Exploring the jet-BLR connection: flare-induced variability in the optical emission lines

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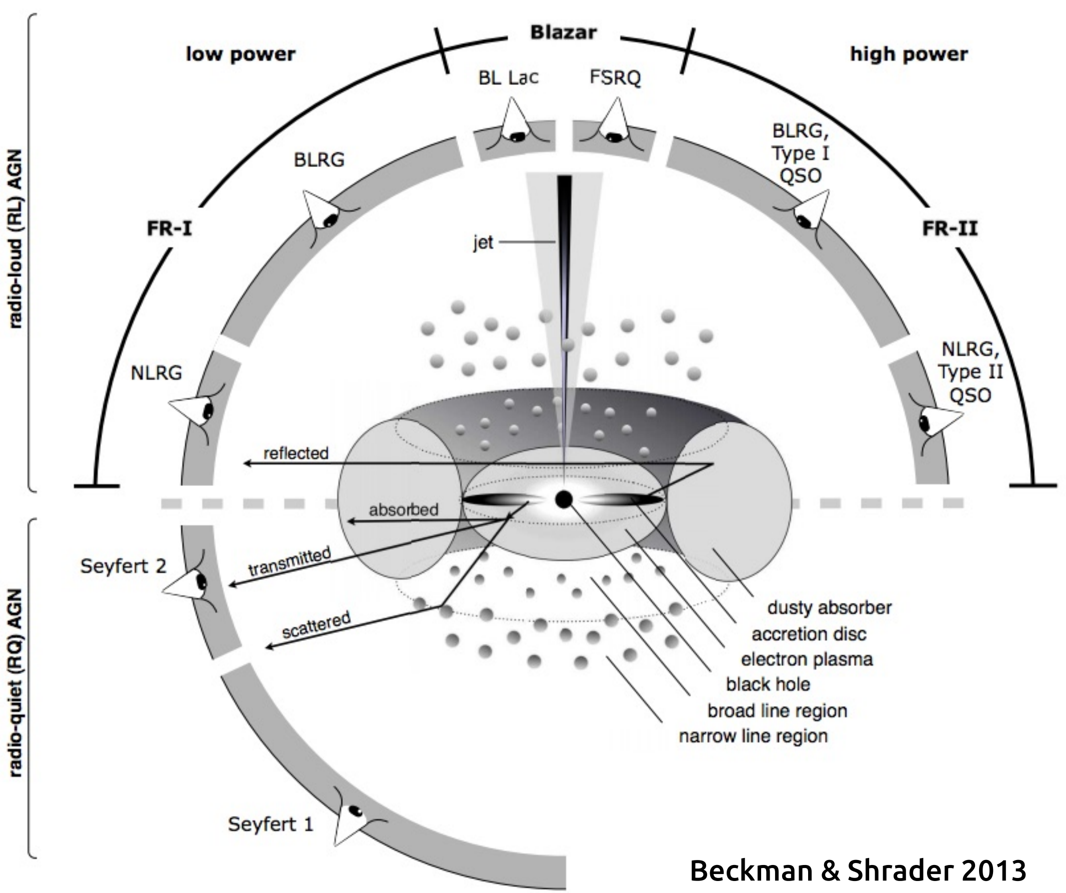
Relativistic jets

Harbored in 10% of AGN

Often identified in radio surveys using the radio-loudness parameter (wrong, ask me later)



Beckman & Shrader 2013

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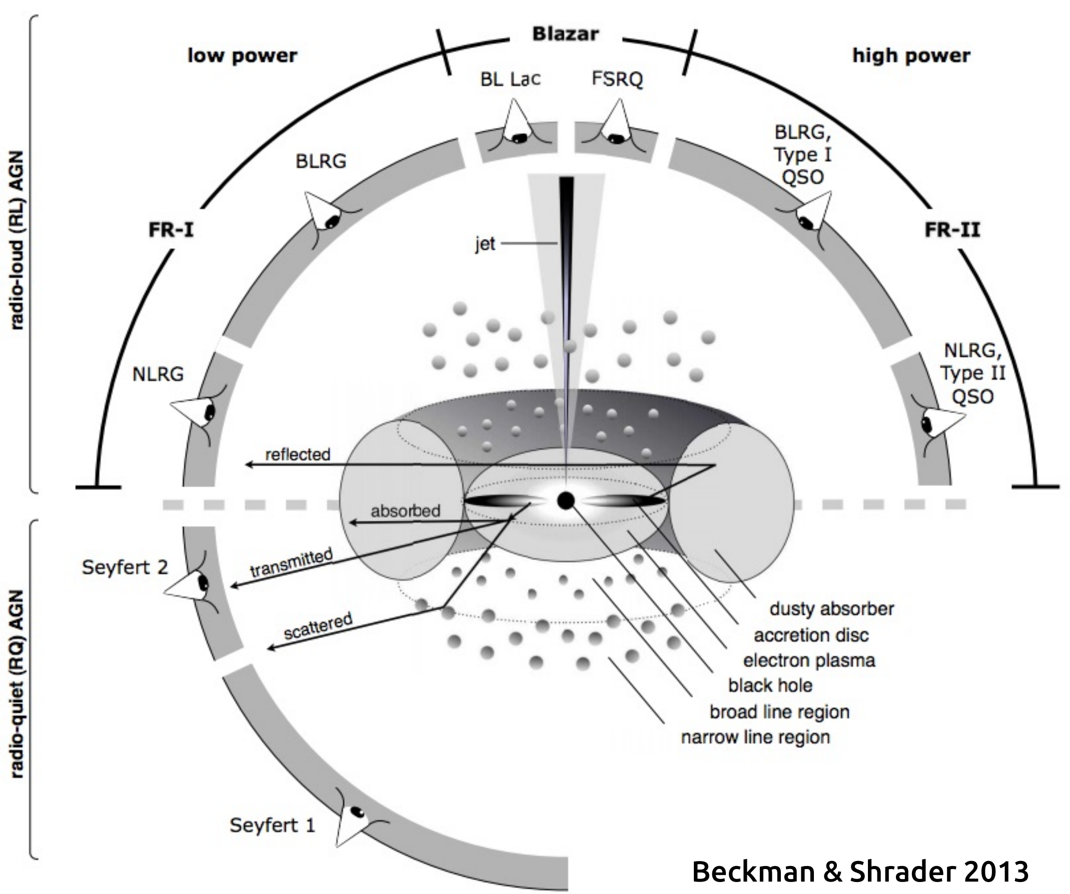
Based on the UM, two main classes of jetted AGN:

- Radio galaxies
- Blazars



Beckman & Shrader 2013

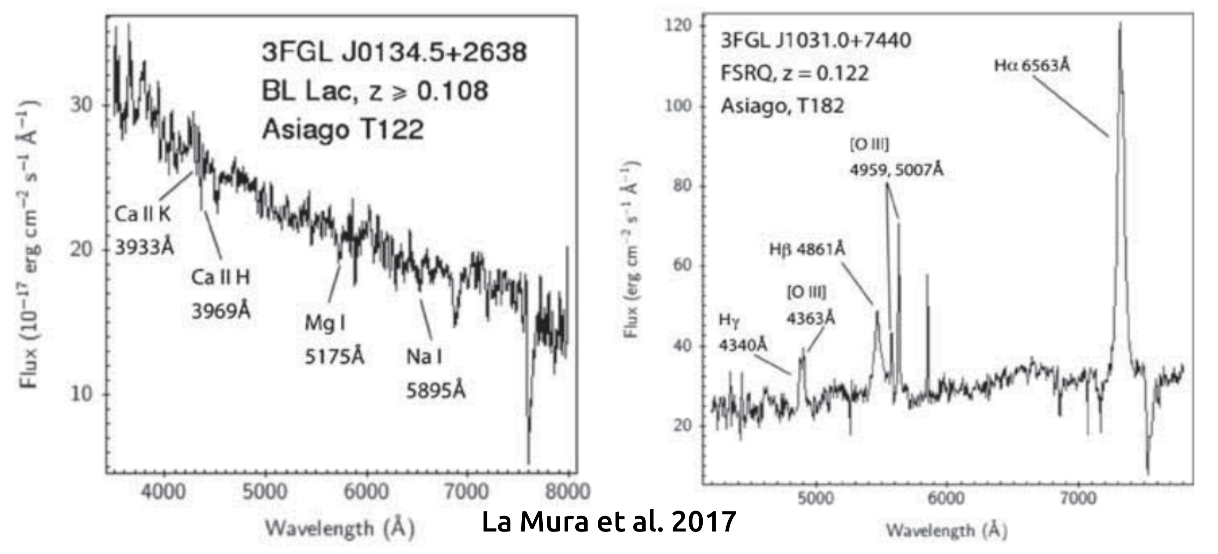
Blazars

The blazar classification is based on the optical spectrum:

- EW > 5 Å → FSRQ
- EW < 5 Å → BL Lac

FSRQs: efficient accretion, high-density circumnuclear environment

BL Lacs: inefficient accretion, low density circumnuclear environment



La Mura et al. 2017

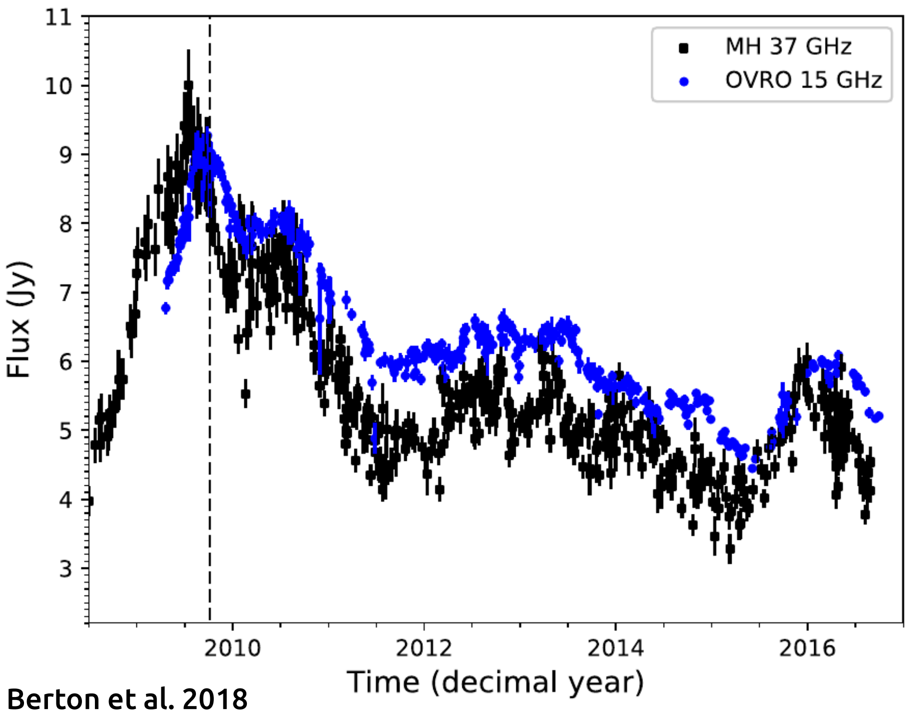
Blazars

Blazars are extremely variable sources

Flares occur at different times in different frequencies

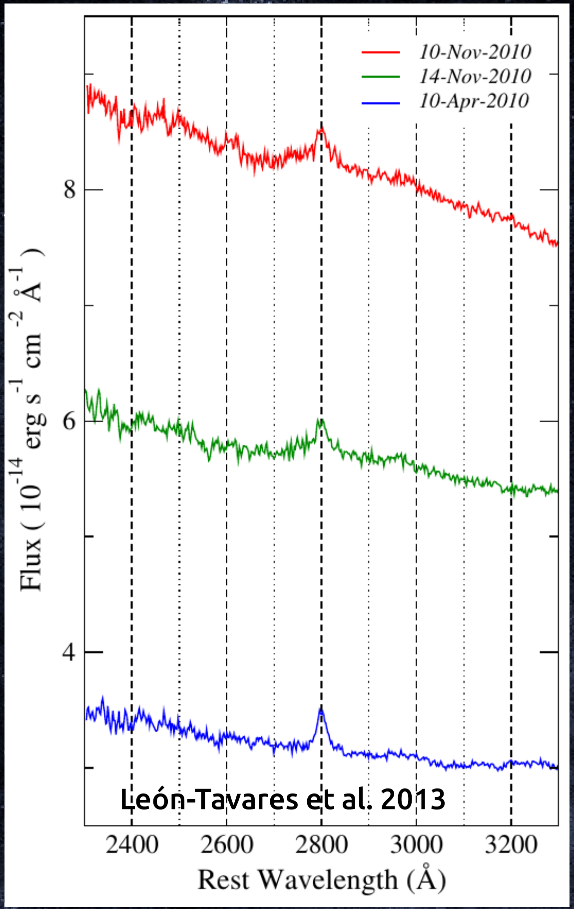
Possible origin: ejection of plasma blobs, standing shocks, jet/ISM interaction, etc. Where is the gamma-ray production zone?

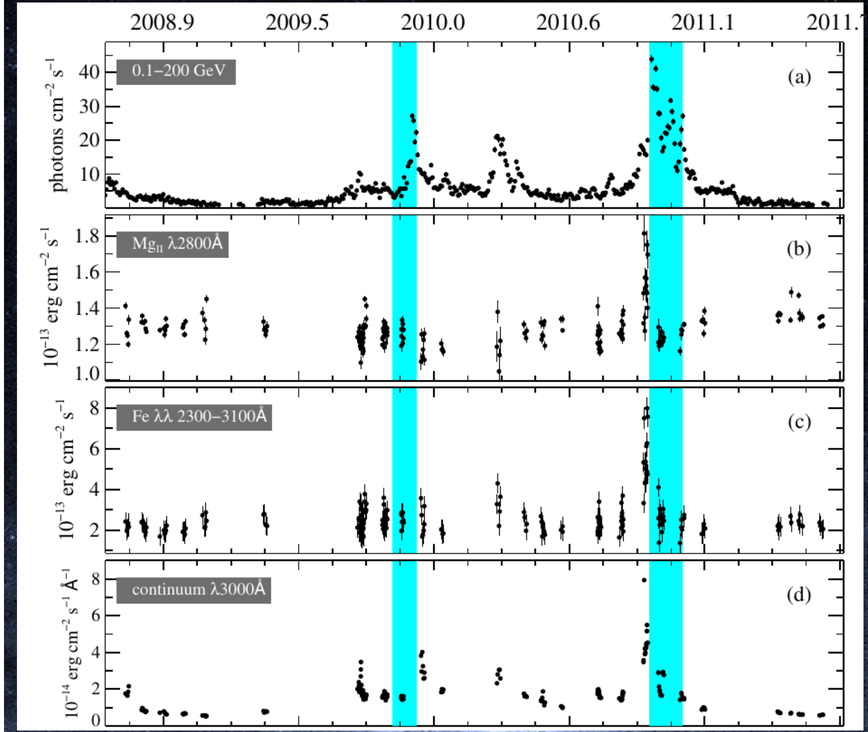
Spectroscopic observations *during* flares are rare



Berton et al. 2018

Emission lines in blazar flares: 3C 454.3



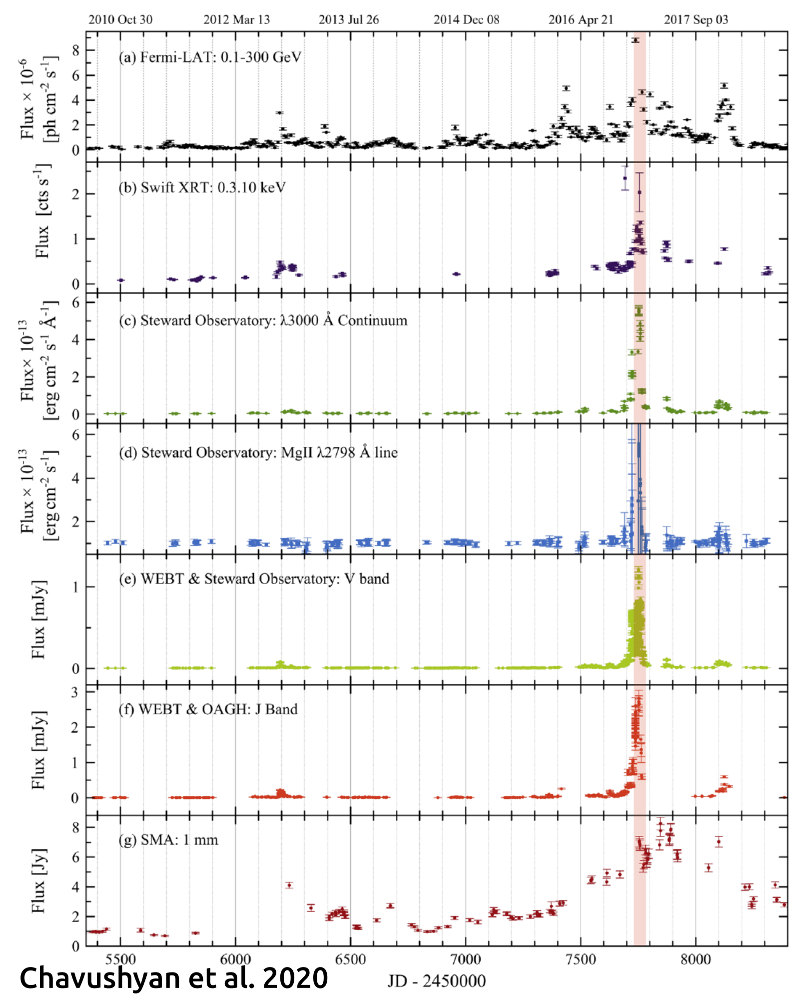


One of the few cases in the literature

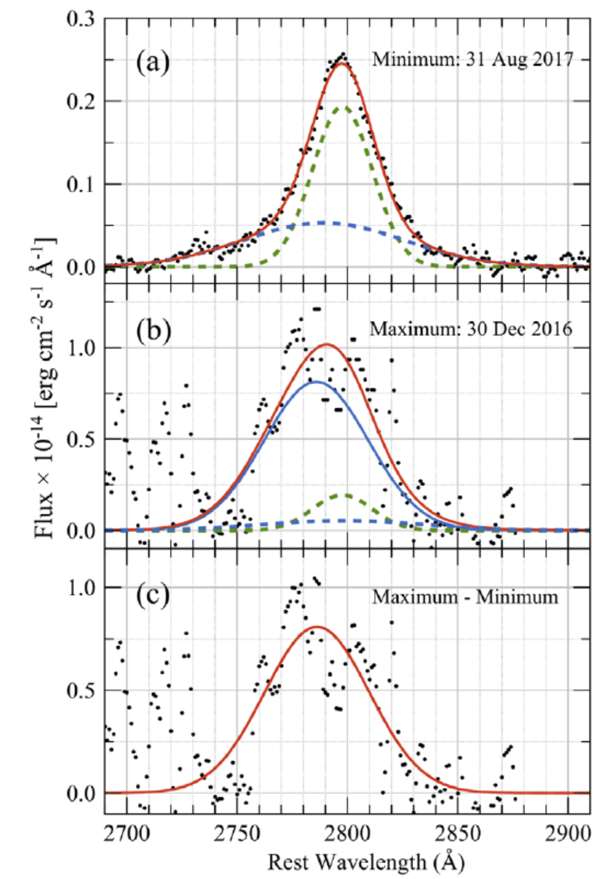
Highest level of Mg II corresponds to ejection of a superluminal component

BLR ionized by the non-thermal continuum!

Emission lines in blazar flares: CTA 102



Chavushyan et al. 2020



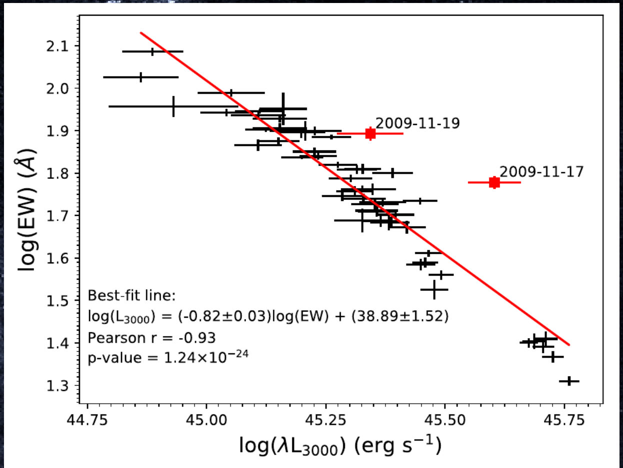
Similar behavior to 3C 454.3

Mg II line flux increases after a multiwavelength flare

This coincides with emission of a superluminal jet component

BLR ionized by the non-thermal continuum *and located 25 pc away from the nucleus!!*

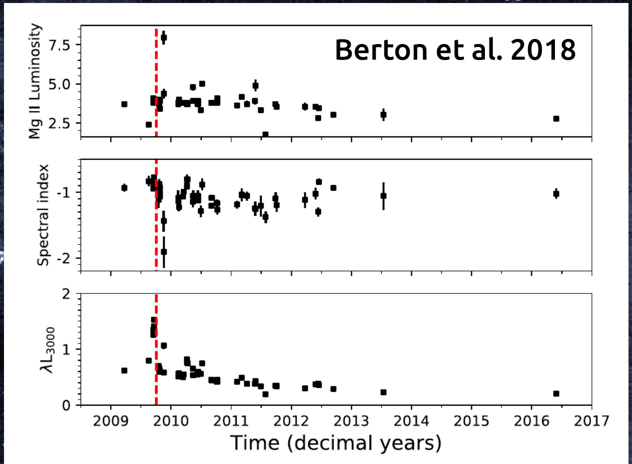
Emission lines in blazar flares: 3C 345

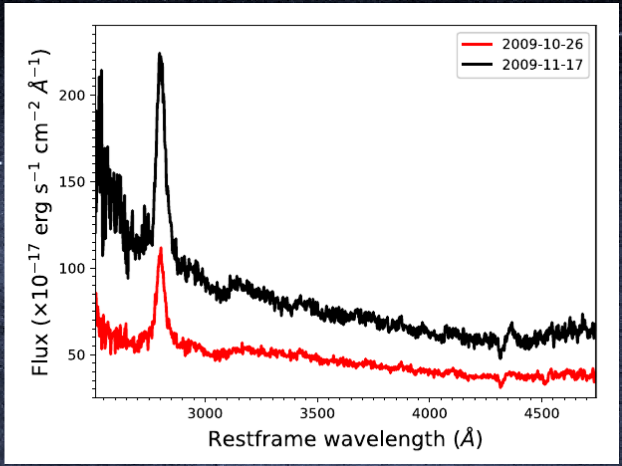


Mg II flaring once again

The only two points that do not obey to the L-EW anticorrelation were measured during the flare

From the measured lag, the production of gamma-rays occurred d < 0.02 pc from the BLR





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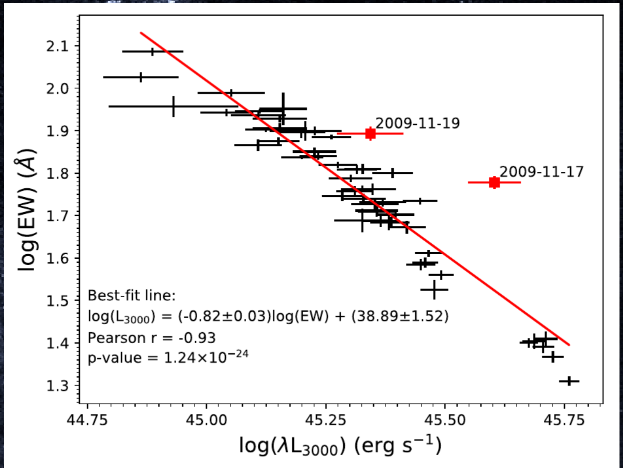

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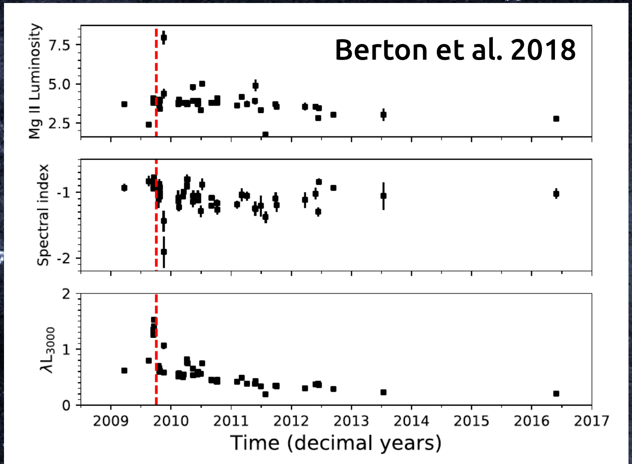
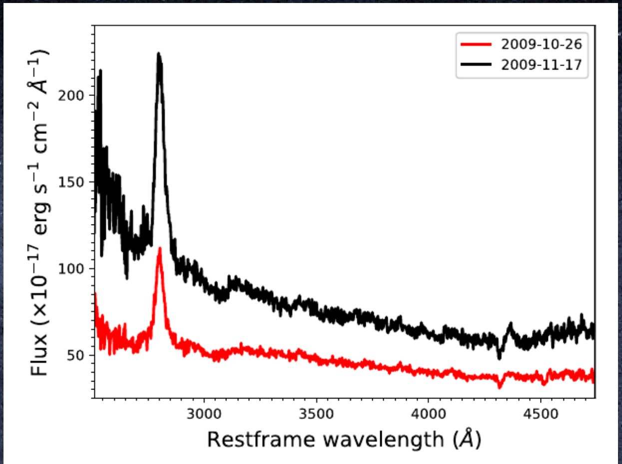




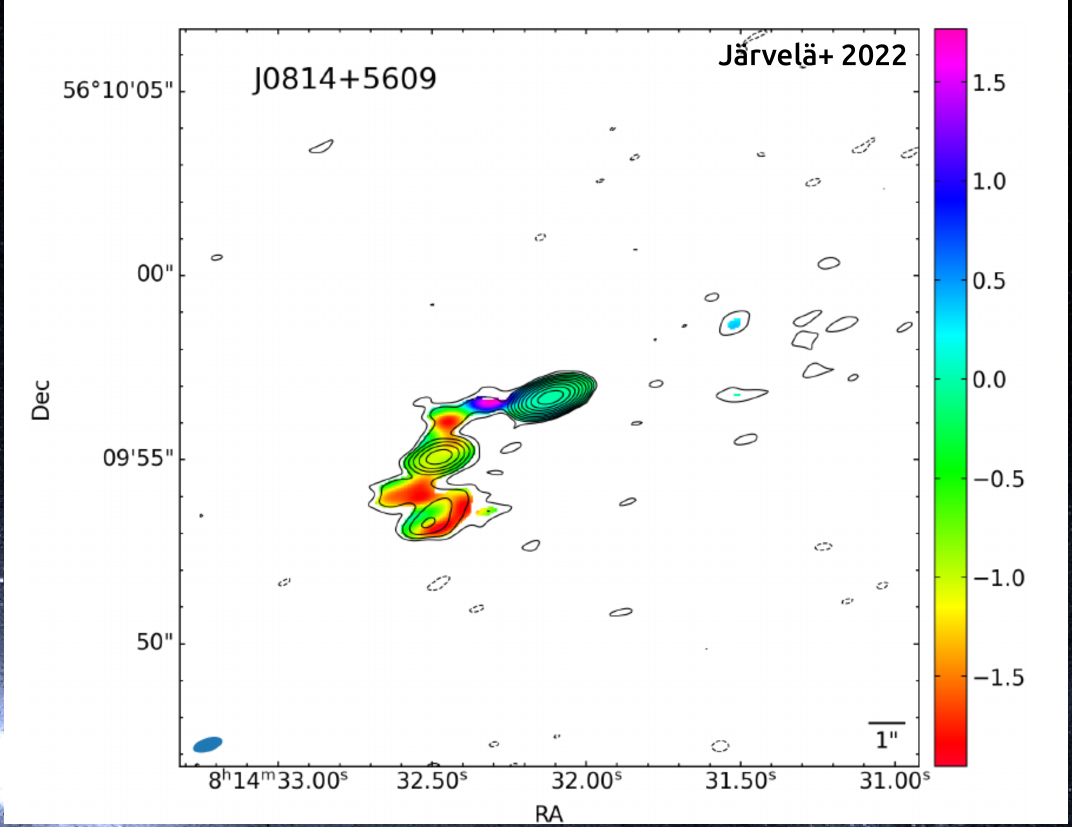
Spectroscopic follow-up of flaring FSRQs is important!!

The third class of blazars: NLS1s

1) low mass/high Eddington AGN
2) strong winds – outflows
3) relativistic jets and gamma-rays
4) radio lobes (or relics!)
5) circumnuclear star formation
6) (polar) dust

They are *complicated* sources (see Järvelä et al., 2022, A&A, 658, 12, to get a headache)

Jetted NLS1s were discovered in the early 2000s...



A special case: PKS 2004-447

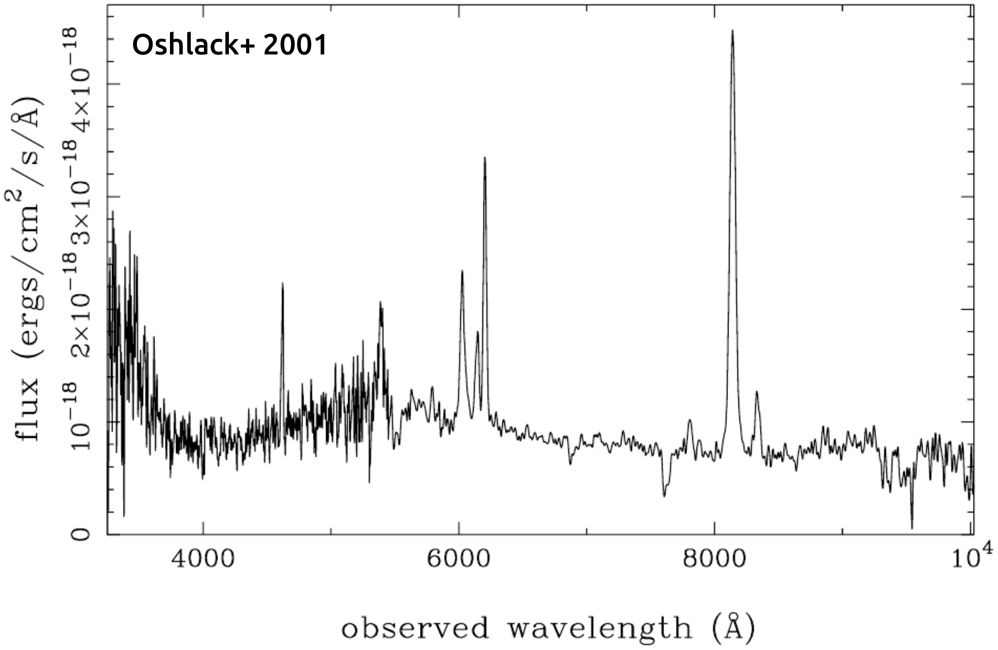


FIG. 2.—Low-resolution spectrum of PKS 2004−447 from RGO spectrograph on the AAT.

Identified as an NLS1s in an optical survey of radio-loud AGN

Original spectrum by Drinkwater+ 1997, analyzed by Oshlack+2001, but with an *error* on the y-axis

Very weak Fe II, some authors proposed NLRG or type 2 classification

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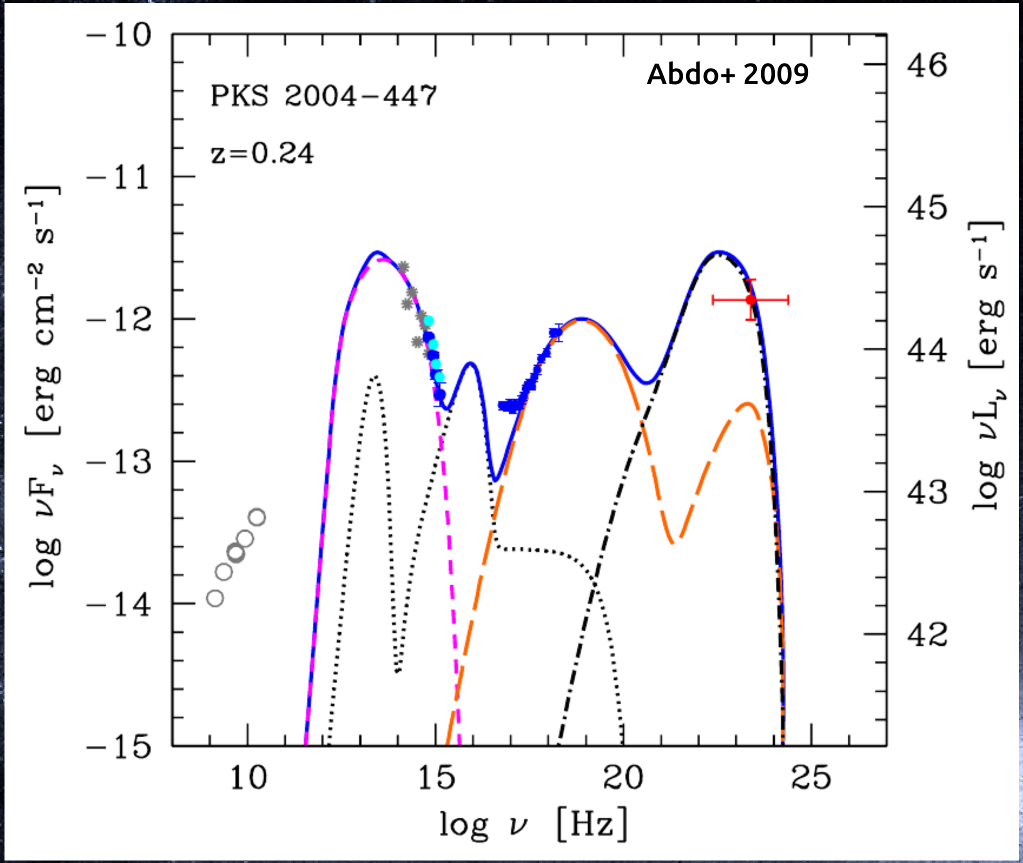

The source was detected in gamma-rays by Fermi

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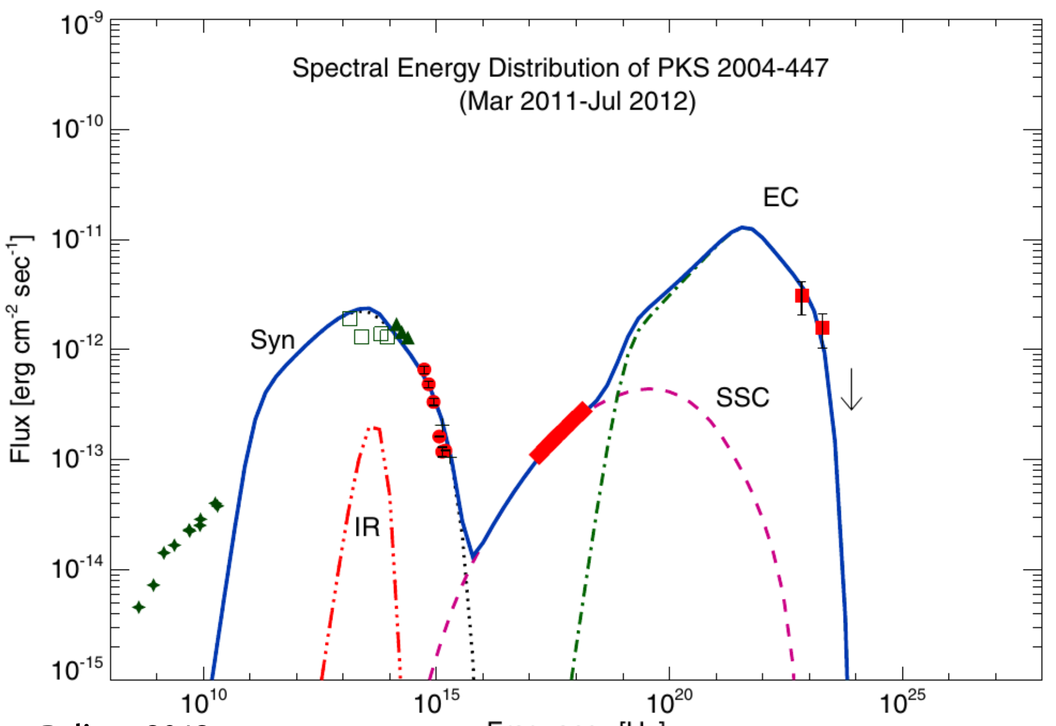

Paliya+ 2013

The source was detected in gamma-rays by Fermi

SED: typical of a low-power FSRQs, with the two humps

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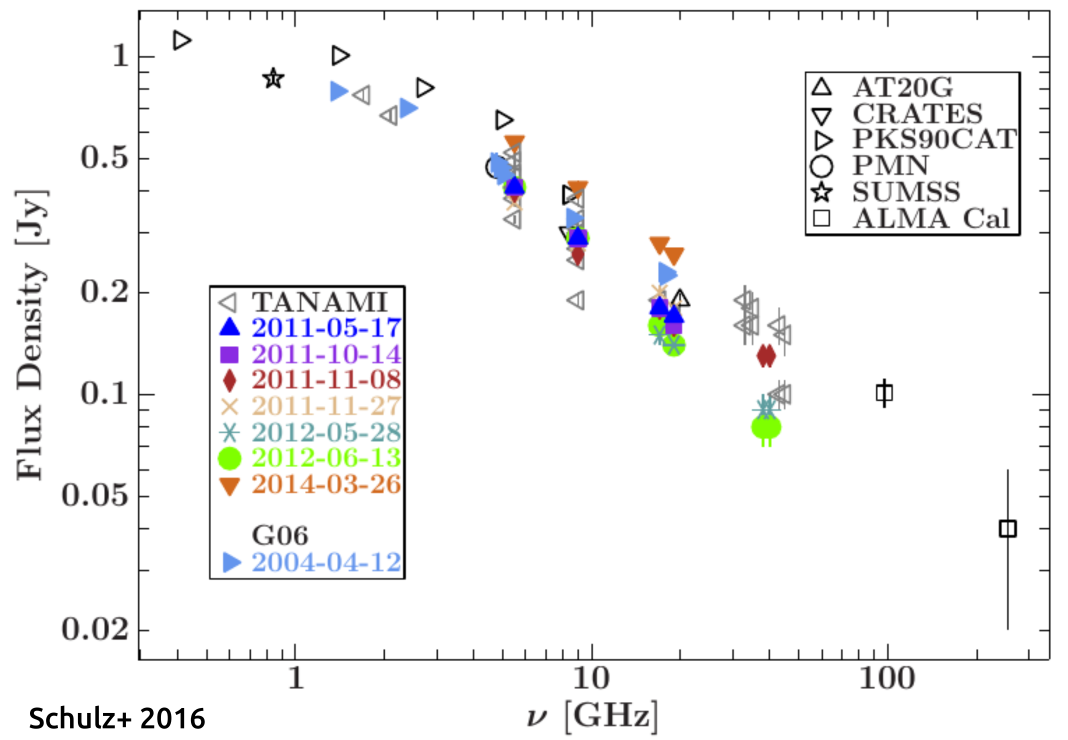

Schulz+ 2016

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Radio: typical of a compact steep-spectrum (CSS) source, i.e. young radio galaxy

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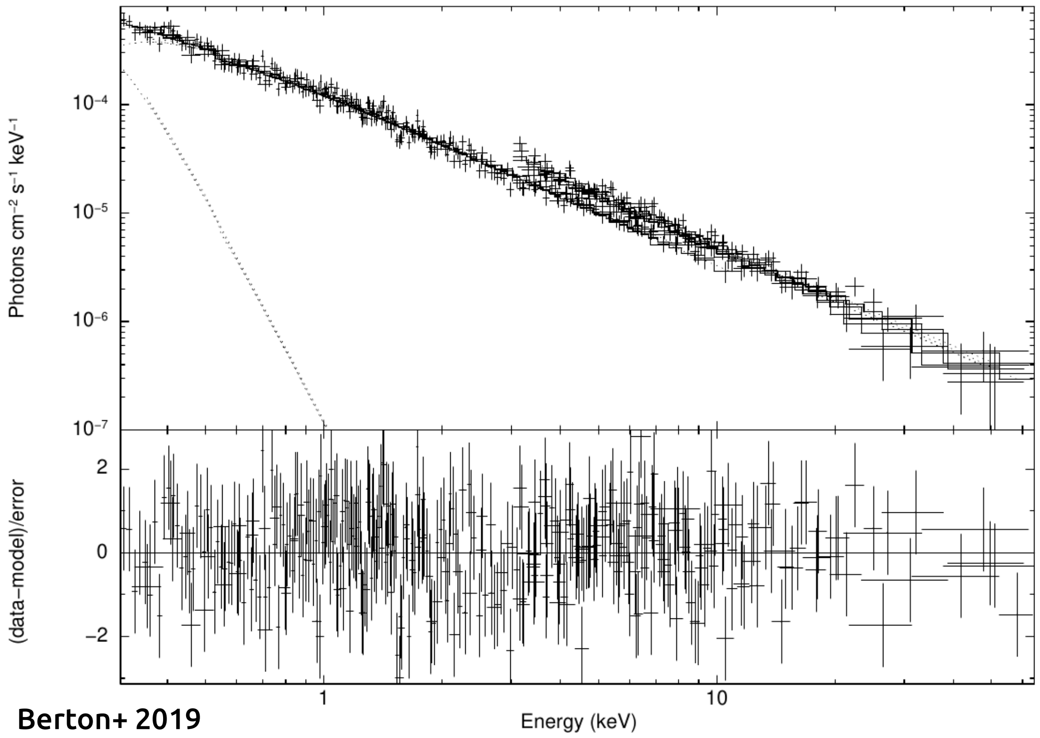

Berton+ 2019

The source was detected in gamma-rays by Fermi

SED: typical of a low-power FSRQs, with the two humps

Radio: typical of a compact steep-spectrum (CSS) source, i.e. young radio galaxy

X-rays: power law, jet dominated. In low state, soft excess emerges.

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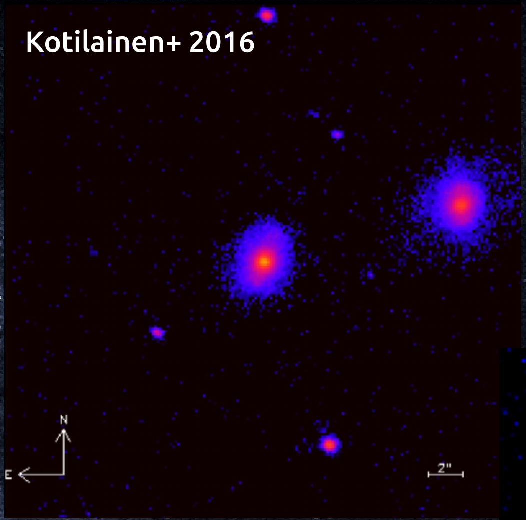
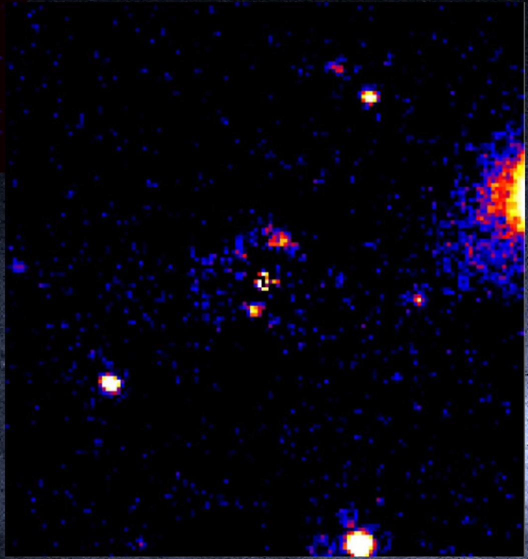




Black hole mass in four ways:

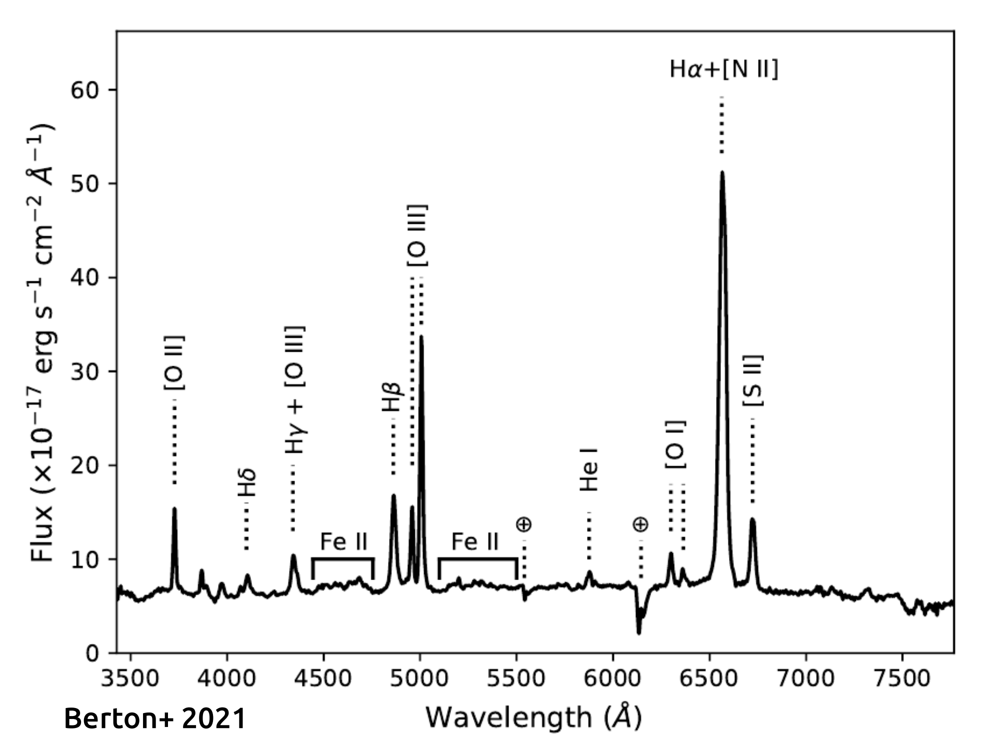
1) Foschini+ 2015: low quality spectrum, $7x10^7$ Msun

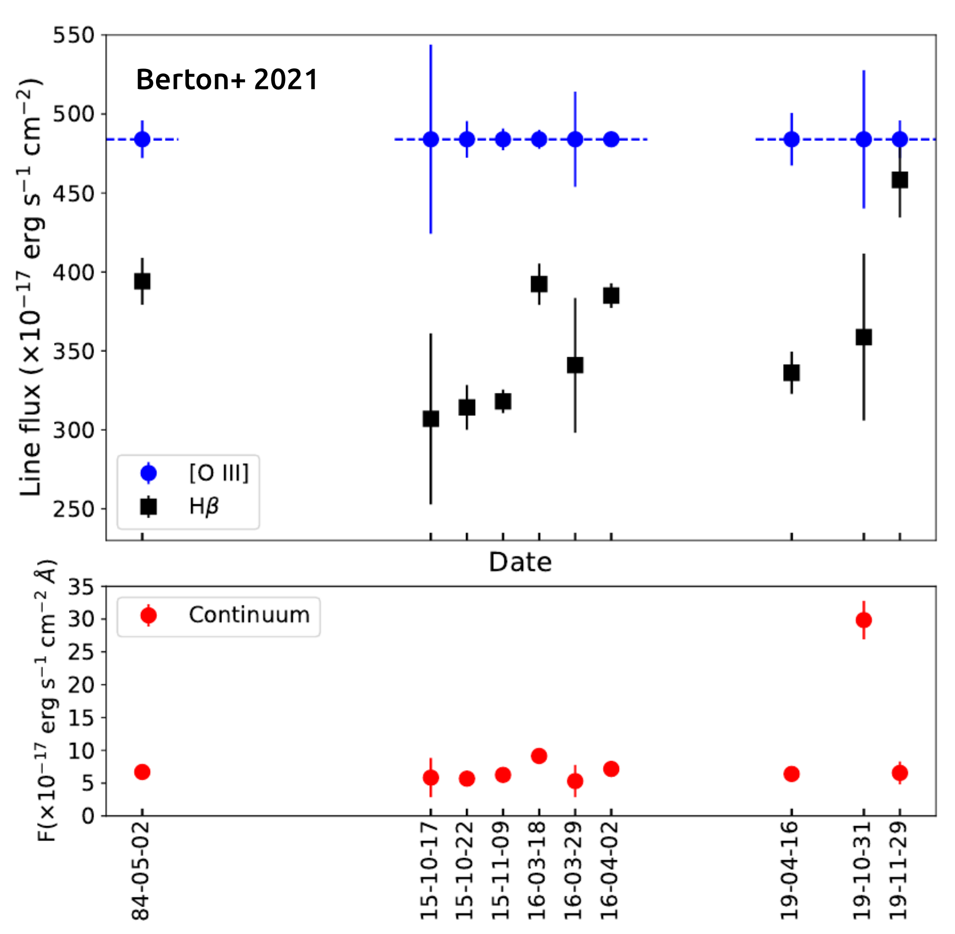
2) Kotilainen+ 2016: spiral host galaxy, K-band bulge luminosity $9x10^7$ Msun

3) Baldi+ 2016: spectropolarimetry of Hα, $6x10^8$ Msun

4) Berton+ 2021: high-quality spectra and Hβ, $1.5x10^7$ Msun

A special case: PKS 2004-447





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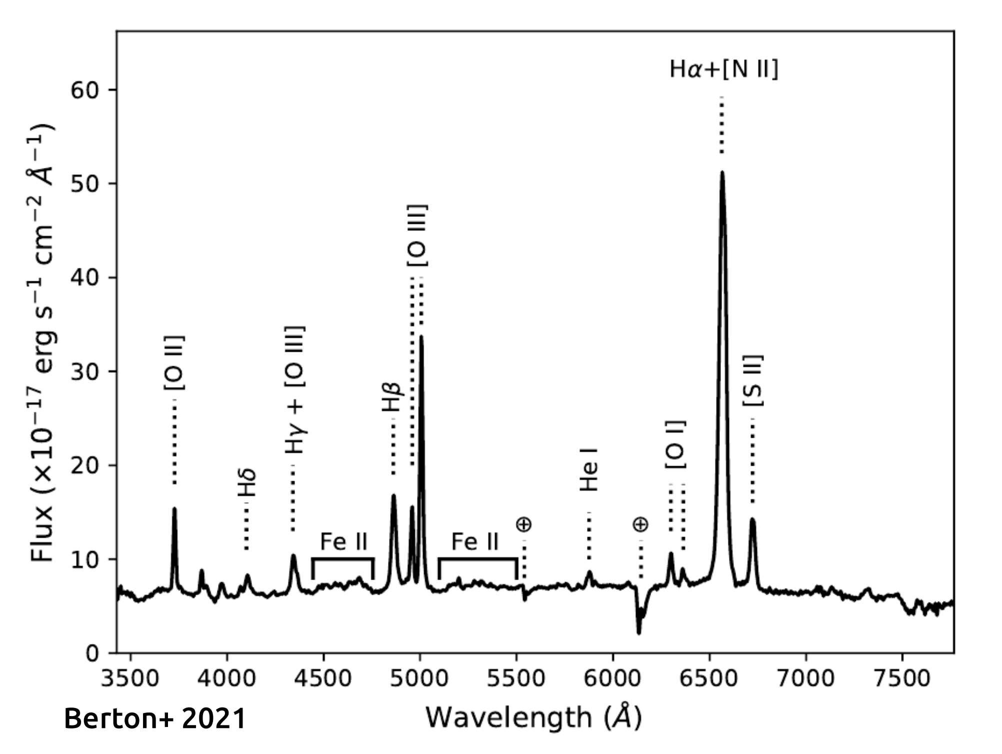
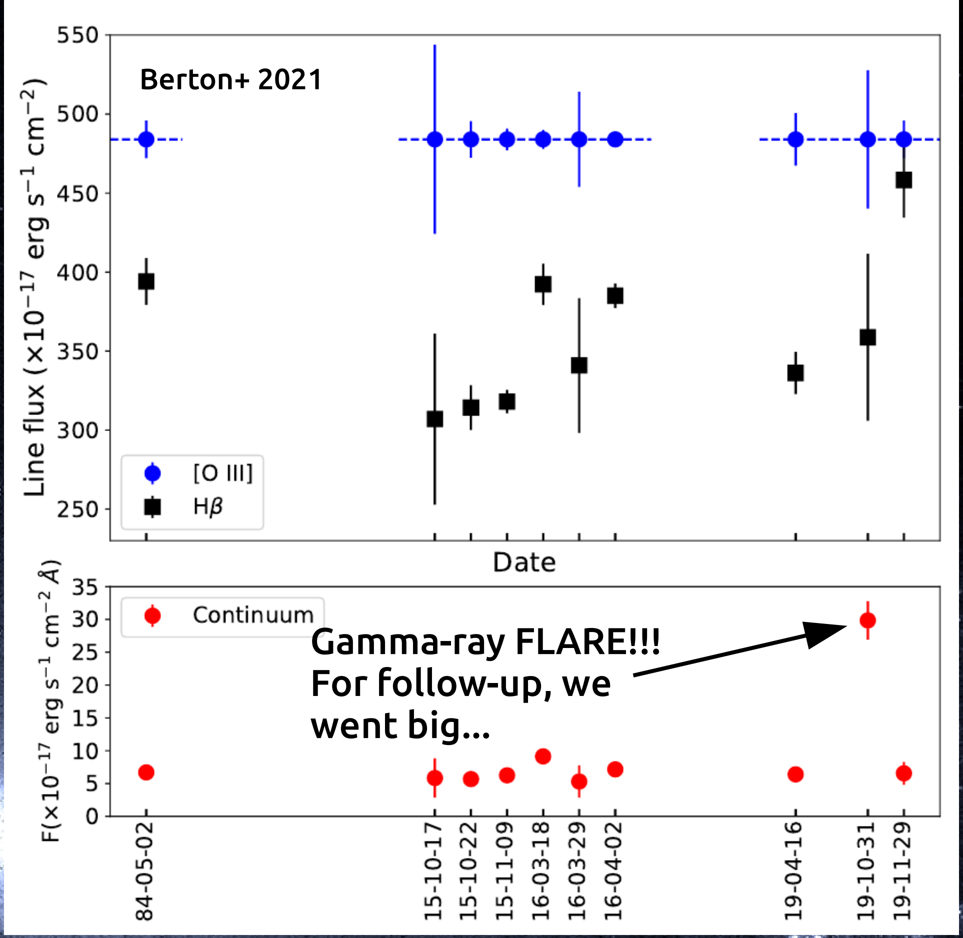
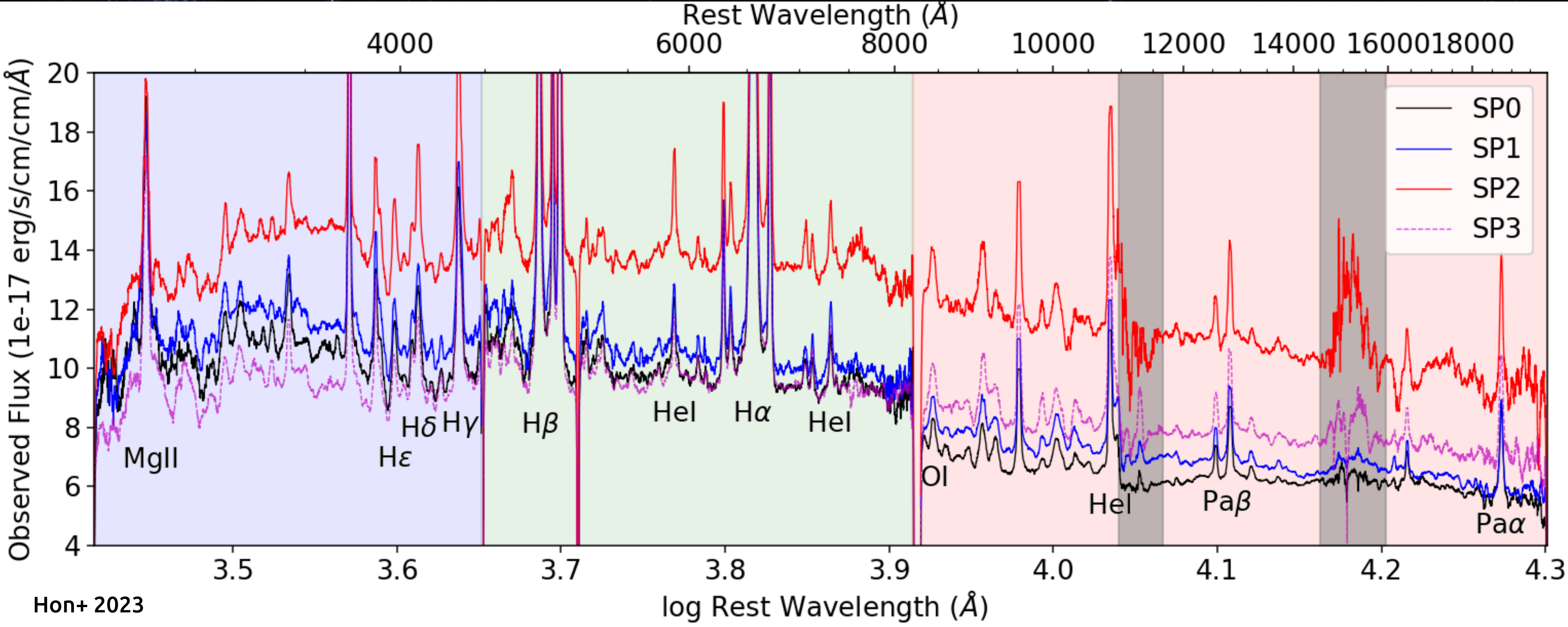




PKS 2004-447 with X-SHOOTER



Hon+ 2023

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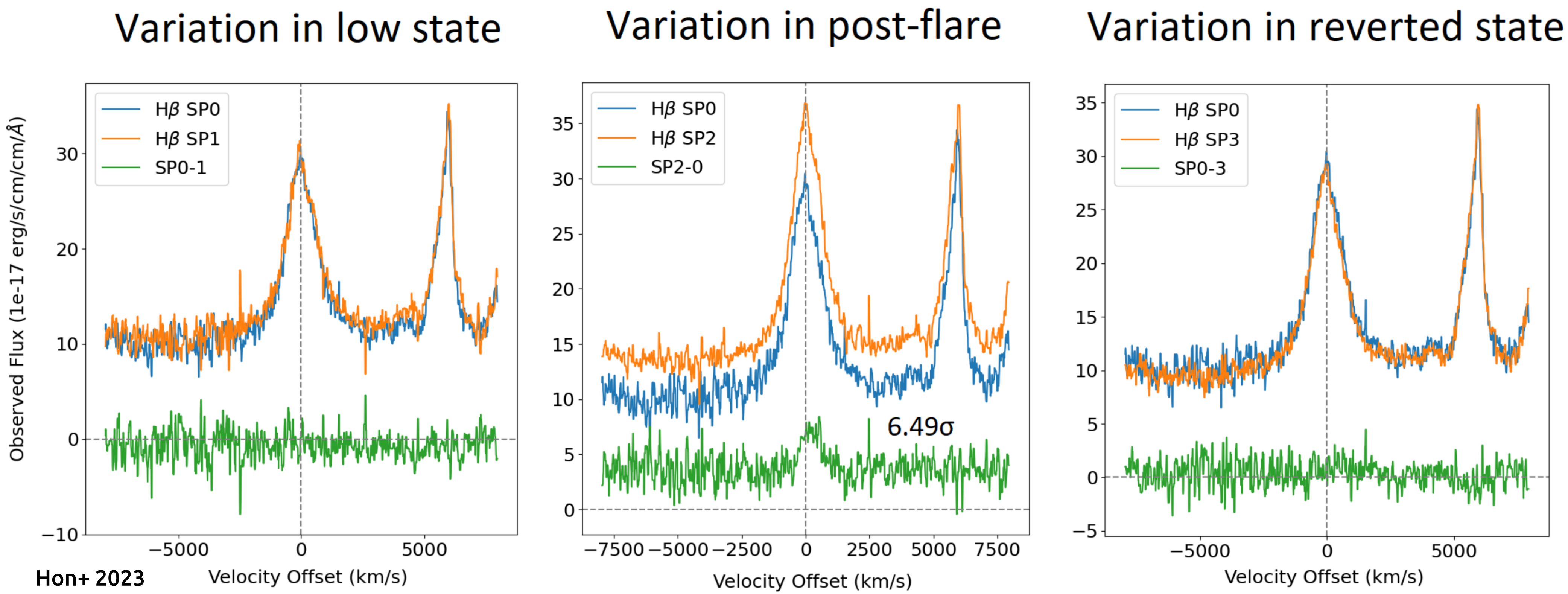

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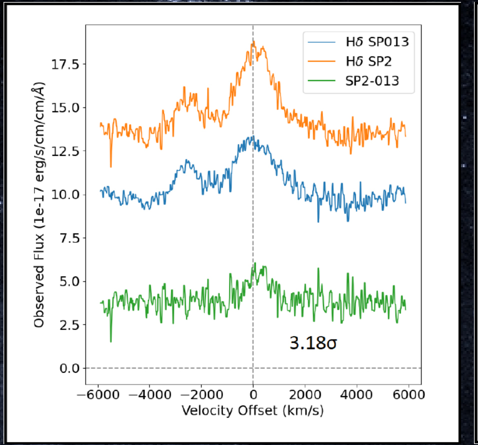
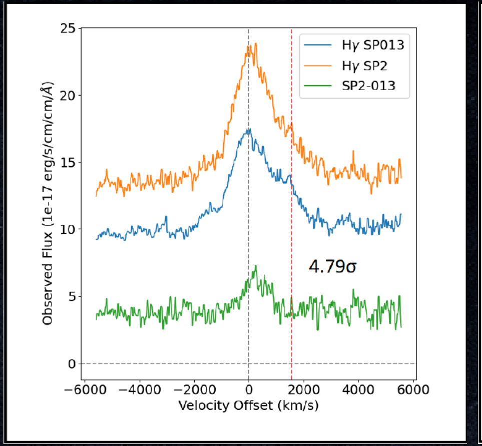
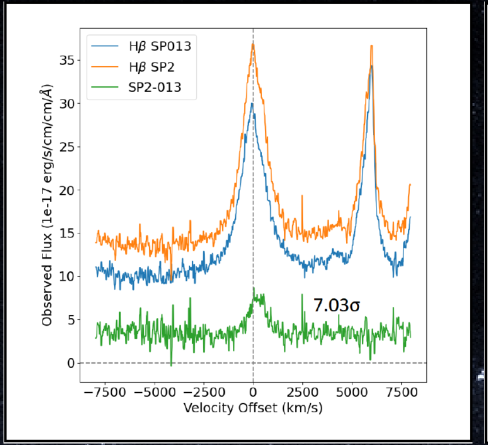
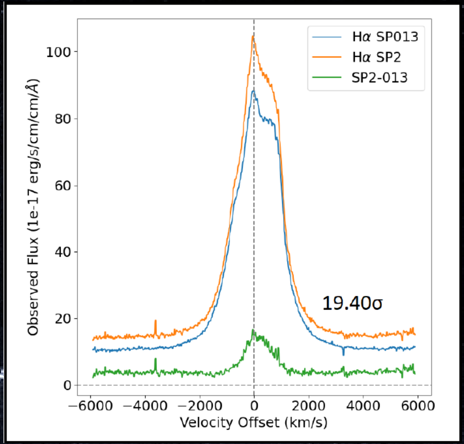
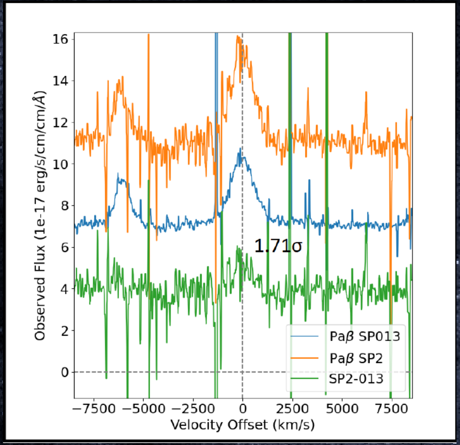
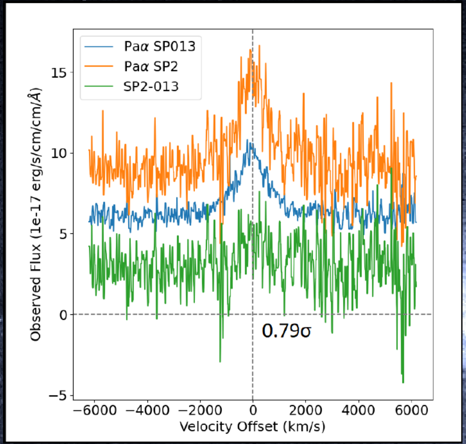


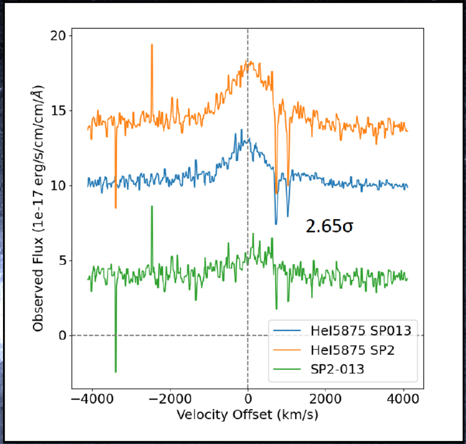








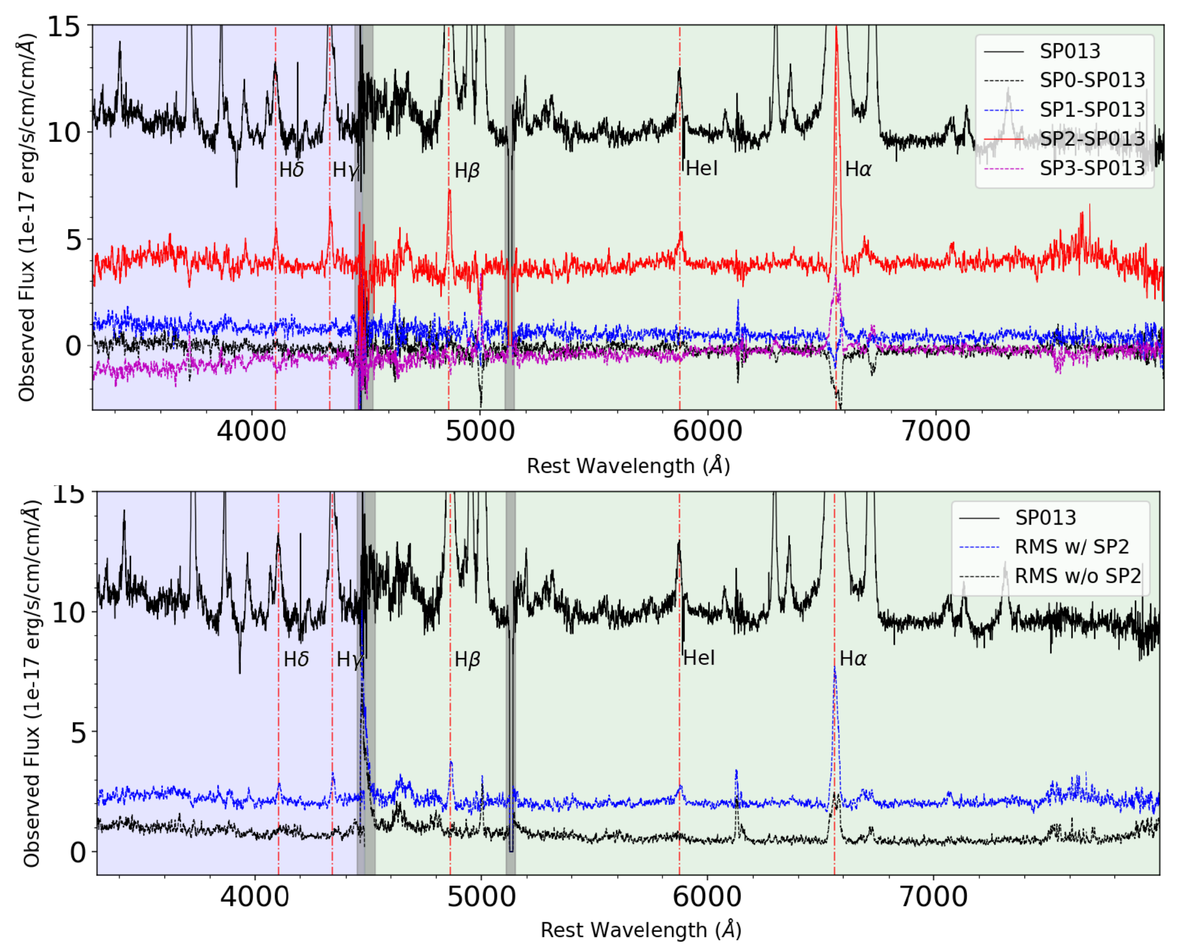




Excess in all permitted lines

Different lines have different velocities

PKS 2004-447 with X-SHOOTER



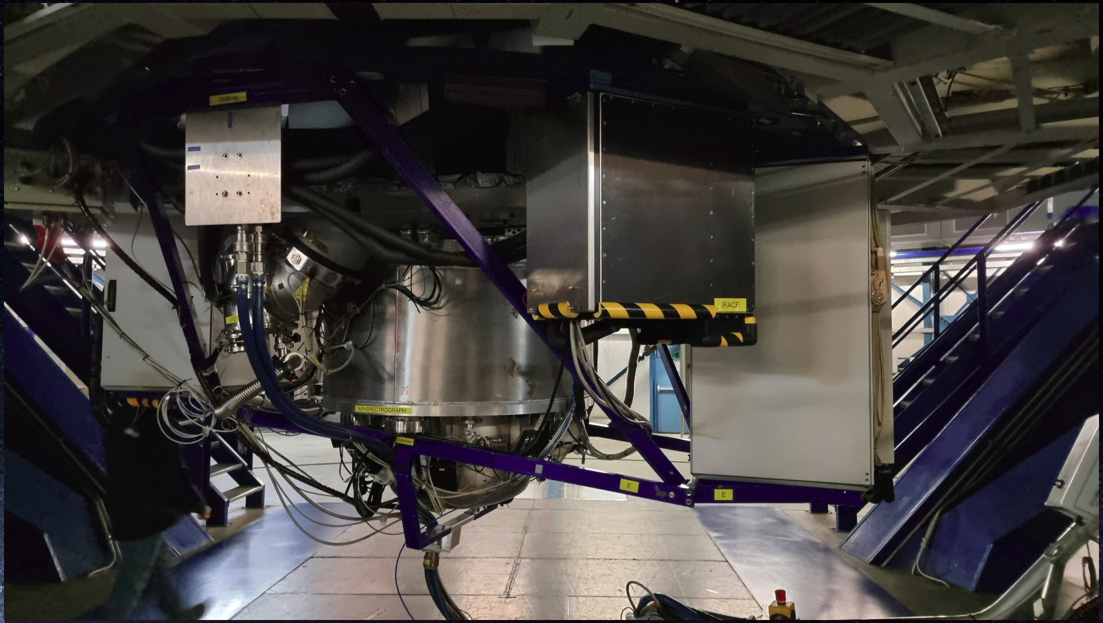
Difference in velocity between H lines and He I lines suggests stratification

Excess redshifted in the Balmer lines, not redshifted in Paschen lines: bipolar outflow?

Does the change in the accretion disk lead to both the gamma-ray flare (jet) and the formation of the excess (BLR)?

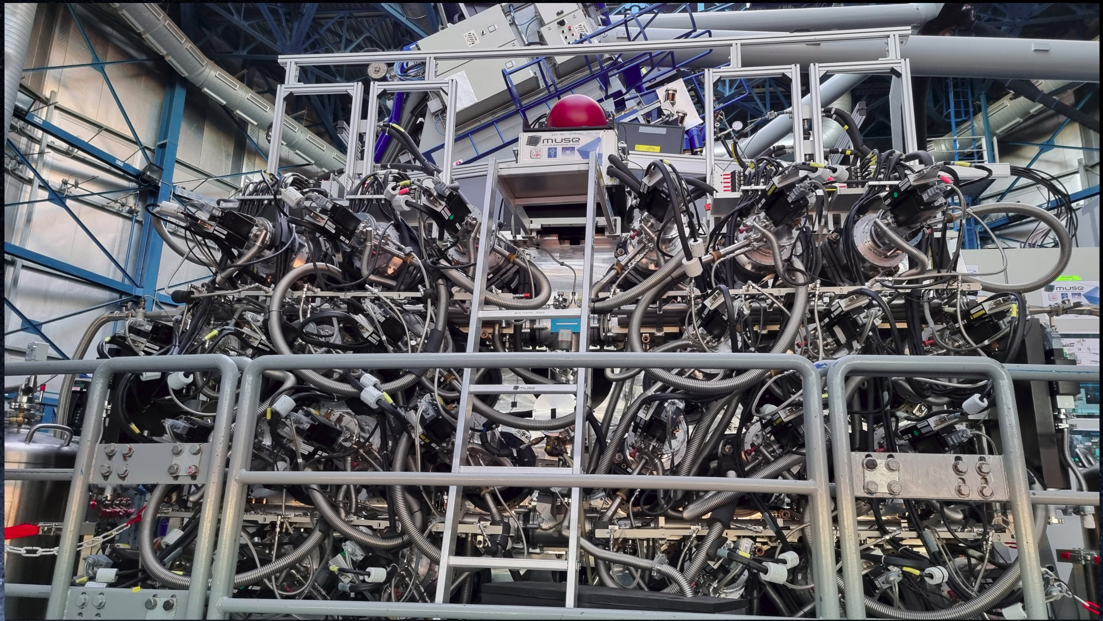
Conclusions

- Flares in jetted AGN can produce an excess in the emission lines
- A few bright FSRQs showed enhanced Mg II flux, but the other lines were not studied
- X-SHOOTER spectroscopy of a gamma-NLS1 revealed the formation of an excess in all the emission lines
- High-resolution spectroscopy is needed to follow-up flares!



X-SHOOTER is needed! And also...

Conclusions



...MUSE spectra are coming!