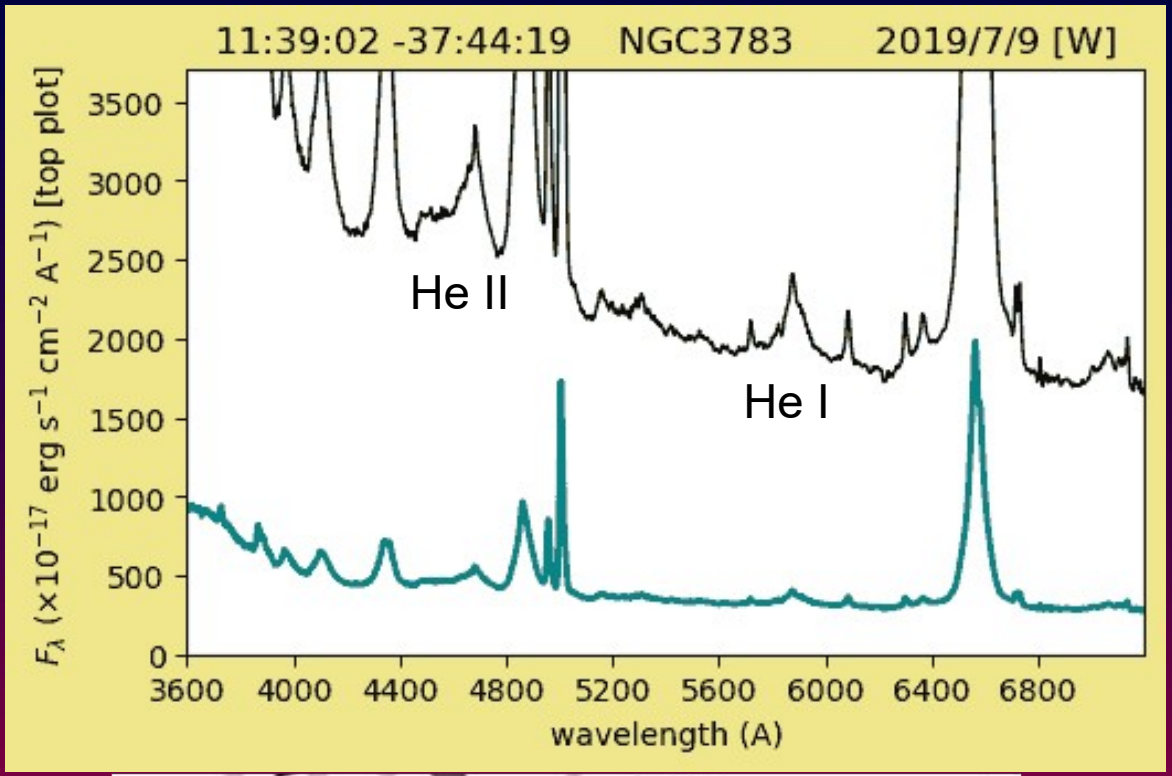
Interpretation of the broad-line width and Fe II strength

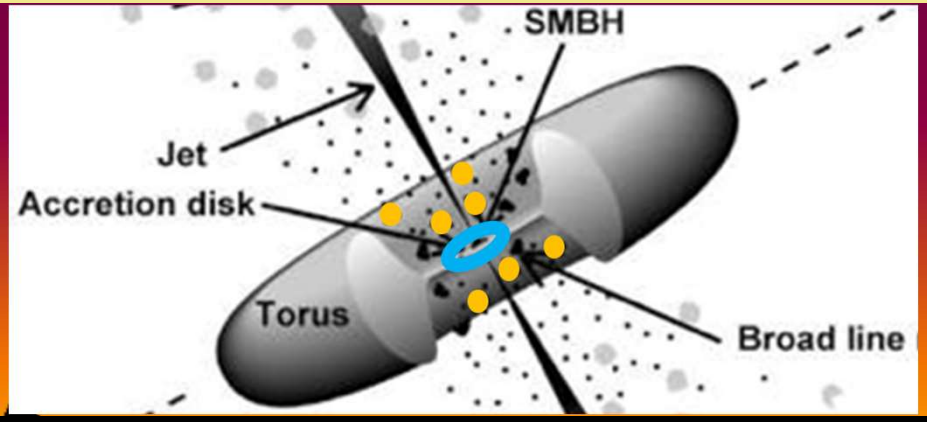


Seyfert 1 galaxies with strong broad He emission

He II (also He I) is more prominent in some AGN than others (He is particularly strong in ‘root-mean-square’ spectra)

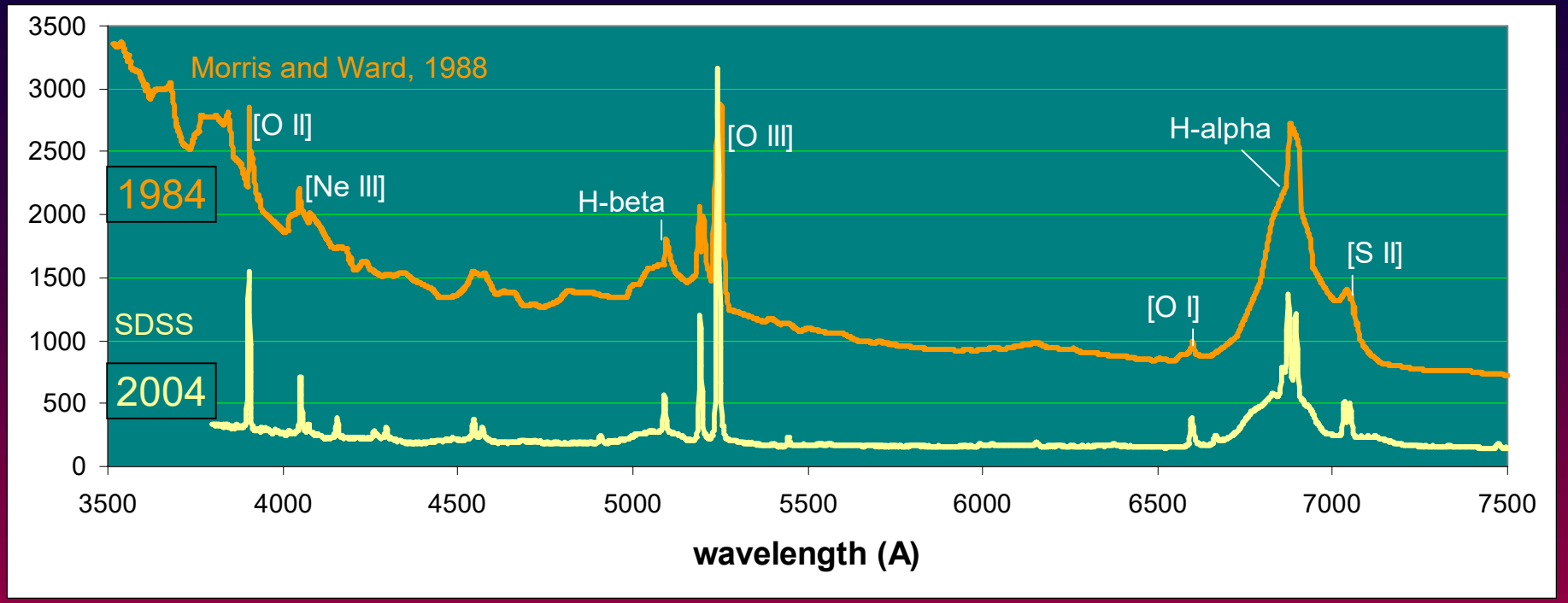
He lines often wider and more variable than the Balmer lines, consistent with being formed particularly close to the black hole





Changing Look AGN and blazars

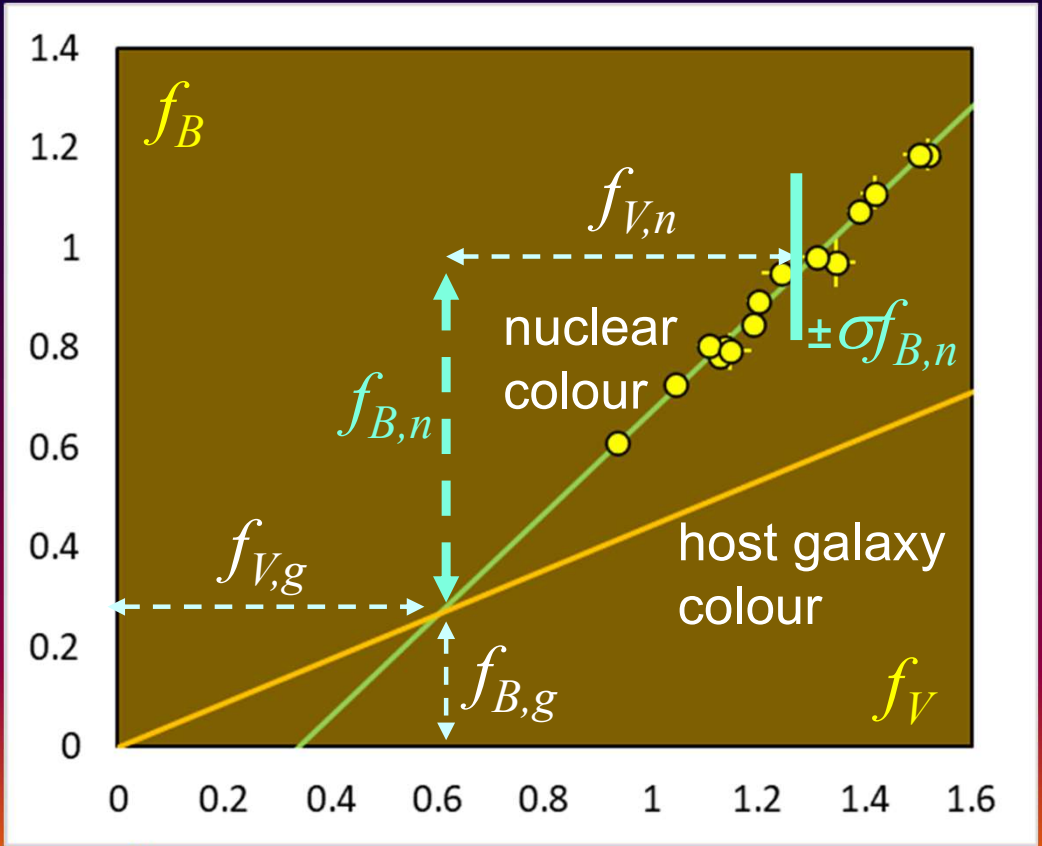
Changing Look AGN:
- Variability during changing look events?
- How do they behave at a later stage?



Blazars: other mechanisms at play (not covered here)

Extracting the variability measure of the nuclear component

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)

The degree of nuclear variability $\sigma f_{B,n}$ is here defined by means of the ratio (given as a percentage) between the standard deviation of $f_{B,n}$ and $f_{B,n}$

Las Cumbres Observatory (LCO) robotic telescope network

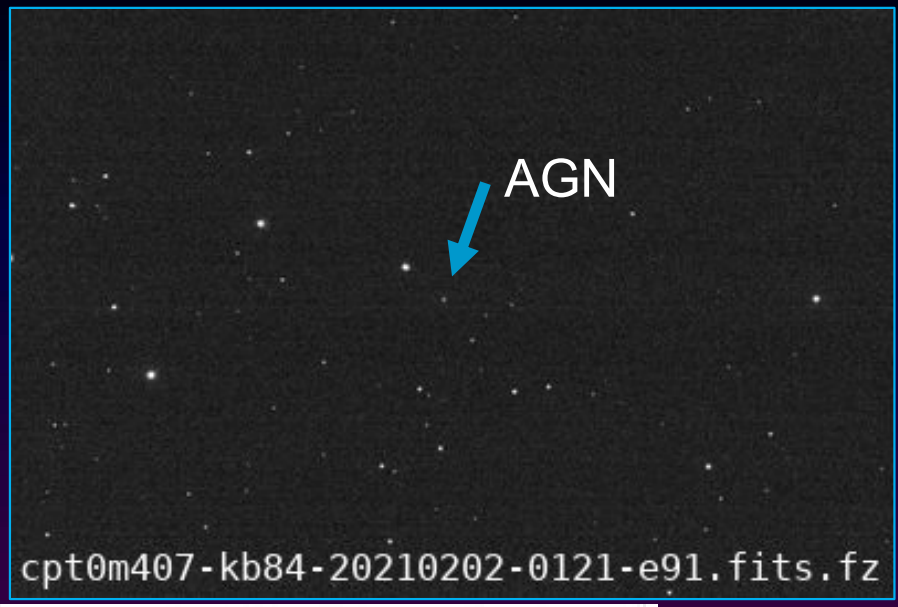
Photometry with LCO

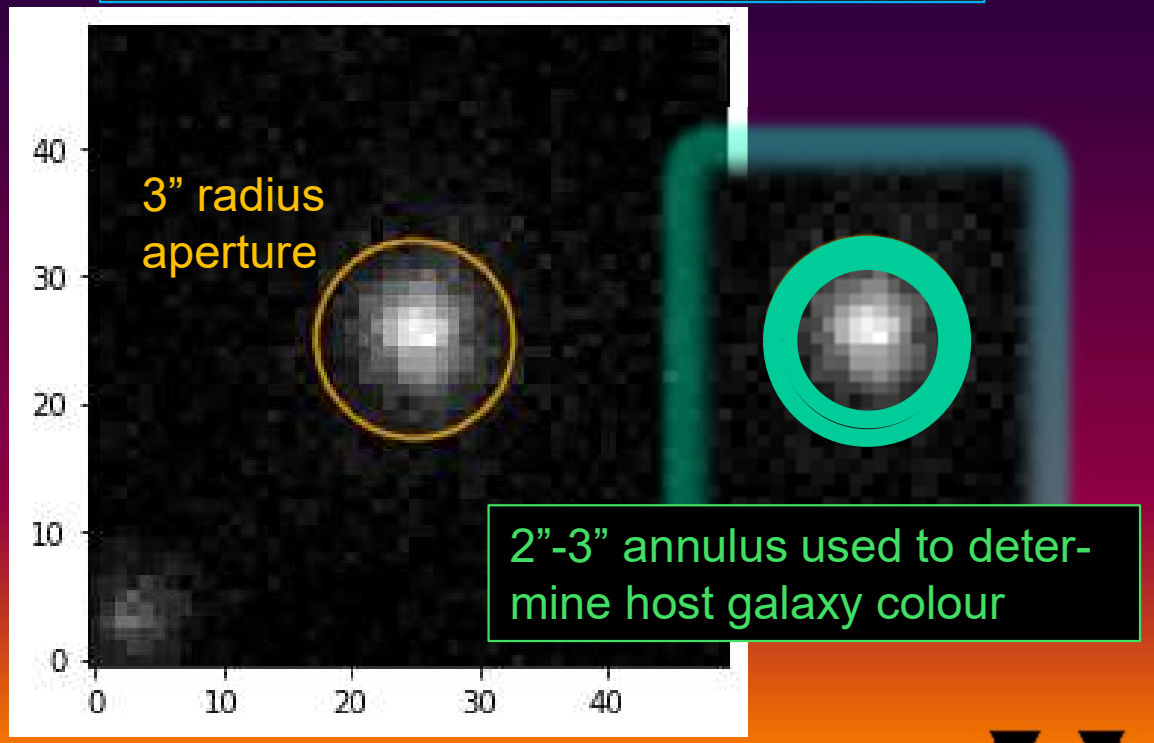
(U)BV(u')g'r' filters
2x images in each filter

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)



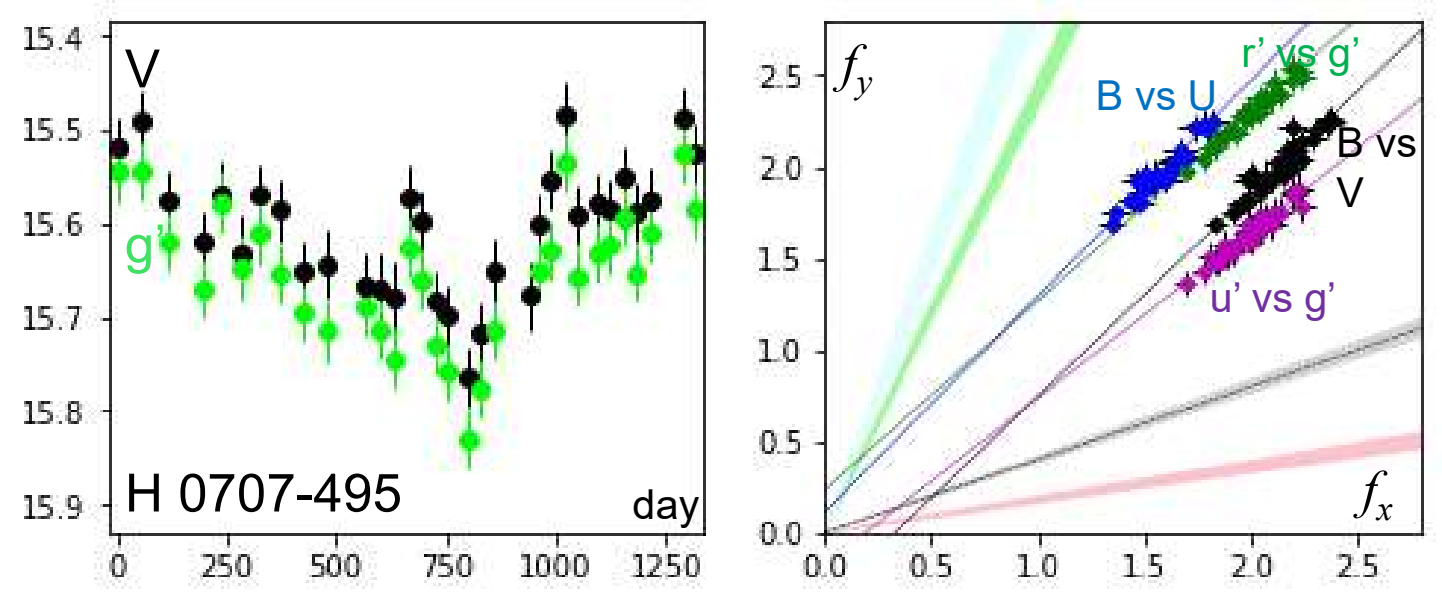


The sample and observing programme

- Programme started in August 2020, ongoing
- To date there have been ~310 h of observations with the 1.0m network and ~620 h with the 0.4m network
- 143 AGN have been observed photometrically between 1 time (for newly added objects) and ~35 times. Of these:
  - 21 were NLSy1 with strong Fe II
  - 19 were AGN with double-peaked broad lines
  - 11 were strong broad He line emitters
  - 9 Changing Look AGN; 6 obscured AGN & 8 blazars
  - The other 69 were ordinary Seyfert 1 galaxies, some 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 …



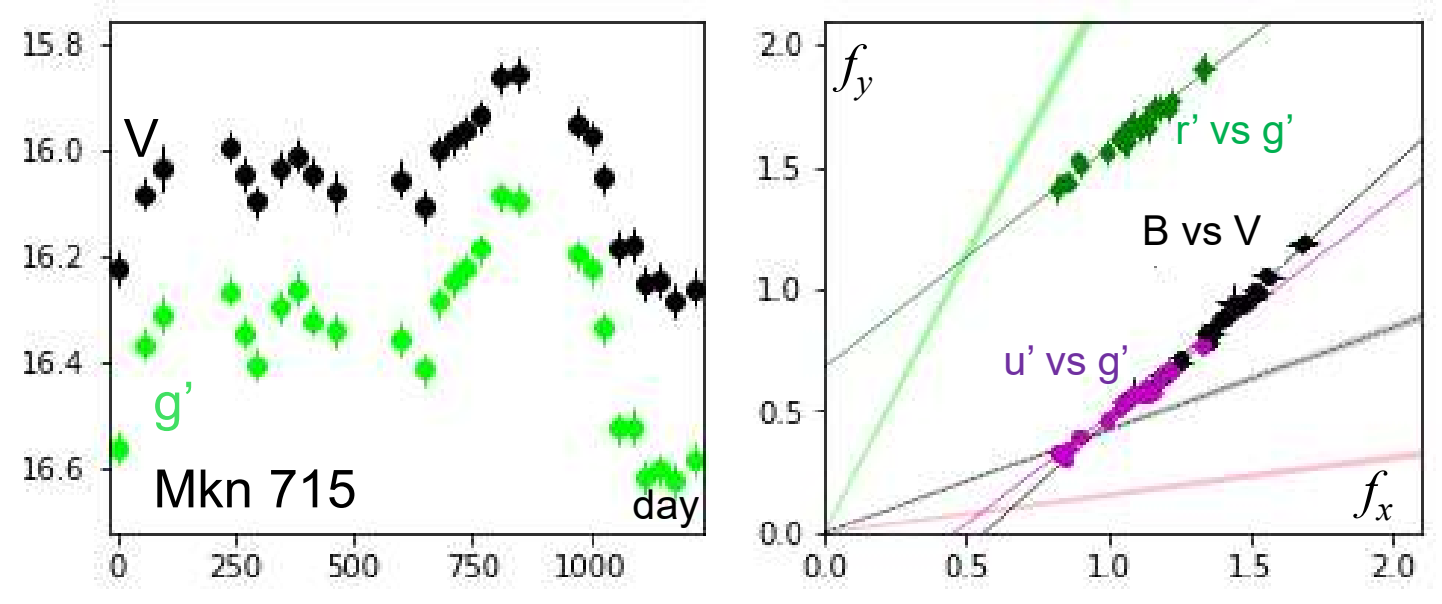
$\sigma f_{B,n} = 8\%$

Out of the 17 targets in this class observed for ≥2 years, 3 only have statistically insignificant variability to date, while for the remaining targets the nuclear range of variations is (14±5)%.

Compare with 'average' Seyferts: (22±10)%

AGN with Keplerian rotator line profiles

Substantial variations were recorded in most targets, and for these the variability parameter averaged (32±10)%

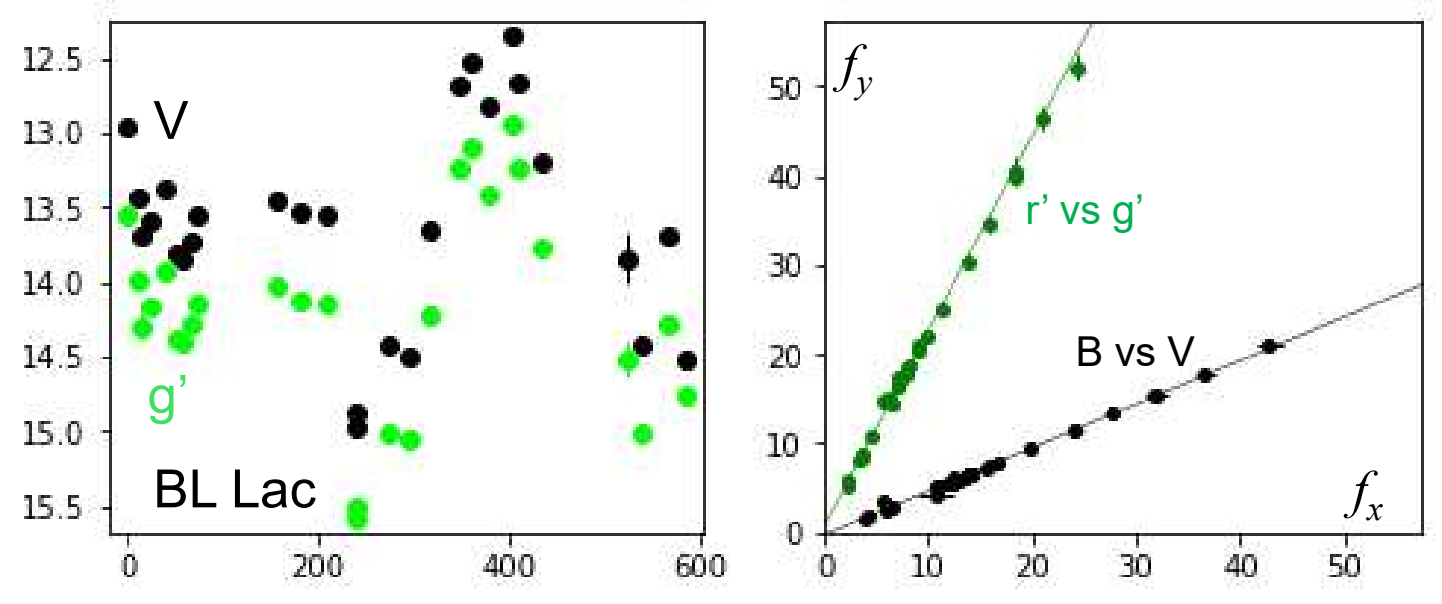


$\sigma f_{B,n} =$ 33%

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) Only a few He-strong have thus far yielded accurate nuclear colours, and these do not appear different to average Seyfert colours
ii) Most blazars highly variable (see HEASA 2023 presentation)

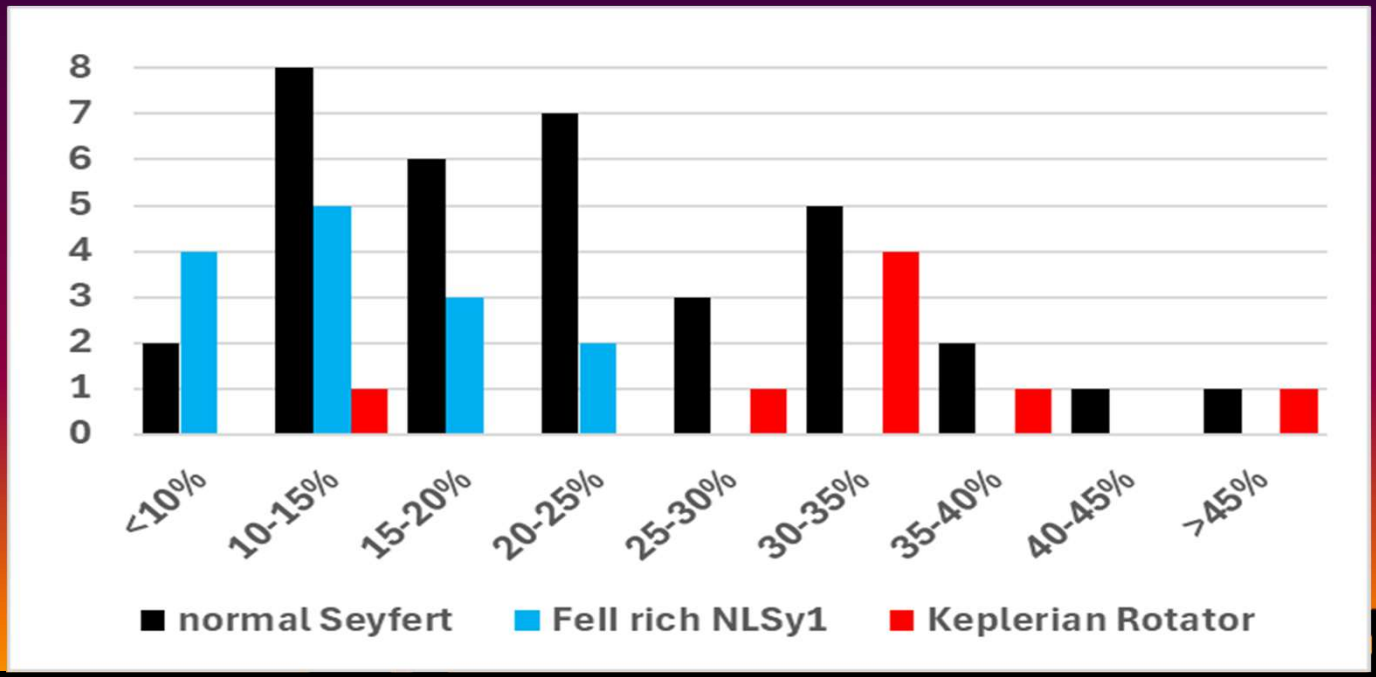


iii) No changing look events have been witnessed in AGN previously known to exhibit such behaviour. Most have been in a faint state, when measuring variability is very difficult

Comparing the relative variability of different Seyfert sub-classes

- The average nuclear variability range for ‘normal’ Seyfert 1 galaxies appears to be of the order of 20%
- NLSy1’s with strong Fe II emission (high Eddington ratios?) have significantly lower nuclear variability amplitudes
- AGN with expected lower Eddington ratios (e.g. Keplerian rotator emission line profiles) tend towards the opposite

Caution: The latter are more difficult to separate from the host galaxy



Summary – preliminary findings of study

- On average, Seyfert galaxies have a nuclear variability $\sigma f_{B,n}$ of about 20%.
- NLSy1 with strong Fe II emission have lower variability ranges. Have substantial nuclear component that is only weakly variable
- Keplerian rotator profiles appear more prominent during optically weak phases, and their $\sigma f_{B,n}$ typically exceeds the average of 'normal' Seyferts
- 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
- He-emission and other classes not unlike normal Seyferts, but more observations needed (currently in progress)
- Finalisation of programme in about 1 year; optimized calibration followed by a re-evaluation of the results

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 for funding HEASA meetings