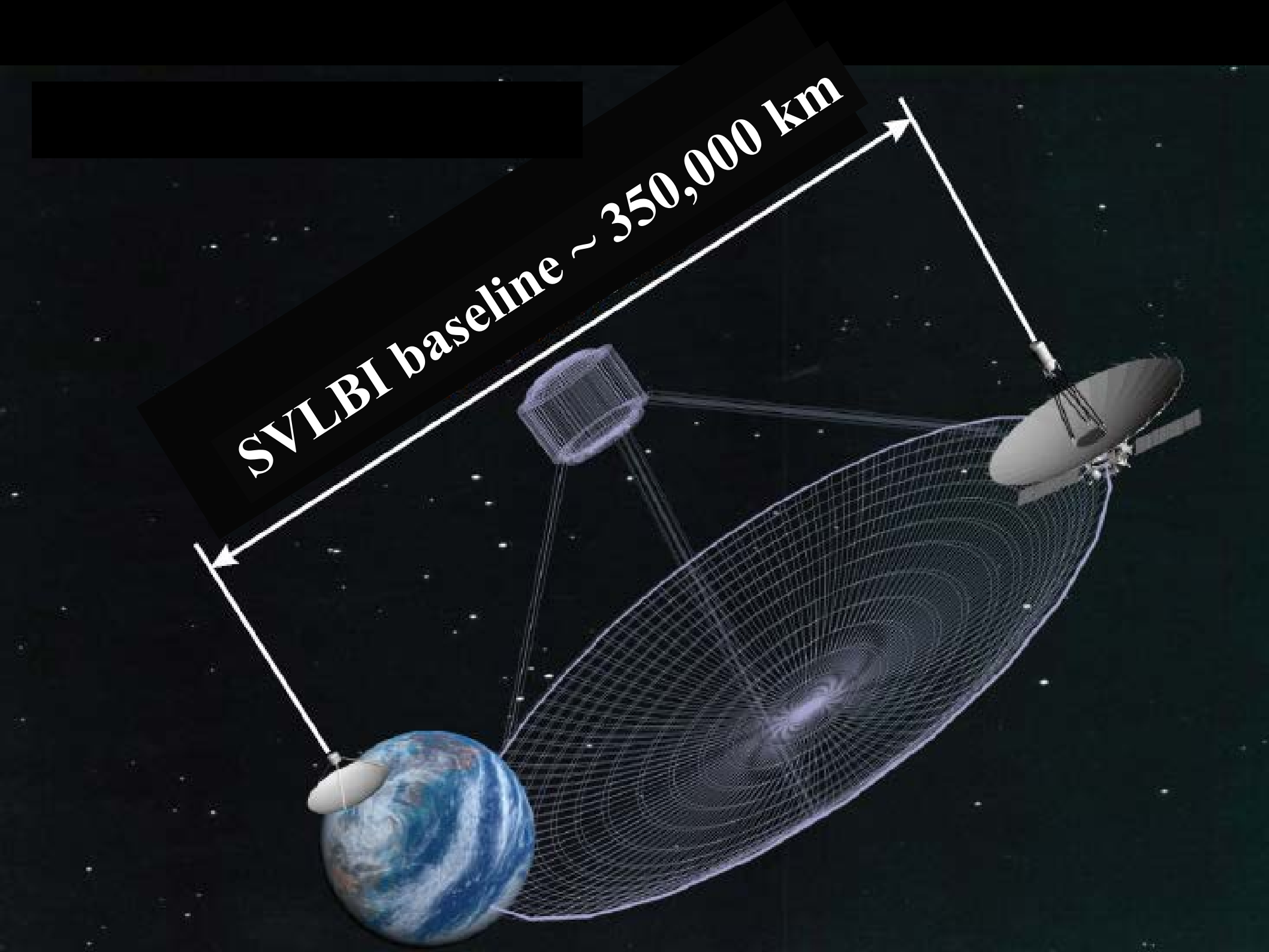
RadioAstron: AGN Tb survey

Yuri Kovalev for the AGN survey team
Astro Space Center of Lebedev Physical Institute, Moscow


SVLBI baseline ~ 350,000 km

GRTs involved in the survey

VLBI:
Kvazar network: Sv, Bd, Zc (Russia);
Kalyazin (Russia);
Evpatoriya (Ukraine);
Irbene (Latvia)
Effelsberg (Germany);
WSRT (the Netherlands);
Torun (Poland);
Medicina, Noto, Sardinia (Italy);
Yebes, Robledo (Spain);
Jodrell Bank 1 & 2 (UK);
Usuda (Japan);
Shanghai 25 & 64, Urumqi (China);
VLA, GBT, VLBA, Arecibo (USA);
HartRAO (South Africa);
LBA (Australia), KVN (S Korea).

Single-dish:
RATAN-600 (Russia);
ATCA (Australia);
WSRT (the Netherlands);
Urumqi (China);
Effelsberg (Germany);
Oven Valley (USA);
GBT (USA).

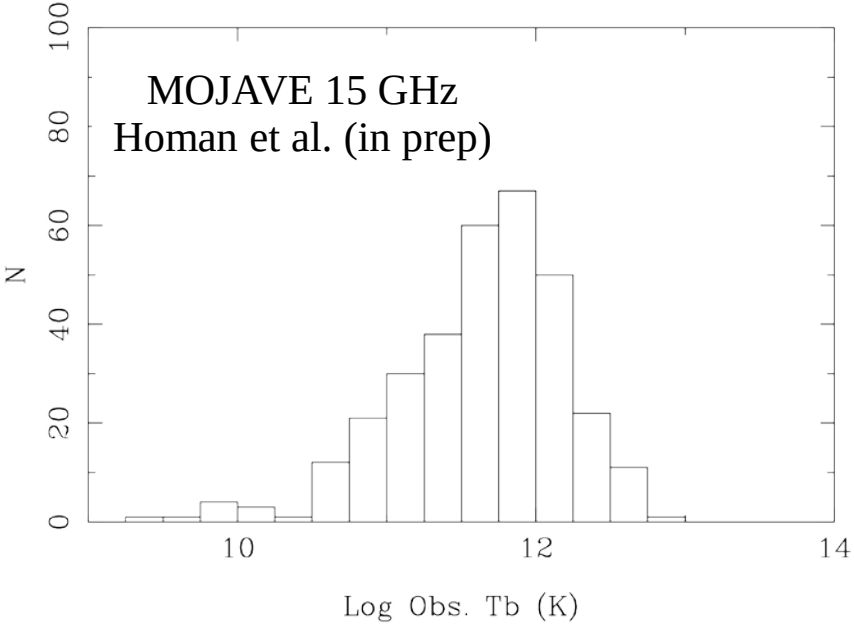
The brightness temperature inverse-Compton limit

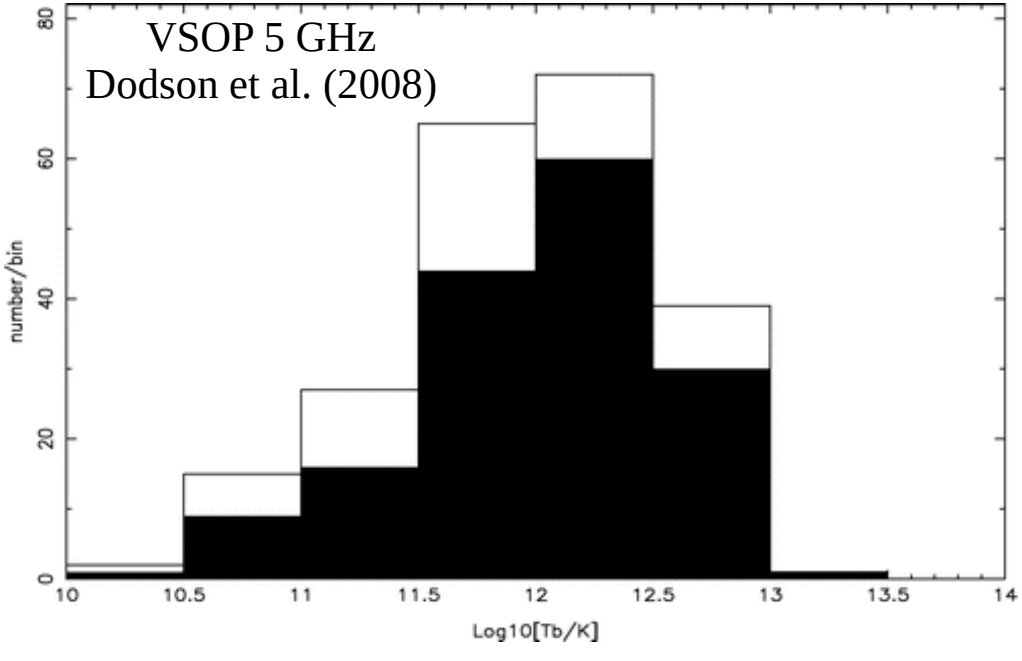
The RadioAstron AGN Tb survey goal:

Measure and study brightness temperature of AGN cores in order to better understand physics of their emission while taking interstellar scattering into consideration.

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.





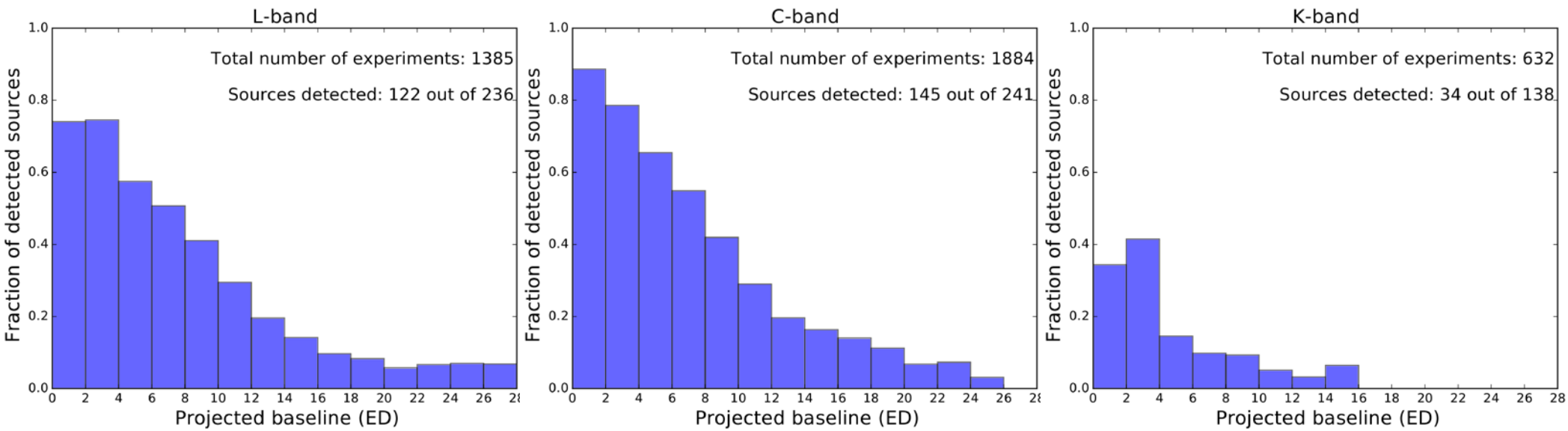
AGN survey results: detection statistics

Sample: ~250 strong AGN

Correlated and post-processed to date: 2000 experiments, significant detections are found for 160 AGNs in 700 experiments at 18 and/or 6 and/or 1.3 cm up to 350,000 km.

The highest resolution: 0235+164 & OJ287 at 1.3 cm, 15 Earth diameters, about 14 μas. Not an absolute record any more…

Summary: typical Tb one order of magnitude higher than what was previously known.

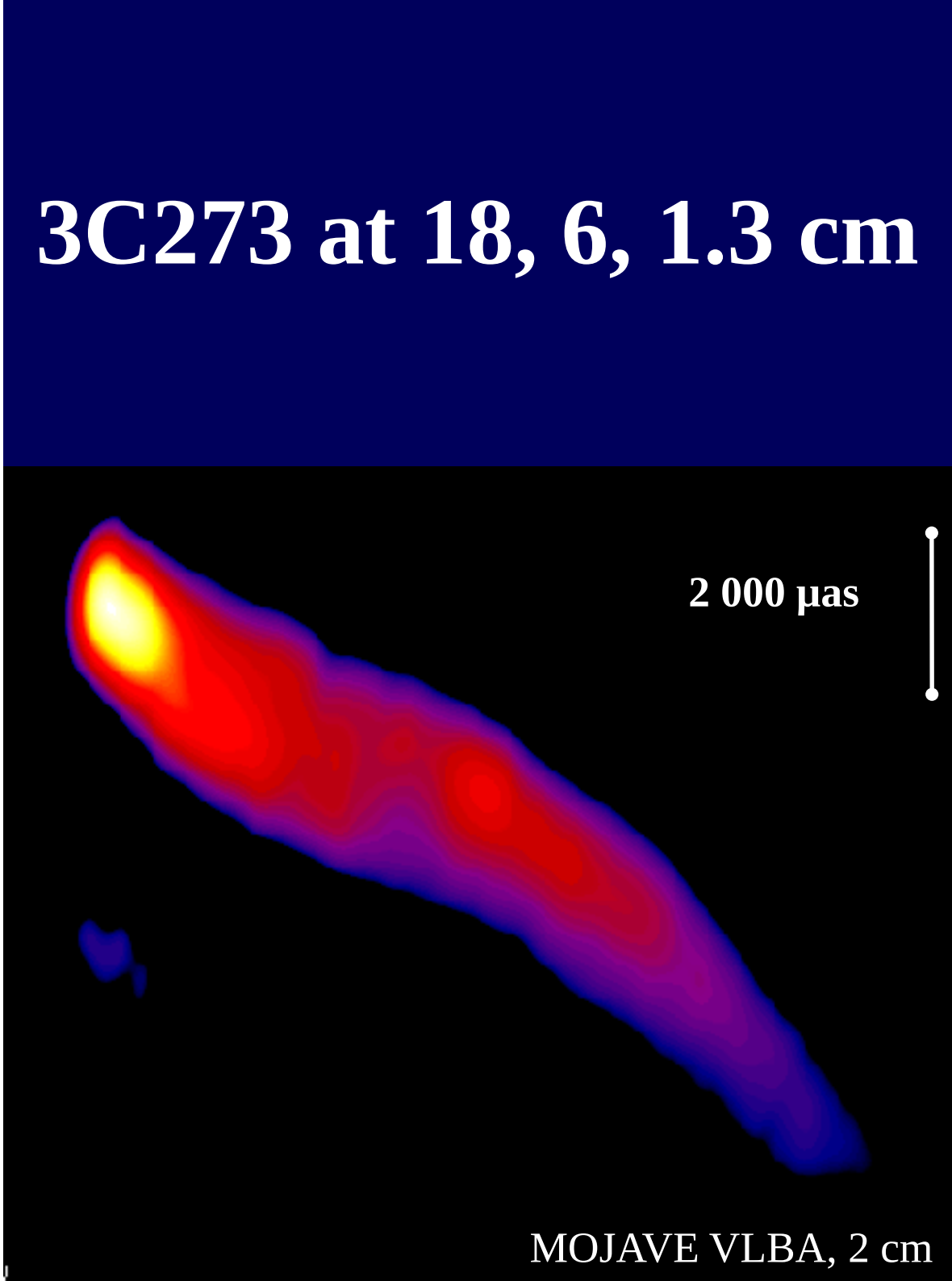


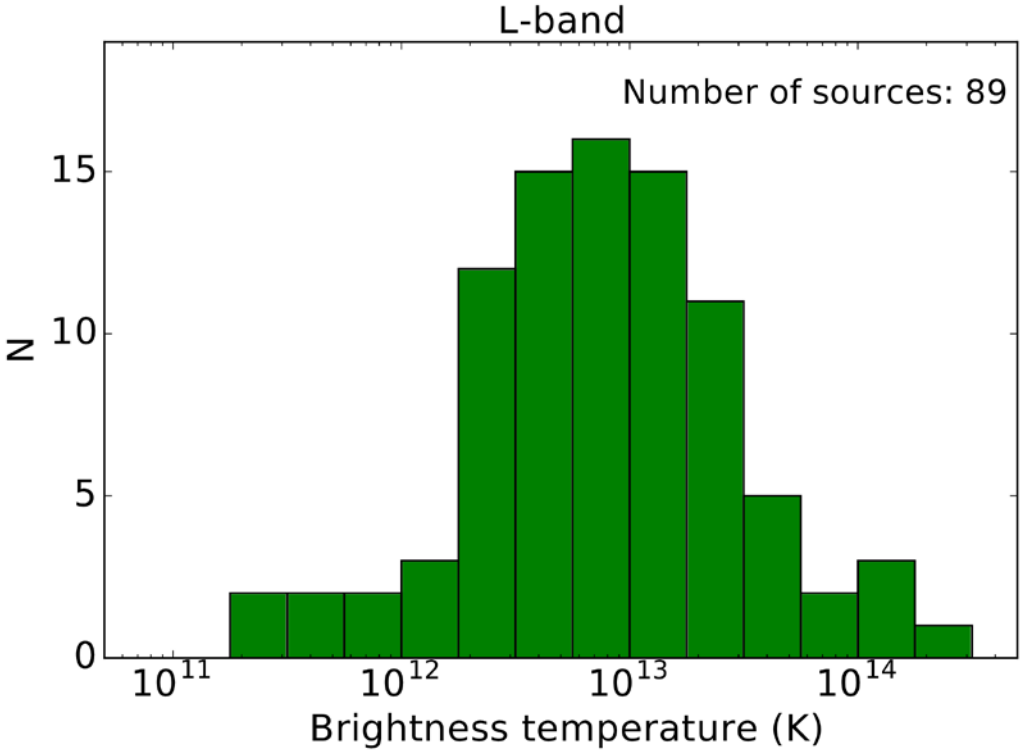
RadioAstron core brightness temperature: 2-4·10^{13} K.

The Doppler factor about or less than 13 (Jorstad et al. 2005, Savolainen et al. 2010) is not high enough to get the brightness temperature down to $10^{11.5}$K.

Note: Gomez et al. (2016) got similar Tb values for the core of BL Lac from RA 1.3 cm imaging.

Kovalev et al. (2016)

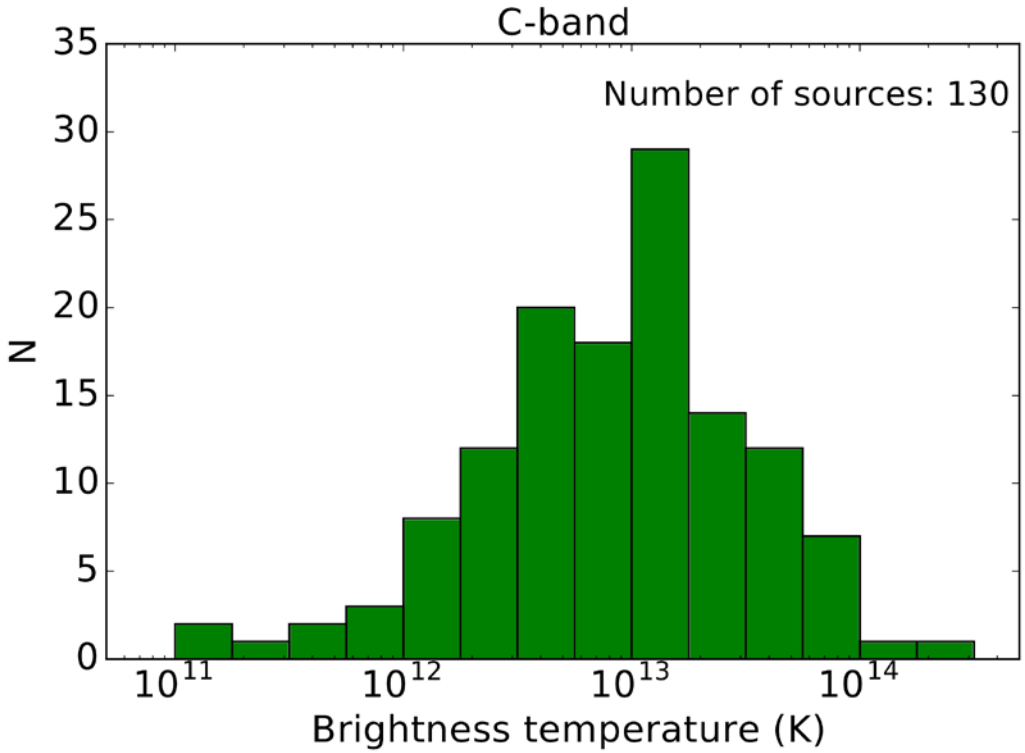


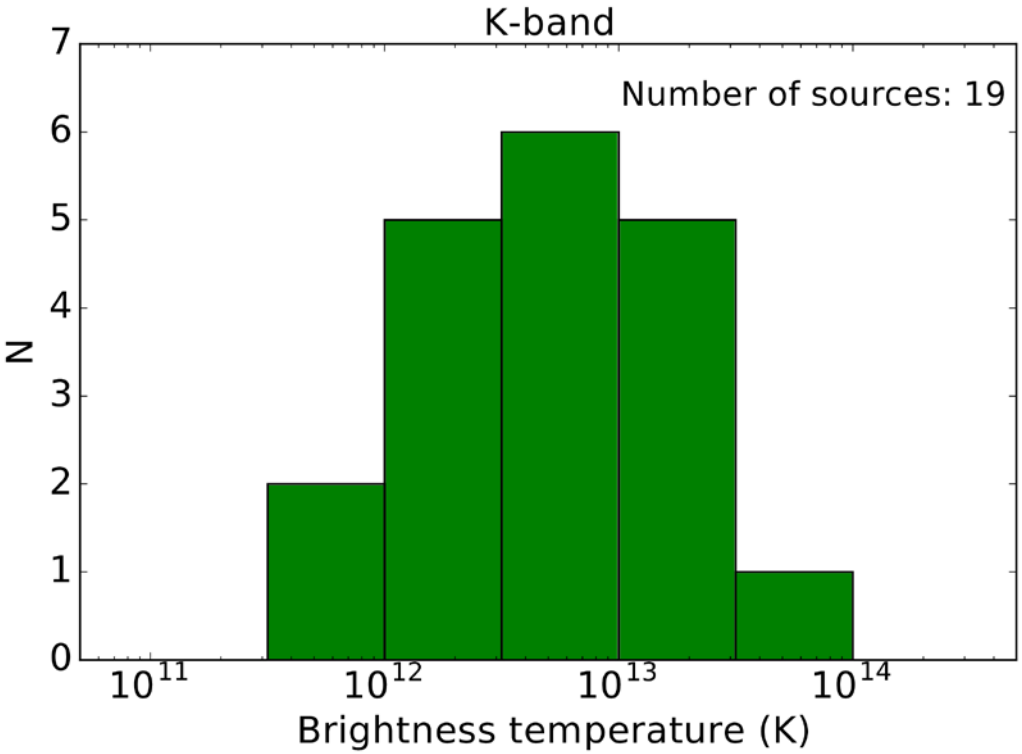


Direct T_b estimates:

median ~10^{13} K

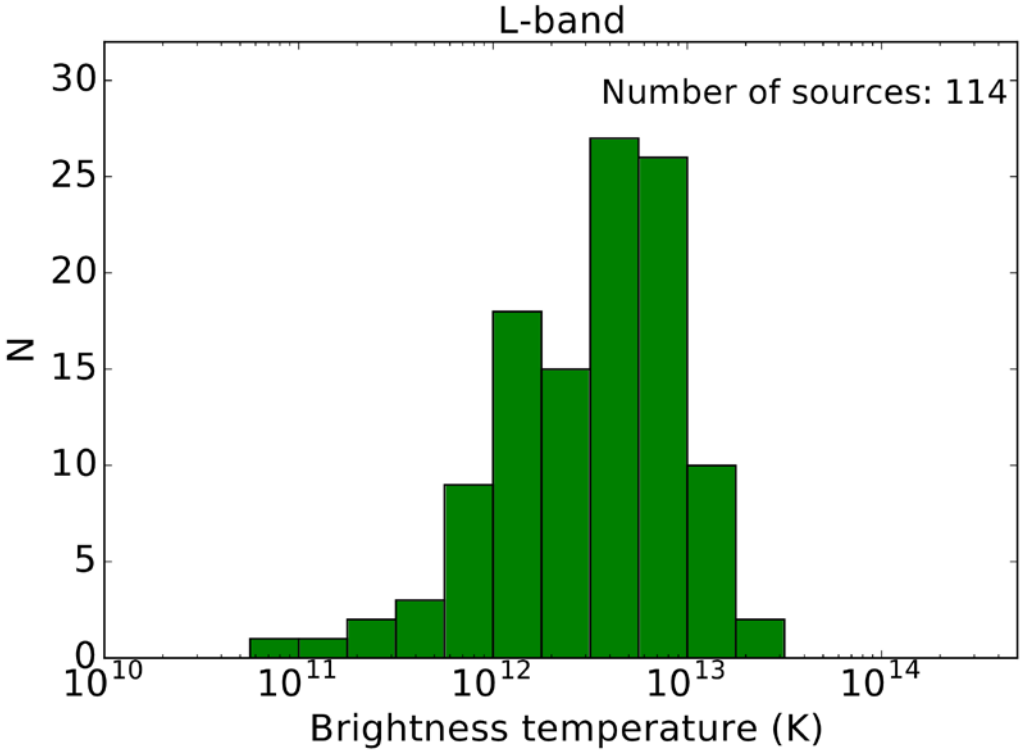
max ~> 10^{14} K

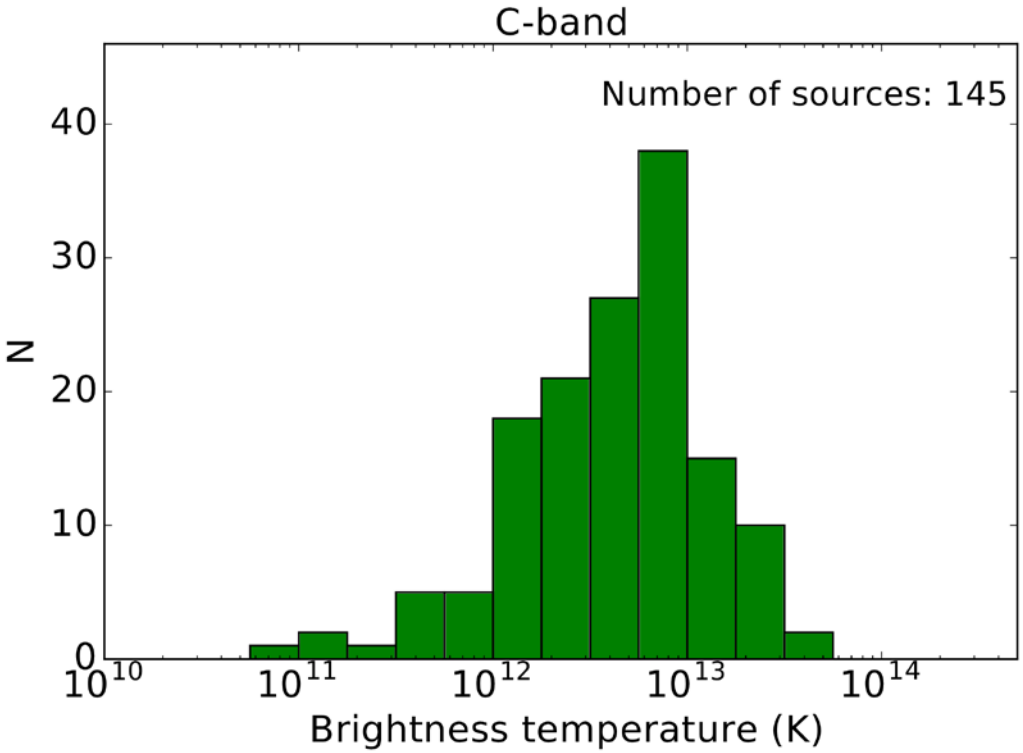


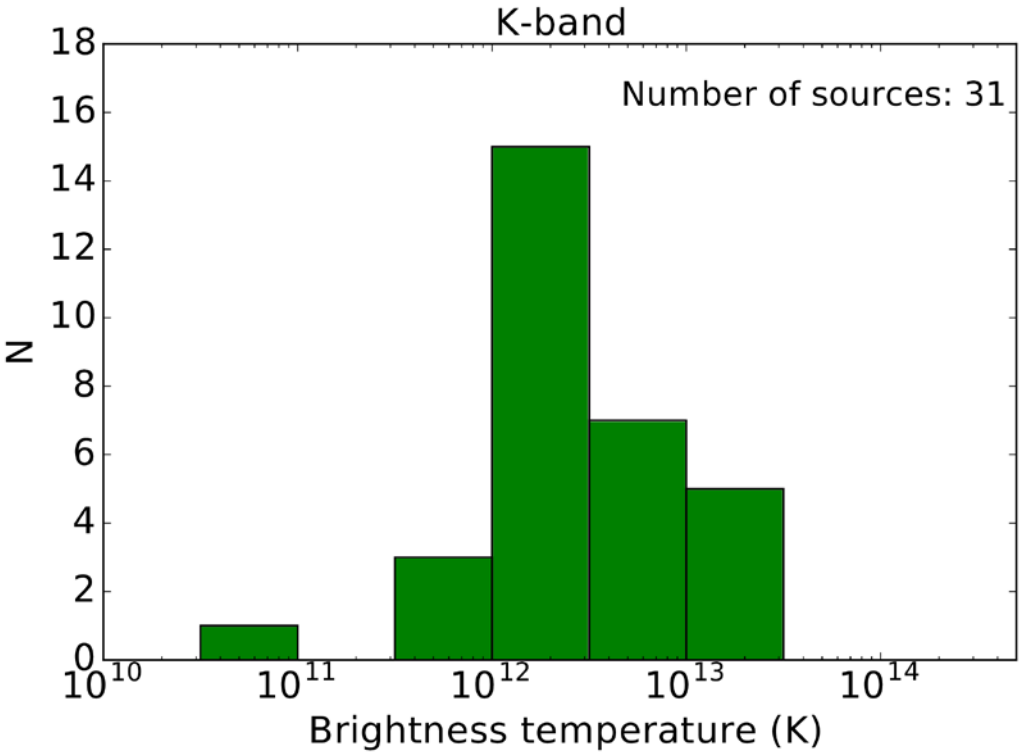


T_b lower limit

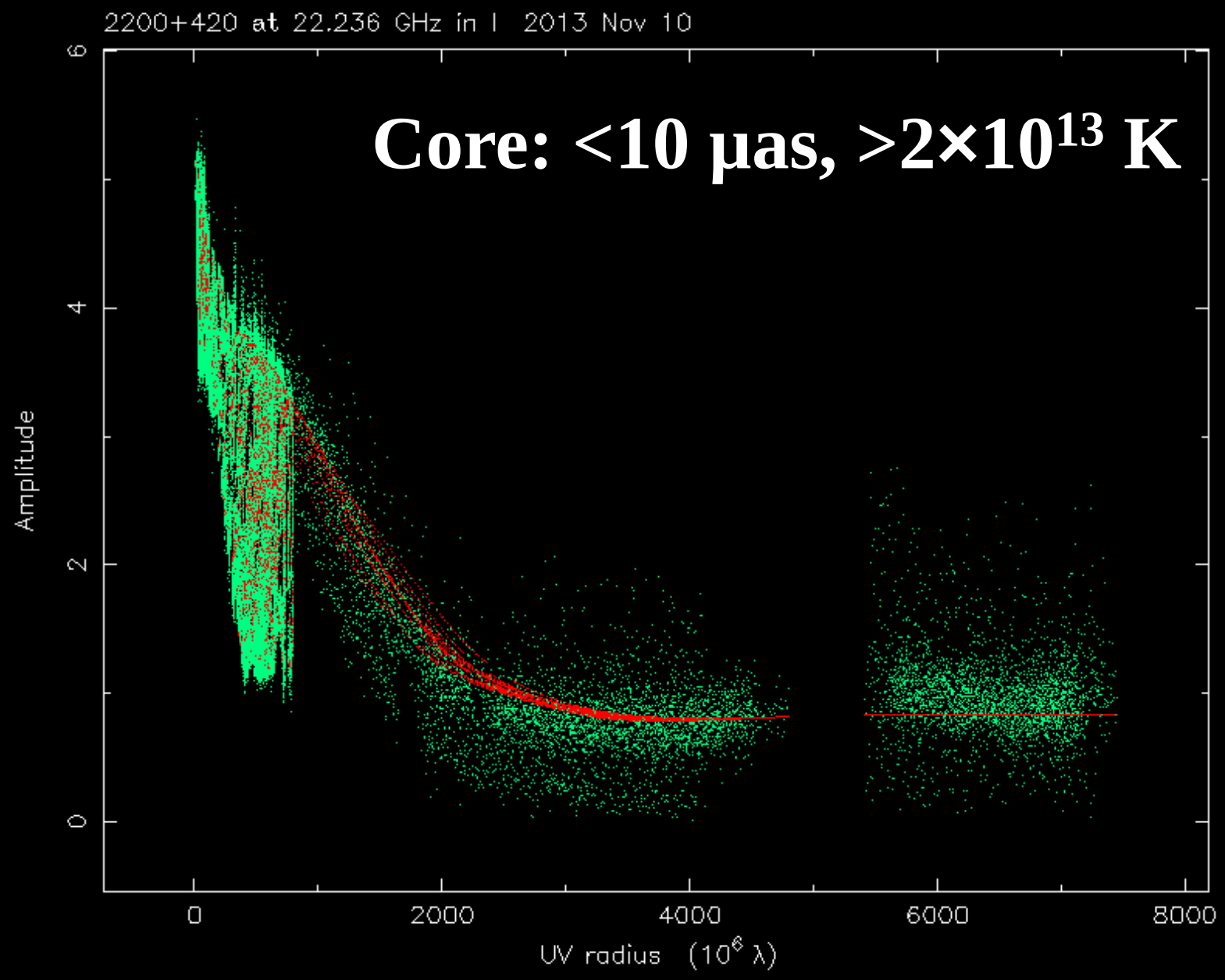
No component flux density assumed, only direct RadioAstron measurements are used following an approach suggested by Lobanov (2015).







Where does the high Tb comes from?
We use the RadioAstron imaging (Gomez et al.)



How to generate high brightness temperature

✓ Very high Doppler boosting with *typical* δ~100 – VLBI kinematics does not confirm it.

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

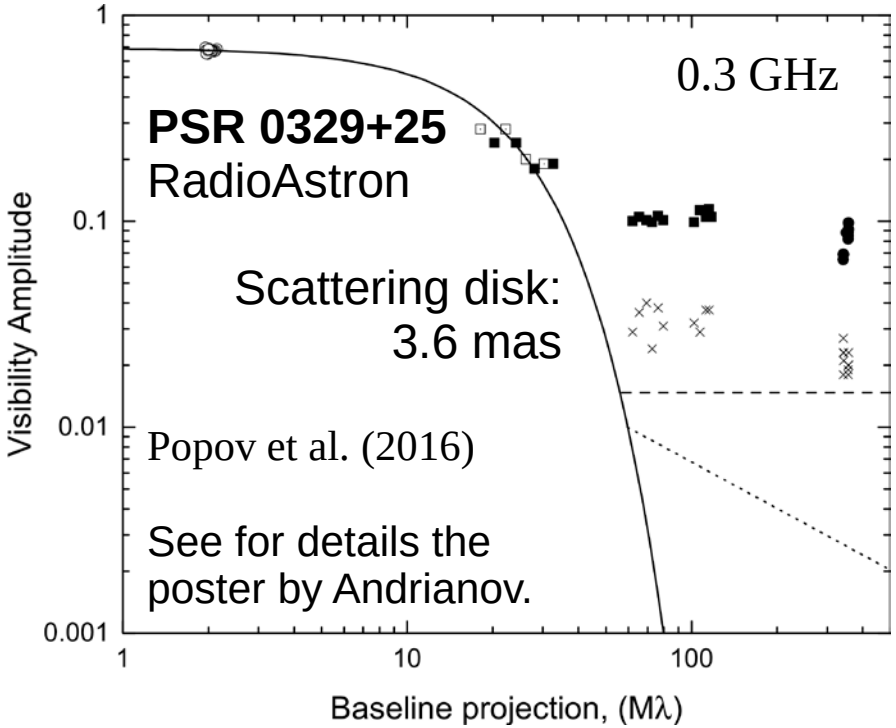
✓ Continuously "excited" core being most of the time at the inverse-Compton limit or continuous re-acceleration several parsecs away from the core.

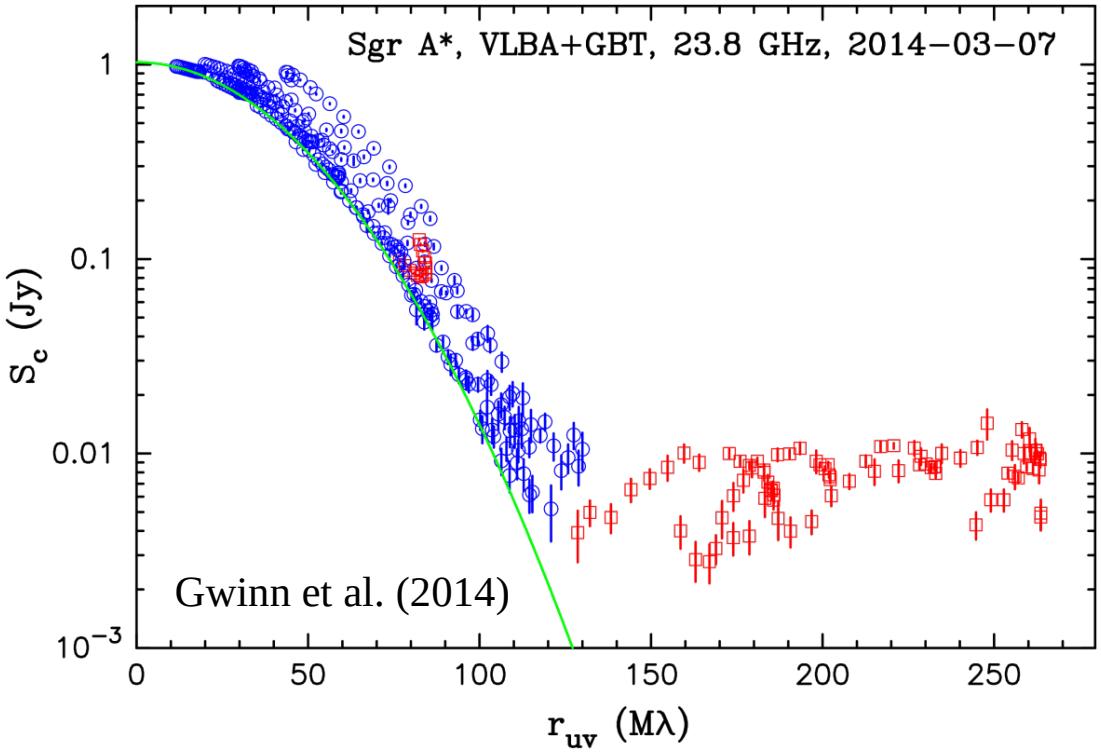
How? Flares do not happen all the time. Magnetic reconnection? Shocks? γ-ray photon flux is not high enough but radio photons could be upscattered to lower energies and increase uv / x-ray flux.

✓ Relativistic protons or coherent processes.

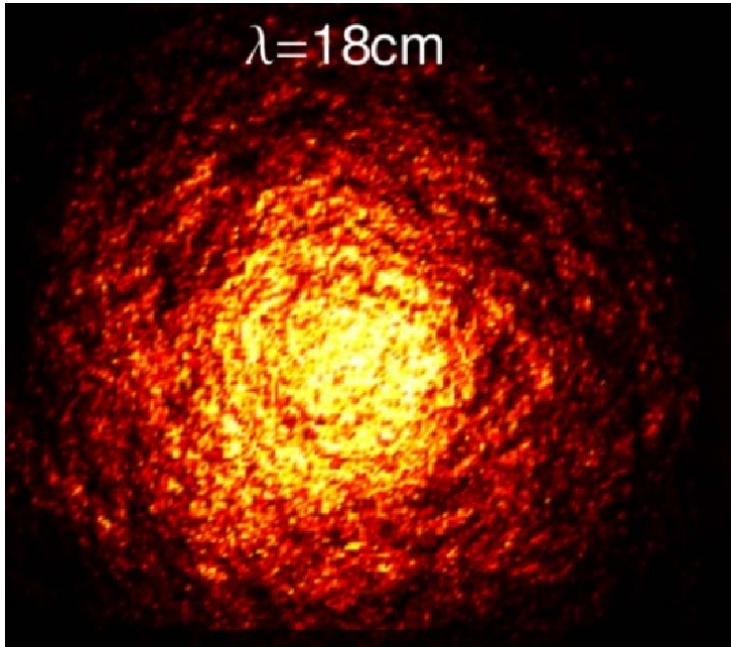
Requires very efficient acceleration and high magnetic field. Many problems.

Discovery of the scattering sub-structure





- Modeling of the scattering substructure effect for AGN at RadioAstron baselines (Johnson et al. 2016): expected at 1% level at 18 and 6 cm, does not affect results significantly.
- Should be taken into account even for EHT SgrA* start observations.
- A new promising tool to reconstruct the background source true image.



Summary

- About 160 AGNs are detected at RadioAstron baselines. Typical brightness of their cores is on the level of 10^{13} K and extends to more than 10^{14} K.

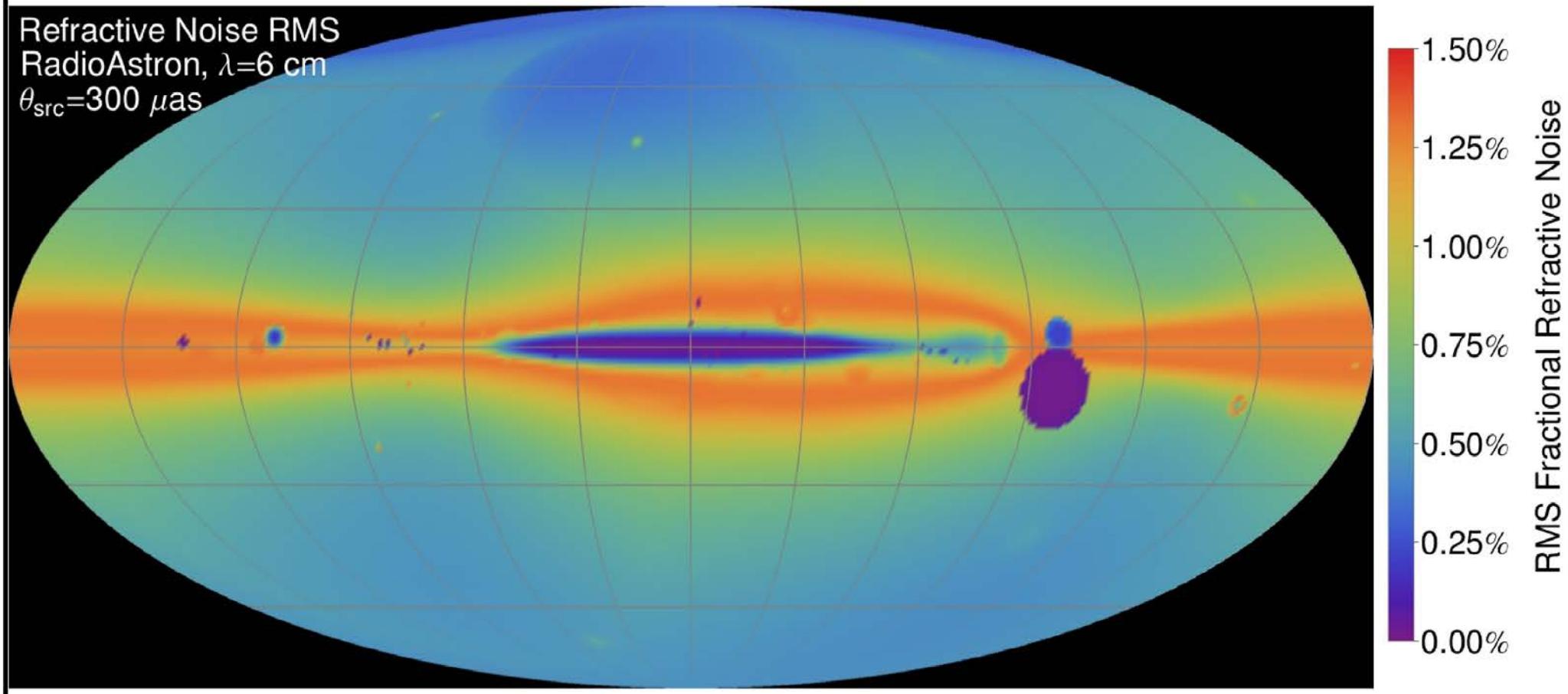
- Typical Doppler factors of a hundred or an efficient acceleration mechanism parsecs away from the core is required to explain it.

- Particles energy should dominate, equipartition does not seem to survive.

- Scattering sub-structure is discovered, affects and helps observations of pulsars, AGNs, SgrA*, interstellar medium.

THANK YOU

Refractive Substructure and RadioAstron



Typical angular broadening is 30 μas
Nominal Resolution of RadioAstron is up to ~35 μas

Johnson & Gwinn (2015)