Why should CSS/GPS people care about narrow-line Seyfert 1 galaxies?

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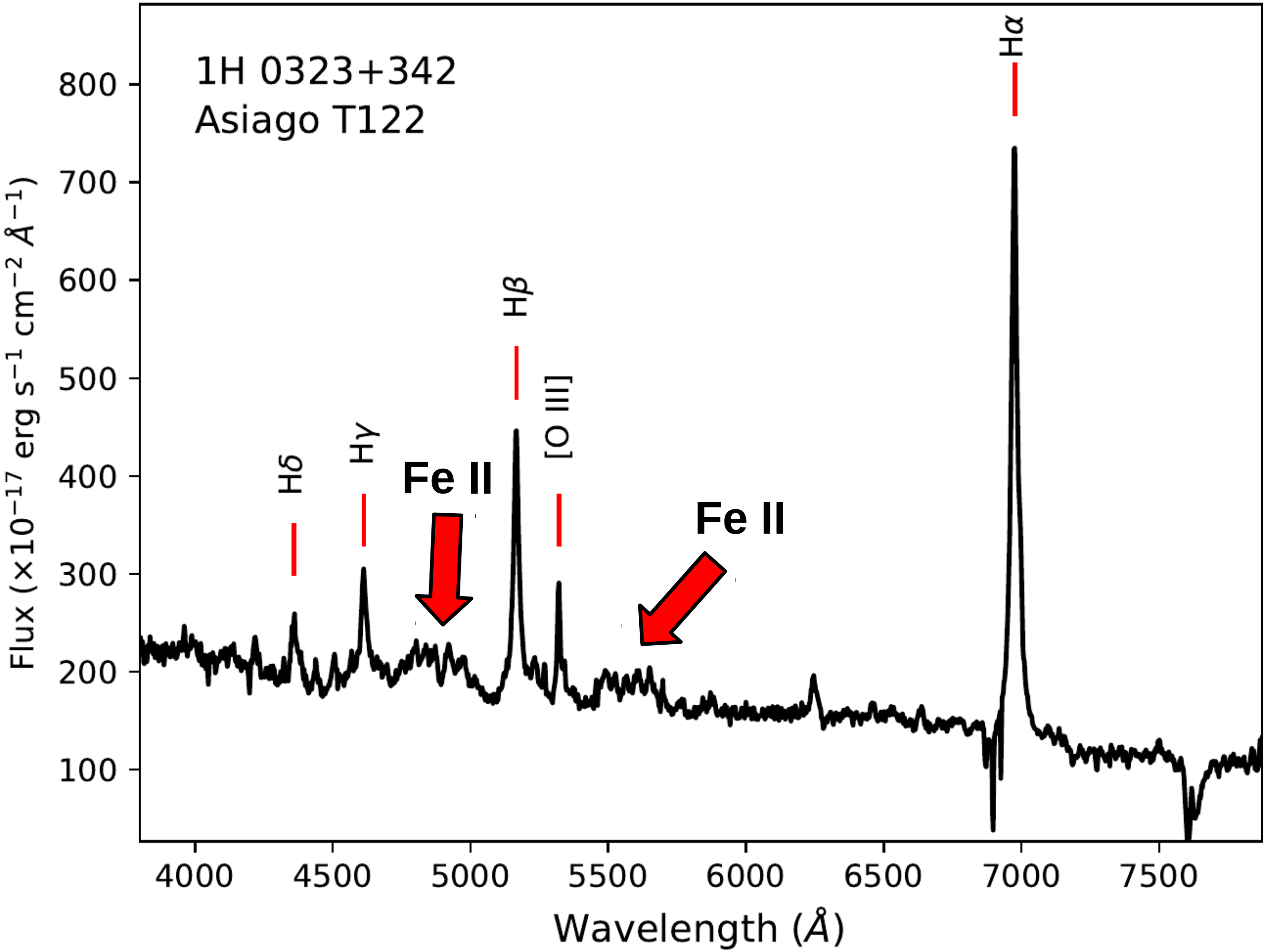
Narrow-line Seyfert 1



FWHM(Hβ) < 2000 km/s

[O III]/Hβ < 3

Strong Fe II multiplets

They may be low-mass/high-Eddington sources

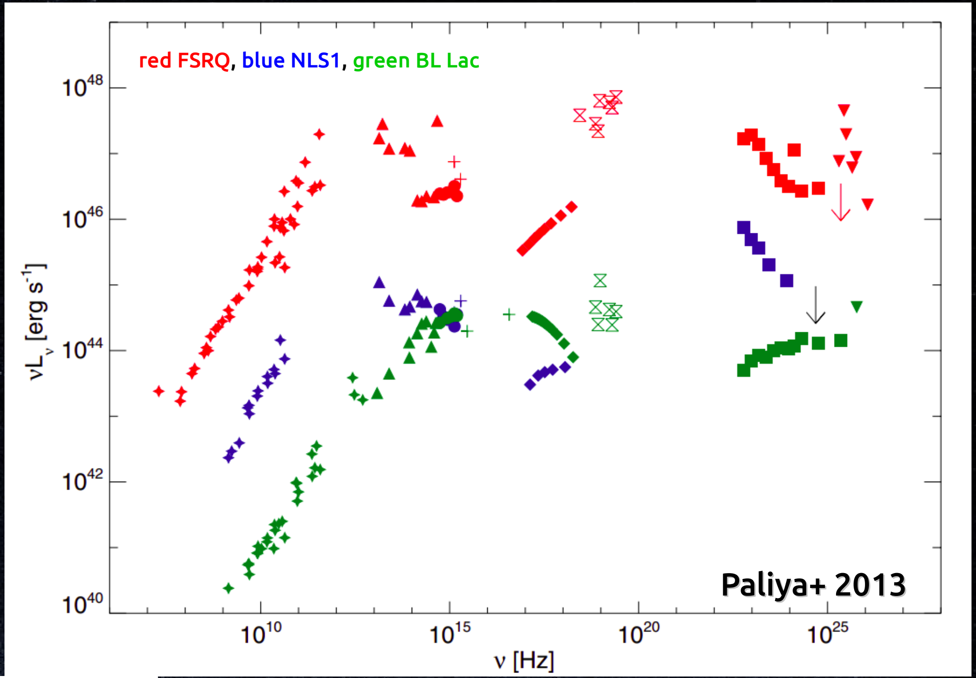
Progenitors of BLS1s?

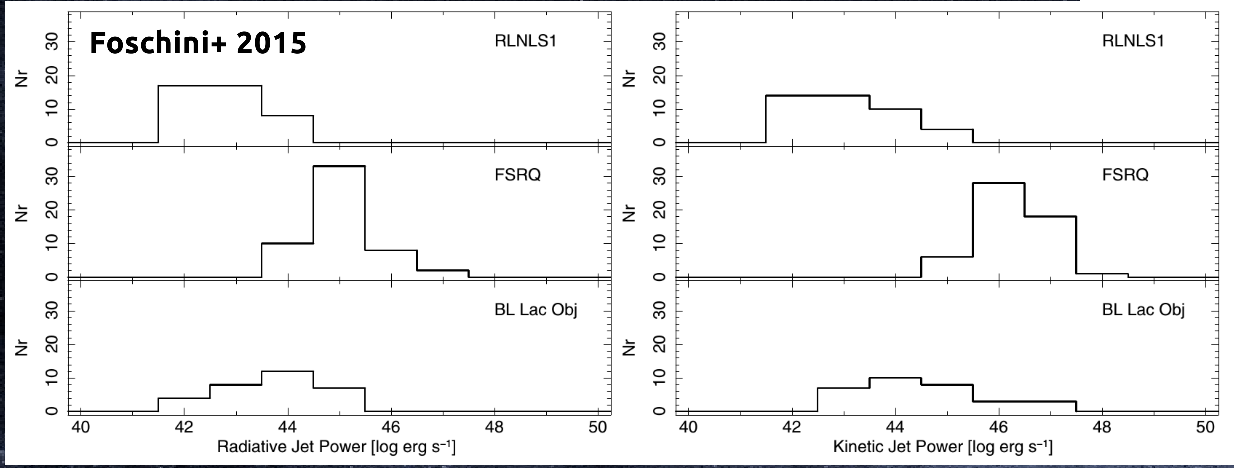
Jetted NLS1s

Identified as a third class of gamma-ray blazars beside FSRQs and BL Lacs.

Their SED is similar to that of FRSQs, but with lower power.

Jet power scales with the black hole mass (Heinz & Sunyaev 2003).





What is the parent population of gamma-ray emitting sources?

Jetted NLS1s vs CSS

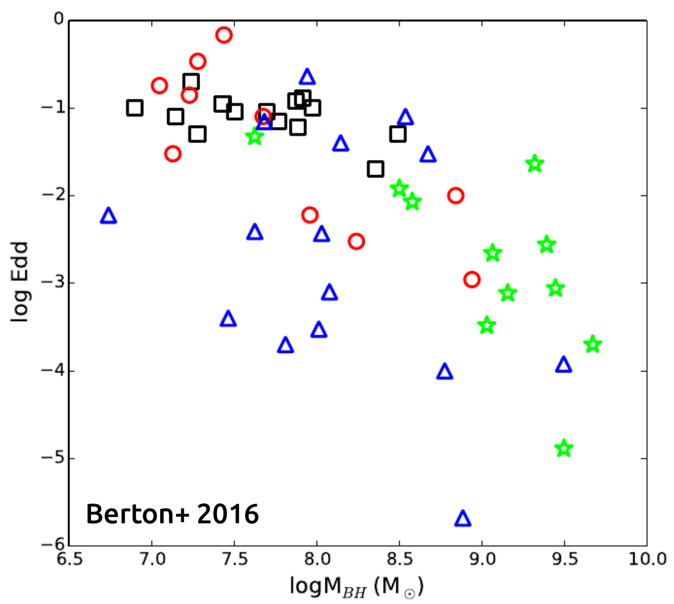


Fig. 1. Logarithm of the BH mass vs. logarithm of the Eddington ratio. Black squares indicate F-NLS1s, red circles indicate CSS/HERGs, blue triangles indicate disk-hosted radio-galaxies and green stars indicate elliptical-hosted radio galaxies. The points of these last two samples are derived from Berton et al. (2015).

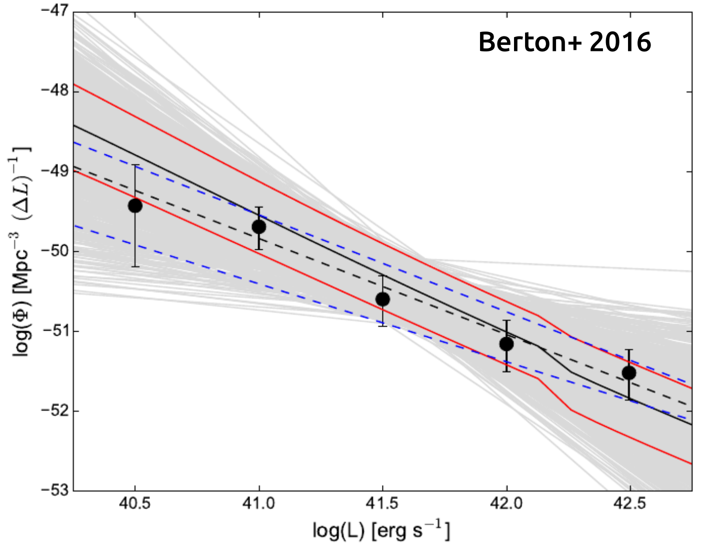


Fig. 5. HERGs LF with relativistic beaming added for bulk Lorentz factor Γ = 10 and ratio f = 1. Black solid line indicates the model; red solid lines indicate the maximum and minimum values for the model. Black circles show F-NLS1s data, black dashed line shows the F-NLS1s LF best-fit, and blue dashed lines indicate the maximum and minimum values for F-NLS1s LF. The light gray lines denote the simulated LFs for F-NLS1s.

NLS1s may be linked with some particular classes of CSS, especially those with the lowest luminosity and HERG classification.

N.B. not all NLS1s are CSS, not all CSS are NLS1s!

A new unified model?

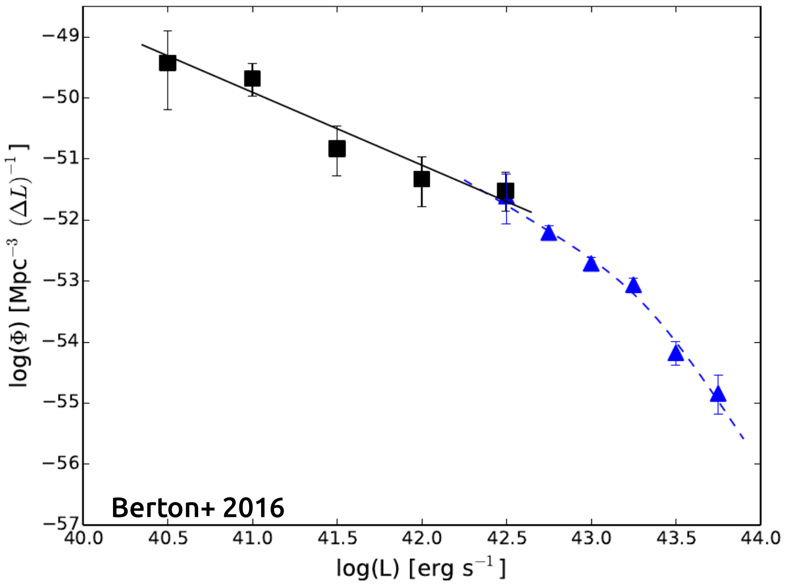
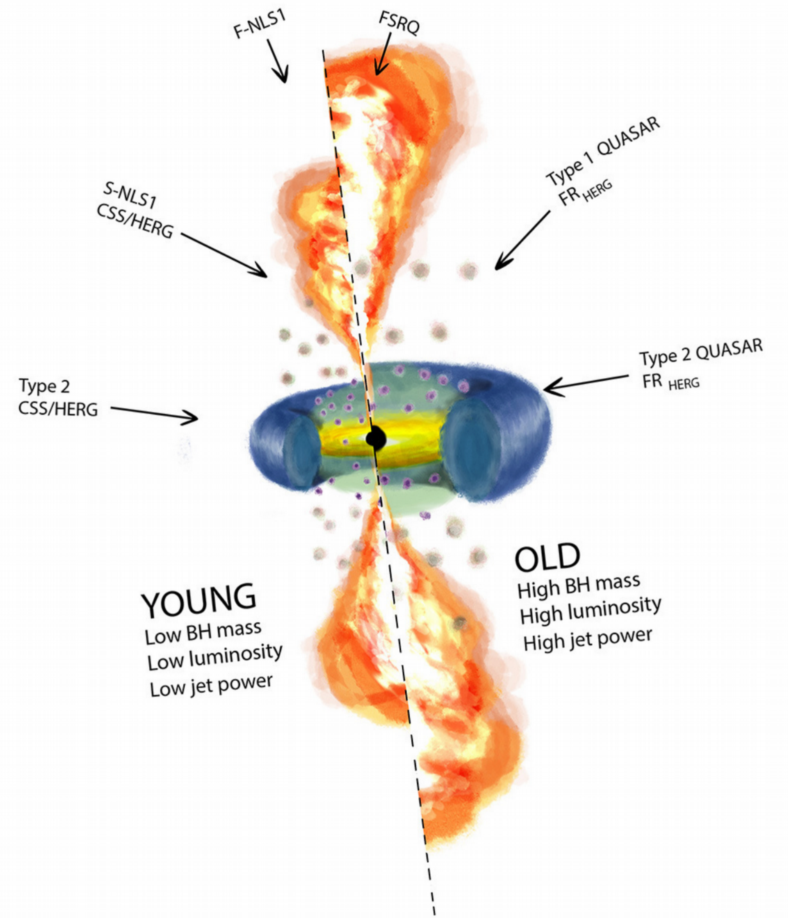


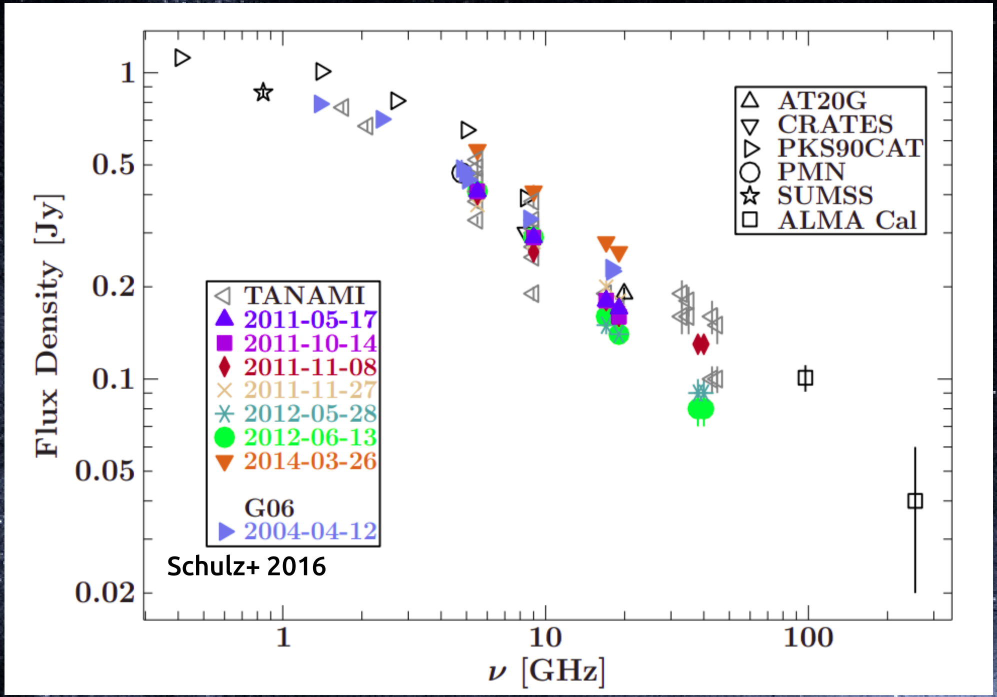
Fig. 4. Monochromatic radio luminosity functions of F-NLS1s and FSRQs at 1.4 GHz. The black squares indicate the F-NLS1s data points, the blue triangles indicate the FSRQs data points. The blue dashed line represents the broken power law best fit for FSRQs, and the black solid line represents the single power law that is best fit for F-NLS1s.

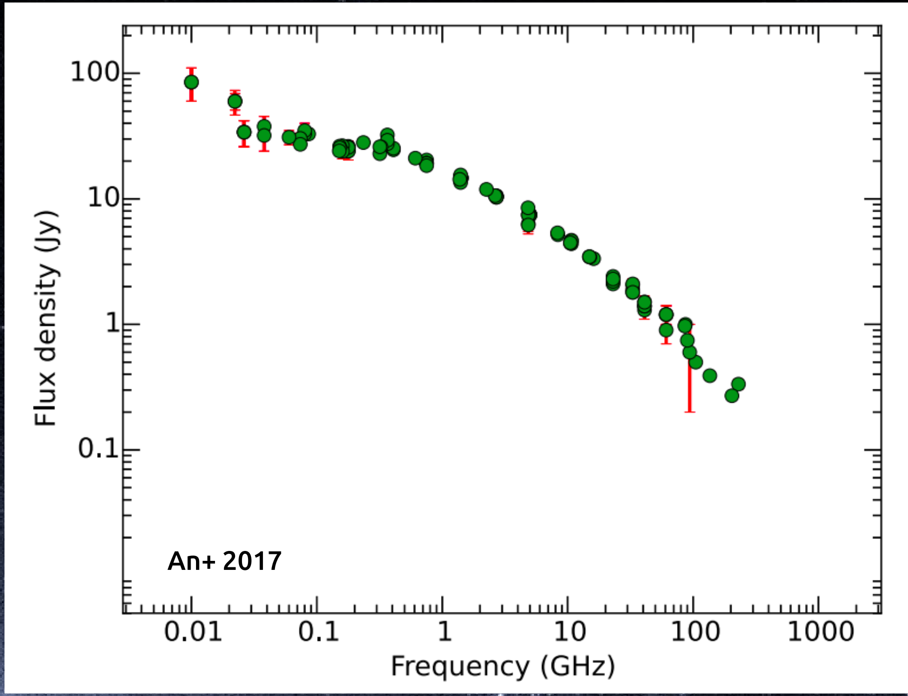


Berton+ 2017

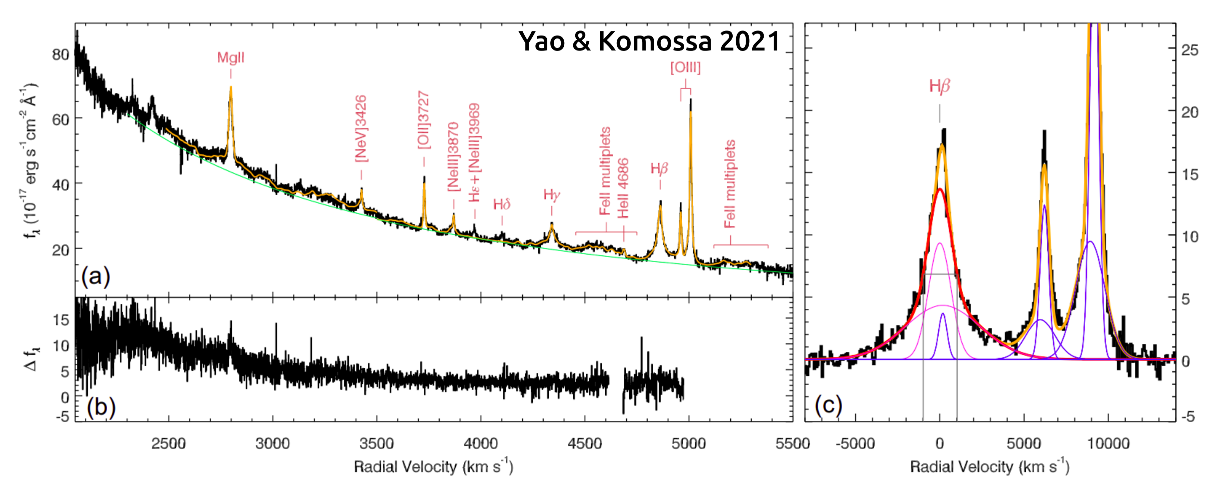
FIGURE 3 | Unification scheme of jetted-AGN with high accretion rate with respect to the Eddington limit and a high-density photon-rich environment. On the left side, young and smaller sources (NLS1s and CSS sources), compared to older and larger objects (FSRQs and FR_{HERG}).

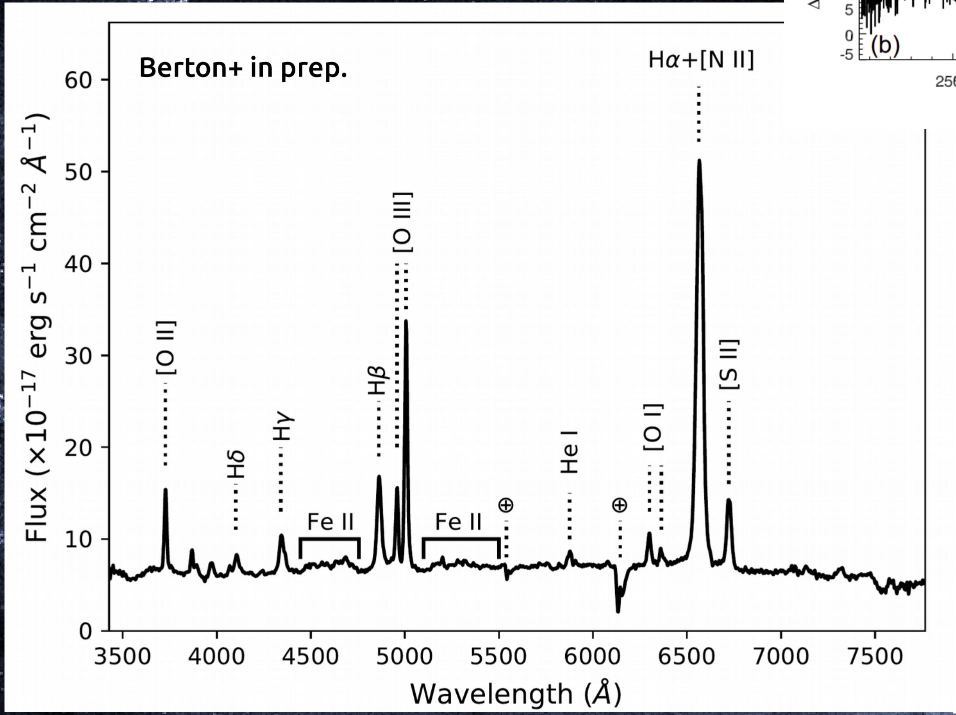
Some examples of this unification exist...

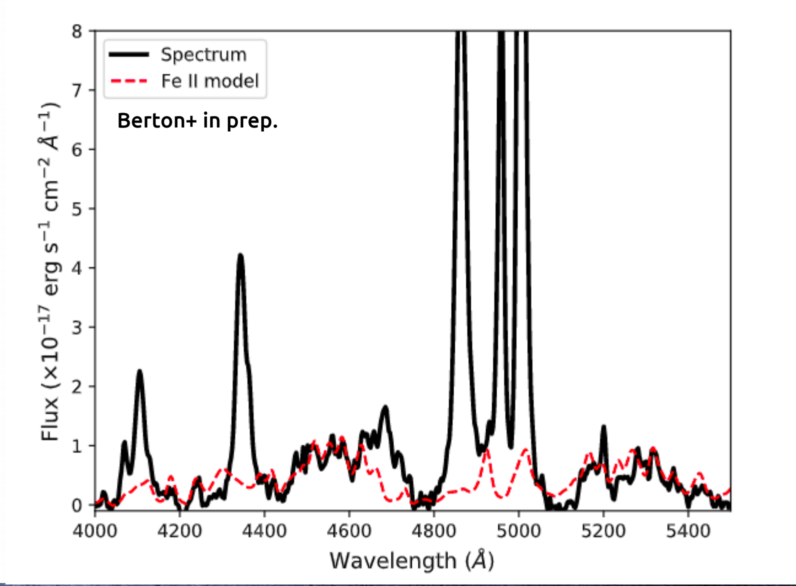




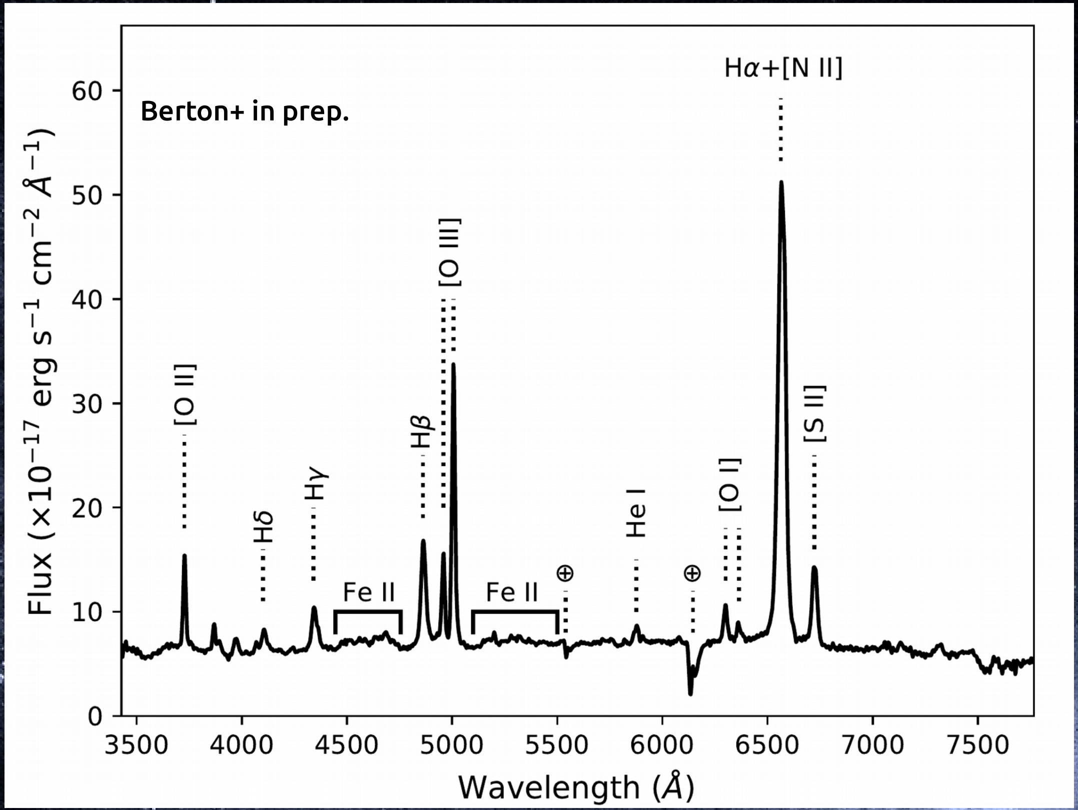
Optical spectroscopy is often essential to understand the nature of AGN.







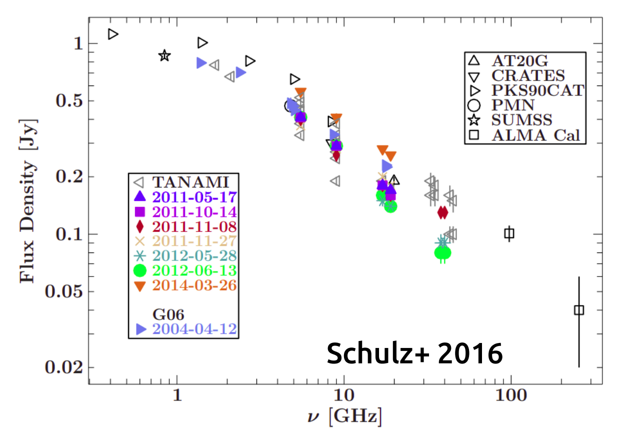
PKS 2004-447



It is one of the first gamma-ray NLS1s detected by *Fermi*.

Oshlack+ 2001 classified it as a hybrid NLS1/CSS. Gallo+ 2006 and Schulz+ 2016 confirmed the CSS nature + turn-over below 1 GHz.

Recent optical spectrum confirms the NLS1 classification.

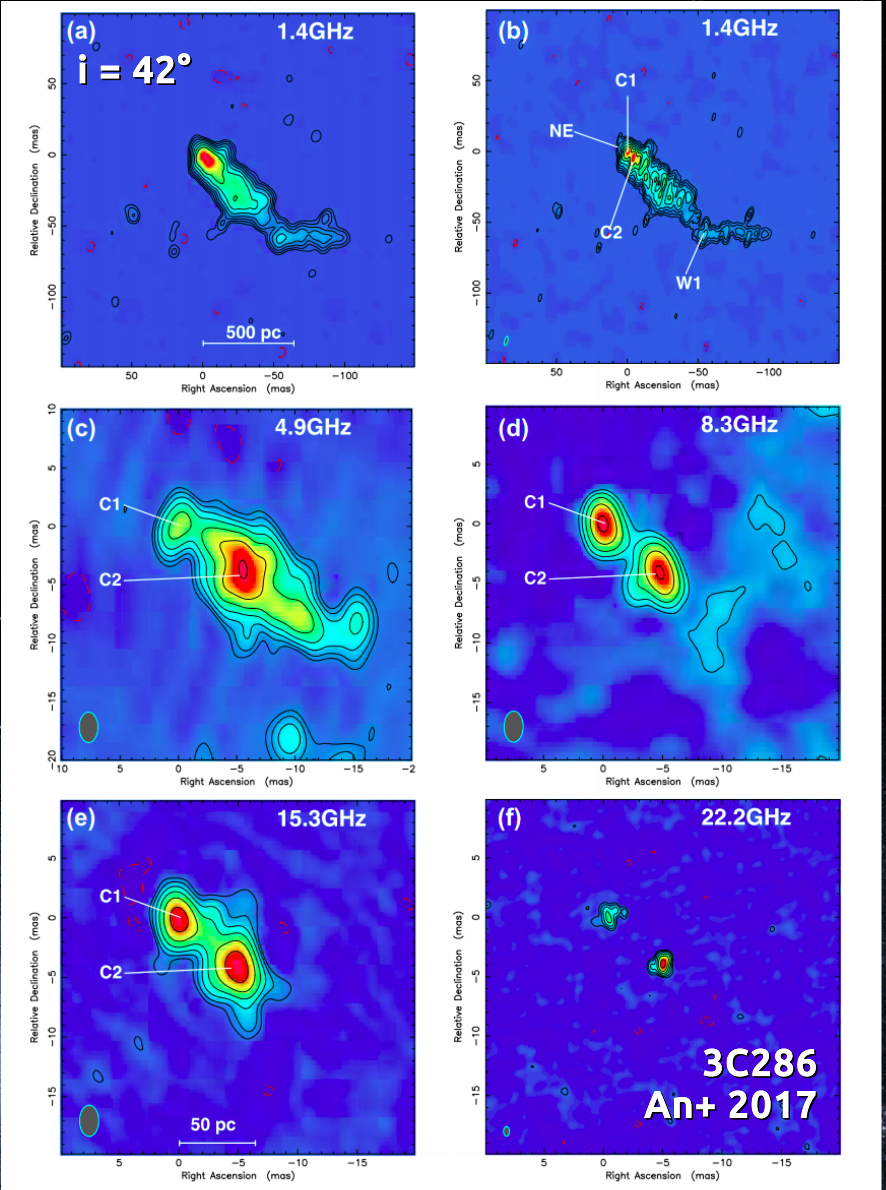


3C 286

3C 286 is a misaligned NLS1 (z = 0.85, Berton+ 2017, Liao & Gu 2020, Yao & Komossa 2021).

Despite the high inclination (42°), it is a gamma-ray source and a CSS, just like PKS 2004-447.

In the *Fermi* catalog, only a handful of CSS have been detected: 2 are NLS1s…



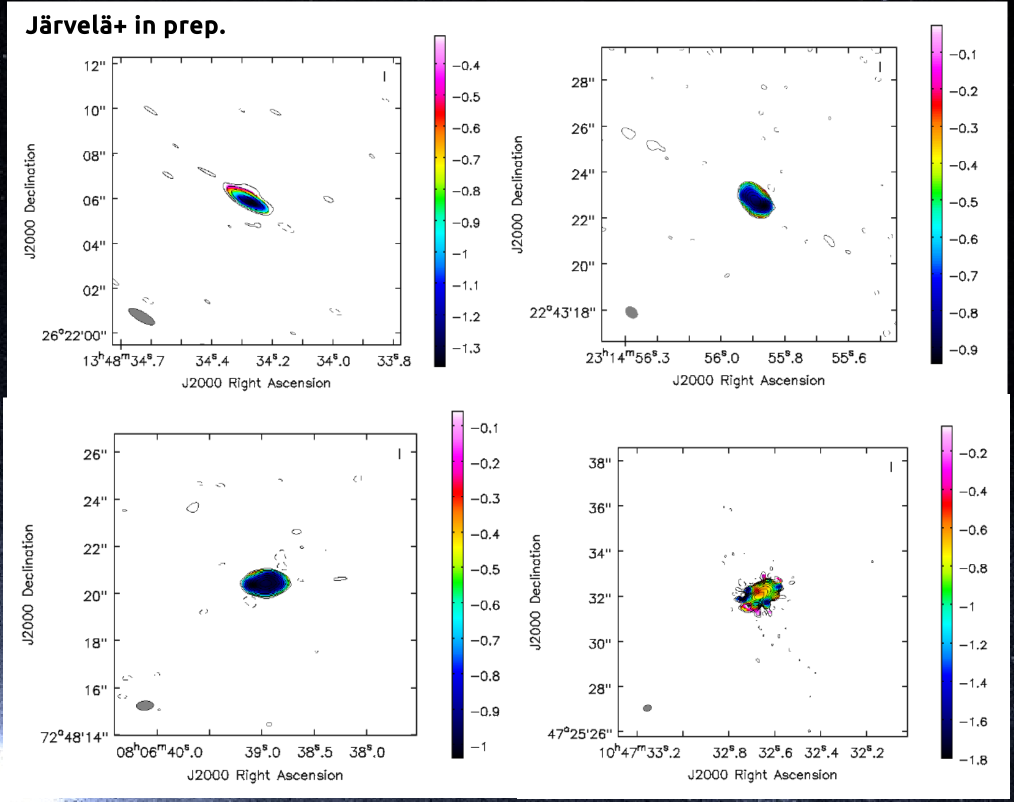
Jetted NLS1s vs CSS

PKS 2004-447 and 3C286 are unique because of their gamma-ray emission, but not the only CSS/NLS1s.

Our JVLA survey of NLS1s at 5 GHz (Berton+ 2018) often showed CSS sources, mostly with low-luminosity (but not as low as star-forming!).

Upcoming study by Järvelä+ (in prep.) on spectral indexes confirms this result. Other examples also exist (J1432, Caccianiga+ 2014,2017).

Are there any other parent population candidates?



The role of Metsähovi

Since 2012 Metsähovi has been observing NLS1s in radio at 37 GHz (high frequency).

The monitoring campaign, beside well-known radio emitters, included some radio-quiet or silent objects.

Image credit: M. Tornikoski

A&A 614, L1 (2018)
https://doi.org/10.1051/0004-6361/201833378

Astronomy & Astrophysics

Letter to the Editor

Radio jets and gamma-ray emission in radio-silent narrow-line Seyfert 1 galaxies★

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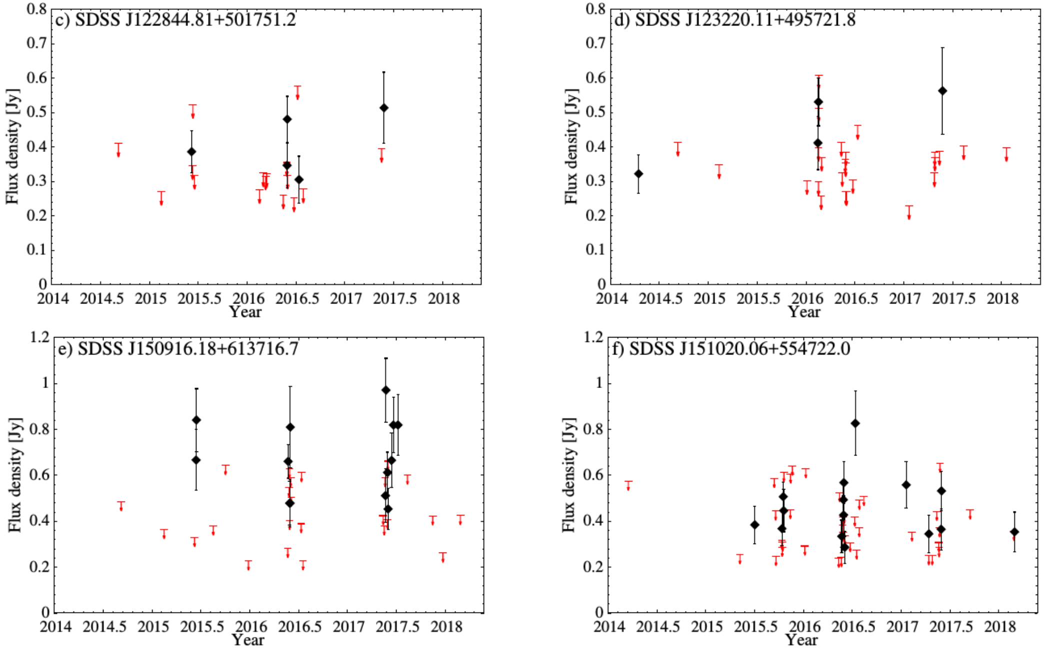
Received 7 May 2018 / Accepted 17 May 2018



Metsähovi detected for the first time several *radio-silent* NLS1s.

The rapid flaring activity at Jy-level indicates jets.

12% of radio-silent sources have been detected.

What is happening?

Radio-silent NLS1s with the JVLA

We observed MH-detected sources with the JVLA at low frequencies (1.6, 5.2, 8.9 GHz).

Metsähovi has a 14m dish
sensitivy 200 mJy

JVLA 27x25m dishes
baseline 36 km
sensitivity 10 μJy

Radio-silent NLS1s with the JVLA

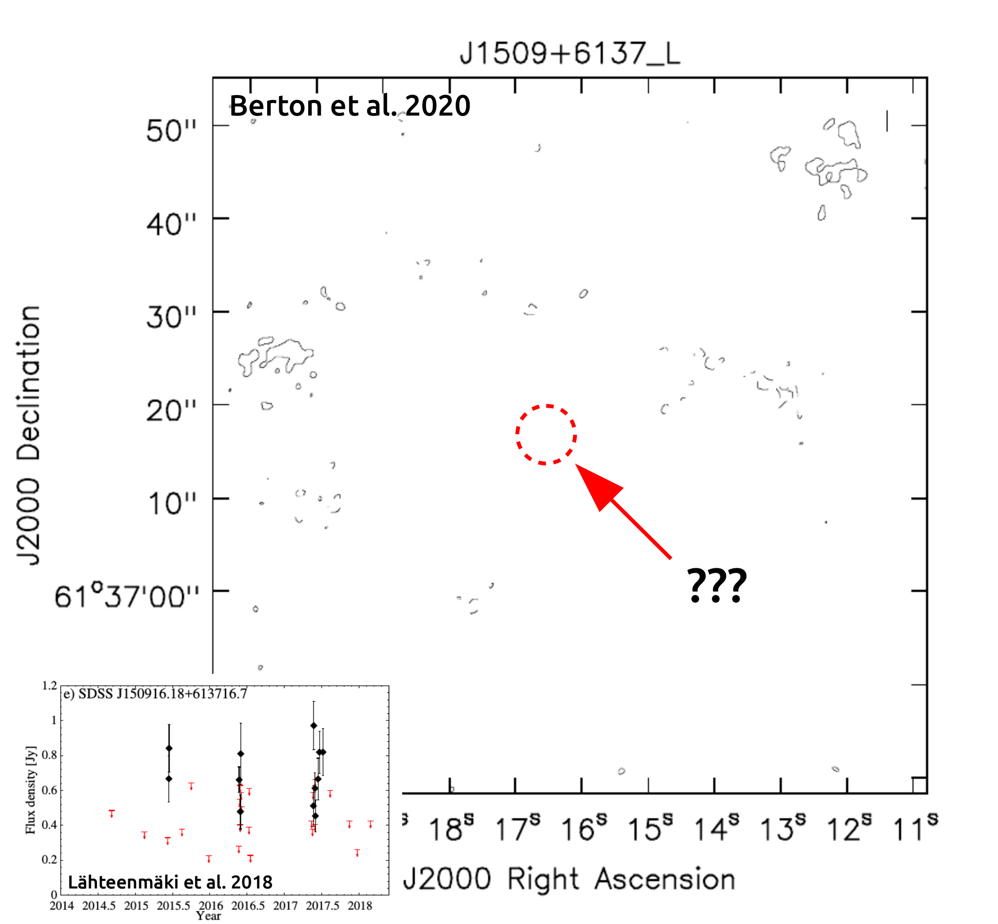
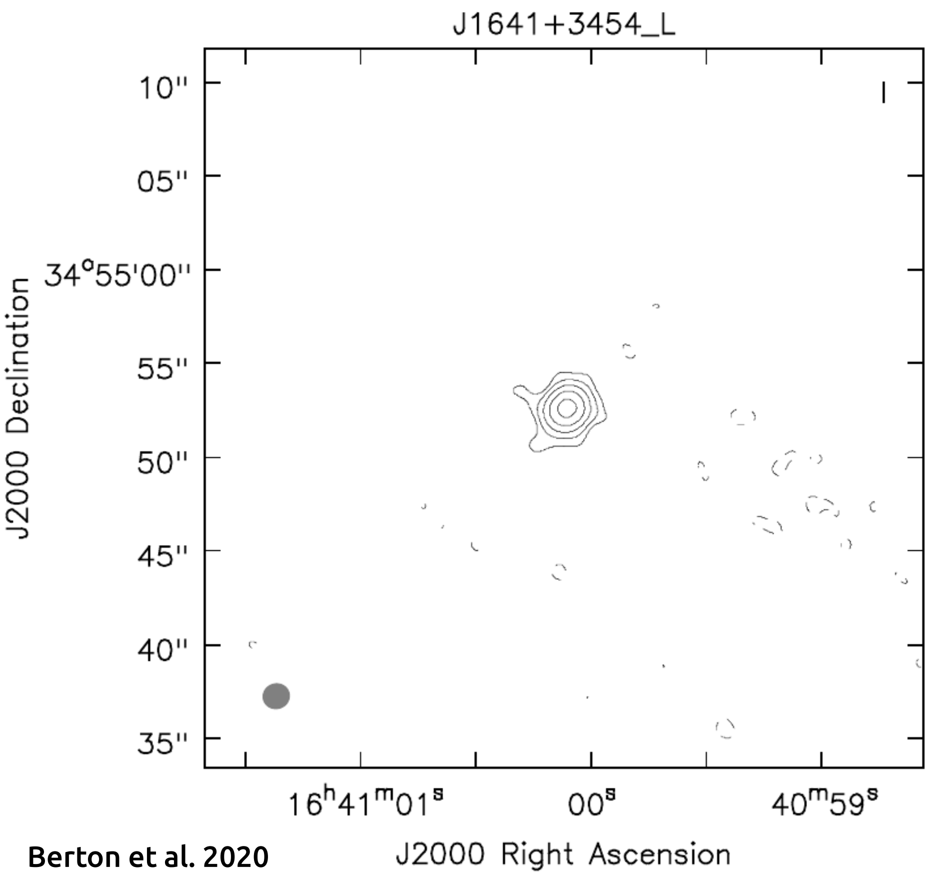


Table 2. Flux densities and luminosities in all bands. Berton et al. 2020

Name	Noise	S_p	S_i	$\log(L_p)$	$\log(L_i)$
		1.6 GHz			
J1029+5556	26	<0.081		<38.99	
J1228+5017	23	0.685 ± 0.024	0.899 ± 0.067	39.35 ± 0.04	39.47 ± 0.07
J1232+4957	21	0.093 ± 0.021	0.234 ± 0.041	38.44 ± 0.23	38.84 ± 0.18
J1509+6137	22	<0.069		<38.09	
J1510+5547	21	0.074 ± 0.022	0.245 ± 0.039	37.84 ± 0.30	38.36 ± 0.16
J1522+3934	21	1.030 ± 0.021	2.030 ± 0.160	38.38 ± 0.02	38.67 ± 0.08
J1641+3454	27	1.721 ± 0.028	2.520 ± 0.097	39.31 ± 0.02	39.48 ± 0.04
		5.2 GHz			
J1029+5556	7	<0.024		<38.46	
J1228+5017	8	0.248 ± 0.009	0.304 ± 0.013	38.91 ± 0.04	39.00 ± 0.04
J1232+4957	7	0.057 ± 0.008	0.050 ± 0.008	38.23 ± 0.14	38.17 ± 0.16
J1509+6137	8	<0.027		<37.68	
J1510+5547	8	0.032 ± 0.009	0.052 ± 0.017	37.48 ± 0.28	37.69 ± 0.33
J1522+3934	12	0.329 ± 0.013	0.380 ± 0.039	37.88 ± 0.04	37.95 ± 0.1
J1641+3454	8	0.518 ± 0.009	0.698 ± 0.035	38.79 ± 0.02	38.92 ± 0.05
		9.0 GHz			
J1029+5556	8	<0.027		<38.31	
J1228+5017	7	0.184 ± 0.008	0.208 ± 0.012	38.75 ± 0.04	38.80 ± 0.06
J1232+4957	7	<0.021		<37.97	
J1509+6137	9	<0.030		<37.65	
J1510+5547	7	0.026 ± 0.008	0.031 ± 0.007	37.37 ± 0.31	37.44 ± 0.23
J1522+3934	7	0.202 ± 0.008	0.273 ± 0.021	37.67 ± 0.04	37.80 ± 0.08
J1641+3454	7	0.291 ± 0.008	0.364 ± 0.018	38.54 ± 0.03	38.64 ± 0.05

Notes. Columns: (1) name; (2) image noise level (in μJy); (3) peak flux (in mJy beam^{-1}); (4) integrated flux (in mJy); (5) logarithm of the peak luminosity (in erg s^{-1}); (6) logarithm of the integrated luminosity.

Radio-silent NLS1s with the JVLA



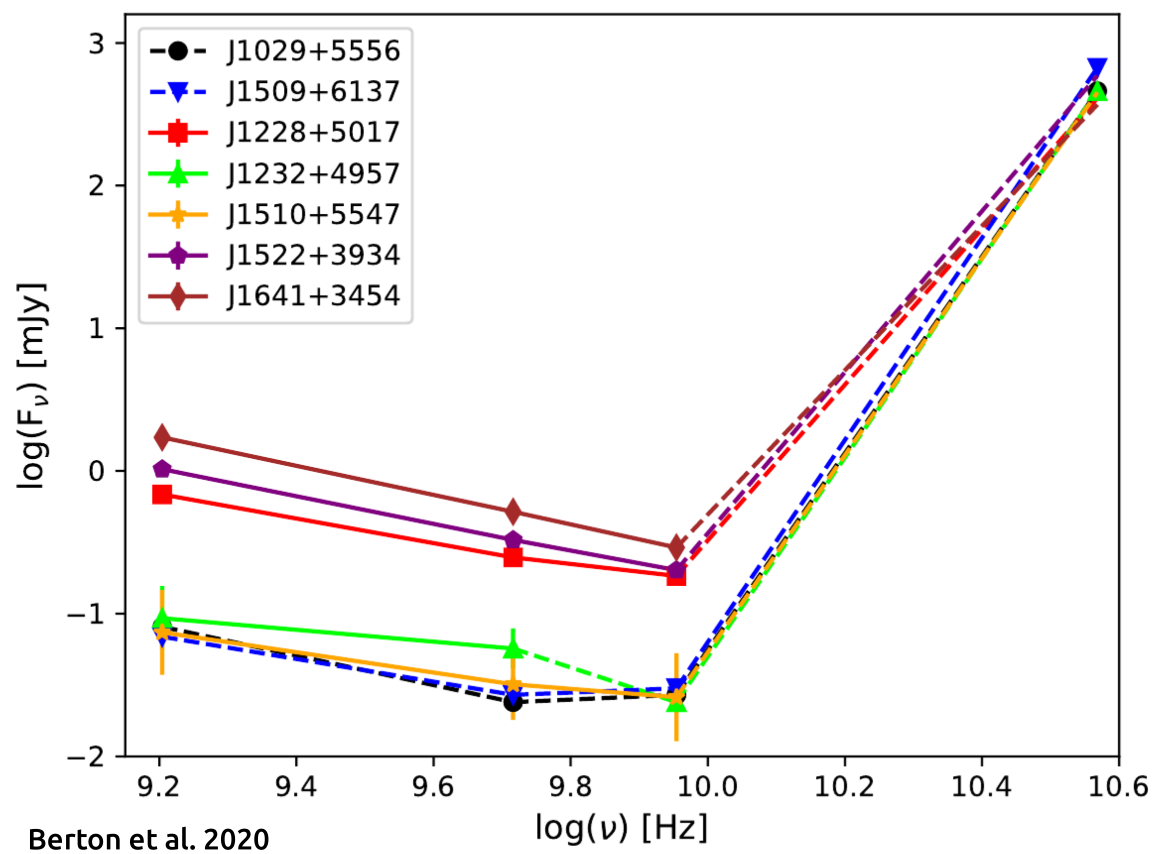
Berton et al. 2020

The radio morphology does not obviously indicate the presence of relativistic jets.

It resembles typical radio-quiet NLS1s.

Infrared indicate the low-frequency radio emission is due to star formation.

Radio-silent NLS1s with the JVLA



Berton et al. 2020

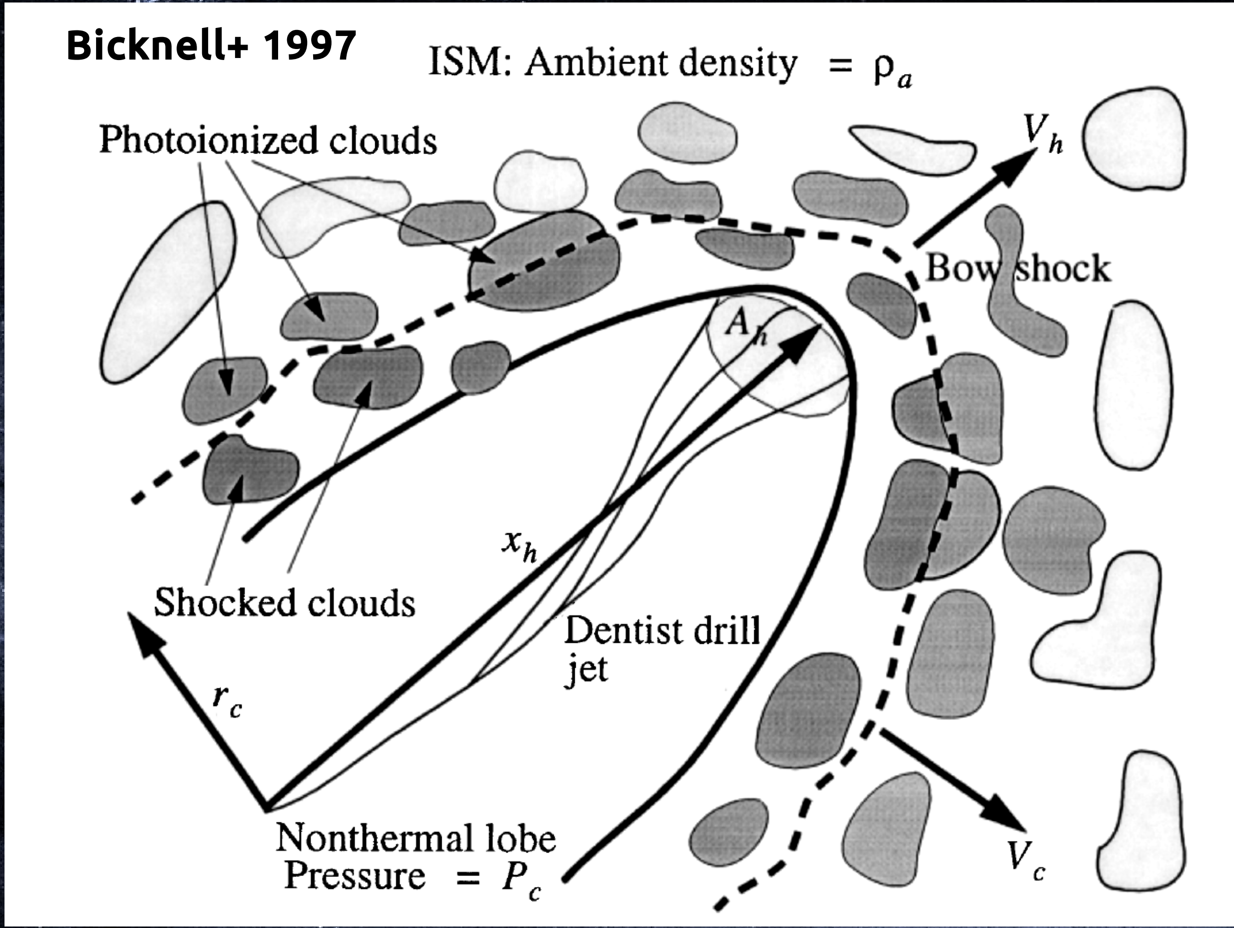
The difference between low and high frequency cannot be due to different beam sizes (Jy-level variability far from the nucleus!?).

At high frequencies, the flares indicate that a jet is present. At low frequencies, the (small-scale) jet is obscured. We only see radio emission from the host galaxy.

Very inverted spectral index = absorption. Similar to GPS/HFP?

Free-free or synchrotron self-absorption?

Radio-silent NLS1s with the JVLA

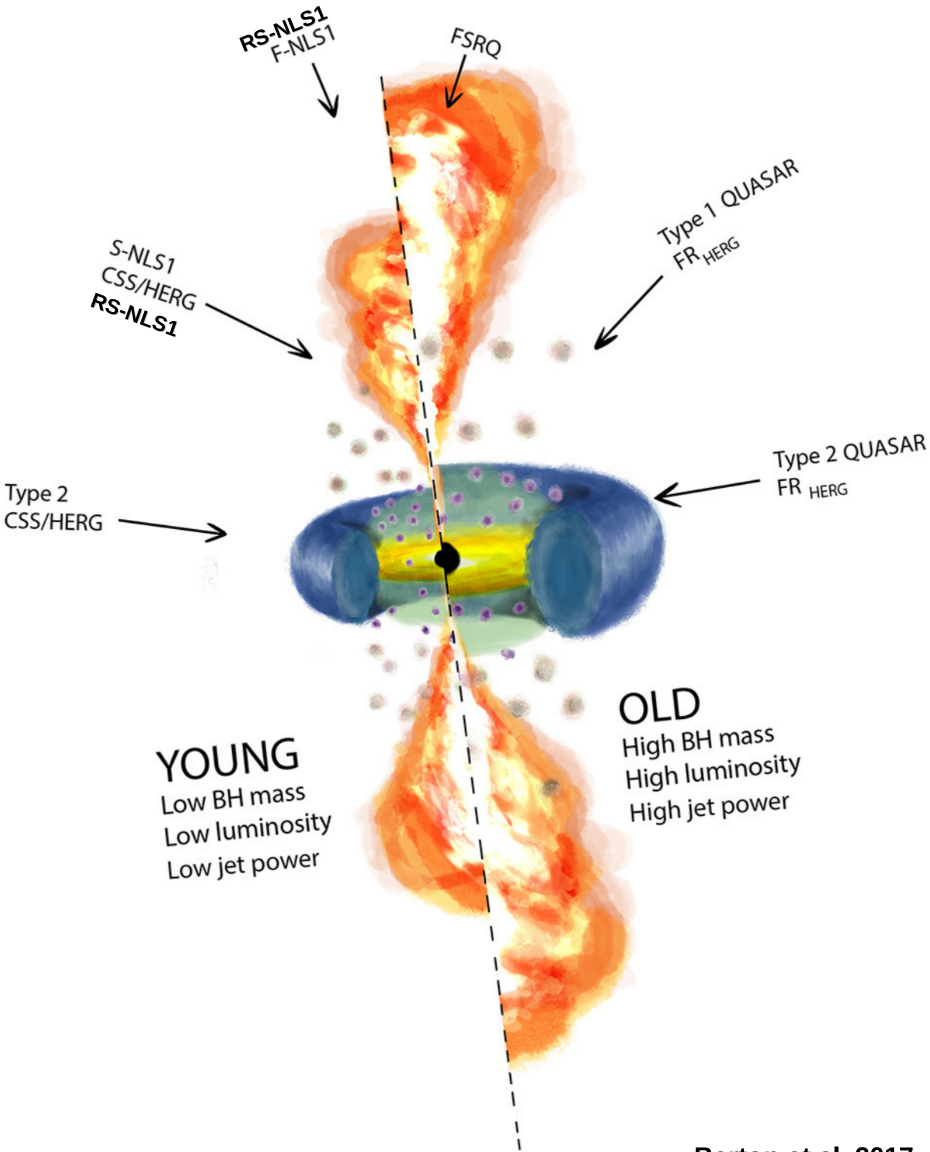


If free-free is the cause, what is the source of ionization?

Star formation is strong in NLS1s.

Is the jet itself ionizing the medium?

Problem: we have used low-frequency radio emission to identify jets for 50 years...



Berton et al. 2017

Even radio-silent NLS1s can harbor relativistic jets!

They may be part of the parent population (or of the beamed population!)

The orientation-based unification needs confirmation.

Future studies will clarify what is going on with NLS1s (hopefully!)

Keep an eye on NLS1s!!