Radio and Gamma-ray loud Narrow-Line Seyfert 1 Galaxies in the Spotlight

Vassilis Karamanavis – Max Planck Institute for Radio Astronomy

With

E. Angelakis, S. Komossa, I. Myserlis and many collaborators

IAUS 324: New Frontiers in Black Hole Astrophysics – 12 to 16 September 2016 – Ljubljana, Slovenia
Narrow-line Seyfert 1 (NLS1) galaxies are a particular class of AGN with:

- small width of their broad optical emission lines \( \text{FWHM}(H_\beta) < 2000 \text{ km/s} \); [Osterbrock & Pogge 1985] — Low BH masses \( (10^6 - 10^8 \, M_\odot) \)
- super-strong iron (Fe II) emission complexes
- rapid X-ray variability — BLR and accretion disk are directly visible
- near-Eddington accretion rates \( (L/L_{Edd} \text{ ratios between 0.1-1}) \); [Boroson & Green 1992]
- super-soft X-ray spectra and
- other intriguing multi-wavelength properties [review by Komossa 2008]

- A small fraction of them is radio-loud, launching relativistic jets, and γ-ray detected with Fermi [Komossa et al. 2006; Abdo et al. 2009a, b]
These few sources are exceptional because they show blazar-like observational attributes such as:

- Radio-loudness and flat radio spectra
- High brightness temperatures (reported $10^{10}$ up to $10^{14}$ K) [D’Ammando et al. 2013, Angelakis et al. 2015, Fuhrmann et al. 2016]
- Doppler boosting
- Gamma-ray emission and
- One-sided relativistic jets

But with non-blazar physical properties:

- 2 orders of magnitude lower BH masses
- High accretion rates

- Represent young AGN rapidly growing their BHs? Clues for accretion physics and AGN evolution at low z
- Orientation effects? Important for accurate BH masses, applying scaling relations, and in case of flat BLRs
- The issue of hosts: Do spirals harbor relativistic jets?
Unique New Insight into the Formation and Evolution of Jets under High Accretion Rate conditions, and in a Regime Not probed by Classical Blazars
1. Our NLS1 galaxies radio monitoring program
2. The curious case of RX J2314.9+2243
3. Very-long-baseline interferometry (VLBI) monitoring of 1H 0323+342
1. The NLS1 galaxies Monitoring program
The most comprehensive (longest duration & most frequencies) monitoring of 4 RL and GL NLS1 galaxies at cm and mm radio bands

Includes the nearest RL gamma-ray emitting NLS1 1H 0323+342 (z=0.02; Zhou et al. 2007) and the most distant one currently known SDSS J1222+0413 (z~1, Yao et al. 2015)

Monthly monitoring

Data at 2.6, 4.8, 8.4, 10, 15, 23, 32, 43, 86, and 142 GHz (10 bands) spanning 5 years

Effort is ongoing and the sample is expanded with 3 additional sources

Identity of the Program

1H 0323+342
SBS 0846+513
PMN J0948+0022
PKS 1502+036
FBQS J1644+2619
SDSS J122222.55+041315.7
B3 1441+476

Angelakis et al. 2015

Monitoring with the Effelsberg 100-m & the IRAM 30-m telescopes
Data: Light Curves and Spectra
**Polarimetry of NLS1 Galaxies**

**Radio polarization**
- At 4 bands from 2.6 to 10.5 GHz
- Most sources at undetectable levels
- Only 1H 0323+342 shows ~3–9% of linear pol.
  High compared to other AGN (Myserlis 2015, PhD Thesis, Univ. Cologne)
- EVPA almost perpendicular to the jet, so projected magnetic field is parallel to the jet axis

**R-band polarization**
- With the RoboPol instrument (Pavlidou et al. 2014)
- Mean fractional pol. from <1% up to 20%
Monitoring Results

- Rapid flaring more prominent at higher frequencies,
- Strong spectral evolution (consistent with the shock-in-jet scenario)
- Moderate variability brightness temperatures (& associated Doppler factors no higher than ~10) --- (only) mildly relativistic jets
- Behaviour overall consistent with blazars, except lower powers, lower jet speeds
- Radio-loud NLS1 galaxies extent the blazar phenomenon into a previously unexplored parameter regime

Angelakis et al. 2015
The curious case of RX J2314.9+2243
Identity of RX J2314.9+2243

× Radio-loud NLS1, R=10–20 (z=0.17; Komossa et al. 2006)
× Close to Eddington accretion rate with BH mass $8\cdot10^7 M_\odot$

× Marginal gamma-ray detection (Foschini et al., priv. com.)

But

× Steep radio spectrum, $a=-0.76$, first measured with Effelsberg (Komossa et al. 2015), and confirmed by our follow-up monitoring

“First steep-spectrum, gamma-emitting NLS1” galaxy, if gamma-ray detection is confirmed

(until now gamma-ray emission has been detected from flat radio spectrum NLS1s)
A Non-Thermal SED for RX J2314.9+2243

- Luminous IR emission
- Very steep UV spectrum, but no evidence for optical reddening/extinction beyond the Galactic value
- Flat, variable X-ray spectrum (*Swift*)
- Possible gamma-ray detection
- SED likely dominated by non-thermal emission (X-rays: corona; IR-UV: synchrotron)
- Very broad & blueshifted ($v=1260$ km/s) [OIII]5007 emission → strong outflow

Likely a case of strong AGN-induced feedback in the local universe

Komossa et al. 2015

A Non-Thermal SED for RX J2314.9+2243
3. VLBI monitoring of 1H 0323+342
Identity of 1H 0323+342

- The most nearby radio loud (R=50) and gamma-ray emitting NLS1 (z=0.06; Zhou et al. 2007)
- High Eddington ratio of \( L/L_{\text{Edd}} = 0.1 \)
- With low BH mass \( \sim 10^7 M_\odot \) [Abdo et al. 2009, Paliya et al. 2014, Yao et al. 2015]
- 1H 0323+342 is highly variable at radio bands (cm to mm)
- Special case: its host galaxy is a ring galaxy or one-armed spiral, while radio-loud sources are typically hosted by ellipticals [see Zhou et al. 2007]
Superluminal motions and Viewing Angle

- Data from the MOJAVE survey at 15 GHz [Lister et al. 2009]
- On parsec scales: One-sided morphology with a prominent core and a straight jet
- Several jet components with speeds between 1 and 7c

Karamanavis 2015, Ph.D, Univ. Cologne
Fuhrmann, VK, Komossa et al. 2016
See also: Wajima et al. 2014, Angelakis et al. 2015
Superluminal motions and Viewing Angle

- Data from the MOJAVE survey at 15 GHz [Lister et al. 2009]
- On parsec scales: One-sided morphology with a prominent core and a straight jet
- Several jet components with speeds between 1 and 7c
- Fast variability seen both with single-dish and VLBI
- Highest $T_B$ of $\sim 6 \cdot 10^{12}$ K and Doppler factor of $\sim 5.2$
Superluminal motions and Viewing Angle

- Data from the MOJAVE survey at 15 GHz [Lister et al. 2009]
- On parsec scales: One-sided morphology with a prominent core and a straight jet
- Several jet components with speeds between 1 and 7c
- Fast variability seen both with single-dish and VLBI
- Highest $T_B$ of $\sim 6 \cdot 10^{12}$ K and Doppler factor of $\sim 5.2$
- Viewing angle towards 1H 0323+342 of $\leq 4^\circ$–$13^\circ$
- Spin-off: viewing angle towards SBS 0846+513 of $\leq 8^\circ$–$9^\circ$
  [based on published data by D’Ammando et al. 2013]
NLS1s are a unique source of insights into accretion and jet physics in the low BH mass and high accretion rate regime.

Radio multi-frequency and polarimetric monitoring of radio-loud and gamma-ray loud NLS1s revealed that they feature relativistic and beamed jets with moderate brightness temperatures and Doppler factors. They flare repeatedly and fast and show intense spectral evolution.

RX J2314.9+2243: A steep-spectrum source with putative gamma-ray emission, featuring a strong outflow.

1H 0323+342: pc-scale imaging of its relativistic jet: superluminal features and viewing angle estimation – Hosted by a ring or spiral galaxy.
Thank you!

Any questions?

You can find me at
vkaramanavis@mpifr.de