Plasma instability in the relativistic flow of 0836+710

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(on behalf of the RadioAstron Key Science Program team)

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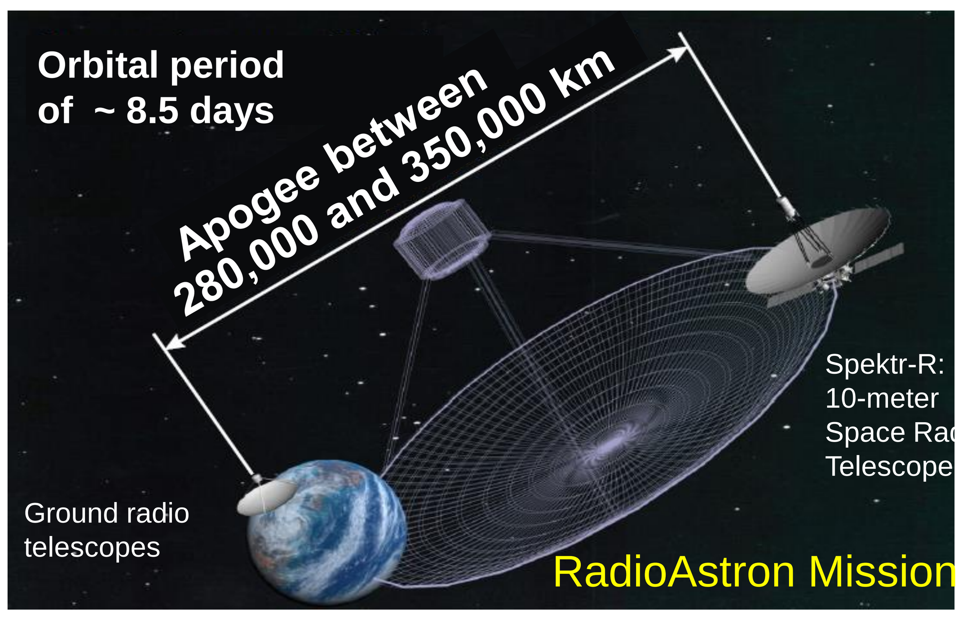
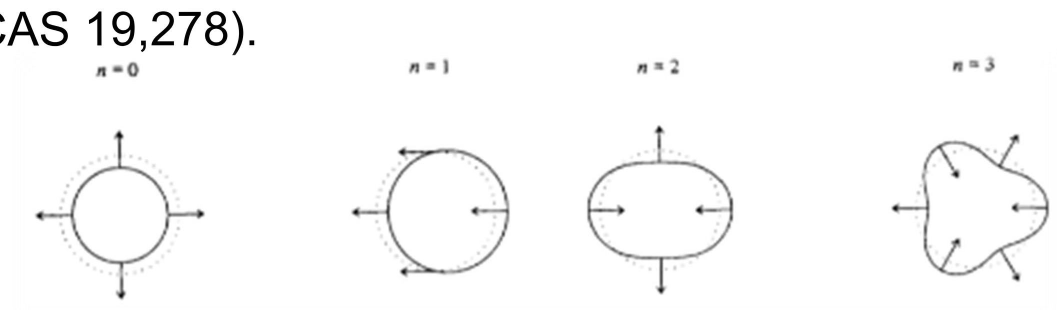


RadioAstron Mission

- Russian-led international collaborative mission
- Features a 10-m radio telescope on an elliptical orbit around the Earth.
- Observations made together with ground VLBI antennas.
- We have observed 0836+710 as part of the RadioAstron Key Science Program to study the physics of extragalactic relativistic jet and the evolution of plasma instability in particular

Plasma Instabilities

- Jets dominated by magnetic field or particle energy.
- If B-filed dominated: Current driven instability
- If particle dominated: Kelvin Helmholtz instability . This instability alters jets cross-section, (n=1) axis (n=2) or both (n=3) depending on the mode (Birkinshaw 1991 CAS 19,278).



Target: 0836+710

- Luminous quasar (m=17.3)
- z=2.17 (D_L = 5.5 Gpc; 8.4 pc/mas)
- Jet viewing angle of 3°
- Powerful radio jet from pc to 2 kpc scales
- Radio luminosity correspondent to a Fanaroff-Ryley Type II
- Kinks observed: Kelvin-Hemlholtz instabilitiy?

RadioAstron Observations

Freq [Hz]	Number of Ground antennas	Date	$\Theta_{min, ground}$ [mas]	$\Theta_{min, space}$ [mas]
1.6	22	24 Oct. 2013	2.37	0.21
5	17	10 Jan. 2014	0.975	0.056
22	13	10 Jan. 2014	0.282	0.016

Global VLBI and RadioAstron images at 1.6 GHz

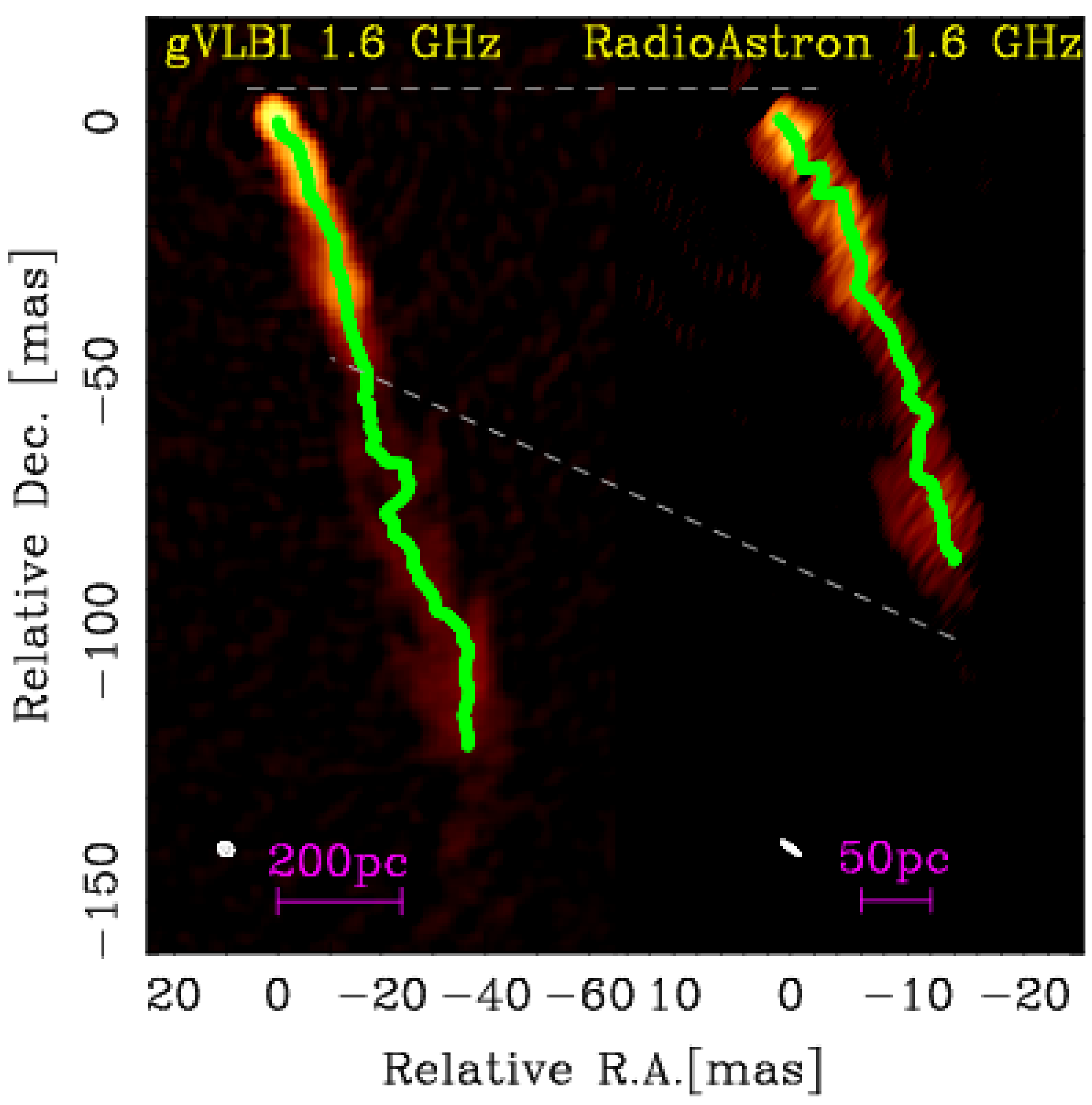
Comparison of the structures detected in 0836+710 on ground baselines (left) and the full-resolution RadioAstron image of the source at 1.6 GHz (right).

The RadioAstron image has a resolution of ~0.2 mas, about 11 times better than the ground VLBI image.

The ground array image shows an extended jet up to ~150 mas.

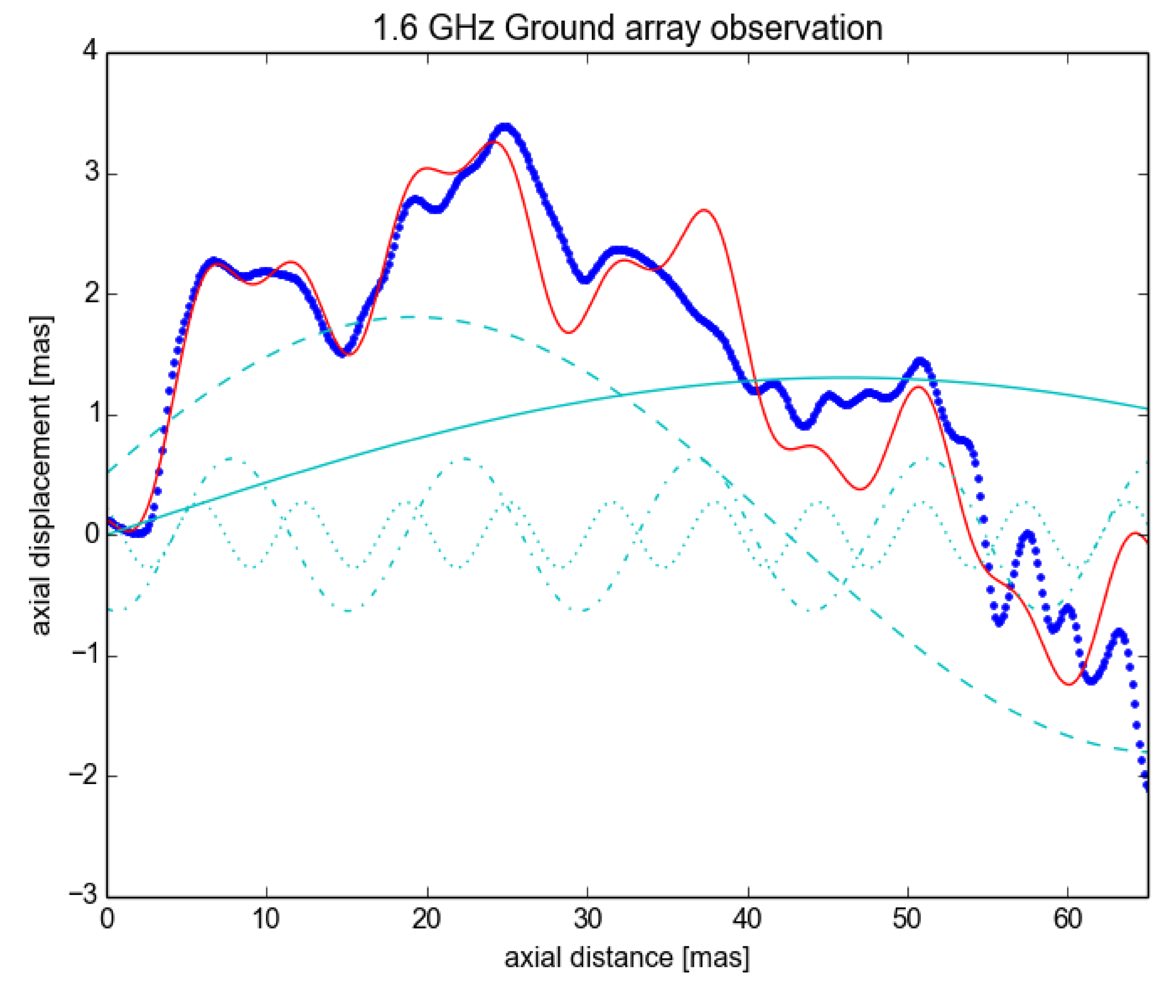
The space VLBI image shows a range up to ~40 mas. The structure observed in this image is more complex than the one in the ground.

The morphology of the jet is studied in both images by determining the ridge line from gaussian fits to transverse profiles of brightness. The resulting ridge lines are plotted in green for both images.



Internal structure of the plasma: Kelvin-Helmholtz instability

The ridge line can be modeled using oscillatory modes, in order to study the evolution of the jet plasma. A constant amplitude of the modes is used as a first approach.



The results of this fit for the ground array image at 1.6 GHz are:

Mode Number	Mode ID	λ [mas]	a [mas]	ψ [°]
1	Precession	185 ± 17	1.30 ± 0.03	0.0 ± 0.3
2	Pinch	94 ± 4	1.81 ± 0.02	16.4 ± 0.3
3	H_S	14.5 ± 0.05	0.632 ± 0.005	-105.2 ± 0.9
4	E_S	6.4 ± 0.02	0.272 ± 0.004	124.8 ± 0.9

The longest mode is most likely caused by the jet precession, and the second longest one may be the pinching mode of Kelvin-Helmholtz instability. The two shorter modes are identified with the helical and elliptical modes of the instability. These modes can be reconciled with a jet with a Mach number of ~5.7 and the jet/ambient medium density ratio of ~0.01.

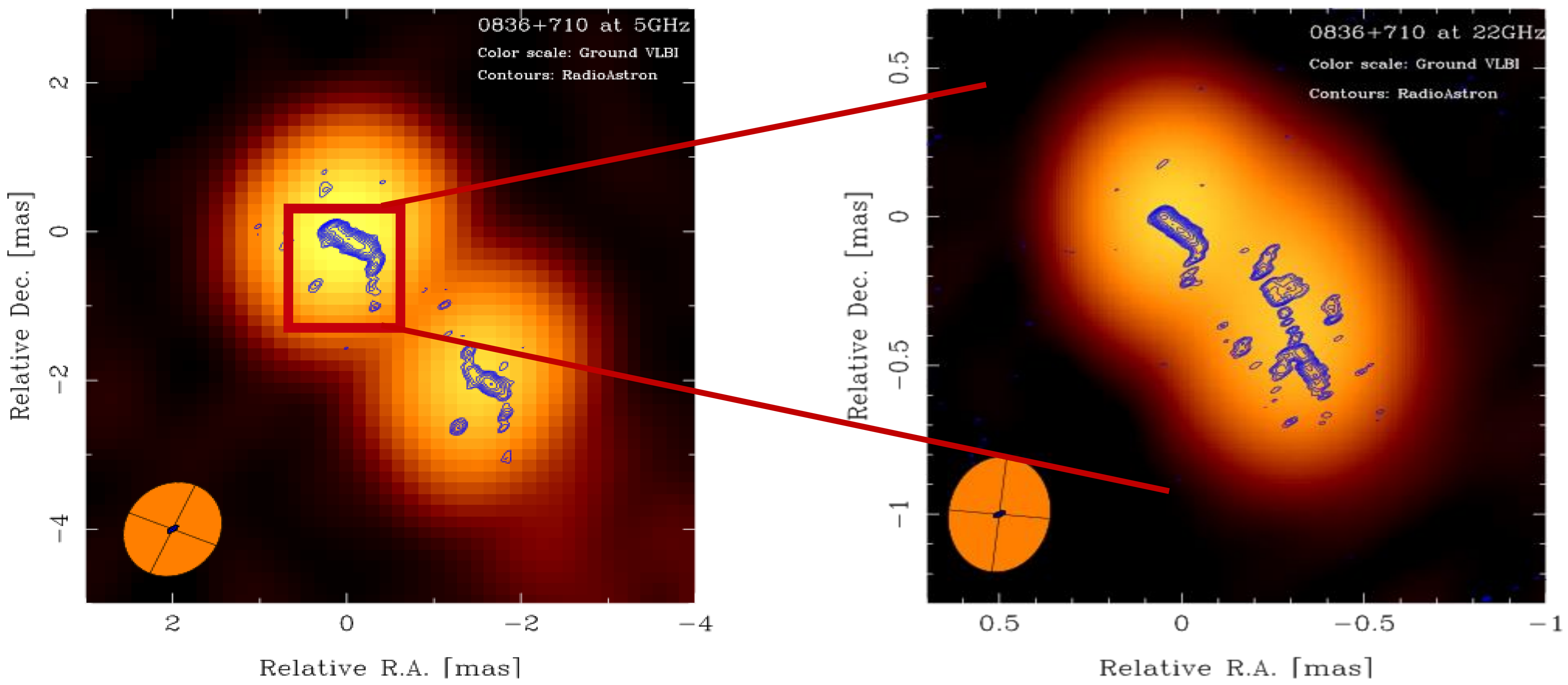
5 GHz and 22 GHz ground and space VLBI images

Overlays of the ground VLBI (color scale) and full-resolution RadioAstron (contours) images of 0836+710 at 5 GHz (left) and 22 GHz (right).

The restoring beams of the ground array (orange) and RadioAstron (blue) images are compared in the lower left corner of each panel.

Both ground array images show a blurred, blobby jet, which shows up in an astoundingly rich structural detail in the respective RadioAstron images.

The image at 22 GHz with RadioAstron features the best angular resolution image of 0836+710 ever obtained, with the jet probed down to ~16 microarcseconds (0.13 pc, at a distance of 5.5 Gpc!).



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