Imaging AGN at record angular resolution

Space-VLBI in the RadioAstron hera

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Abstract

RadioAstron is a 10m antenna orbiting on the Russian Spekt-R spacecraft, able to provide for the first time Space-Earth baselines up to 25 Earth-diameters in full polarization.
A new DiFX version (*ra*) has been developed at the Max Planck Institute for Radioastronomy (MPIfR), in order to manage the correlation of a space-based antenna, co-observing with ground stations. The *ra* version has been running on the High-Performance Computing (HPC) cluster in Bonn, and it has been used for data processing of the three AGN imaging Key Science Projects (KSPs) ongoing with RadioAstron, based at MPIfR.
To date, record angular resolution has been achieved in the framework of the AGN Polarization KSP, together with detection of brightness temperature exceeding the theoretical limit for BL Lac (Gómez et al. 2016)

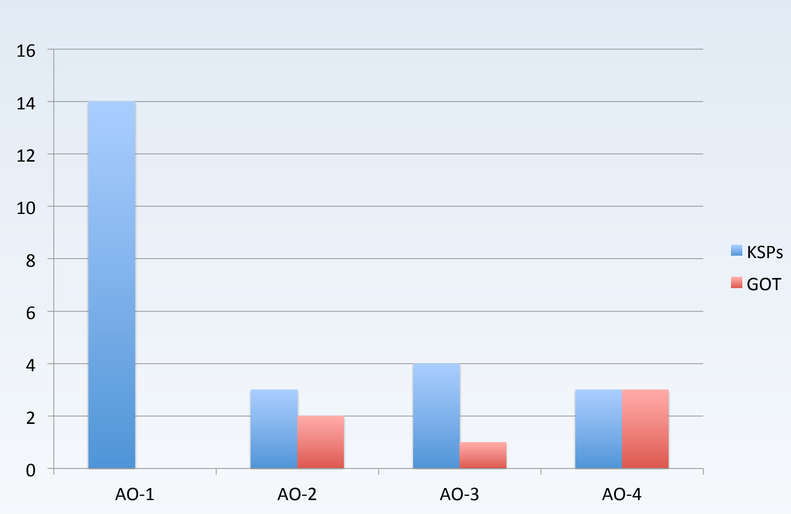
A space-VLBI extension for DiFX

In order to enable correlating RadioAstron data, the DiFX software correlator was upgraded by MPIfR staff for space-VLBI (SVLBI), by implementing the necessary changes to the correlator model, and addressing specific aspects of data and telemetry formats of the space radio telescope (SRT) on-board the Spektr-R spacecraft (Bruni et al. 2014).
The upgraded DiFX correlator, branched from the latest version (2.4), is presently in use at MPIfR for correlation of RadioAstron experiments.

Data processing at the MPIfR correlator

Since summer of 2013, the start of the first RadioAstron science observing period (AO-1, July 2013 – July 2014), the MPIfR correlator has been processing data from the three AGN imaging Key Science Projects (KSP): Nearby AGNs, Powerful AGNs, and Polarisation in AGNs. All projects will take advantage of the extremely high angular resolution offered by RadioAstron. Ground arrays from all over the world have been supporting the observations.

Since AO-2 (July 2014 – July 2015), also General Observing Time (GOT) experiments led by international PIs have been observed, and correlated at MPIfR.



Summary of KSPs and GOT experiments processed at the MPIfR correlator.

Post-correlation data processing

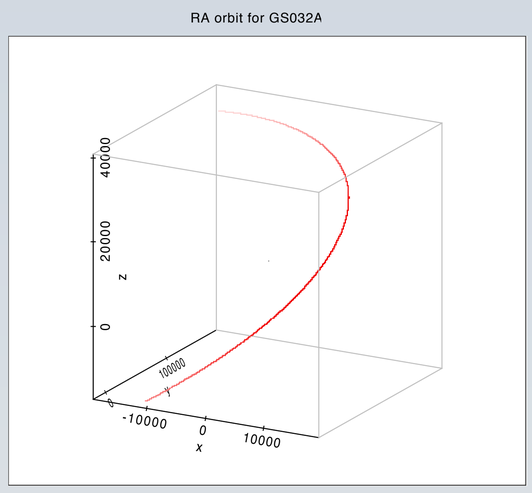
Post-correlation processing is performed as a diagnostic tool to check residual acceleration terms of the spacecraft signal.

- The PIMA software, installed at the cluster, is capable of finding such terms through a baseline-based fringe search algorithm, using the spacecraft orbit as an input parameter.

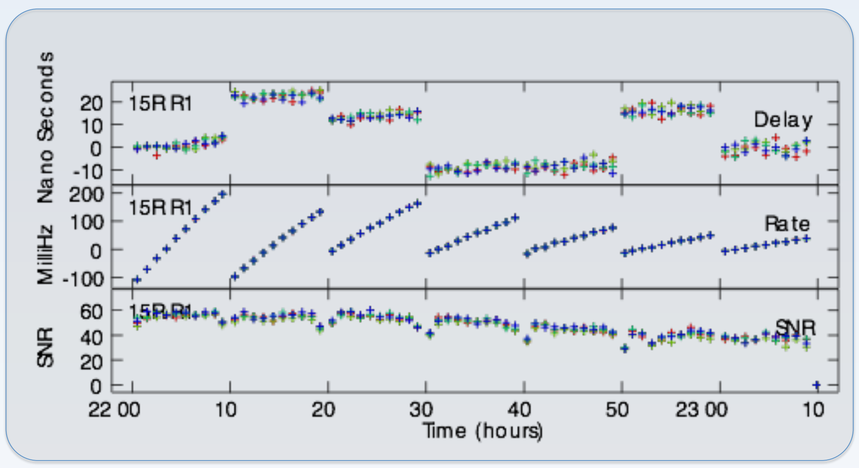
- AIPS is used to perform fringe search between the phased ground array and RadioAstron, by applying baseline stacking.

Output from both softwares can be used to refine the correlation, applying the delay offset and rate solutions found.

With this method, it has been possible to recover fringes at the longest space-baselines in several experiments, correcting for possible uncertainties in orbit reconstruction or fast fringe drift near perigee, where acceleration terms are larger.



Example of an orbit segment for a RadioAstron experiment. Perigee is visible in the middle point of the curve.



Residual acceleration terms visible as steepening of the rate solutions near to perigee (beginning of the experiment, AO-1 observations of BL Lac from the Polarization KSP, Gómez et al. 2016).

Record angular resolution of 21 μas has been achived during BL Lac observations (polarization KSP, Gómez et al. 2016), detecting fringes up to a distance of 8 Earth diameters. Instrumental polarization has proven to be under 10%, allowing detailed studies of the magnetic fields configuration in AGN.

Acknowledgements

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- Gómez J.L., Lobanov A.P., Bruni G. et al. 2016, ApJ, 817, 96

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www.mpifr-bonn.mpg.de/research/vlbi