Ultra-compact regions with high polarization are found in quasars

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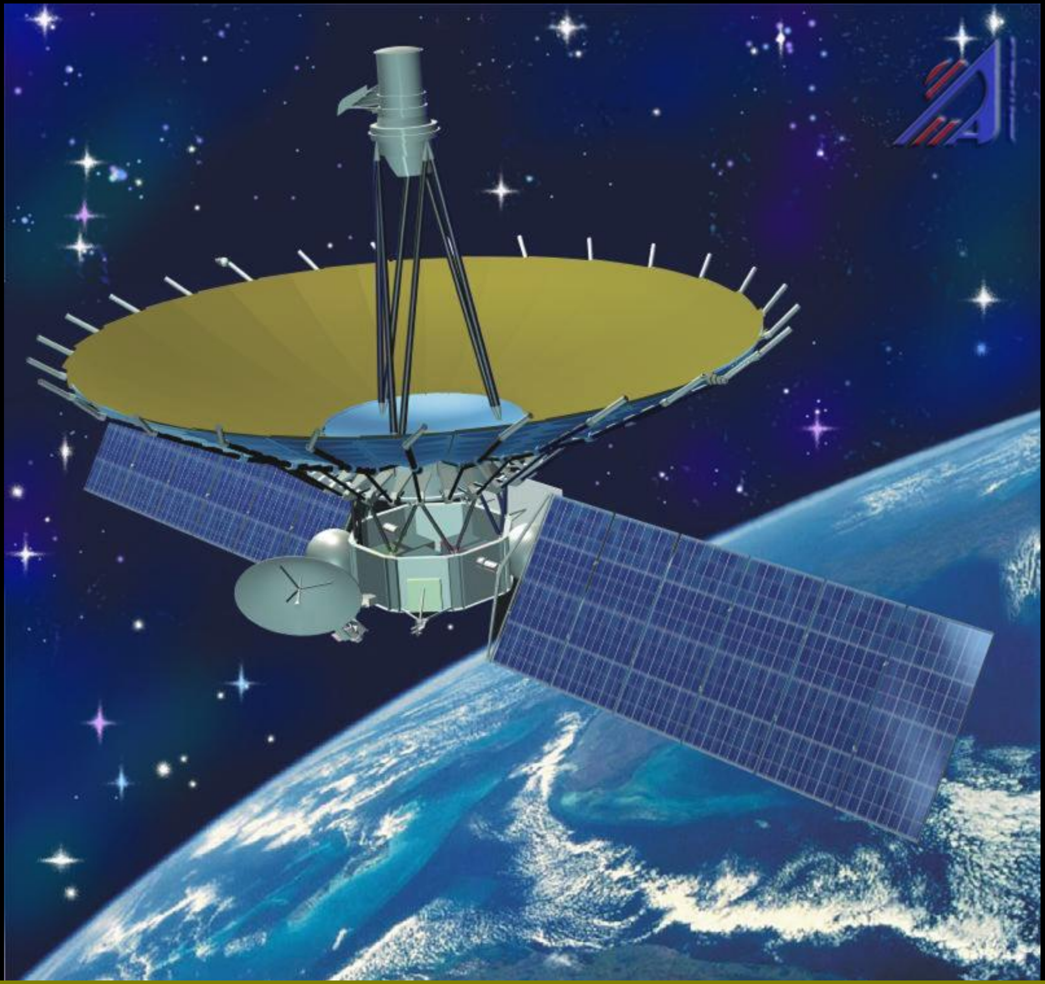


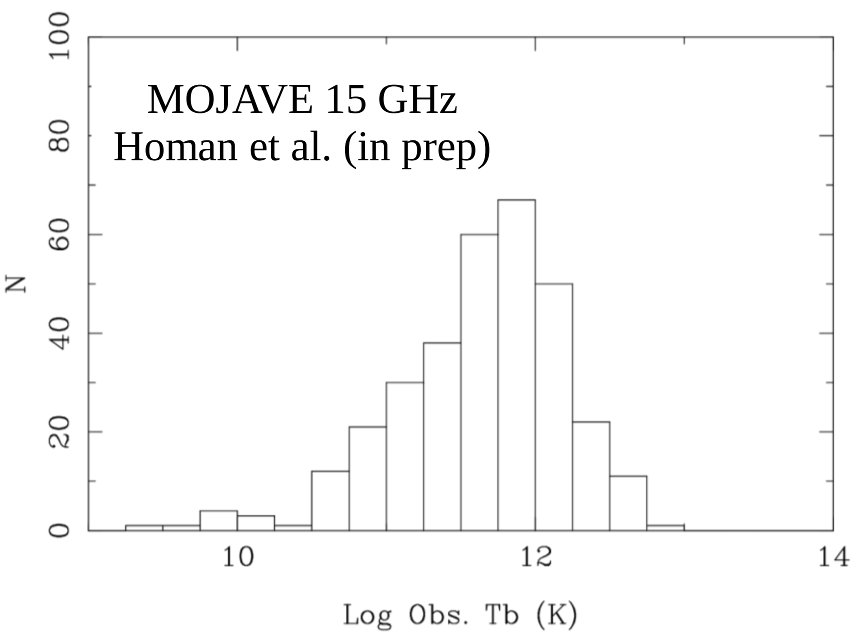
Brightness of Active Galactic Nuclei

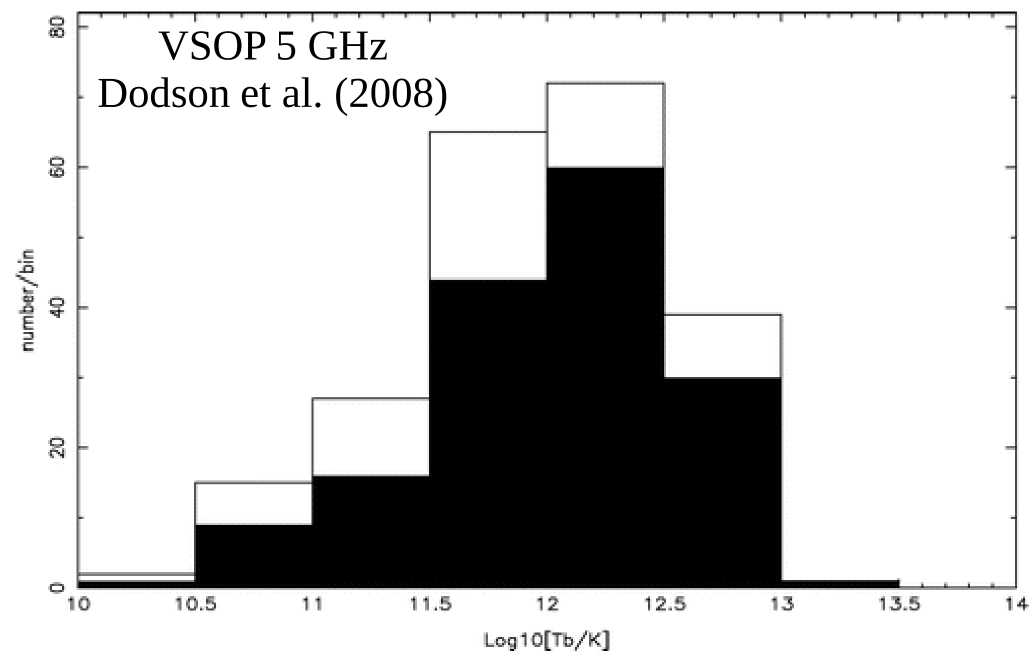
<u>The RadioAstron AGN Tb survey goal:</u>

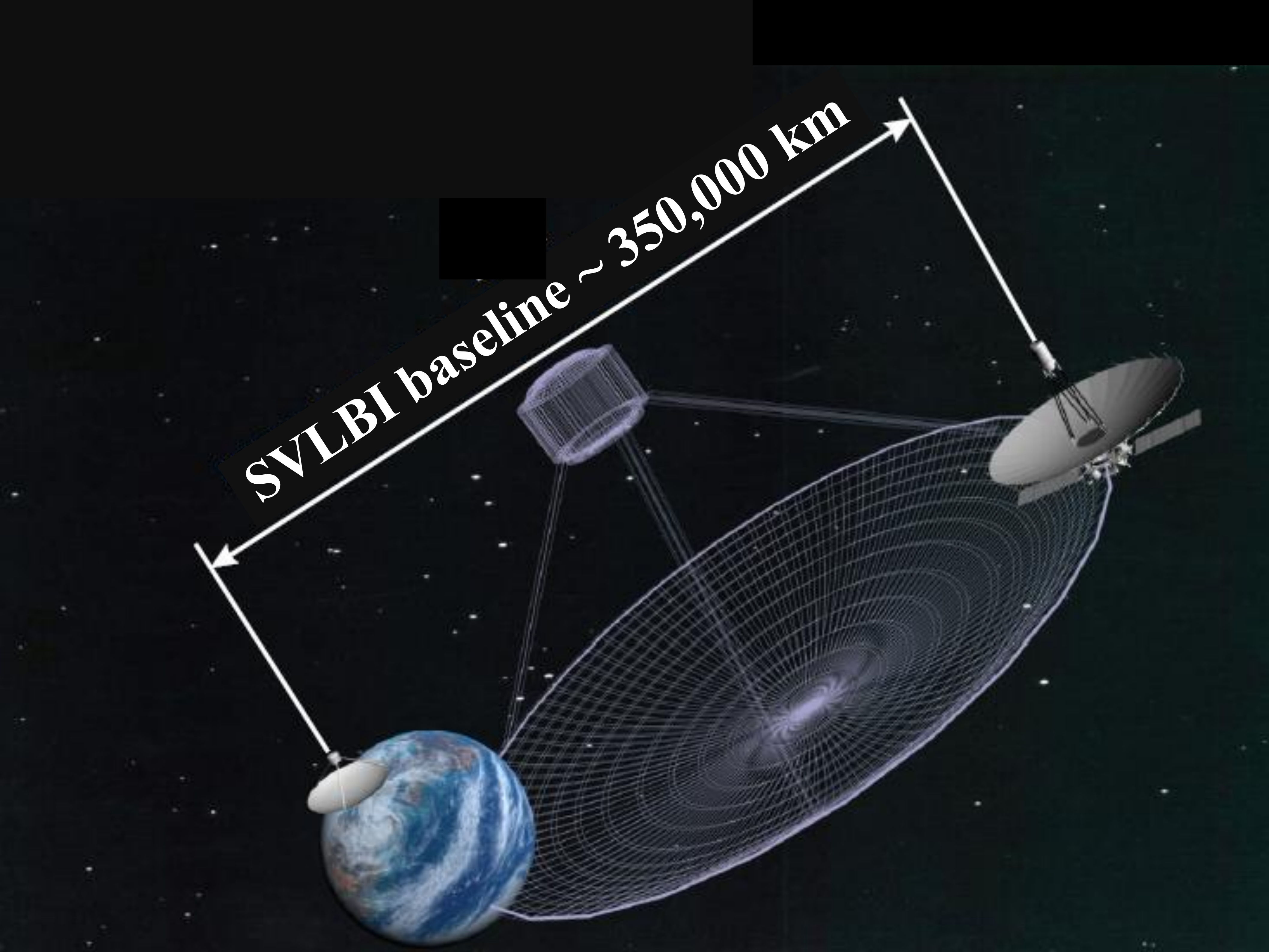
Measure and study brightness temperature of AGN cores in order to better understand physics of their emission.

The inverse-Compton limit of $10^{11.5}$ K is confirmed by previous studies if Doppler boosting is involved. VLBI kinematics estimates a typical Doppler boosting to be ~10. RadioAstron survey probes values up to about 10^{16} K.

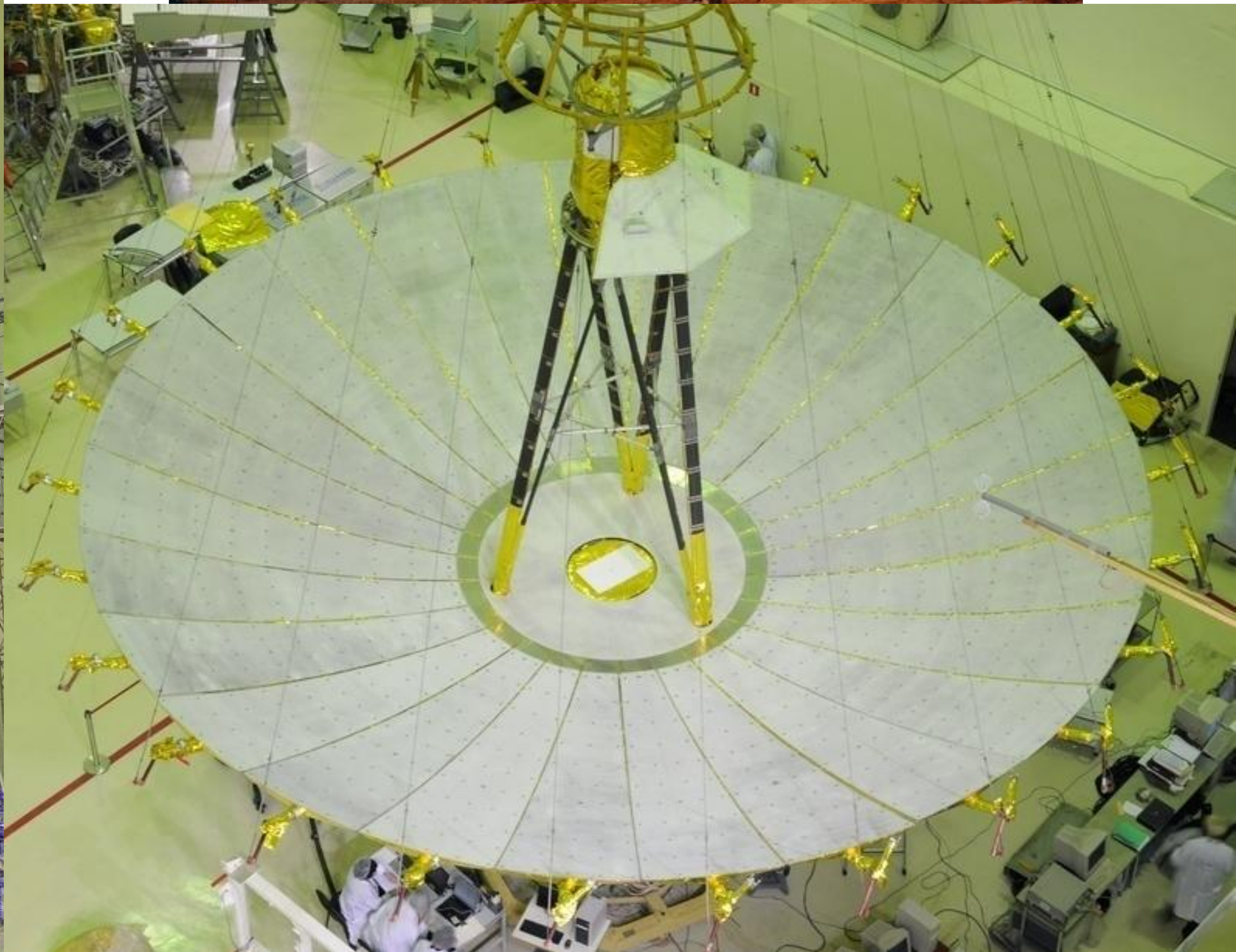
Median $T_b = 10^{12}$ K, max $T_b = 5{\cdot}10^{13}$ K.






SVLBI baseline ~ 350,000 km

Current status: extended until the end of 2019



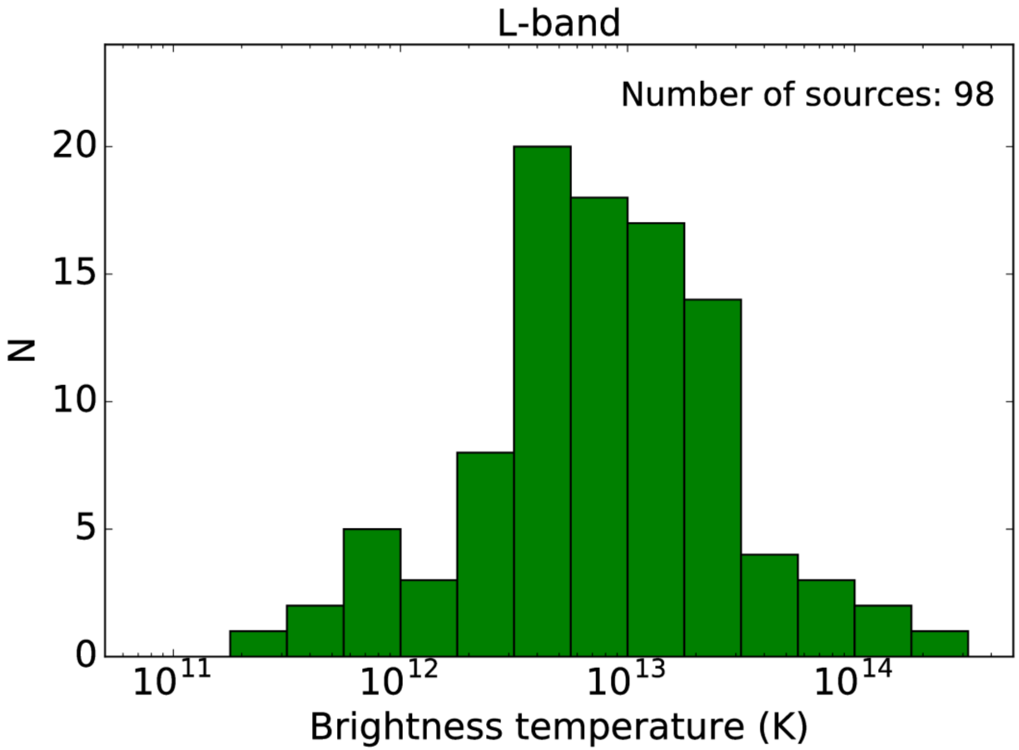
Direct T_b estimates: AGN survey completed
median ~10^{13} K, max ~> 10^{14} K

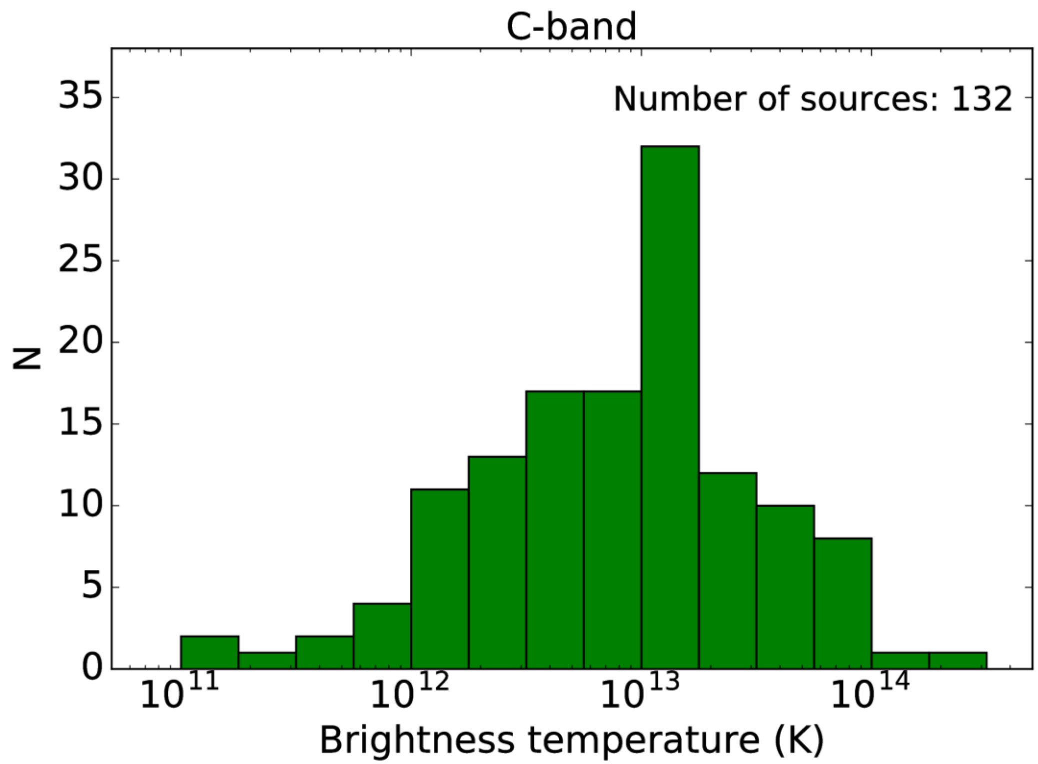
Observed AGNs at 18, 6, 1.3 cm: 248.

Detected AGNs: 164 in about 1/3 of 2600 segments.

AGNs were detected at projections up to 350,000 km at 18 and 6 cm, up to 180,000 km at 1.3 cm.

Cores of AGNs are found to be 10 times brighter than predicted and observed before. The inverse Compton limit is a problem now even if corrected for boosting.





AGN survey analysis

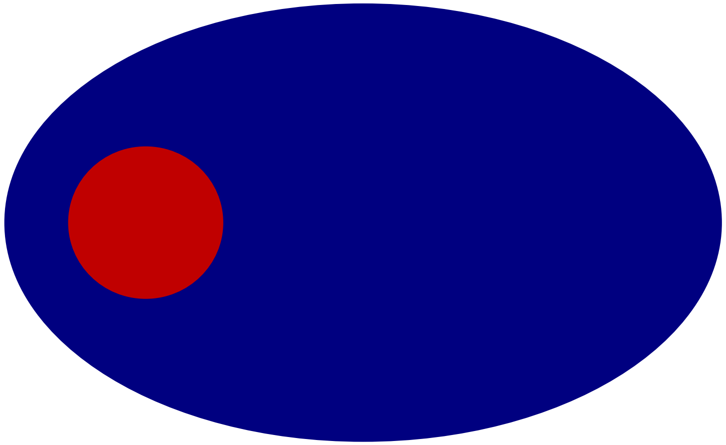
Strange cross-hand correlation results: 3C279

18 cm, 13 Earth diameters, RadioAstron – Effelsberg:
Parallel hand signal SNR = 7
Cross-hand SNR = 11.5

Typically, we cross-correlate everything with everything to check for possible polarization swap.
Was that an expected mistake?
No. Ground-ground results looked "normal". This is a robust and significant measurement.

More examples are found at 6 cm as well, including 16 Earth diameters, RadioAstron-Effelsberg:
Parallel hand signal SNR = 8
Cross-hand SNR = 9

How can we explain this extremely high polarization?



Compact core contains a more compact region with high polarization.

Conservative modeling of **3C279** data suggests the following.

- The 18 cm result:

  Total corr flux density: 20 mJy.

  Cross-hand corr flux density: 30 mJy.

  → 0.3 mas core with 0.1 mas polarized feature.

- The 6 cm result:

  Total corr flux density: 50 mJy.

  Cross-hand corr flux density: 50 mJy.

  → 75 μas core with 25 μas polarized feature.

Another clear case of highly polarized compact core region: 0235+164

0235+164 shows similar (or even more extreme) behavior at 17-26 Earth diameters at 6 cm from two independent measurements at the RadioAstron-Arecibo baselines.

Conservative modeling suggests:

- 6 cm data:

  Total corr flux density: 20-50 mJy.

  Cross-hand corr flux density: 20-40 mJy.

  → 40-60 μas core with 20-13 μas polarized feature.

An indication of a high fractional polarization (ordered field in an optically thin region?). Difficult to make a firm conclusion.

Summary

- ✓ Highly polarized very compact regions in the cores of 0235+164 and 3C279 are found at 18 and 6 cm on the RadioAstron Space VLBI baselines up to 25 Earth diameters.
  More to come from a dedicated analysis of the RadioAstron AGN survey data.

- ✓ This is an indication of highly compact regions with ordered magnetic field in quasar cores.

- ✓ High fractional polarization possible.

THANK YOU

How to generate high brightness temperature

✓ Very high Doppler boosting with *typical* $\delta \sim 100$ – VLBI kinematics does not confirm it.

Typical observed VLBI kinematics does not reflects the plasma bulk motion in many cases?

✓ Continuously “excited” core being most of the time at the inverse-Compton limit or continuous re-acceleration several parsecs away from the core.

How? Flares do not happen all the time. Magnetic reconnection? Shocks? γ-ray photon flux is not high enough but radio photons could be upscattered to lower energies and increase uv / x-ray flux.

✓ Relativistic protons or coherent processes.

Requires very efficient acceleration and high magnetic field. Many problems.

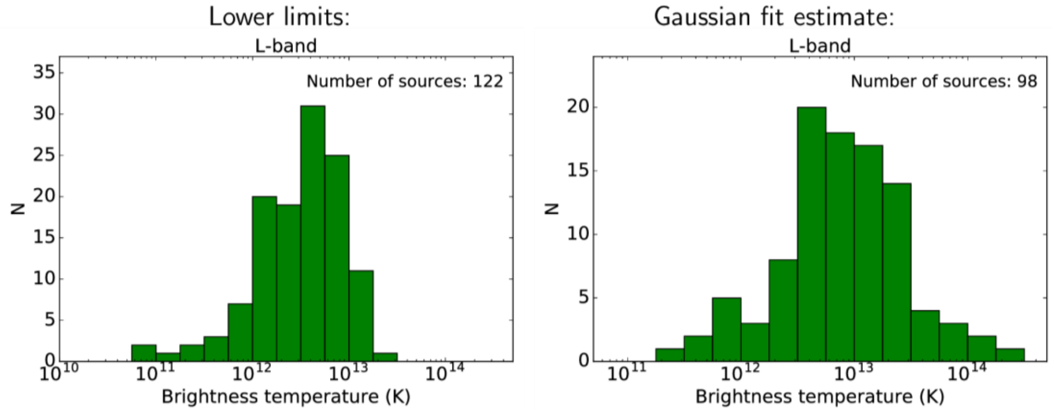


Figure 10: Observed source frame brightness temperature values at 18 cm. The ultimate lower limits are estimated following Lobanov (2015) from SVLBI flux density only. No $(1+z)$ correction.

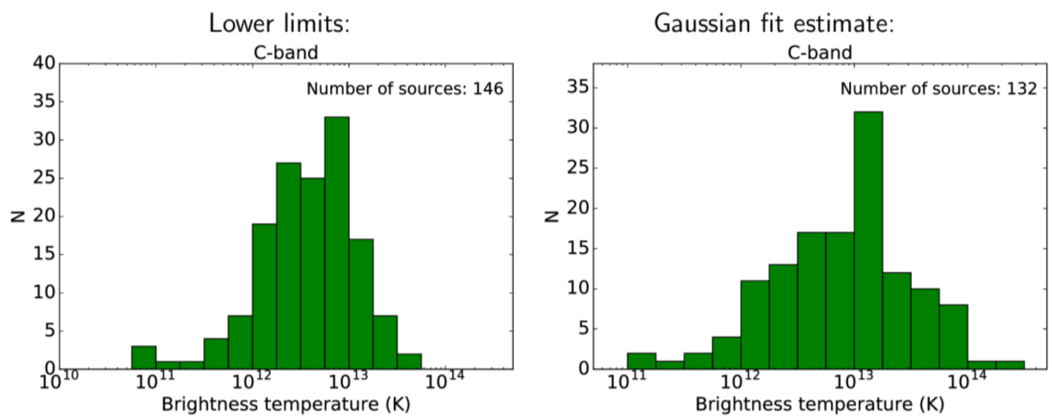


Figure 11: Observed source frame brightness temperature values at 6 cm.

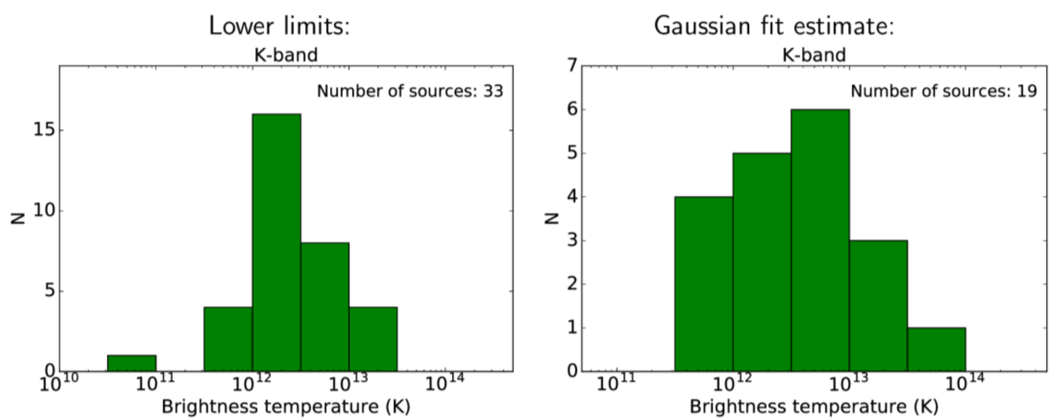


Figure 12: Observed source frame brightness temperature values at 1.3 cm.