Il Colle di Galileo

Report on the 4th RadioNet3 European Radio Astronomy Technical Forum Workshop on "Multi-frequency mm-wave radio telescopes & other software controlled operations"

October 5-7, 2015, Florence, Italy

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Abstract. The 4th RadioNet3 European Radio Astronomy Technical Forum Workshop, entitled "Multi-Frequency mm-wave radio telescopes & other software controlled operations", was held at the Department of Physics and Astronomy "Garbasso building" in Arcetri on October 5 – 7, 2015. The Workshop was to provide a unique opportunity to connect the different communities and enhance communication between engineers, scientists and operators.

Keywords. Radio Astronomy, Very Long Baseline Interferometry, radio telescope control software.

1. Introduction

The workshop covered two different research areas: *(i)* simultaneous or near-simultaneous high frequency Very Long Baseline Interferometry (VLBI, high frequency VLBI is hereafter mm-VLBI) observations and *(ii)* new and approved procedures for software-controlled operation of radio telescopes. This workshop

ISSN 2281-7727 (print)
ISSN 2281-9711 (online)
Vol. 5, 2, 2016, pp. 33-37
DOI: 10.13128/Colle_Galileo-19146
www.fupress.com/cdg

was the continuation of a series of technical workshops, organized and sponsored by the EU Consortium RadioNet3 within the Seventh Framework Program of the European Union, combining several aspects of engineering and operational issues at European radio observatories. Previous workshops in the same series were:

- "Radio Interference with Large Bandwidth Observations", April 8-12, 2013, Bonn, Germany
- "Calibration of Multi-Beam receivers", October 28-29, 2013, Bologna, Italy
- "Metrologies at Radio Astronomy Antennas", September 1-2, 2014, Gothenburg, Sweden

During this workshop there were a total of 61 participants, 9 of them women. In addition, 3 persons participated via video streaming on some of the days. 10 participants came from outside the European Union (Australia, Russia, South Korea), three of whom were invited speakers. On Tuesday afternoon, the participants joined a guided visit to the Arcetri Astrophysical Observatory and to "Villa il Gioiello". After that, the official dinner took place at Omero Restaurant, preceded by a cocktail in front of "Villa il Gioiello".

2. Scientific report

At the beginning of the workshop, Gianni Comoretto welcomed the community, introducing the very historic site of the meeting: the Arcetri Astrophysical Observatory. After him, Reinhard Keller welcomed the community in the name of RadioNet3.

2.1 The Power of Simultaneous Multi-Frequency mm-wavelength observations

The first sessions focused on results from the demonstration instrument, the Korean VLBI Network (KVN) and the science drivers for observations with such instruments. The example of astrometric phase referencing between five sources at 130-GHz (2mm) using KVN [Rioja et al., 2015] illustrated the power of these techniques. Not only it is possible to perform astrometry between frequencies (22, 43, 87 and 130-GHz) for comparative studies of emission mechanisms with *Source Frequency Phase Referencing* (SFPR), but also the coherence time can be increased by two orders of magnitude by the simpler *Frequency Phase Transfer* (FPT) method. Figure 1 plots the astrometric measurements at 130 GHz and Figure 2 shows the coherence times for SFPR and FPT. The increase in coherence time would be equivalent to an increase in bandwidth of two orders of magnitude or an increase in dish diameter by a factor of three.

The science drivers come from cases where either the atmospheric phase is a significant issue, i.e. for interferometers, or for highly variable events where the physics is encoded in the emission across wide frequency ranges. In VLBI the main areas of interest were in astrometric alignment. For spectral lines maser

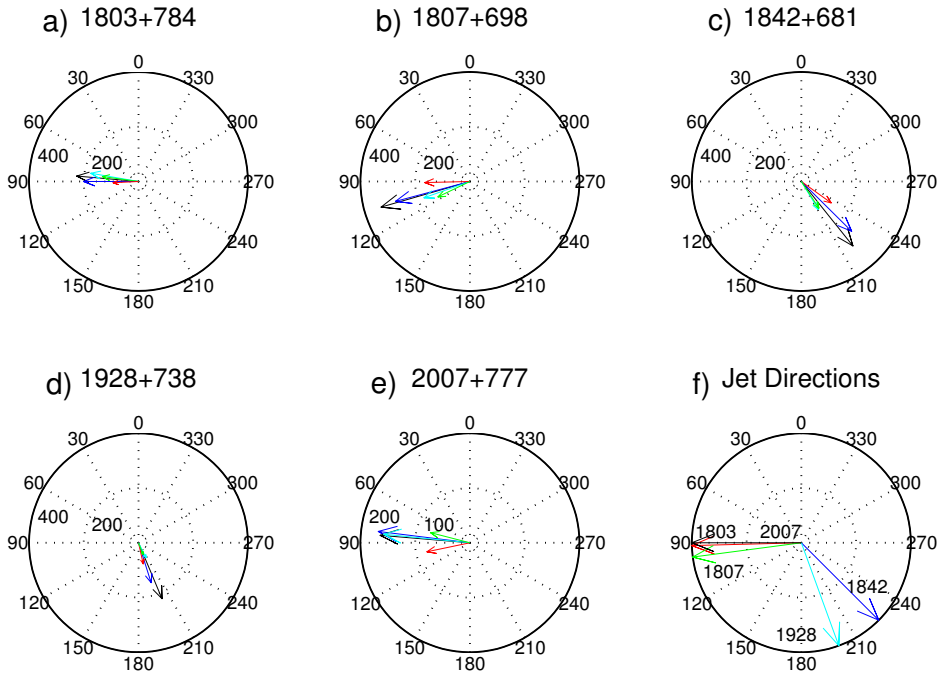

Figure 1. Polar plots of the astrometric measurements of the five sources in Rioja et al. 2015, between 22→43GHz (red), 22→87GHz (blue), 22→130GHz (black), 43→87GHz (blue) and 43→130GHz (cyan). The final plot shows the jet directions, which would be the expected core-shift directions.

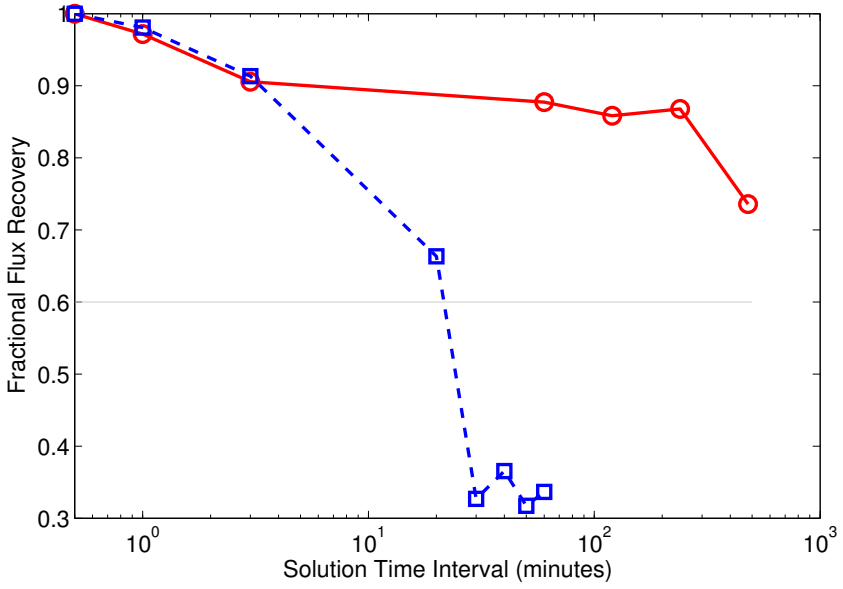

Figure 2. Coherence timescales at 130-GHz for FTP data (blue dashed) and SFPR data (red solid). This is to be compared to the coherence times at 130GHz of ~tens of seconds. The FPT correction alone provides a hundred-fold improvement in coherence time.

Figure 3. Workshop participants.

emission provides detailed probes of the conditions around the target sources. For continuum the accurate alignment of images across frequencies is mandatory to form spectral index and rotation measure images.

The leading hardware system for multi-frequency observations is that of the KVN, which uses quasi optics low pass filters [Han et al., 2008]. Similar systems have been installed on the Japanese VLBI array VERA and on the Spanish Yebes Radio Telescope. The Australia Telescope Compact Array (ATCA) demonstrated an alternative approach by dividing the antennas into two sub-arrays, one operating at 43 GHz and the other at 86 GHz, resulting in simultaneous multi-frequency operation. Several alternative approaches for multi-frequency observations were also presented, including: fast frequency switching, exotic materials with strongly frequency-dependent refractive indexes, Multiband receivers and a compact development of the KVN system within a single Dewar. A new joint research activity in RadioNet4 'BRAND EVN' on a low frequency but ultra-broadband receiver was reported.

2.2. Software controlled operations of radio telescopes

On the third day, the focus of the workshop was on telescope control software. The speakers gave an overview of the software concepts and designs at various telescope facilities from European observatories, like the APEX telescope in Chile,

the 100m Effelsberg telescope, the 30m IRAM telescope, the SRT and the other Italian telescopes, which share a common code base, the Onsala telescopes and the Yebes OAN Antenna. The newer telescopes often use ESO/NRAO ALMA Common Software, whereas older projects depend fully on proprietary software developed at the operating institutes. Besides single-dish control software, several talks concentrated on Interferometric software for e-Merlin and JIVE. Finally, the possibility of remote control of telescopes by a safe and encrypted internet connection was presented, as well as Pre- and Post-observation tools that aid the observer and the observatory by using a dedicated observatory feedback tool.

All presentations, the program and the recorded streams can be found on the workshop webpage: http://www.ira.inaf.it/eratec/florence/

References

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[Rioja, et al., 2015], *The Power of Simultaneous Multi-Frequency Observations: Astrometry up to 130 GHz with the KVN*, AJ, 150, 202