RadioAstron survey of AGN cores

Yuri Kovalev (ASC Lebedev, Moscow) for the survey team

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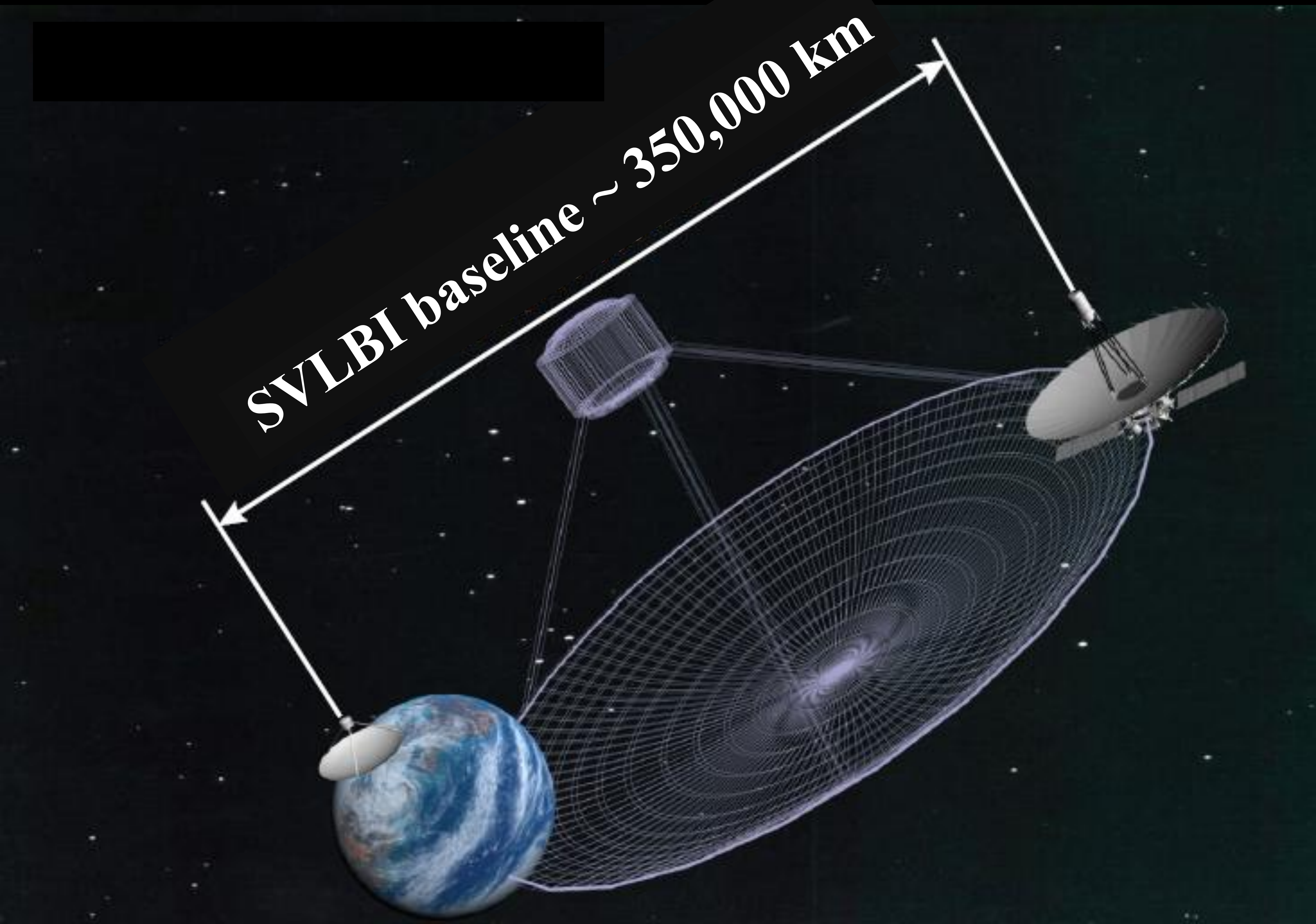
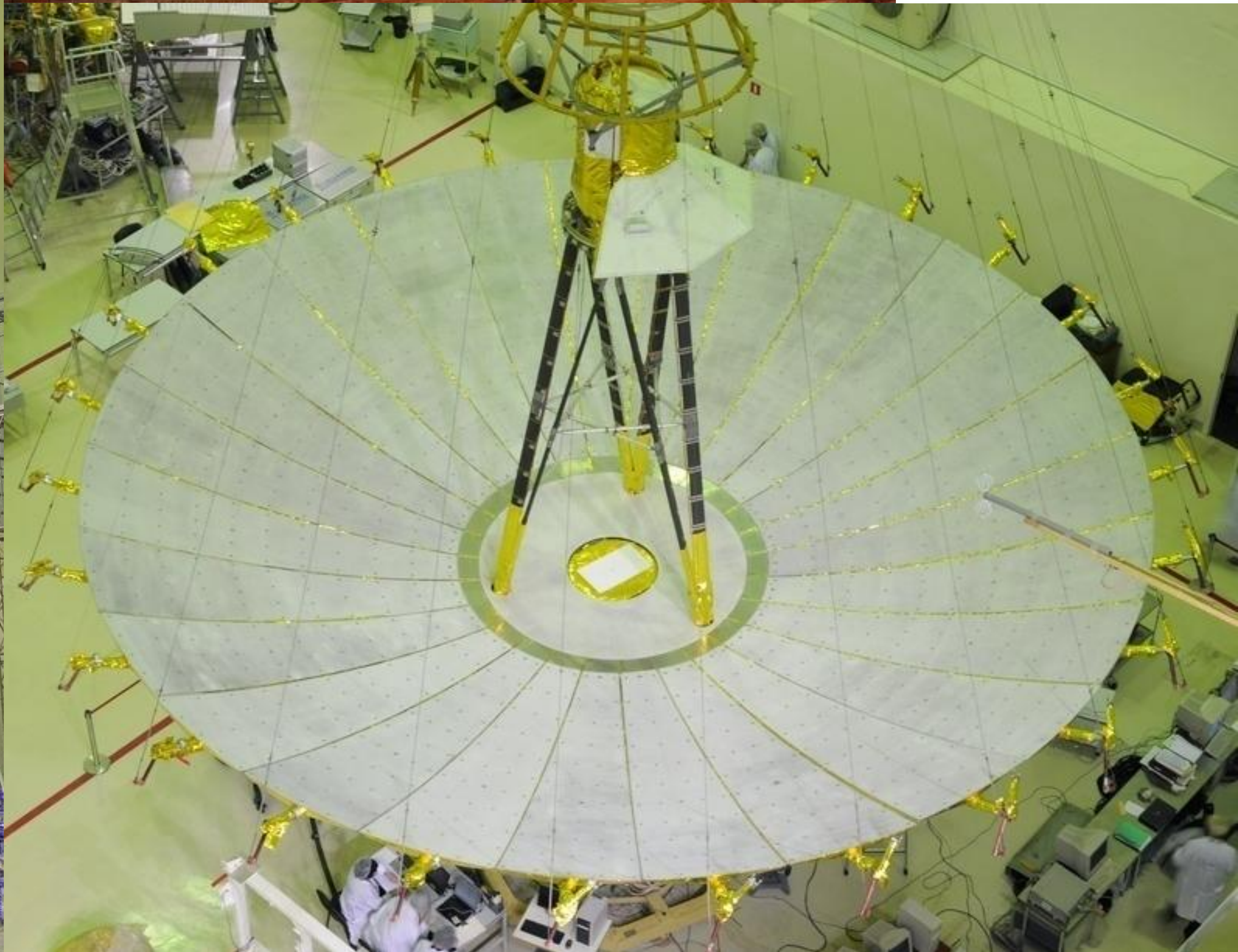


Launch in 2011



RadioAstron AGN survey: the team

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Many participating ground radio telescopes

VLBI:

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

Single-dish:

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

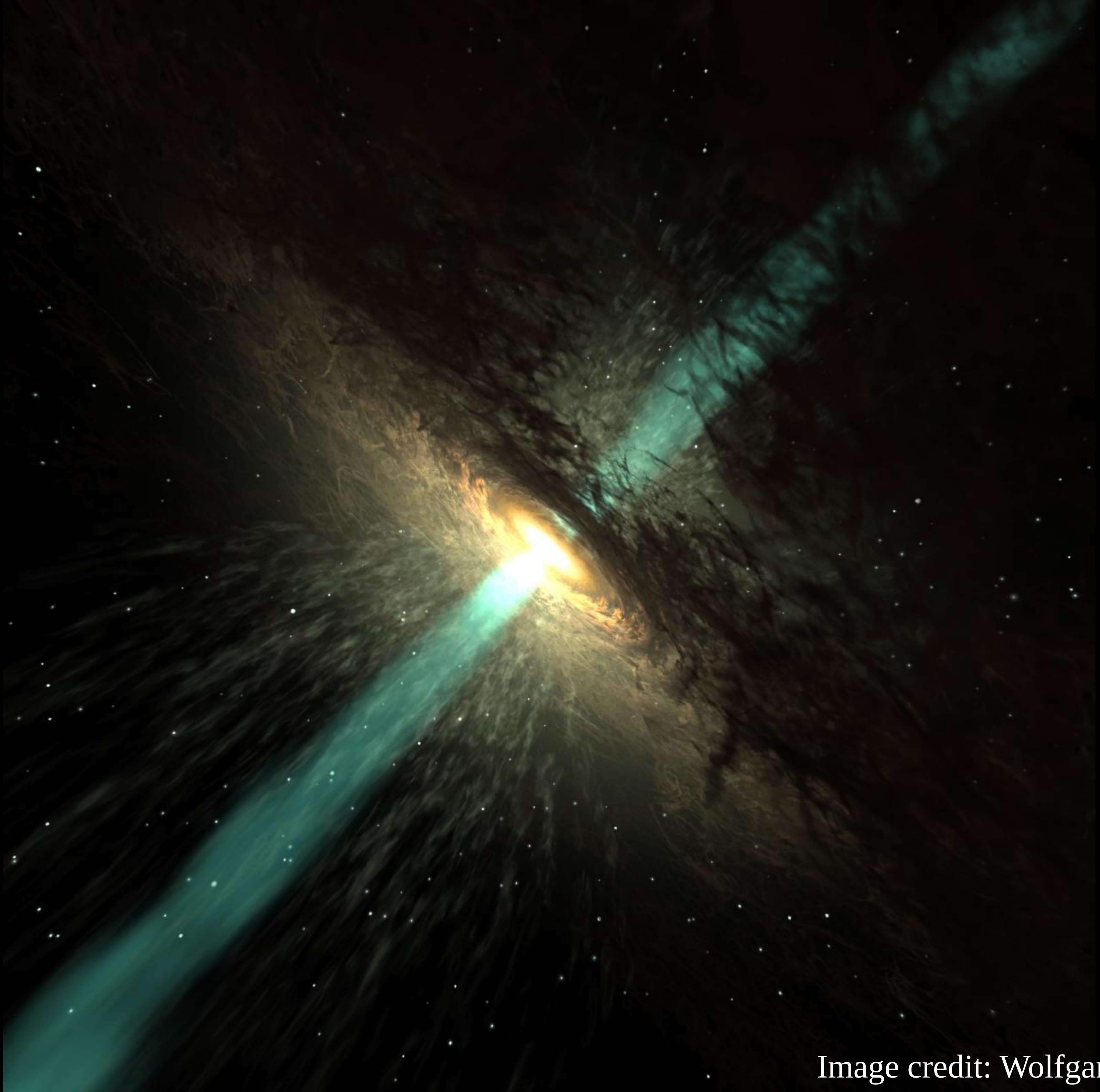


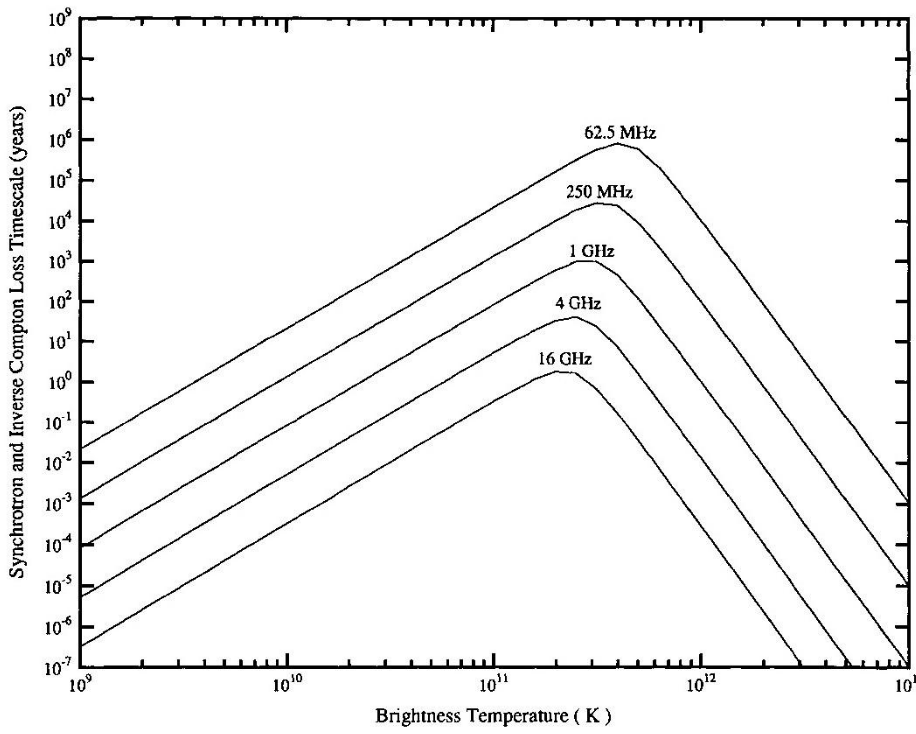
Image credit: Wolfgang Steffen

RadioAstron AGN survey: main goal

The goal:

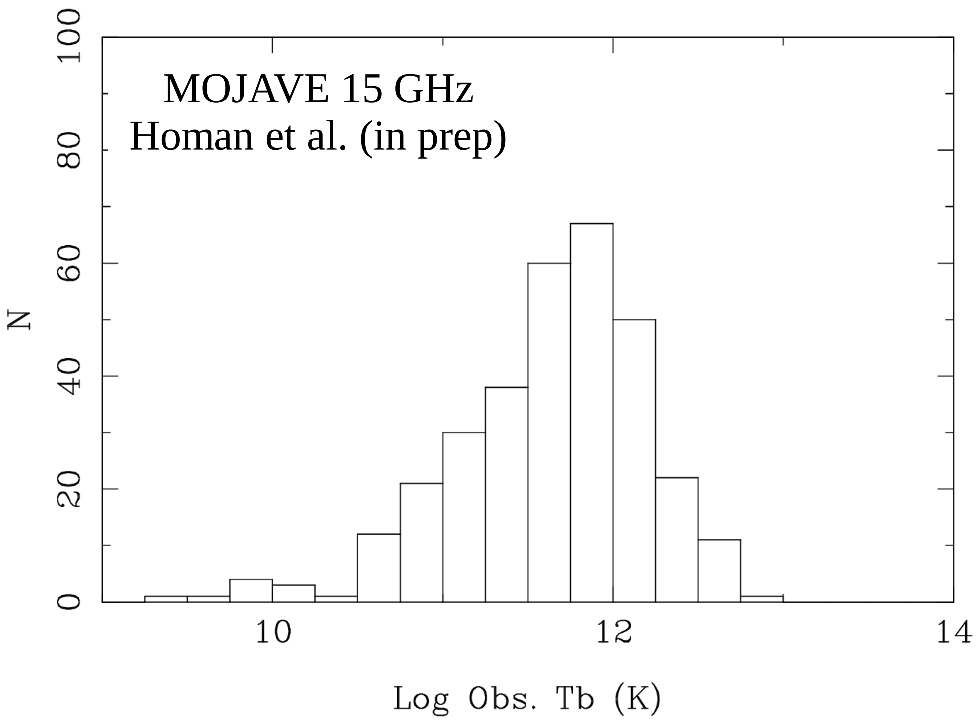
Measure and study brightness temperature of AGN cores in order to better understand physics of their emission while taking interstellar scattering into consideration.

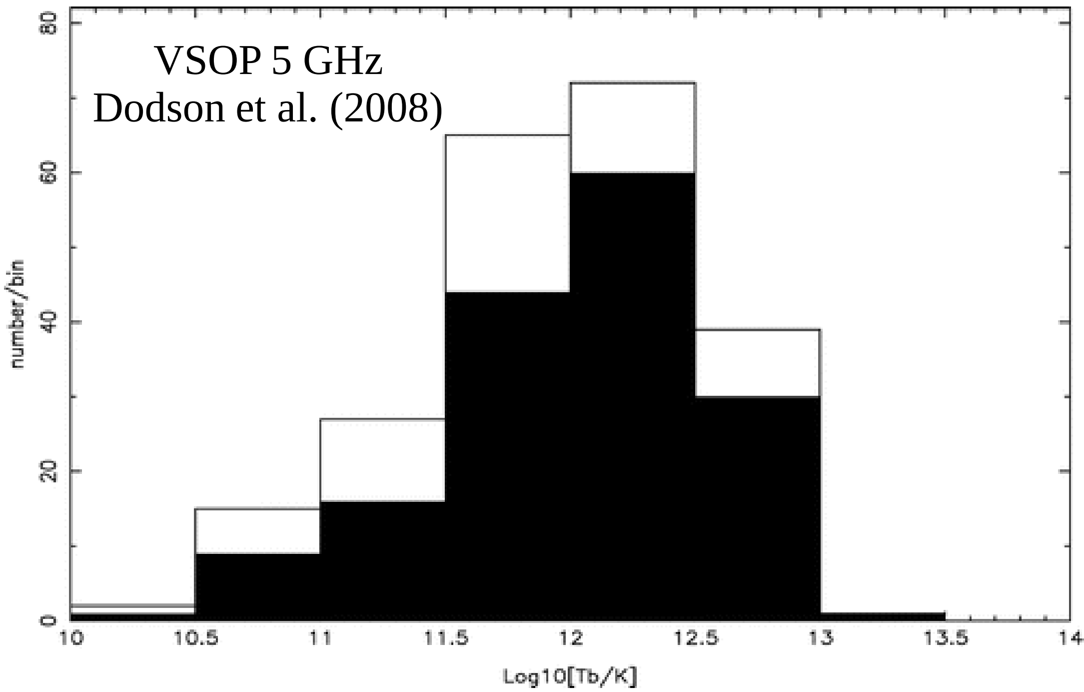
Estimate brightness temperature of most compact structure(s) in the AGN jet base, test the predicted inverse-Compton limit ($10^{11.5}$ K for electrons) boosted by the Doppler factor. We overcome the Earth-based T_b limit. This can not be done by going to higher frequencies on the ground; only Space VLBI. Critical to test emission mechanism.



Readhead (1994)

The brightness temperature inverse-Compton limit





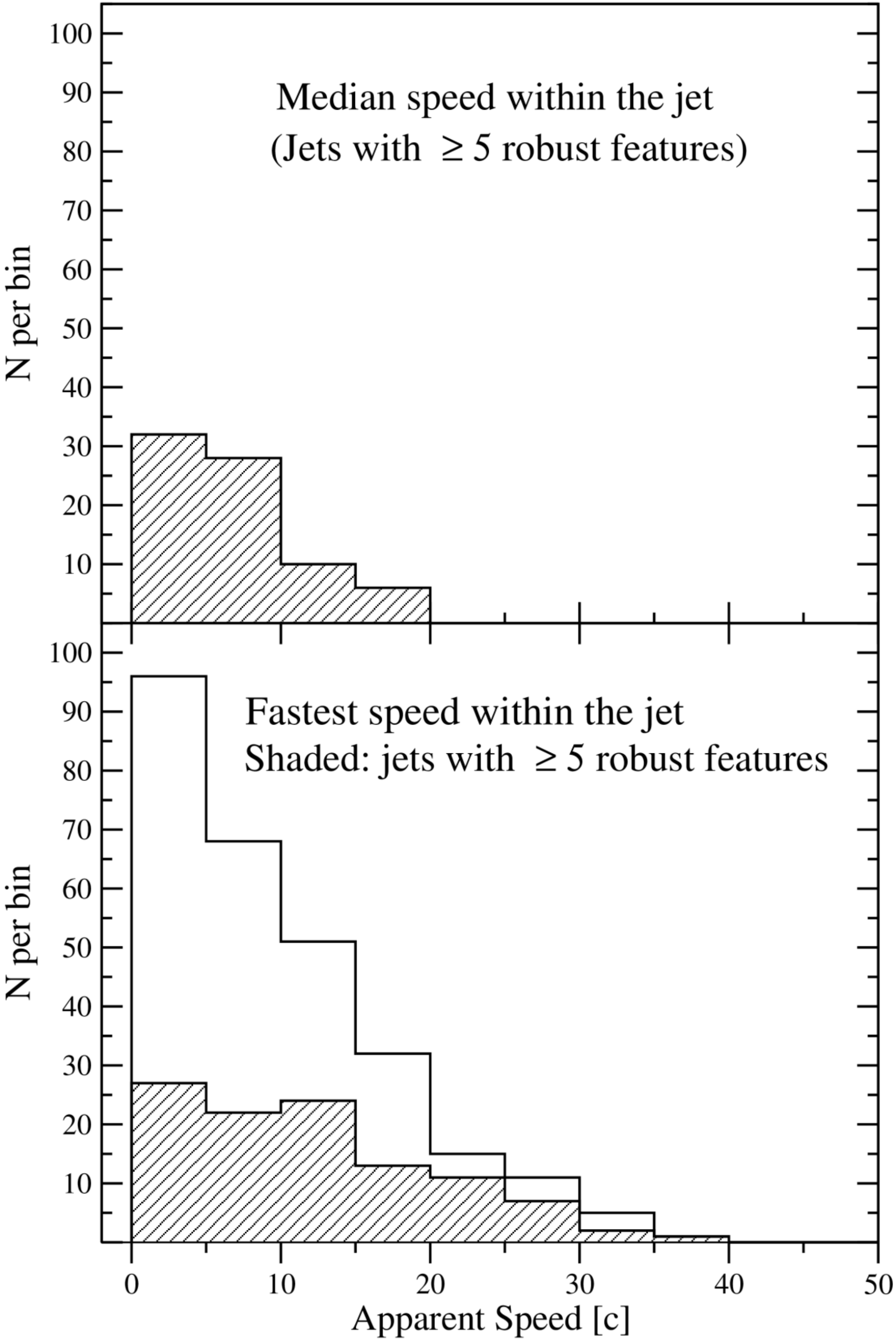
Median $T_b = 10^{12}$ *K, max* $T_b = 5 \cdot 10^{13}$ *K.*

The inverse-Compton limit of 10^{12} K is confirmed if Doppler boosting is involved. And we know from VLBI kinematics measurements (Lorentz factors up to 50 are estimated – talk by Matt Lister) that jet emission is indeed boosted.

The most recent MOJAVE VLBI kinematics data

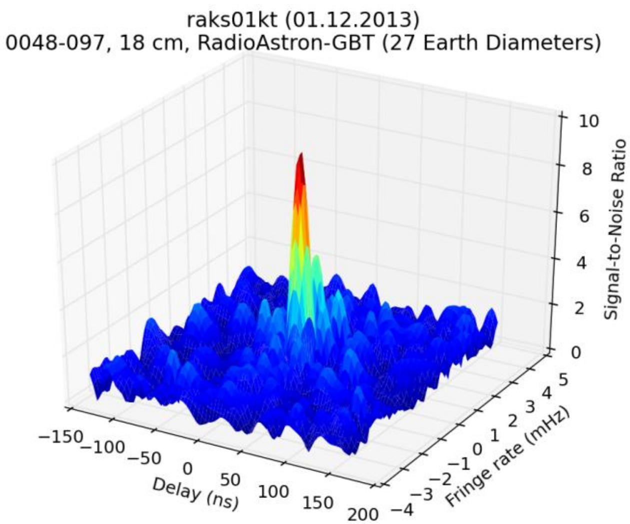
Talk by Matt from yesterday.
Lister et al. (2016).

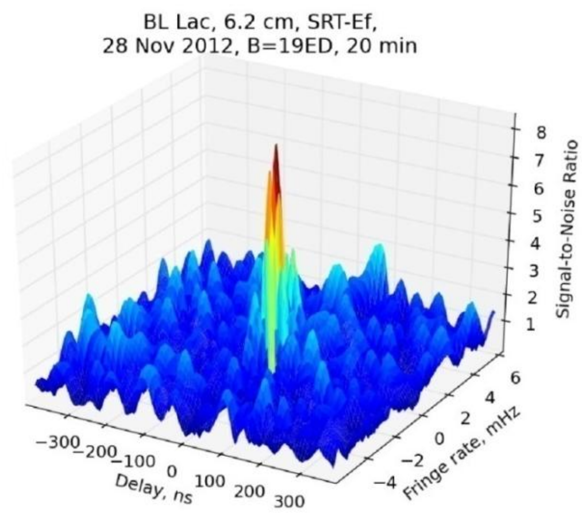
Typical Doppler and Lorentz factors for the MOJAVE sample and also observed by RadioAstron:
about or less than 10.

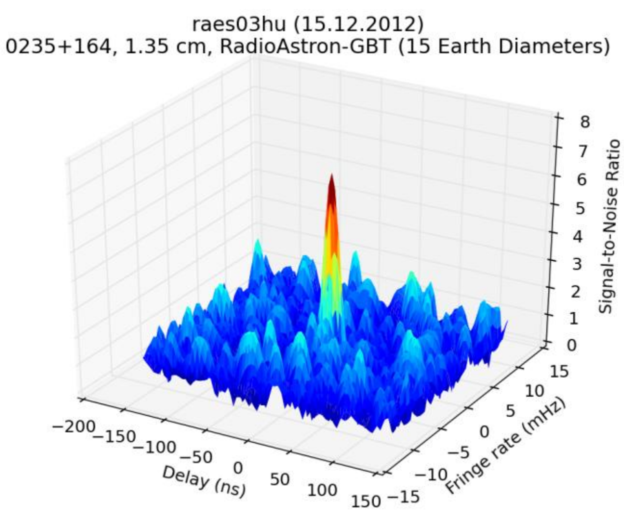


AGN survey results: statistics

Sample: ~250 strong AGN
Correlated and post-processed to date: 1930 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.
Summary: typical Tb one order of magnitude higher than what was previously known.







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

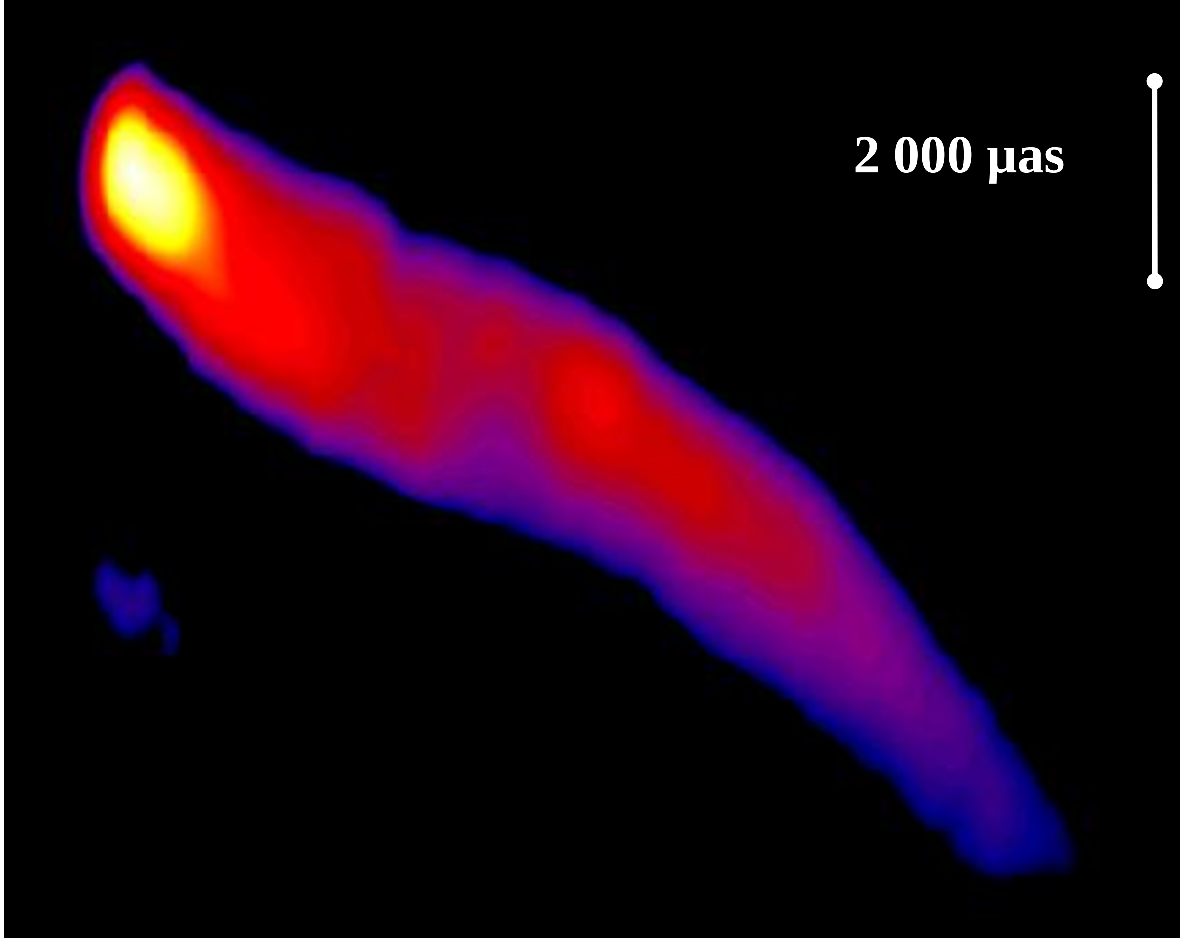
The Doppler factor about or less than 13 (Jorstad et al. 2005, Savolainen et al. 2010) is not high enough to get the brightness temperature down to $10^{11.5}$K.

Remind the talk by Markos from yesterday.

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)

3C273 at 18, 6, 1.3 cm



MOJAVE VLBA, 2 cm

How to generate high brightness temperature

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

Typical observed VLBI kinematics does not reflects the bulk motion? See talks from yesterday and today on the diverse M87 kinematics as well as the poster by Kutkin et al.

✓ Continuously “excited” core being most of the time at the Kel-Pau 10^{12} K limit or continuous re-acceleration several parsecs away from the core.

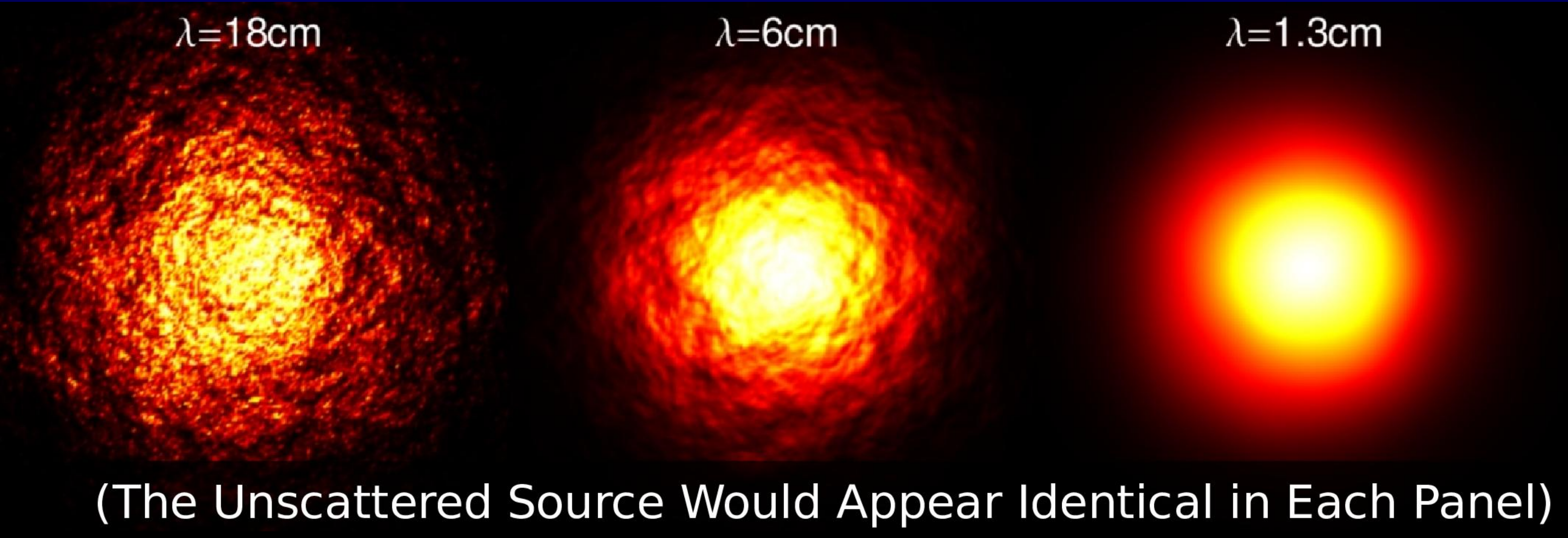
Flares do not happen all the time, γ-ray photon flux is not high enough.

✓ Relativistic protons or coherent processes.

Requires very efficient acceleration and high magnetic field.

Scattering sub-structure: now in quasars

Most probably seen already in 3C273 at 18 cm Johnson et al. (2016)



- The effect is expected at about 1% level.
- Does not affect results at 1.3 cm.
- The fraction of cases for which SVLBI correlated flux density ≤ 1% of the total flux density at 18 and 6 cm is about 10-15%. Does not affect the peak of the Tb distribution but might change the tale. A detailed analysis is ongoing.

Summary

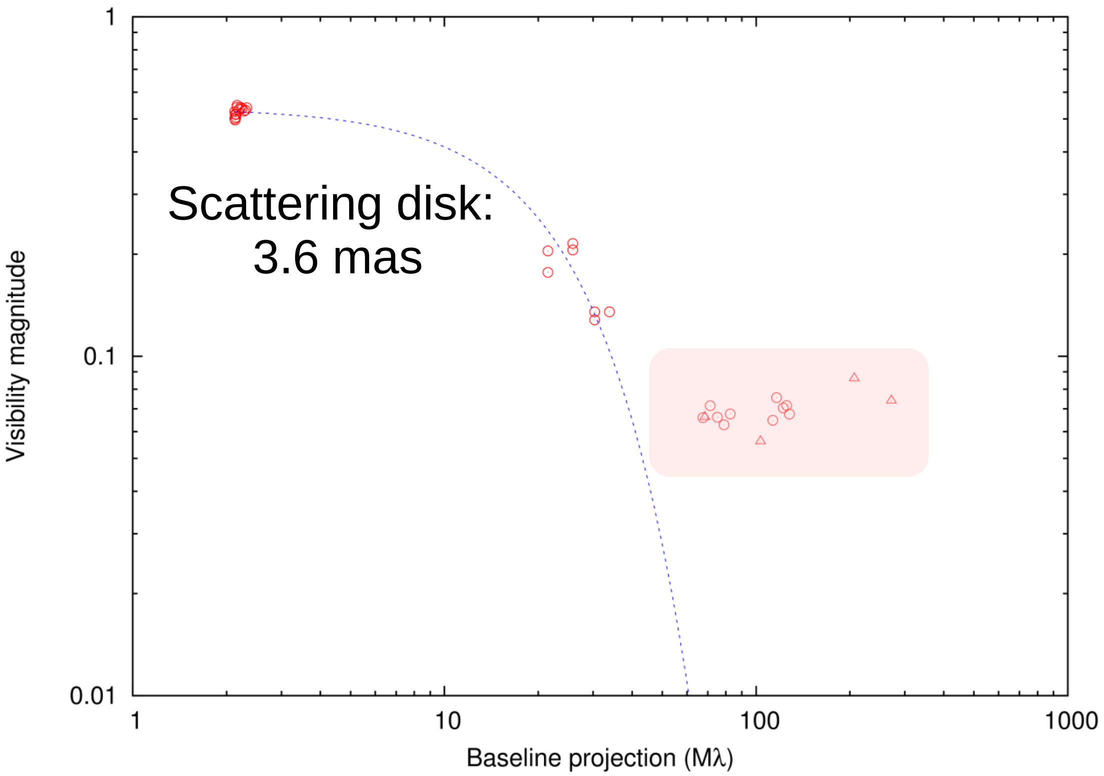
- AGN cores appear in RadioAstron observations as bright as 10^{12}-10^{14} K or even higher, at least about 10 times brighter than what was known before. In the same time, no 10^{15}-10^{16} Tb values are found within our conservative method of measurements.

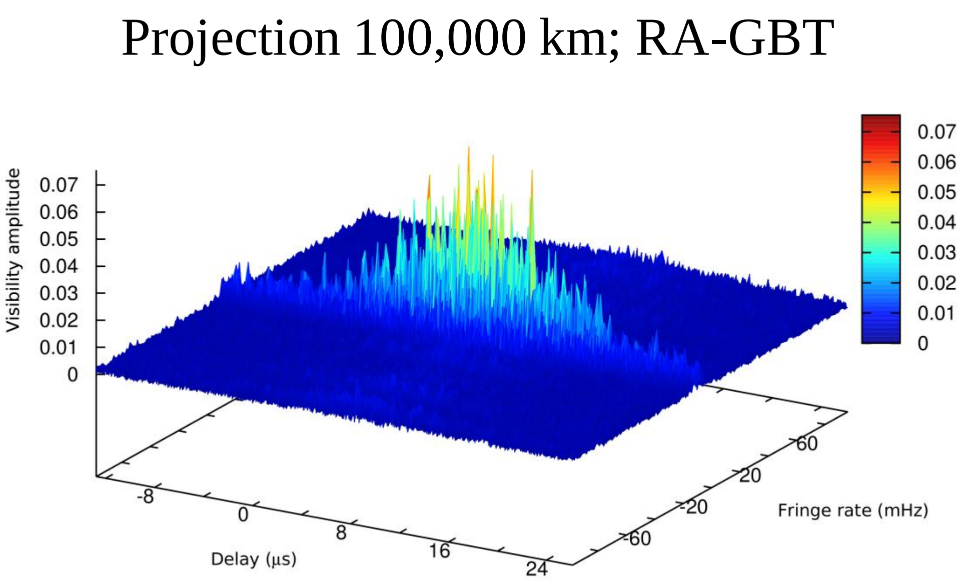
- No apparent explanation why this could be the case. Equipartition between particles and magnetic field clearly does not seem to be typical in blazar cores.

Thank you

PSR B0329+54: RadioAstrion-GBT, WSRT, Kalyazin at 92 cm

Gwinn, Popov et al. (2016)



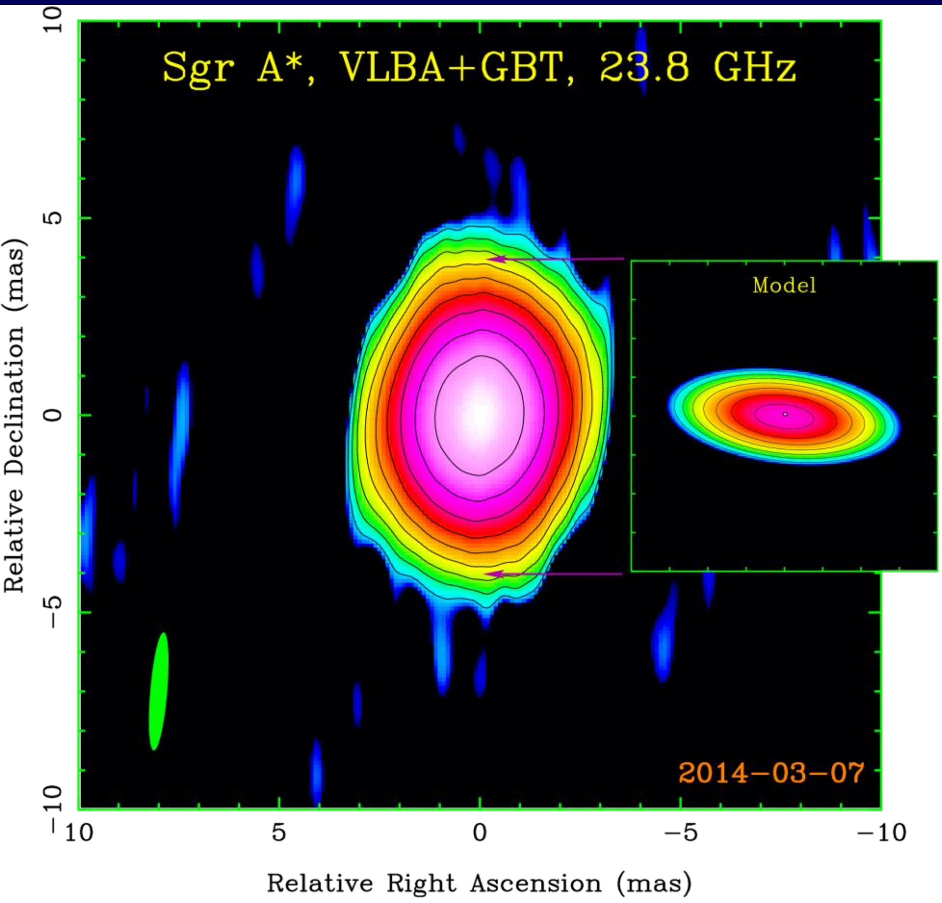


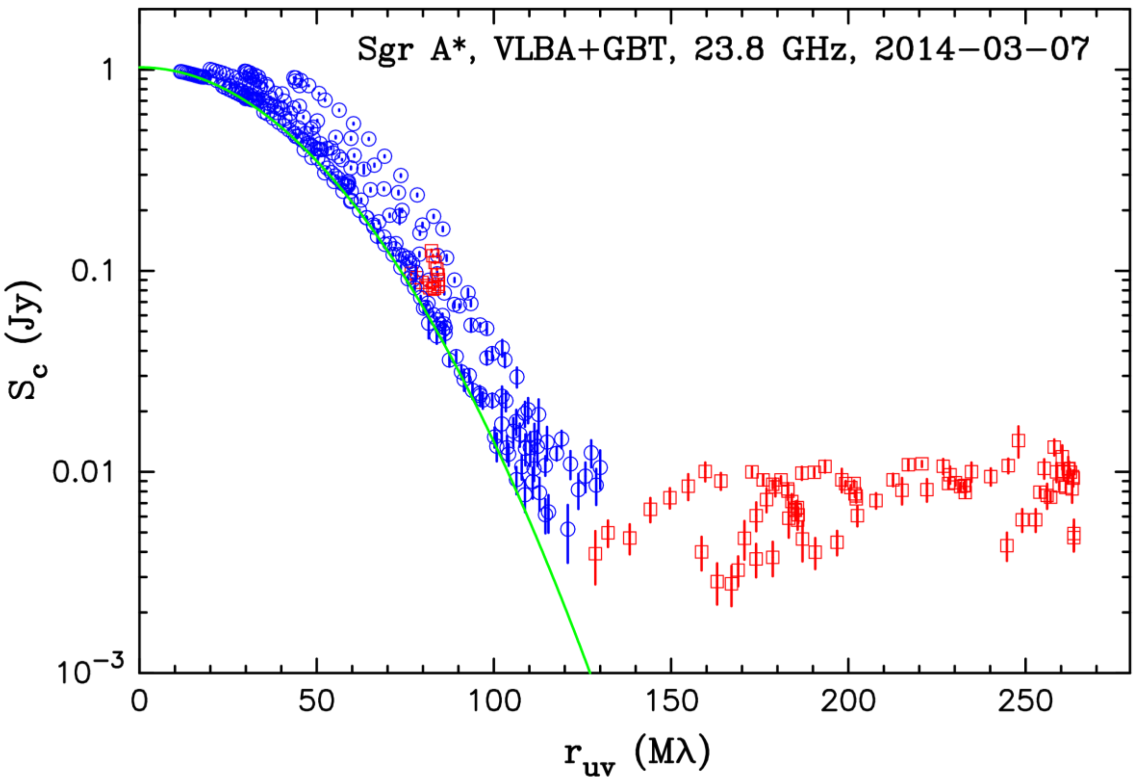
✓ Fine structure of visibility function in delay and its evolution with time reflects a random interference of many scattered rays.

✓ Scattering screen is estimated to be at 2/3 of the distance to the source.

✓ The flattening of the visibility function reflects a presence of a **refractive sub-structure within the scattering disk**. Provides new tool to probe interstellar density irregularities.

Follow up on SgrA* – ground VLBI
discovery of the sub-structure in the scattering disk
Gwinn et al. (2014)

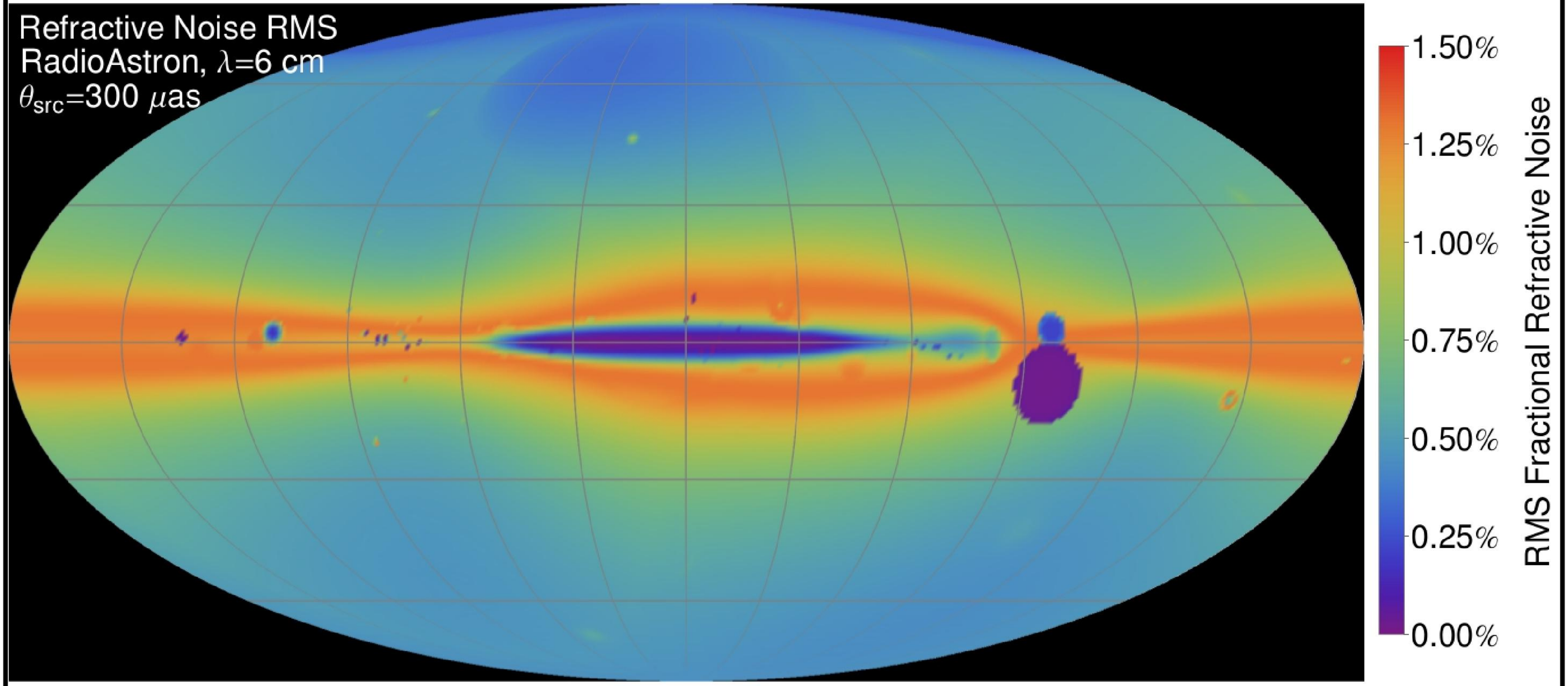




✓ Refractive sub-structure within the scattering disk: result is confirmed, the sub-structure in SgrA* is found.

✓ Parameters of the scattering material and true structure of the background source can be reconstructed – a new window of opportunity to study SgrA* structure.

Refractive Substructure and RadioAstron



Typical angular broadening is 30 μas

Nominal Resolution of RadioAstron is up to ~35 μas

Johnson & Gwinn (2015)