Faint compact radio quasars at redshifts z > 5 observed with the EVN

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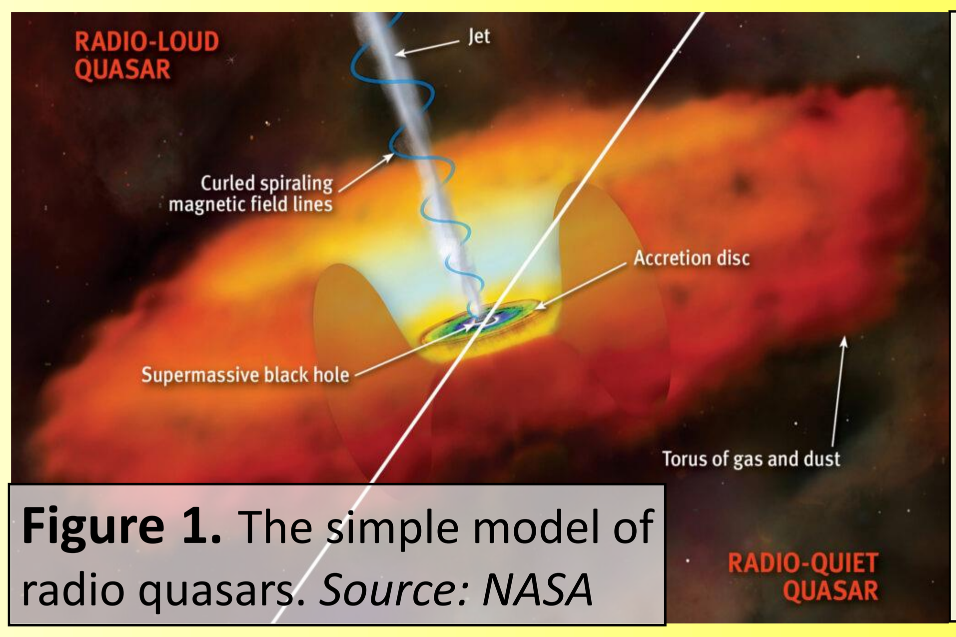

Figure 1. The simple model of radio quasars. *Source: NASA*

Motivation: **High-redshift radio quasars** are unique probes of the **early Universe (z > 5)**. Radio quasars are accreting supermassive black holes which eject powerful **relativistic plasma jets** (see ***Fig. 1***). They are extreme luminous objects seen even from the high-redshift Universe, therefore able to provide insights into the formation and evolution of the first galaxies and supermassive black holes. Even from these distances, **VLBI** can reveal the compact innermost parts of the radio-emitting relativistic jets on millarcsecond (mas) scale. To date, only a dozen of the known quasars have been observed with VLBI at redshifts z > 5. We aimed to investigate how **radio loudness** (i.e. the radio-to-optical luminosity ratio) affects the jet physical parameters. One burning question of this field: **what are the differences between radio-loud (jetted) and radio-quiet (non-jetted) quasars at high redshift**?

Targets and observations: We targeted 9 faint radio emitters (3 radio-quiet and 6 radio-loud) with the lowest radio luminosity from a catalogue of known z > 5 quasars *(Ross & Cross, 2020, MNRAS, 494, 789)*. Another aspect was to select sources with different radio-loudness indices. These sources were not observed with VLBI yet. A 10th, radio-quiet target was also included, *J0306+1853*, which was previously examined by *Sbarrato et al. (2021b, A&A, 655,A95)* using the Very Large Array (VLA) and suspected to host a compact jet. The targets were observed in **2022 June and October at 1.7-GHz** with the **European VLBI Network** combined with the **e-MERLIN**. Except for *J0306+1853*, all quasars have been detected with a single compact component (see ***Fig. 3***). The detection rate of compact pc-scale jets in our radio quiet quasars is 3 out of 4 sources. In addition to the VLBI radio observations, we collected low-resolution radio data from the literature. The ***Gaia*** optical astrometric mission detected five of our sources (including *J0306+1853*), and we found the *Gaia*–VLBI positional offsets to be insignificant, which indicates that the detected radio features could be related to the inner jet, located close to the central engine.

Source ID	z
J0306+1853	5.363
J0616−1338	5.580
J0741+2520	5.194
J0747+1153	5.260
J0901+1615	5.630
J1034+2033	5.010
J1614+4640	5.313
J2239+0030	5.090
J2245+0024	5.170
J2344+1653	5.000

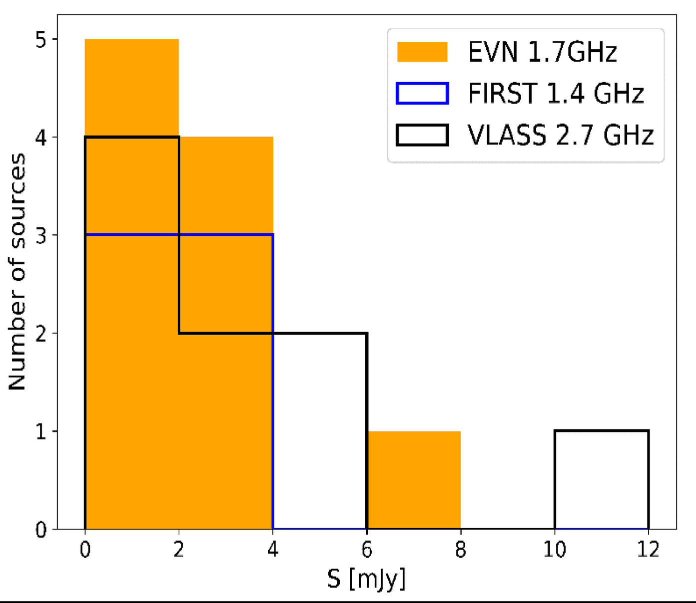

Figure 2. **Left:** The list of the target sources and their redshift. **Right:** Histogram of the flux density distribution in the source sample.

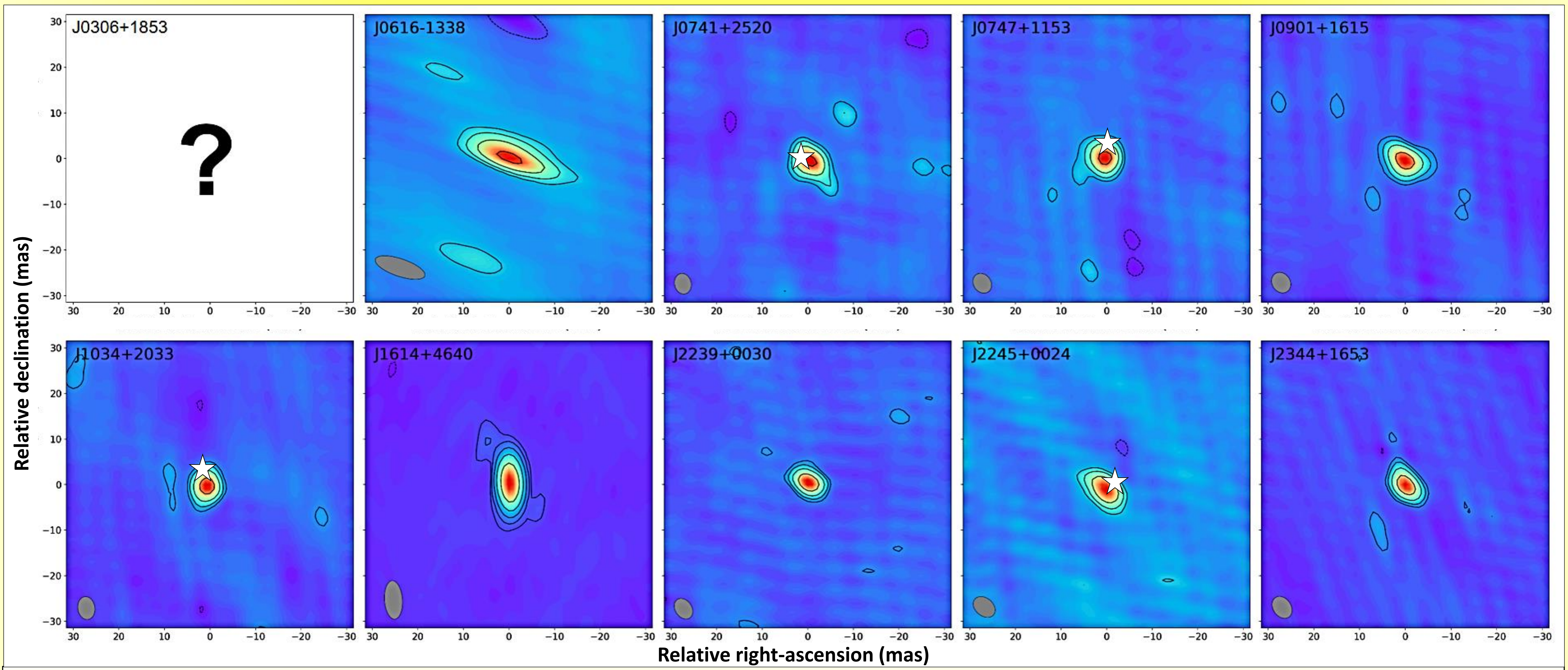

Figure 3. The naturally weighted **EVN 1.7-GHz VLBI images** of the radio quasars. *J0306+1853* remained undetected at this resolution. The grey ellipses are the beams and are representing the resolution of the array. The white star symbols represent the *Gaia* optical positions (when available) and their uncertainties can be considered ~1 mas.

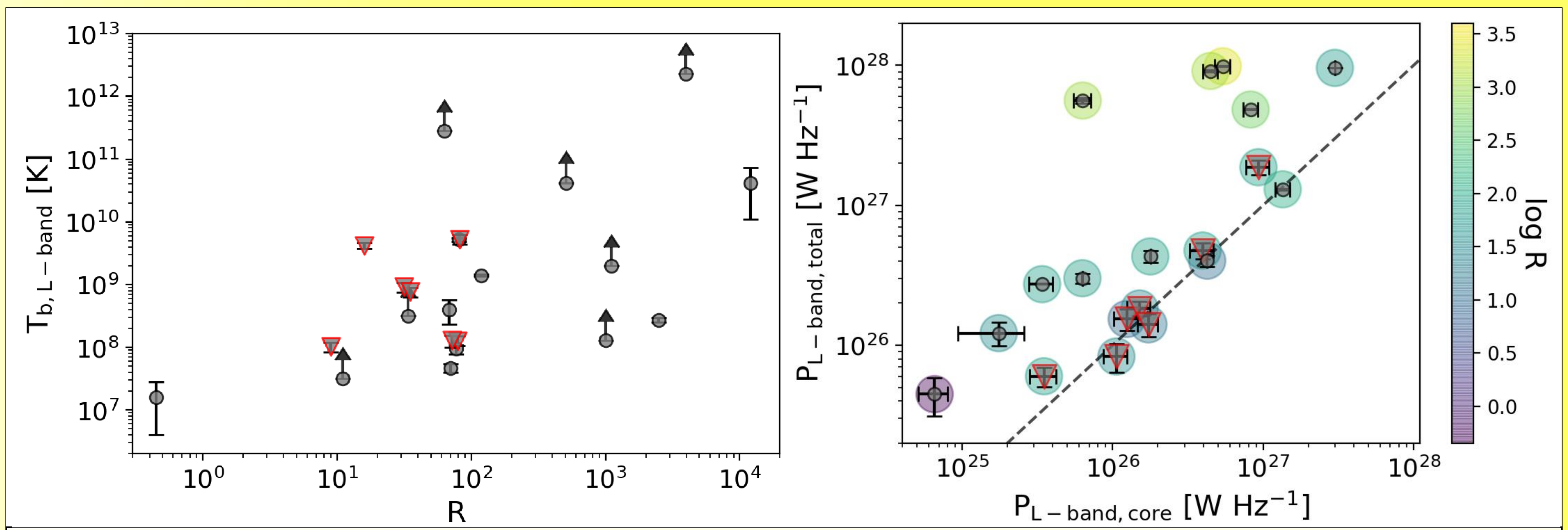

Figure 4. Relations between physical parameters. The new sources presented in this study are marked with red triangles. **Left:** The redshift-corrected 1.7-GHz brightness temperatures as a function of radio loudness. **Right:** The comparison of 1.7-GHz core monochromatic radio power and the 1.7-GHz total monochromatic radio power for z > 5 sources where both values are available. The dashed line represents the $P_{total} = P_{core}$.

Radio quasars at z > 5: To examine the physical properties of a larger sample, we collected data of other z > 5 quasars, including **radio-loudness indices** (R), 1.7-GHz **core brightness temperatures** (T_b), 1.7-GHz **total** and **core monochromatic radio powers** (P_{total} and P_{core}). We found that the core brightness temperatures and monochromatic radio powers seem to increase with increasing radio loudness (see ***Fig. 4***). However, for the R–T_b relation, the radio-quiet and the extreme radio-loud regimes are still undersampled. Obtaining high-resolution VLBI observations for more z > 5 radio quasars would be desirable as it would further constrain these relations.

For more details, check out the paper:

Acknowledgements: The EVN is a joint facility of independent European, African, Asian and North American radio astronomy institutes. Scientific results from data presented in this publication are derived from the following EVN project code: EG119. Supported by the ÚNKP-23-3 New National Excellence Program of the Ministry for Culture and Innovation from the source of the National Research, Development and Innovation Fund. We thank the Hungarian National Research, Development and Innovation Office (NKFIH, grant no. OTKA K134213) for support. This work was also supported by the NKFIH excellence grant TKP2021-NKTA-64. This research was supported by HUN-REN.