High-resolution Imaging of Two Radio Quasars at the End of Reionization

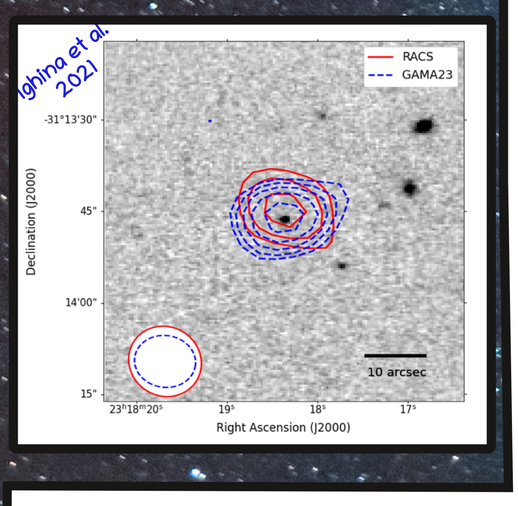
Krisztina Perger[1], Yingkang Zhang[2], Sándor Frey[1,3], Tao An[2], Krisztina É. Gabányi[4,5,1], Leonid I. Gurvits[6,7], Chorng-Yuan Hwang[8], Ekaterina Koptelova[8], Zsolt Paragi[6], and Ailing Wang[2]

[1]Konkoly Observatory, ELKH Research Centre for Astronomy and Earth Sciences (MTA Centre of Excellence), Budapest, Hungary [2]Shanghai Astronomical Observatory, Chinese Academy of Sciences, Shanghai, China [3]Institute of Physics, ELTE Eötvös Loránd University, Budapest, Hungary [4]Department of Astronomy, Institute of Geography and Earth Sciences, ELTE Eötvös Loránd University, Budapest, Hungary [5]ELKH-ELTE Extragalactic Astrophysics Research Group, Eötvös Loránd University, Budapest, Hungary [6]Joint Institute for VLBI ERIC, Dwingeloo, The Netherlands [7]Faculty of Aerospace Engineering, Delft University of Technology, Delft, The Netherlands [8]Graduate Institute of Astronomy, National Central University, Taoyuan City, Taiwan

High-redshift active galactic nuclei

There are approximately 250 quasars discovered at redshift $z > 6$, of which only a handful were detected in radio bands, and even fewer were imaged with the highest resolution very long baseline interferometry (VLBI) technique (Perger et al. 2017). Here we report the results of our dual-frequency observations of two recently discovered such quasars with the Very Long Baseline Array (VLBA). Both extremely distant sources were imaged with VLBI for the first time.

VIKING J231818.35-311346.3



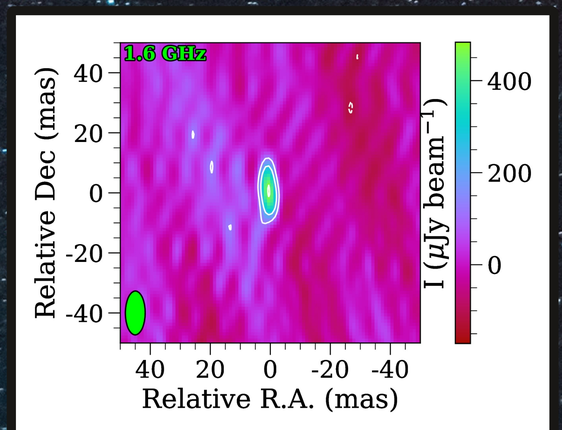
At kiloparsec scales...

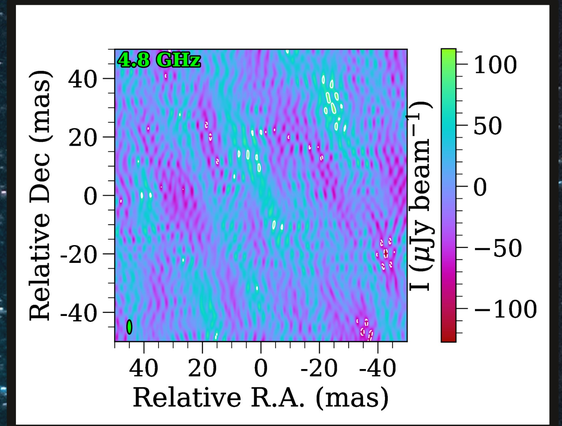
This z=6.44 quasar was first detected in the radio regime at 888 MHz in the Galaxy and Mass Assembly and Rapid ASKAP Continuum Surveys.

It was found radio-loud (R=70, Ighina et al. 2021), and has a steep spectrum between 888 MHz and 5.5 GHz ($S_\nu \sim \nu^\alpha$; α=-1.24, Ighina et al. 2022).

Revealing the structure at parsec scales

The 4.7 and 1.6 GHz observations were conducted on August 2 and 16 in 2021, respectively. The source was detected as a compact 'core' at 1.6 GHz with a flux density of 550 μJy. No compact component was detected at 4.7 GHz (S<130 μJy). This puts an upper limit on the spectral index of α<-1.2, which is consistent with the value found for the kpc-scale radio emission, and implies that the emission originates from one of the youngest quasar jets (Zhang et al. 2022).

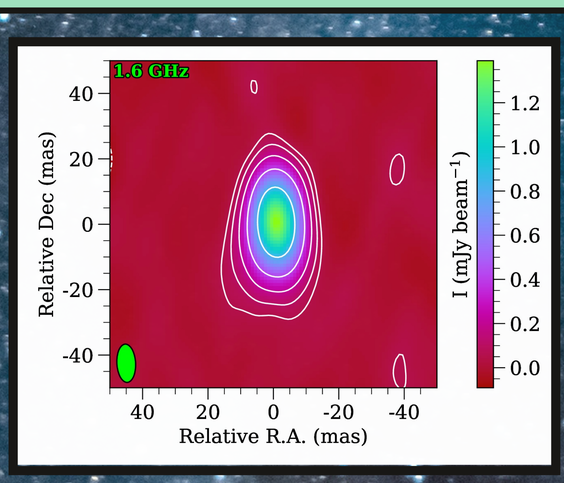




FIRST J233153.20+112952.11

The most distant BL Lac known

This quasar has a spectral energy distribution consistent with those of blazars, shows variabilty over year-long time scales, and has a flat radio spectrum (α=-0.01). Interestingly, there are no emission lines in its spectrum. Based on the the Gunn-Peterson trough found at 0.921 μm, a lower limit of z=6.57 was estimated for its redshift. The spectral properties are indications that this quasar may be the highest-redshift BL Lac object discovered to date, of which none was found beyond z>4 (Koptelova & Hwang 2022).



Zooming into the heart of the system

The quasar was observed with the VLBA at 1.6 and 4.8 GHz on February 1 and 4 in 2022, and was detected at both frequencies. We found that the source is compact, and has flux densities $S_{1.6}$=1.8 mJy and $S_{4.8}$=1.6 mJy, indicating a flat spectrum (α=-0.11). The brightness temperature values confirm the nonthermal nature of the radio emission ($T_b \sim 10^8$-10^9 K), while the high 1.4 GHz rest-frame power ($P_{1.4}=1.4\times10^{26}$ W Hz^{-1}) suggests that it originates from AGN activity. However, there is no evidence for strongly Doppler-boosted radiation that would be expected from a BL Lac jet closely aligned with the line of sight.

Acknowledgements

This research was funded by National Key R&D Programme of China under grant number 2018YFA0404603 and the China-Hungary project funded by the the Ministry of Science and Technology of China and Chinese Academy of Sciences. YKZ was sponsored by Shanghai Sailing Program under grant number 22YF1456100. This research was supported by the Hungarian National Research, Development and Innovation Office (NKFIH), grant number OTKA K134213. The National Radio Astronomy Observatory is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc. We acknowledge the use of data from the Astrogeo Center database maintained by Leonid Petrov.

References

Ighina et al. 2021, A&A, 674, L11
Ighina et al. 2022, A&A, in press
Koptelova & Hwang 2022, ApJL, 929, L7
Perger et al. 2017, FrASS, 4, 9
Zhang et al. 2022, A&A, 662, L2