

The SRT as a Science Facility

Astronomical Validation & Scientific Perspectives

Isabella Prandoni
Project Scientist SRT

INAF- Istituto di Radioastronomia
Bologna



ISTITUTO NAZIONALE DI ASTROFISICA
NATIONAL INSTITUTE FOR ASTROPHYSICS

I. Prandoni - 12th EVN Symp. - 08/10/2014



Team AV

- **PS:** Isabella Prandoni
 - **Co-PS:** Matteo Murgia, Andrea Tarchi, Sandro Orfei, Gianni Comoretto
 - **+ ~30 people**
covering various
technical/astronomical
expertises (8 IRA/Med;
24 OACa; 2 Arcetri)
- Pulsar; Galactic & Extra-galactic, etc.
→ Continuum, Line, Mapping, VLBI, etc.
→ SW, Receivers, Backends, etc.
[interface with commissioning team]

ASTROPHYSICAL VALIDATION TEAM

The SRT astrophysical validation team

1. **Isabella Prandoni**, i.prandoni@ira.inaf.it (Project Scientist)
2. **Nichi D'Amico**, damico@oa-cagliari.inaf.it (Project Director)
3. **Alessandro Orfei**, a.orfei@ira.inaf.it
4. **Andrea Orlati**, a.orlati@ira.inaf.it
5. **Simona Righini**, s.righini@ira.inaf.it
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11. **Alberto Pellizzoni**, apellizz@oa-cagliari.inaf.it
12. **Federica Govoni**, fgovoni@oa-cagliari.inaf.it
13. **Tonino Pisanu**, tpisanu@oa-cagliari.inaf.it
14. **Andrea Melis**, amelis@oa-cagliari.inaf.it
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18. **Alessio Trois**, atrois@oa-cagliari.inaf.it
19. **Antonietta Fara**, fara@oa-cagliari.inaf.it
20. **Paola Castangia**, pcastang@oa-cagliari.inaf.it
21. **Valentina Vacca**, vvacca@oa-cagliari.inaf.it
22. **Maria Noemi Iacolina**, iacolina@oa-cagliari.inaf.it
23. **Ignazio Porceddu**, ignazio.porceddu@inaf.it
24. **Pietro Bolli**, pbolli@oa-cagliari.inaf.it
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26. **Alessandra Zanichelli**, a.zanichelli@ira.inaf.it
27. **Carlo Stanghellini**, cstan@ira.inaf.it
28. **Francesco Nasyr**, nasyr@oa-cagliari.inaf.it
29. **Delphine Perrodin**, delphine@oa-cagliari.inaf.it
30. **Francesco Gaudiomonte**, fgaudiom@oa-cagliari.inaf.it
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33. **Caterina Tiburzi**, ctiburzi@oa-cagliari.inaf.it
34. **Alessandro Ridolfi**, aridolfi@oa-cagliari.inaf.it
35. **Fabrizio Massi**, fmassi@arcetri.astro.it
36. **Raimondo Concu**, rconcu@oa-cagliari.inaf.it
37. **Marco bartolini**, bartolini@ira.inaf.it
38. **Marco Buttu**, mbuttu@oa-cagliari.inaf.it
39. **Daria Guidetti**, d.guidetti@ira.inaf.it

SARDINIA RADIO TELESCOPE

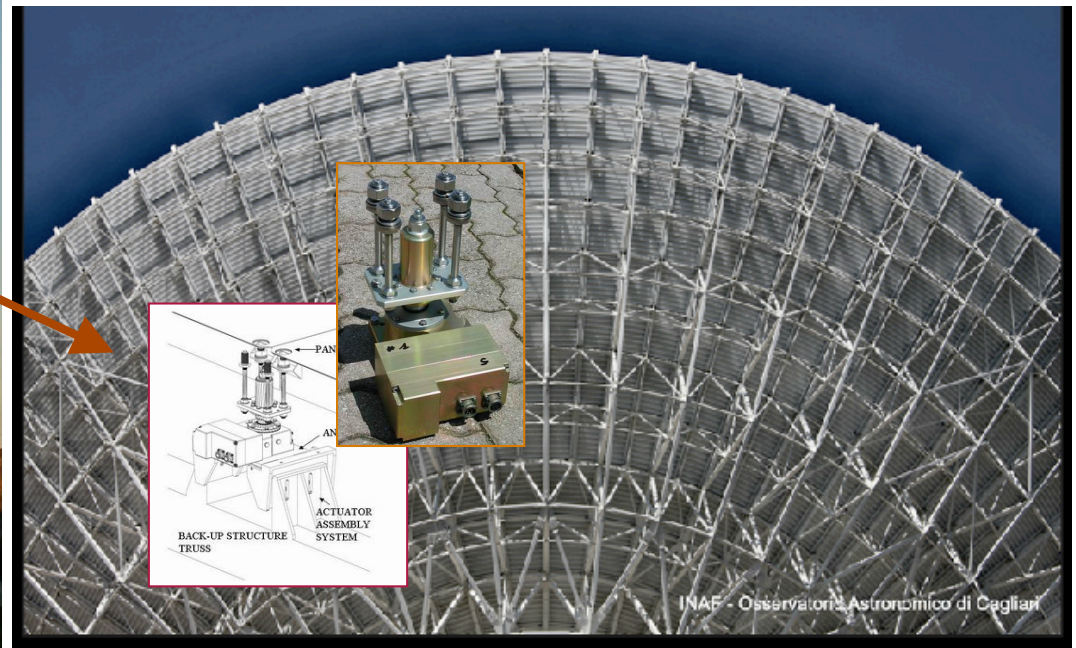
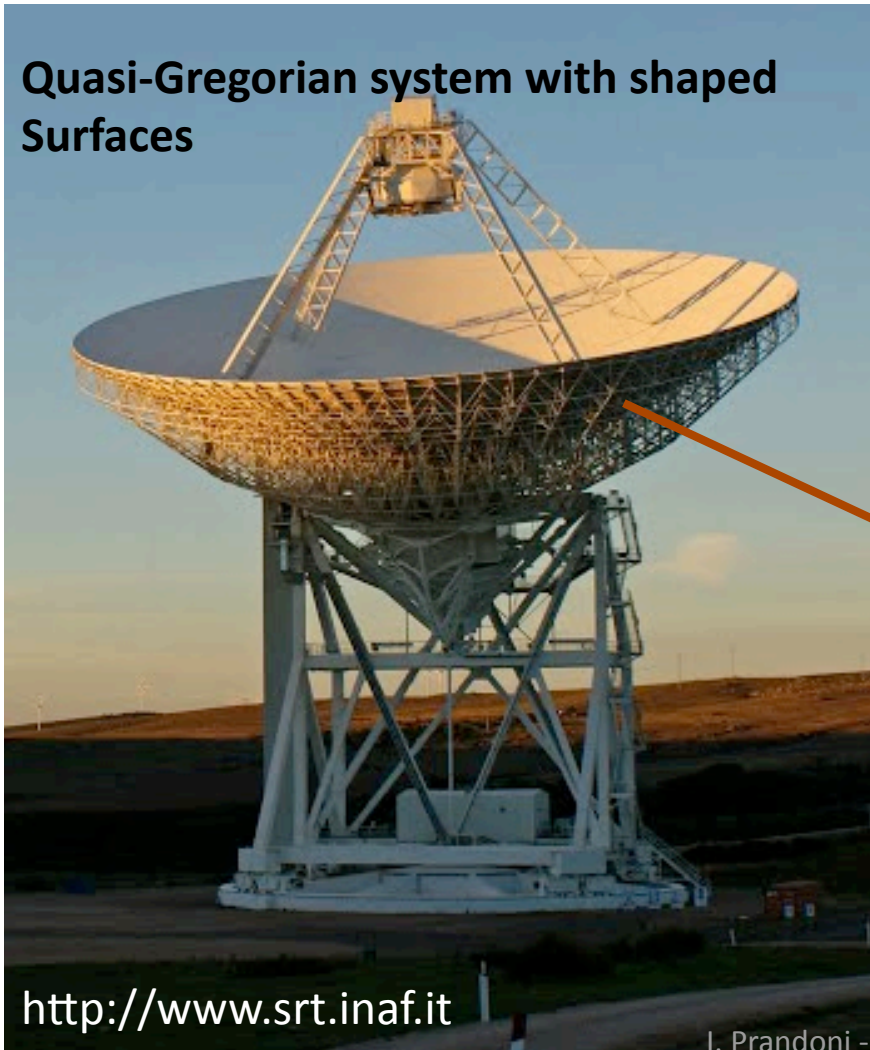
Largest (64-m) Italian radio telescope

Quasi-Gregorian system with shaped Surfaces

Multiple focal position (P, G, 4 BWG):

→ up to 20 receivers, frequency agility

Active Surface: 1008 panels, 1116 electro-mechanical actuators with remote control



<http://www.srt.inaf.it>

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Ministero dell'Istruzione
dell'Università e Ricerca

PROJECT STATUS



Telescope Commissioning (end 2013)



Advanced technical activities/Precursors (from Jan 2014)

Fine-tuning, integration of sub-systems (derotator, f-track), backends commissioning (DFB, XARCOS, etc.), metrology, site monitoring, etc.

Astronomical Validation (running in parallel – 16^h-24^h time slot)

Astronomical Validation (AV) ***toward a radio observatory!***

- Last phase before first astronomical observations (*shared risk, early science*)
- **Goal 1:** *Tests on predefined sources to characterize the SRT astronomical performance in all standard observing modes; identification of technical problems and/or limitations*
- **Goal 2:** *Transforming the SRT into a real Observatory (HW/SW development, observing/analysis tools, cook-book, etc.);*
- **Goal 3:** *maximization of science exploitation since first light*

AV - SW DEVELOPMENT

Observing with SRT:

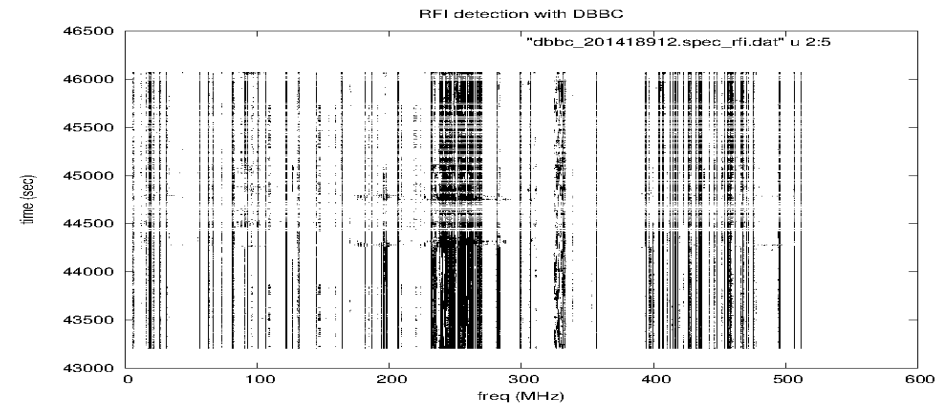
- **ETC:** SRT Exposure Time Calculator
Zanichelli et al.
- **CASTIA:** Source Visibility
>30 telescopes (incl. EVN), on line
Vacca, Iacolina et al.
- **ScheduleCreator**
Nuraghe SD Operations (TP/XARCOS)
Righini et al.
- **SEADAS**
Interface for Pulsar Obs. (DFB/ROACH)
Corongiu et al.

Data Monitoring/Handling:

- **Cross Scan Quick Look/Reduction**
Righini et al.
- **SDI:** SD multi-feed Imager (OTF)
Pellizzoni et al.
- **RFI monitoring (DBBC)**
Melis et al.
- **RFI detection/excision**
Ricci et al.
- **Format Converter**
FITS to CLASS
Trois et al.

The image shows two screenshots of software interfaces. The top-left screenshot is a table listing various astronomical sources and their visibility parameters. The top-right screenshot is a line graph showing the visibility of a source over time. The bottom screenshot is a screenshot of the CASTIA web interface, which includes a search form for source names, date, site name, and elevation, and a 'Run CASTIA' button. The interface also displays the SRT logo and the text 'Available on-line/SRT site'.

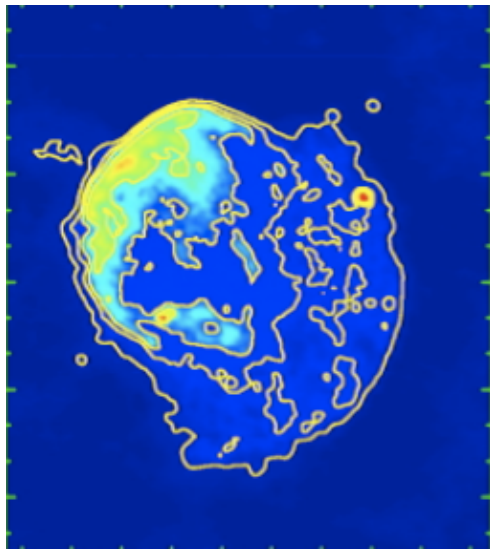
Source Name	Max El (deg)
NGC7027	87.19
3C295	77.36
3C286	89.84
3C147	79.64
3C123	80.20
3C48	83.74
G106	68.58
Kes75	47.54
4c-04.7	45.59
Tycho	65.26
3C397	57.67
Kes79	51.21
3C391	49.61
W508	59.64
S4	81.59
S3	70.70
HB9	82.81
HB3	66.68
RS	66.25
S2	66.16
HC40	69.48
S1	46.13
3C157	73.07
DR4	89.00
Cygnus	81.24
W51	54.64
3C392	51.90



SRT Single-Dish Imager (SDI): Early Applications at C-band

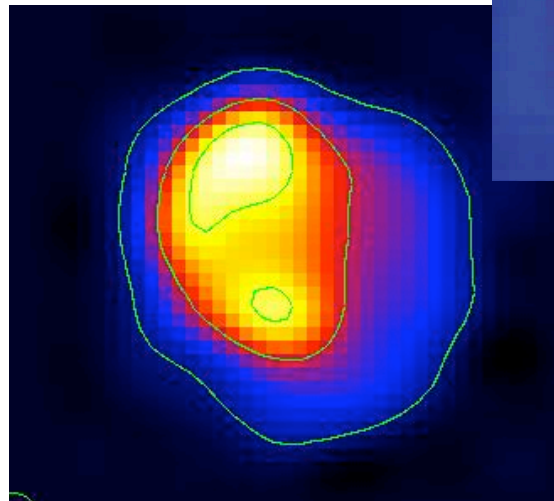
SNR 3C157/IC 443

VLA 330 MHz
64"x74" resolution

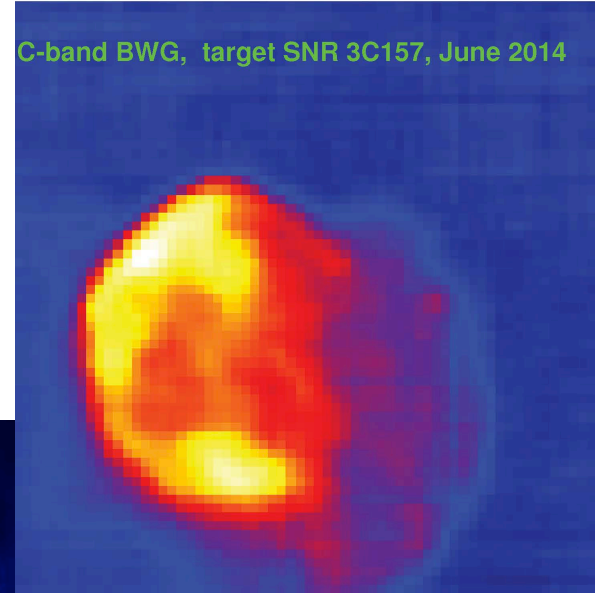


Hewitt et al. 2006

Calibrated 5 GHz
image - Medicina
Febr. 2013 – 6.4' res.

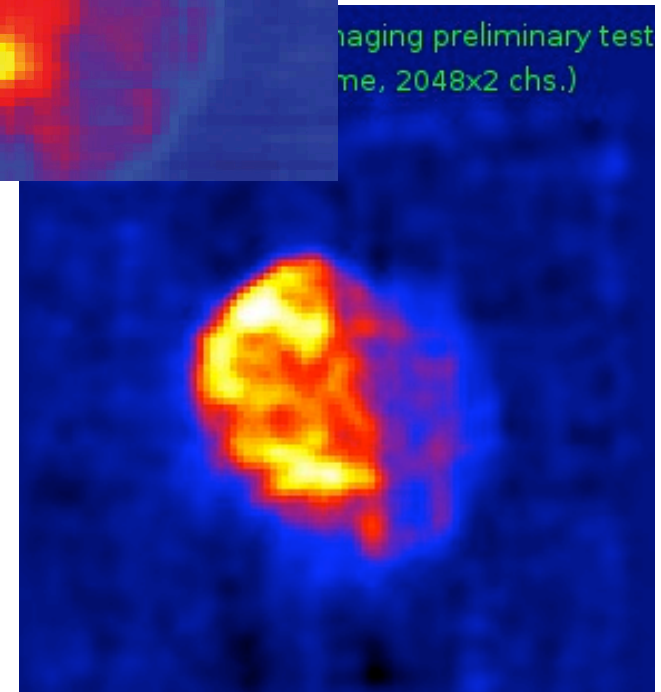


C-band BWG, target SNR 3C157, June 2014



SRT C Band
TP vs ROACH2
June 2014 –
2.8' res.

Imaging preliminary test
(time, 2048x2 chs.)

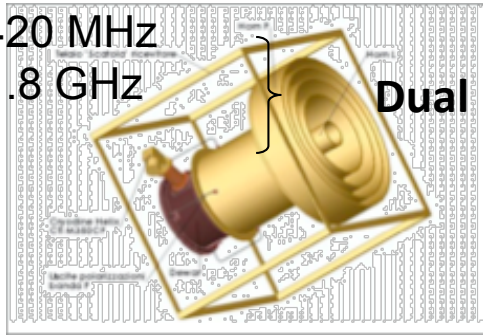


Credits SDI Team: A.Pellizzoni, E.Egron, N.Iacolina,
S.Righini, A.Trois, V.Vacca

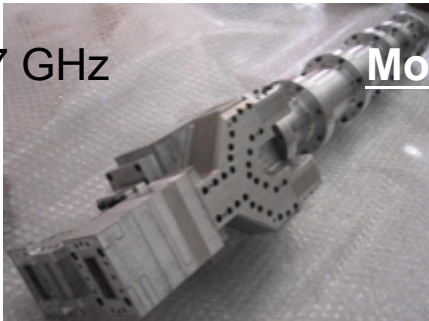
1st GENERATION INSTRUMENTATION

RECEIVERS

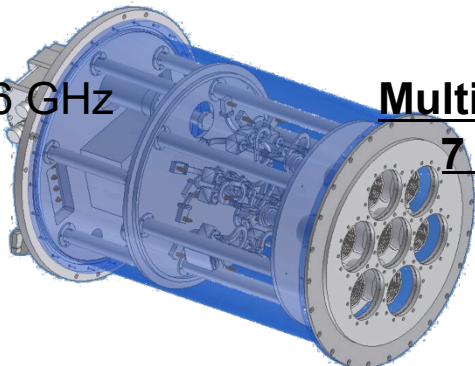
310-420 MHz
1.3-1.8 GHz } **Dual Band**



5.7-7.7 GHz **Mono-feed**



18-26 GHz **Multi-feed**
7 elements

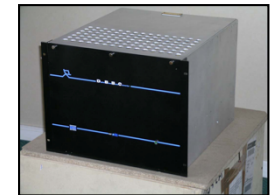


BACK-ENDS

DFB: Digital Spectrometer (pulsar)
(ATNF Pulsar Digital Filter-Bank)
1 GHz BW, up to 16384 chan

ROACH: 2x512 MHz/1x1024 MHz

DBBC2 (1 GHz, 4 IFs) + Mark5C
(VLBI) + SW Corr (DIFX)



TP: analog back-end Total Power
7x2 outputs, 2 GHz BW

XARCOS: Digital Spectrometer
8 outputs, 60 MHz BW,
4096 channels



The SRT: INTERNATIONAL CONTEXT

•Single-Dish Operations: Competitors

-60/100m class radio telescopes: SRT, JB (70m), Eff (100m), GBT(100m), Parkes (64m)

- Dishes with active surface: SRT, Effelsberg, GBT

+ Yebes (40m), Noto (32m), IRAM (30m), Onsala (25m), Metshaovi (14m)

→State-of-the-art RX, Back-end (multi-feeds, etc.)

→Ad hoc observing strategies/pipelines (large surveys, imaging SW, etc)

→Coordinated use of Italian antennas (exploit synergies)

→High frequency science (Dynamic scheduling, metrology, multi-feeds, etc.)

•Networks: Cooperation

- EVN, eVLBI, Space-VLBI, mm-VLBI, Italian VLBI, AVN,...

- PTAs/LEAP

→High priority for ad hoc RX, Back-ends (eg 43/86 GHz; ROACH, etc.)

→SW Correlation for Italian VLBI, AVN (DIFX)

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•Single-Dish Operations: Competitors

- 60/100m class radio telescopes: SRT, JB (70m), Eff (100m), GBT(100m), Parkes (64m)
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Yebes (40m), Noto (32m), IRAM (30m), Onizuka (25m), Metebeevi (14m)

Highest Priority:

- Include SRT in International Networks: **EVN, LEAP** (, etc)
- SD Operations: Pulsars (dual-band RX)/Surveys (multi-feed) s, etc.)

•Networks: Cooperation

- EVN, eVLBI, Space-VLBI, mm-VLBI, Italian VLBI, AVN,...
- PTAs/LEAP

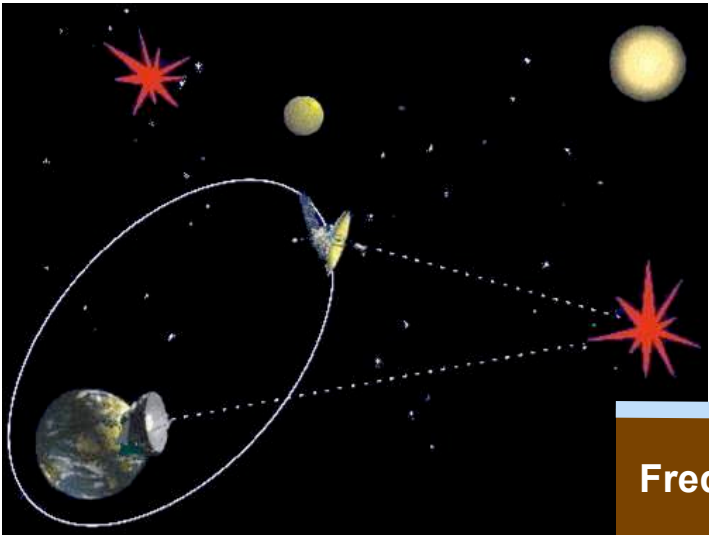
- High priority for ad hoc RX, Back-ends (eg 43/86 GHz; ROACH, etc.)
- SW Correlation for Italian VLBI, AVN (DIFX)

DBBC2 + Mark5C

SRT as part of VLBI Networks

- **EVN** → Medicina & Noto + **SRT from 2015**
- **Space-VLBI** (RadioAstron) → Medicina & Noto, **SRT test experiments ongoing**
- **eVLBI**: Optic fibre connection to Medicina & Noto + **SRT in 1-1.5 years**
- **mm-VLBI** (7/3 mm) → high-v capability Noto + **SRT 43 GHz funded; 86 GHz IRAM**
- **Italian VLBI** → **Medicina, Noto, SRT + SW correlator (DIFX) – tests ongoing (talk by Stagni)**

RadioAstron



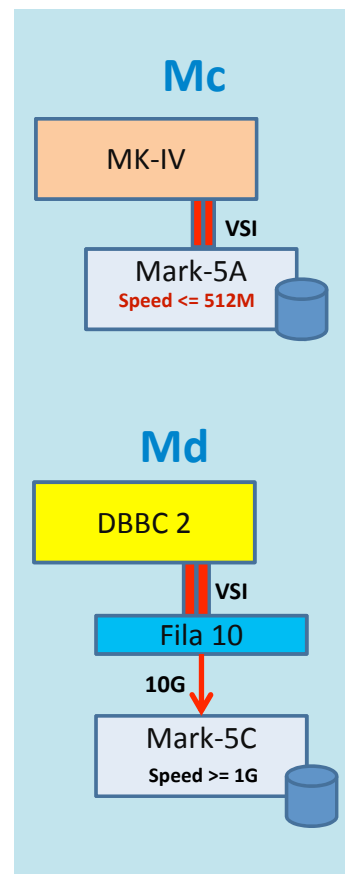
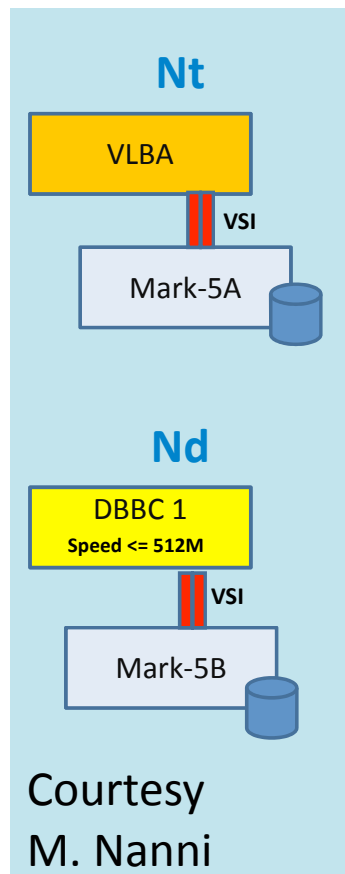
Orbital Period: 7-10 gg
 Apogee : 310.000-390.00 km
 Perigee : 300-7.000 km

Frequency band [GHz]	0,327	1,665	4,83	18 - 25
Ang. Res. At 350.000 km baseline [microas]	540	106	37	7 - 10

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AV – FIRST VLBI TESTS

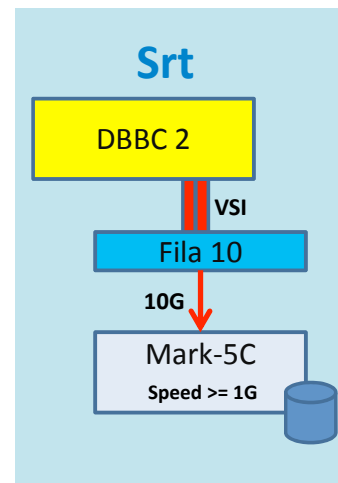
Credits: VLBI tests involve experts at IRA, Medicina and Noto, who are not part of AV team
Coordination M. Nanni



2013, Oct. 10 → First Italian VLBI test:
Medicina-Noto-SRT + SW correlator

- Several unknowns (Scheduling, SW Corr., Mark5C)
- Synchronization problem with DBBC2-Fila10-MK5C

First fringes Med-SRT 27-01-2014!



Antenna Coordinates
measurements (17/02/2014)

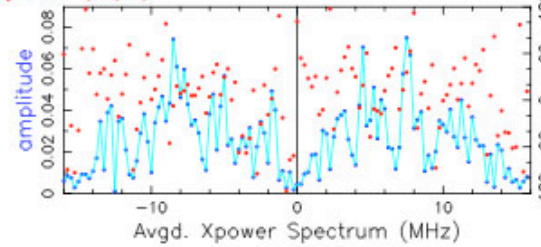
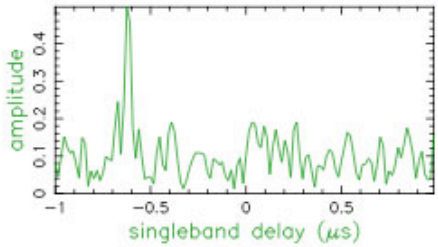
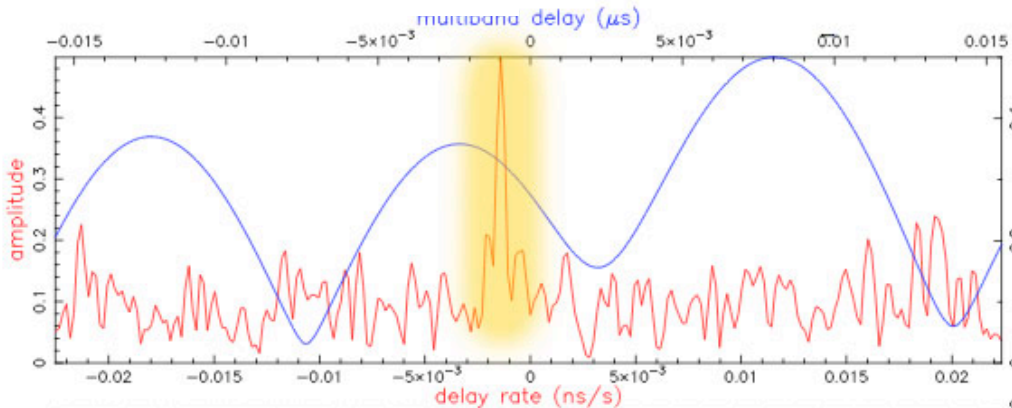
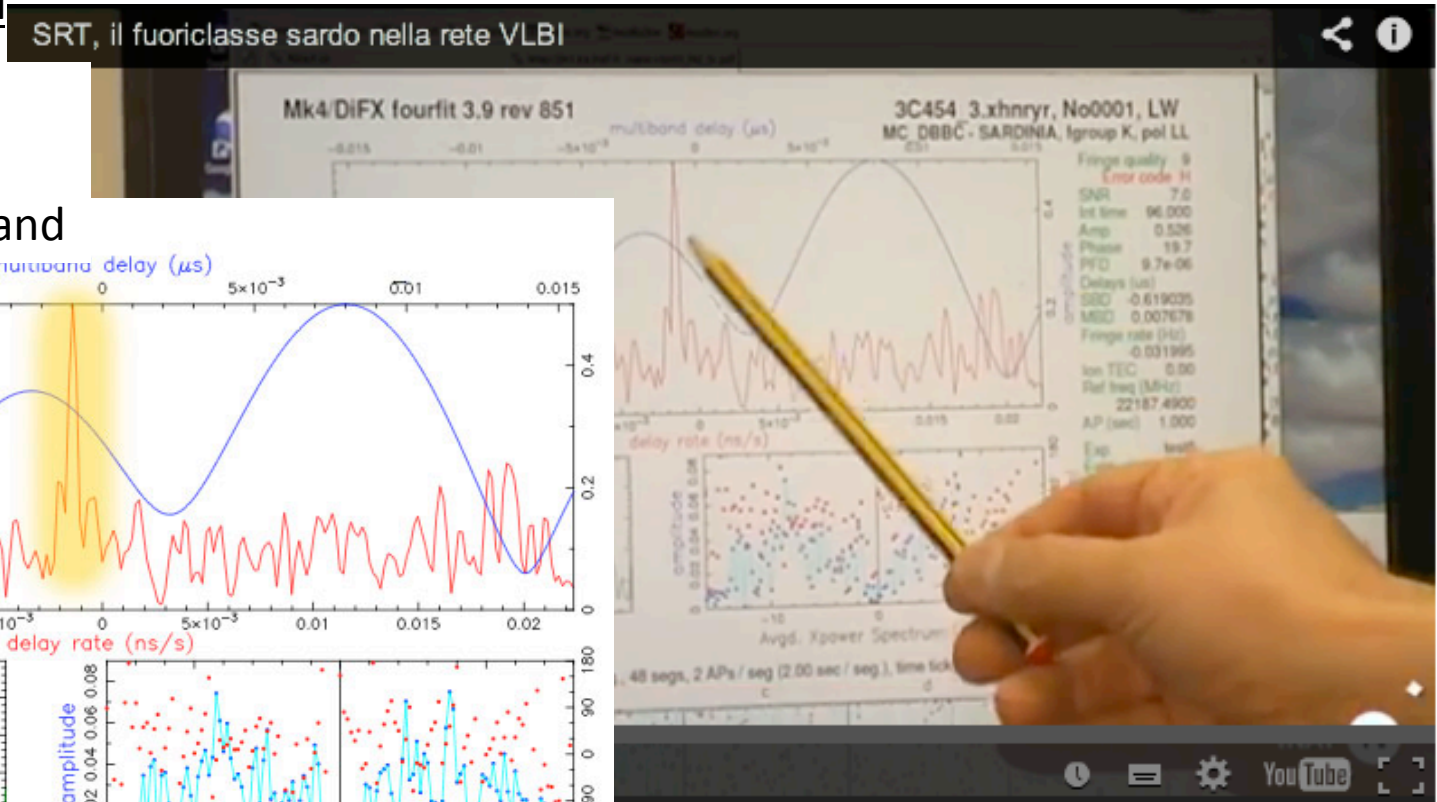
AV – FIRST VLBI TESTS

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 Coordination M. Nanni

First Fringe:

27 Jan 2014

SRT-Medicina, K-band



Courtesy
 M. Nanni

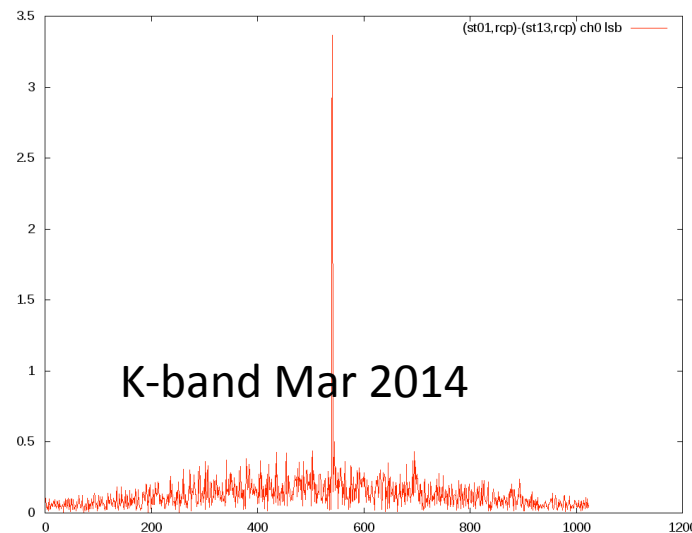
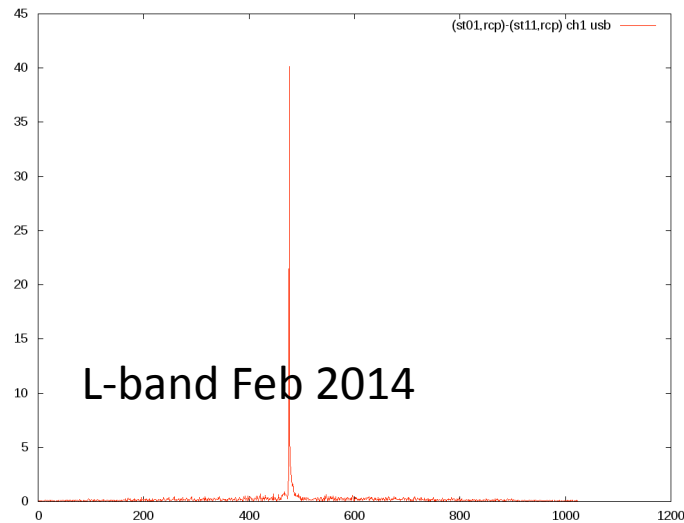
AV - EVN TESTS



First EVN tests February/March 2014 Session:
5 tests performed, 3 successful (2 L-band + 1 K-band)

Problems to be solved: - fringe amplitude (DBBC conf)
- stability in synchronization

PLAN: get problems solved for May/June 2014 EVN run



Credits:
C. Migoni

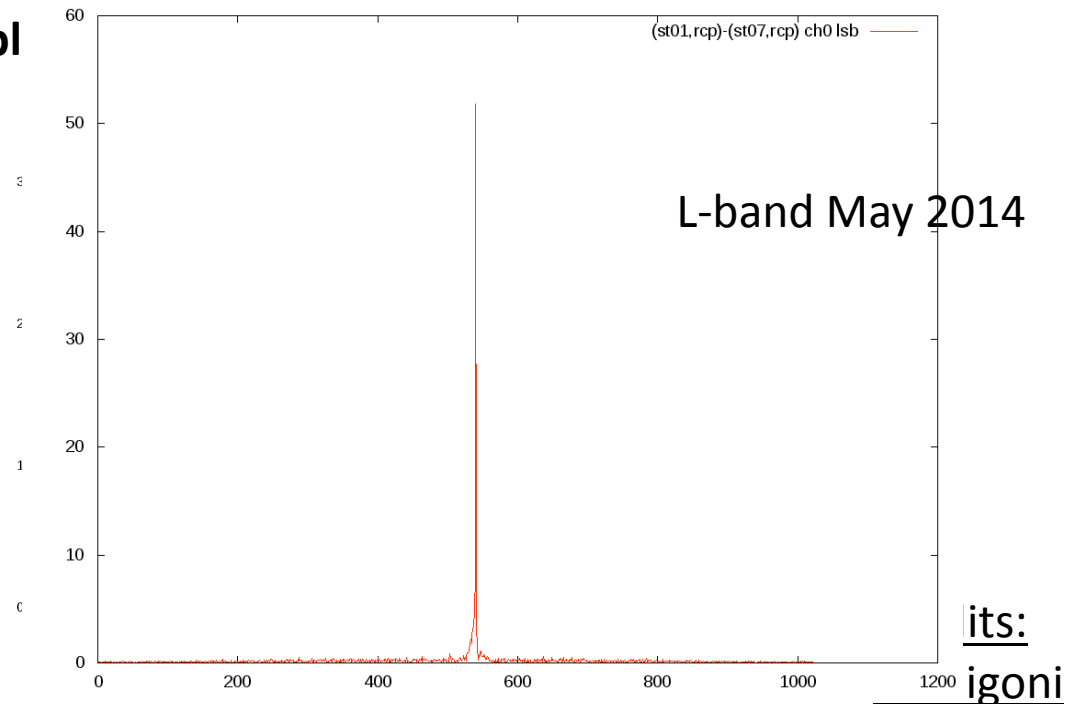
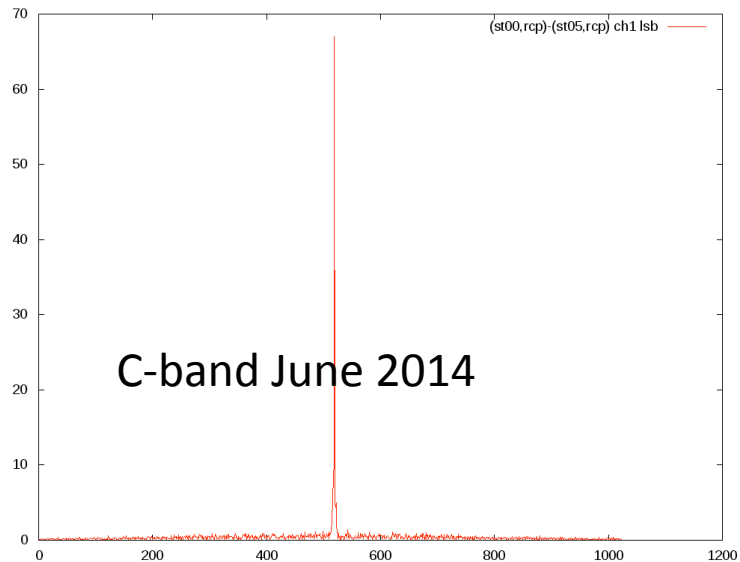
AV - EVN TESTS



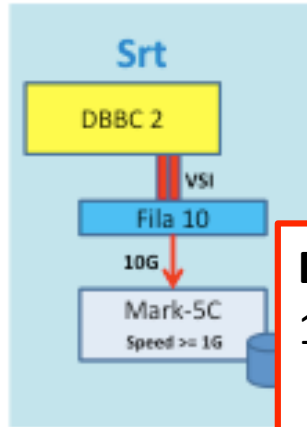
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PLAN: get probl



AV - EVN TESTS



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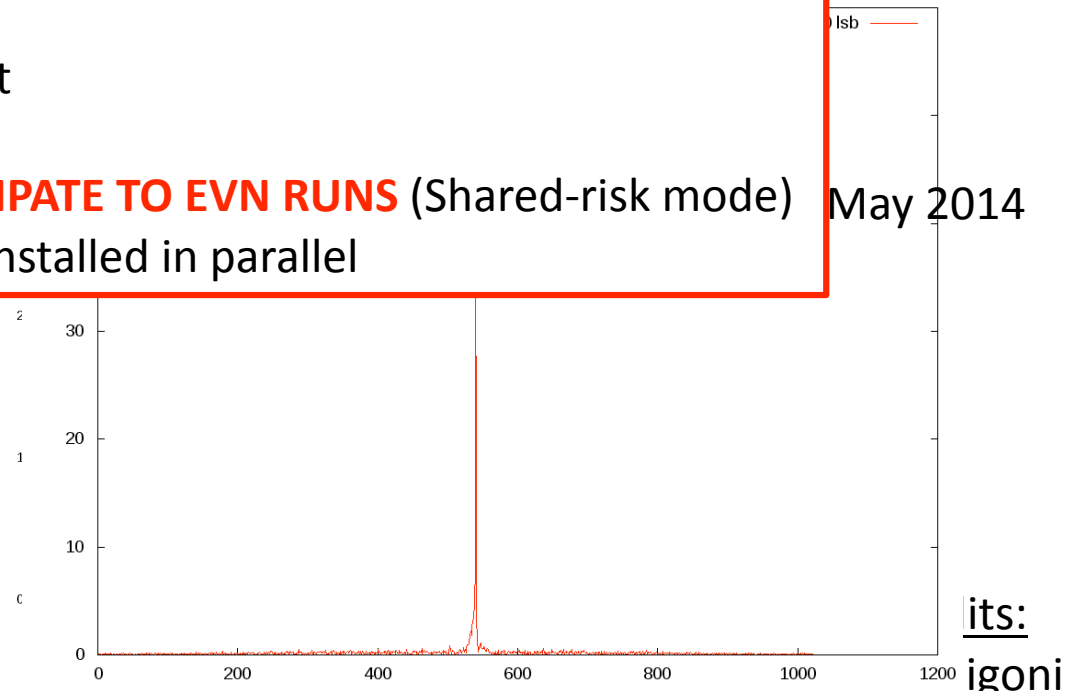
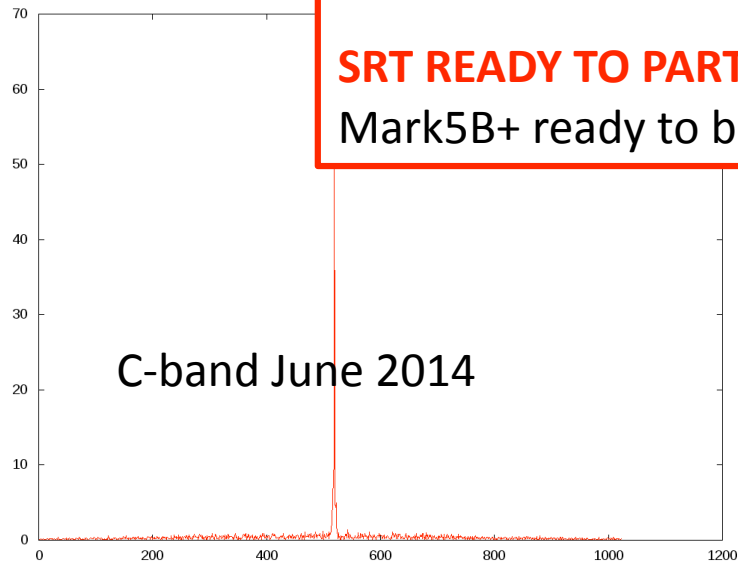
Problems to be solved: fringe amplitude (DBBC conf)

EVN May/June 2014 run:

1st L-band EVN experiment (29 May): PI Perez-Torres 6h

Data not correlated yet

SRT READY TO PARTICIPATE TO EVN RUNS (Shared-risk mode)
Mark5B+ ready to be installed in parallel



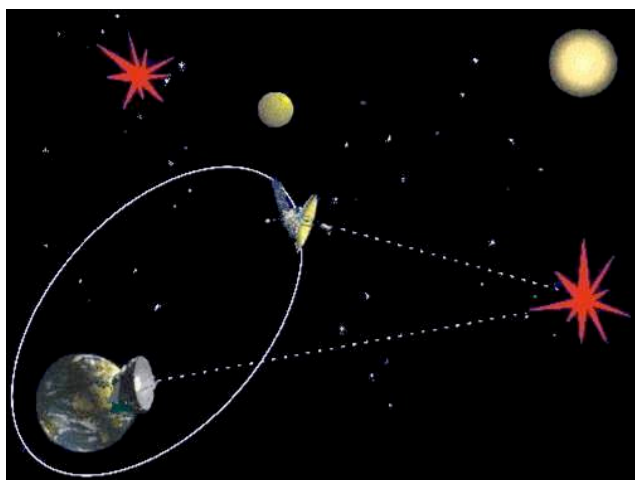
its:
igoni

AV – SRT & RadioAstron

- **1st L-band RadioAstron Experiment (4/5 June 14):**
13.5h - PI Sovolainen
- **Other RadioAstron Experiments: K-band - July 17 & 26**

Data not correlated yet

Credits: C. Migoni



Orbit: 7-10 days
Apogee : 310.000-390.00 km
Perigee : 300-7.000 km

RadioAstron:
Medicina & Noto
SRT – tests ongoing

Telescope	Effective diameter (m)
Arecibo	300
GMRT	246
VLA	125
GBT	100
Effelsberg	100
WSRT	93
Jodrell Bank	76
DSN Goldstone	70
DSN Robledo	70
DSN Tidbibilla	70
Ussuriisk	70
Eupatoria	70
Parkes	64
Kalyazin	64
Usuda	64
Sardinia	64

Frequency band [GHz]	0,327	1,665	4,83	18 - 25
Ang. Res. At 350.000 km baseline [microas]	540	106	37	7 - 10

L/P Dual Band
+ ROACH1

PULSAR STUDIES WITH SRT

- Dual band 20+90 cm receiver → unique capability to remove interstellar medium effects

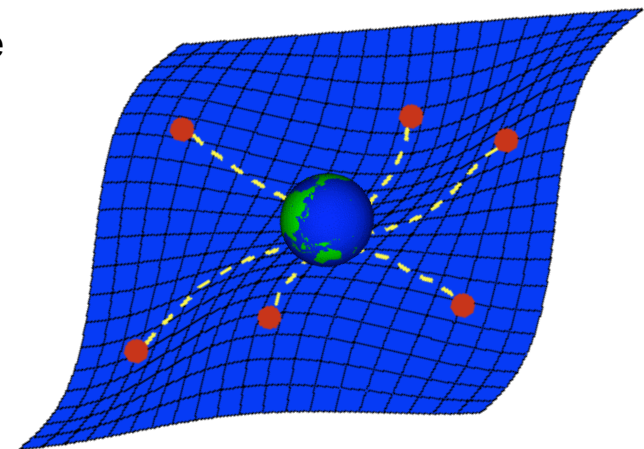
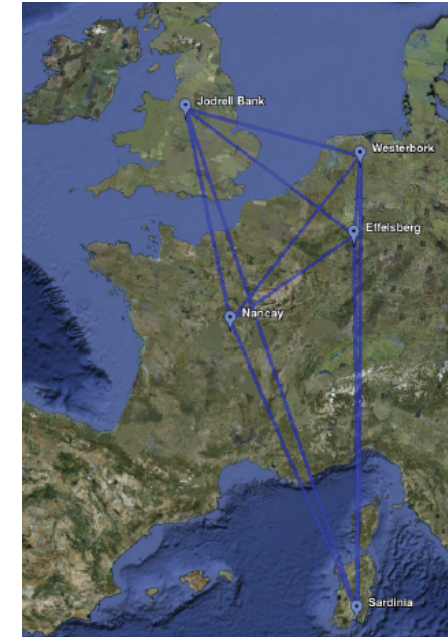
- LEAP: Large European Array for Pulsars

(Westerbork, JB, Effelsberg, Nancay, SRT)

Phased Array: ‘Coherent’ combination of the 5 major European telescopes
→ **most sensitive telescope at L-band for timing** (~200m, ie ~ Arecibo-illuminated dish, but able to track sources, and observe larger region of sky)

➔ **Ultra-precision Pulsar Timing**: Searching for signature of space-time perturbations in pulsar timing residuals

Leader experiment for detecting GW from cosmological background or from local SMBH in merging systems



Courtesy A. Possenti

AV – PULSARS: LEAP (ROACH)

Pulsar Group OAC: Perrodin, Concu, Melis et al.

1. **First LEAP session** including SRT (5 telescopes):
2013, July 27th (ROACH installed)

ROACH tests limited to 16 MHz → Only brightest pulsars
Goal: 128 MHz → LEAP; 500 MHz → EPTA

2. **Feb. 2014:** 8-node cluster available
→ **31/03/14: First LEAP session with 8 bands (128 MHz)!**

→ tests ongoing: SRT participate to all monthly 25^h LEAP sessions (nearly all msec pulsars detected)

3. **May 9, 2014: Correlation between SRT and Westerbork**

4. **Sept. 2014:** data acquisition completely automatized
(SEADAS+NURAGHE)

Next Step: 5 Telescope LEAP coherent addition

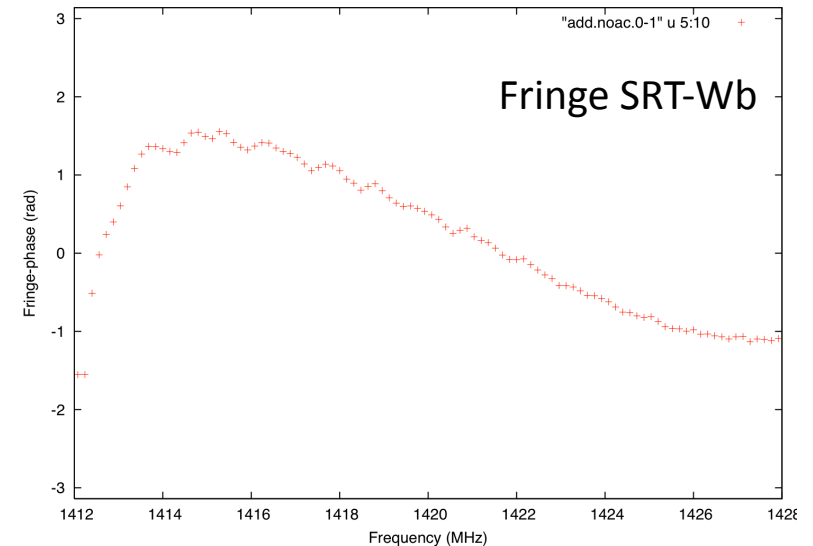
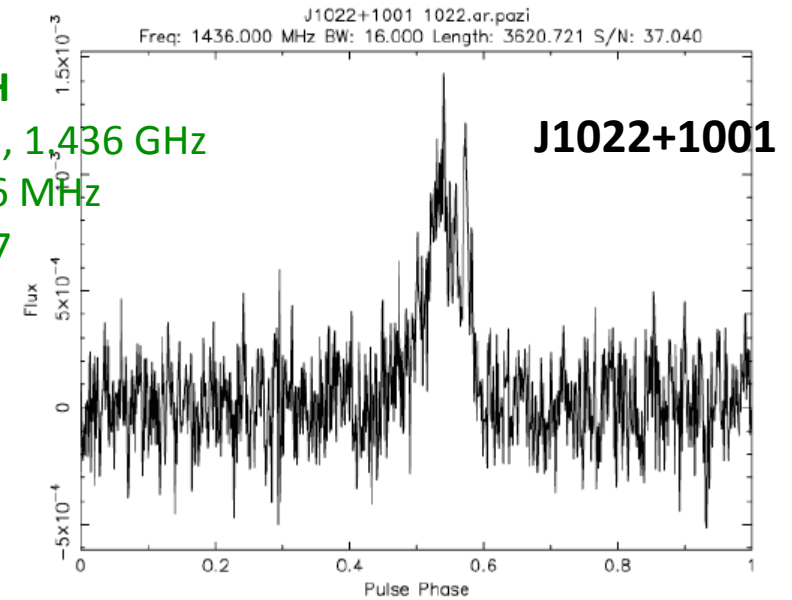
Main Issue: Strong RFIs in L-band → Site + nearby radar (RFI up to 1460 in 1 pol)

ROACH

15 min, 1,436 GHz

BW=16 MHz

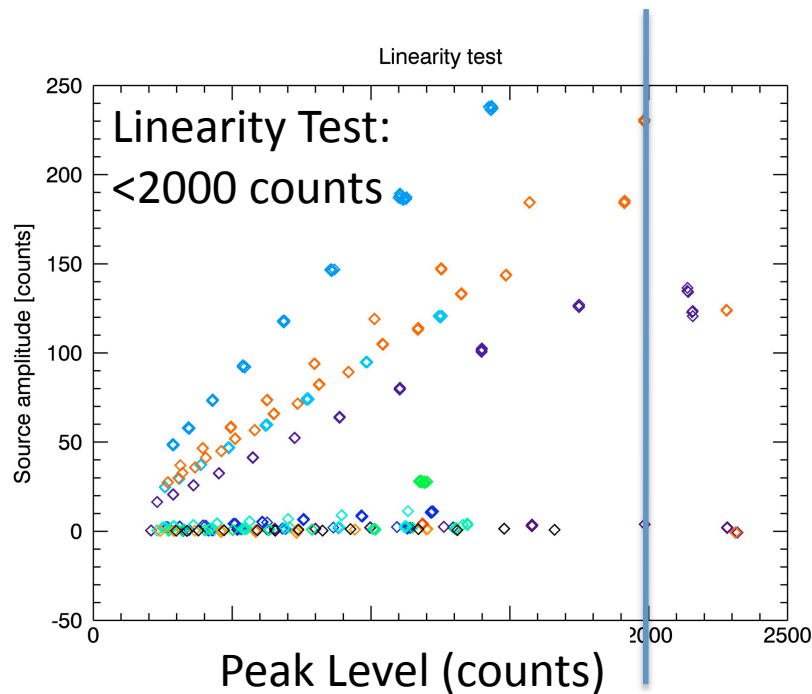
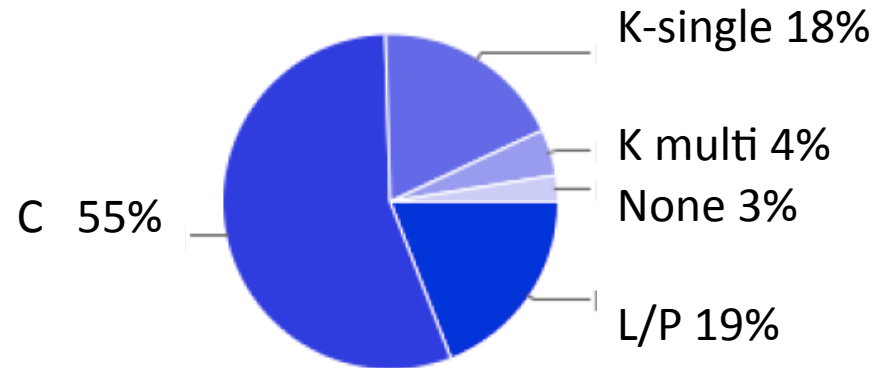
S/N=37



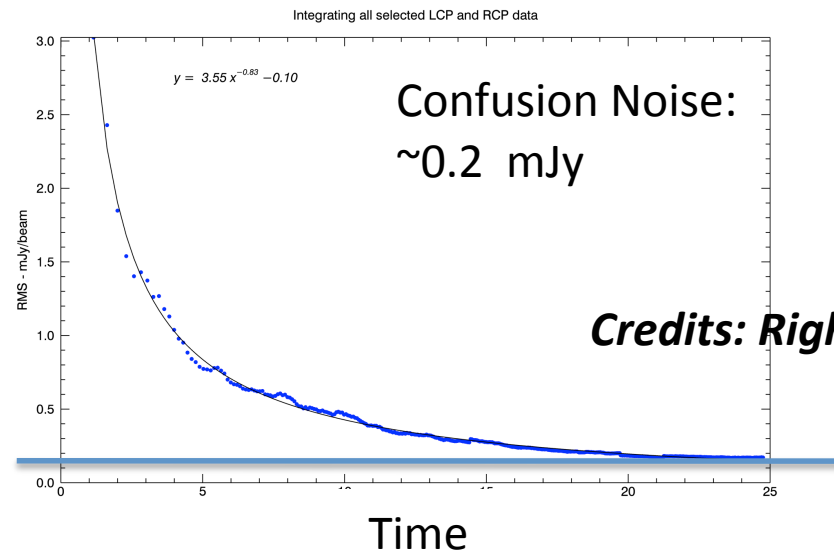
AV – Single Dish

- Mainly C-band:
 - Continuum (TP)
 - Pulsars (TP/DFB)

Receiver



•Monitoring Calibrator Campaign



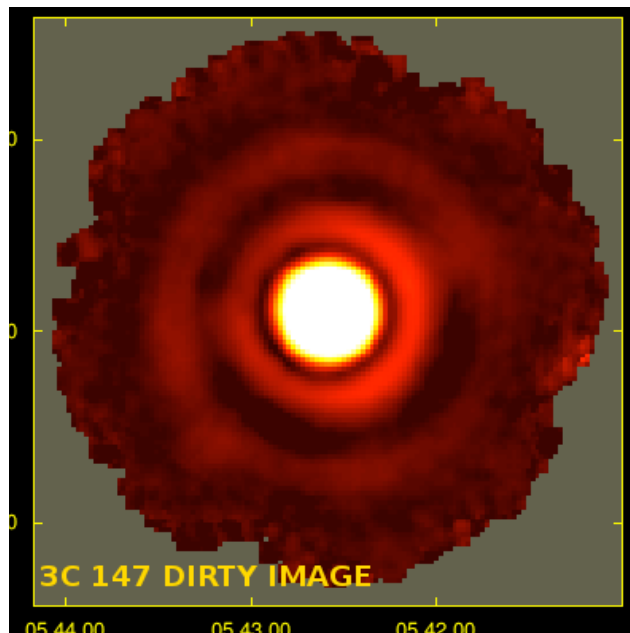
Credits: Righini

C-Band - High Dynamic Range Imaging Test

ADVANCED TEST:

Observations with TP (C Band) to test/debug beam deconvolution procedures (based on Imaging SW SCUBE (Govoni et al.)). 300 1x1 deg² maps of 3C147

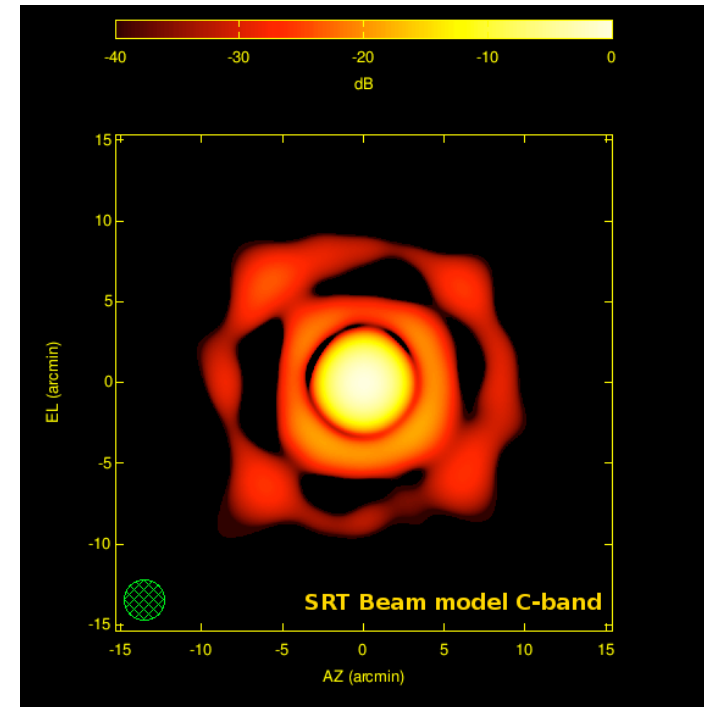
- Beam reconstruction and shapelet modeling works fine
→ DR~7000
- Need deep beam pattern measurements at fine El. steps



Restoring beam FWHM=2.8'

3C147: Beam Model

- Beam reconstruction and shapelet modeling works fine
→ DR~7000



3C147: Dirty/Cleaned Image

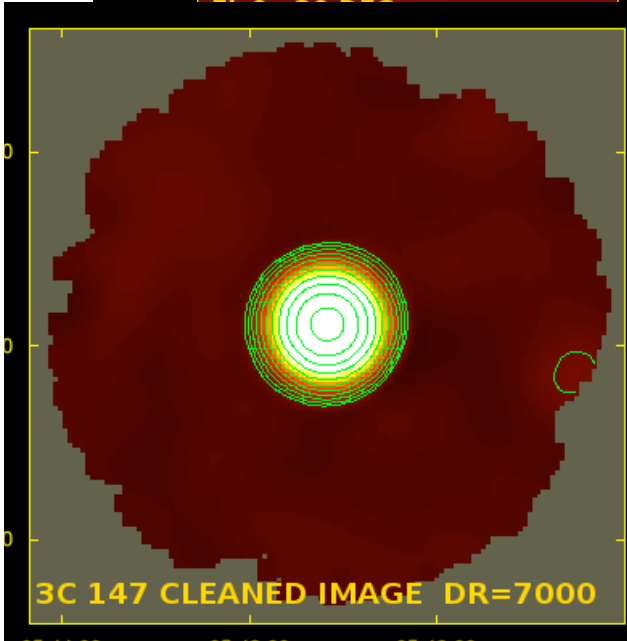
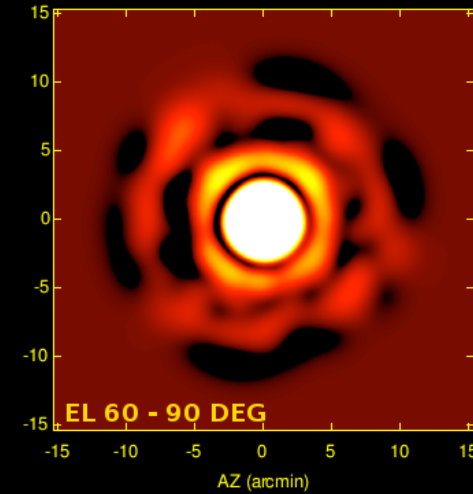
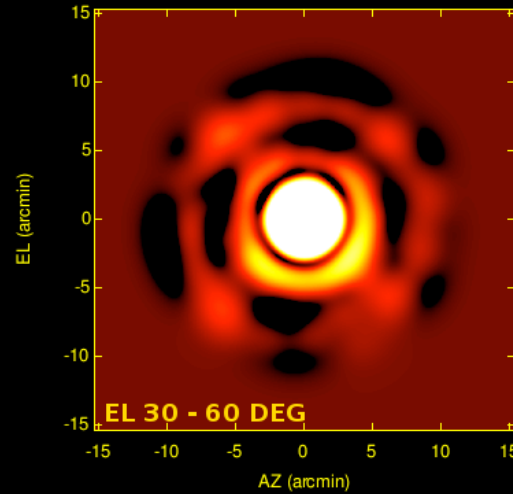
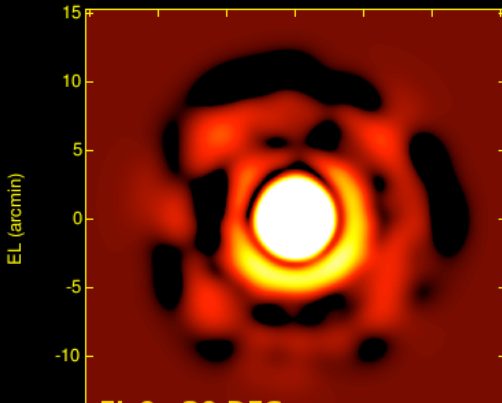
Credits:

M. Murgia, F. Govoni,
S. Poppi, V. Vacca,
P. Castangia, A. Tarchi

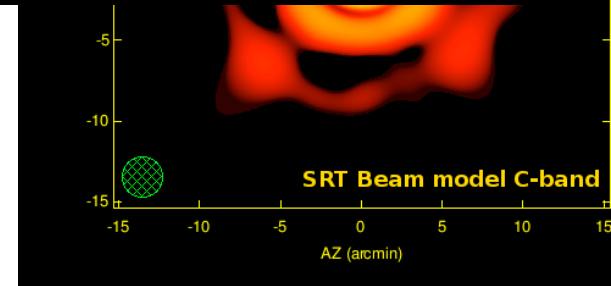
C-Band - High Dynamic Range Imaging Test

ADVANCED TEST:

- Ob
- Im
- Be
- No



• Beam reconstruction and shapelet modeling works fine
→ DR~7000



Restoring beam FWHM=2.8'

3C147: Dirty/Cleaned Image

I. Prandoni - 12th EVN Symp. - 08/10/2014

Credits:

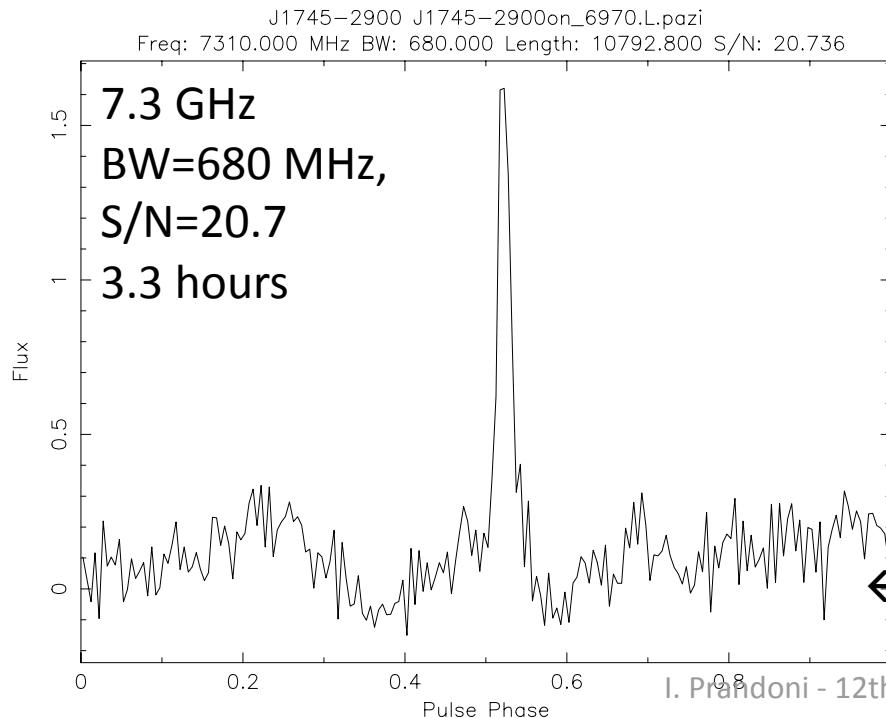
M. Murgia, F. Govoni,
S. Poppi, V. Vacca,
P. Castangia, A. Tarchi

AV – PULSARS: SD (TP)

PSR J1745-2900, firstly detected as an X-ray flare from Sgr A* by Swift and then identified as a 3.76 s X-ray magnetar

2013, May 6th → **First Observations with SRT (1 hour) @ C-band with TP thanks to long period + flat spectrum**

Regularly re-observed in the following months:



2013 Nov. 9th : Magnetar observed in L Band with ROACH

TP not suited BUT produced
First SRT publication!

ATEL#5053 – 14 May 2013 - *Buttu et al.*

← Credits: M. Burgay + Pulsar Group OAC

AV – PULSARS: SD (TP)

PS
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0.5
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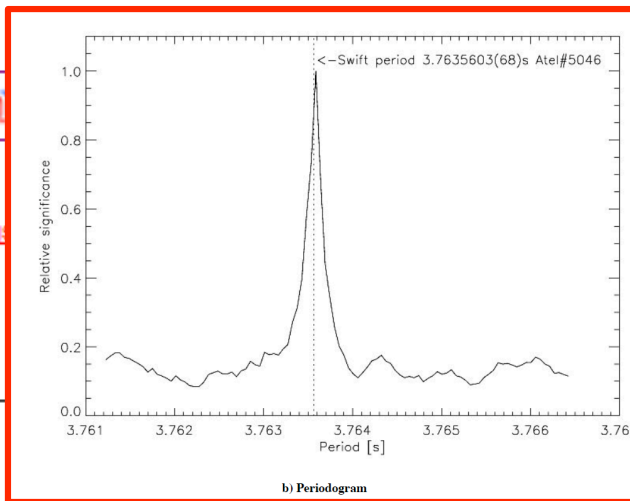
Outside
[GCN](#)
[IAUCs](#)
Other
 MacOS: [Dashboard Widget](#)
 Follow ATel on [Twitter](#)
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The Astronomer's Telegram

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Present Time: 14 May 2013; 15:10 UT

[[Previous](#) | [Next](#)]



Detection by Sardinia Radio Telescope of radio pulses at 7 GHz from the Magnetar PSR J1745-2900 in the Galactic center region

ATel #5053: [Marco Buttu \(INAF-Osservatorio Astronomico di Cagliari\)](#), [Nichi D'Amico \(INAF-OAC\)](#), [Elise Egron \(INAF-OAC\)](#), [Maria Noemi Iacolina \(INAF-OAC\)](#), [Pasqualino Marongiu \(INAF-OAC\)](#), [Carlo Migoni \(INAF-OAC\)](#), [Alberto Pellizzoni \(INAF-OAC\)](#), [Sergio Poppi \(INAF-OAC\)](#), [Andrea Possenti \(INAF-OAC\)](#), [Alessio Trois \(INAF-OAC\)](#), [Gian Paolo Vargiu \(INAF-OAC\)](#), on behalf of the [Sardinia Radio Telescope Science Validation Team and the Commissioning Team](#) on 7 May 2013; 19:19 UT
 Credential Certification: [Marta Burgay \(burgay@oa-cagliari.inaf.it\)](mailto:burgay@oa-cagliari.inaf.it)

Subjects: Radio, Neutron Star, Soft Gamma-ray Repeater, Pulsar

Referred to by ATel #: [5058](#)

During the Sardinia Radio Telescope (SRT) science verification phase, we observed

- [rotation measure of PSR J1745-2900 measured at Effelsberg](#)
- 5058 [On-going radio observations of PSR J1745-2900 at Effelsberg, Nancay, and Jodrell Bank: flux density estimates, polarisation properties, spin-down measurement, and the highest dispersion measure measured.](#)
- 5053 [Detection by Sardinia Radio Telescope of radio pulses at 7 GHz from the Magnetar PSR J1745-2900 in the Galactic center region](#)
- 5046 [Spin-down Measurement of PSR J1745-2900: a New Magnetar](#)
- 5043 [Further radio pulsations from the direction of the NuSTAR 3.76-second X-ray pulsar, and a dispersion](#)

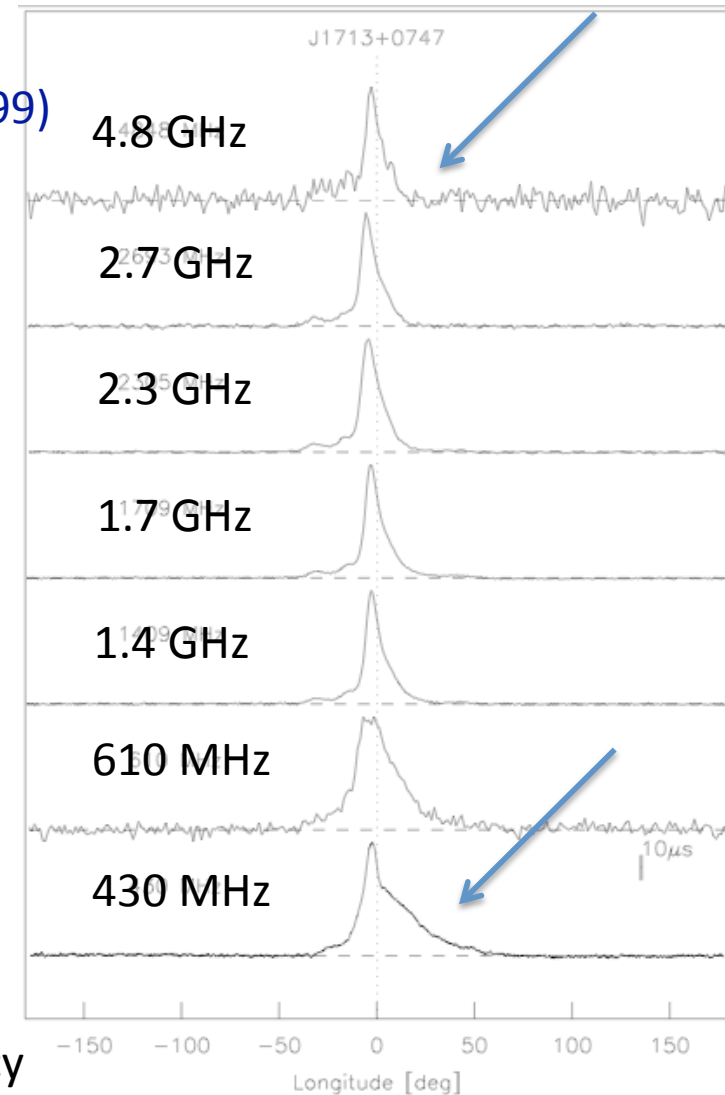
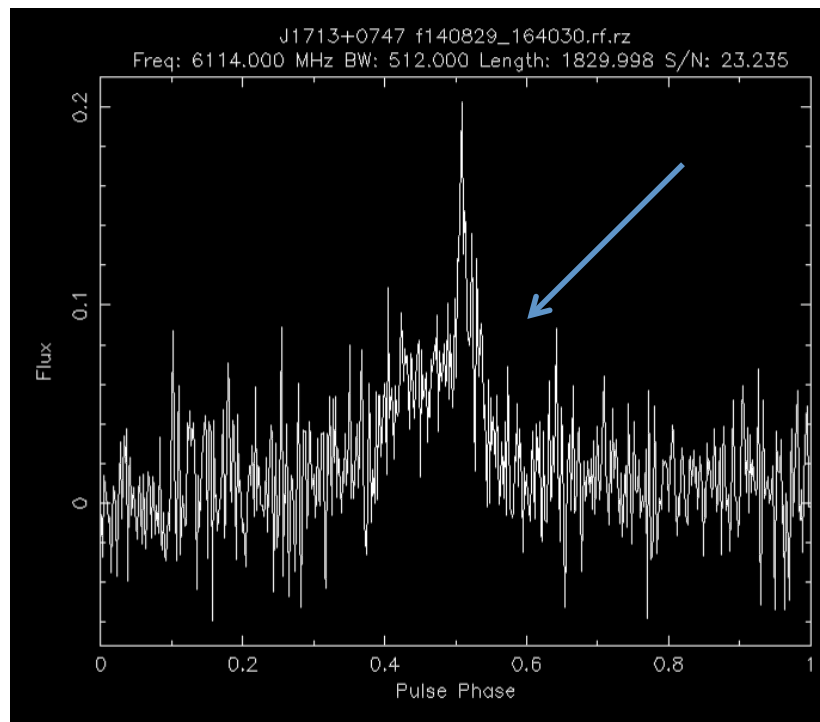
AV – PULSARS: SD (DFB)

Credits: M. Burgay + Pulsar Group OAC

PSR J1713+0747 Effelsberg (Kramer et al. 1999)

SRT: **6.1 GHz** (400 MHz BW, 512 channels)

→ one of highest frequency detection of MSP!



Intrinsic profile asymmetry disappearing with frequency
J1713+0747: one of the best for timing arrays (regular pulses)

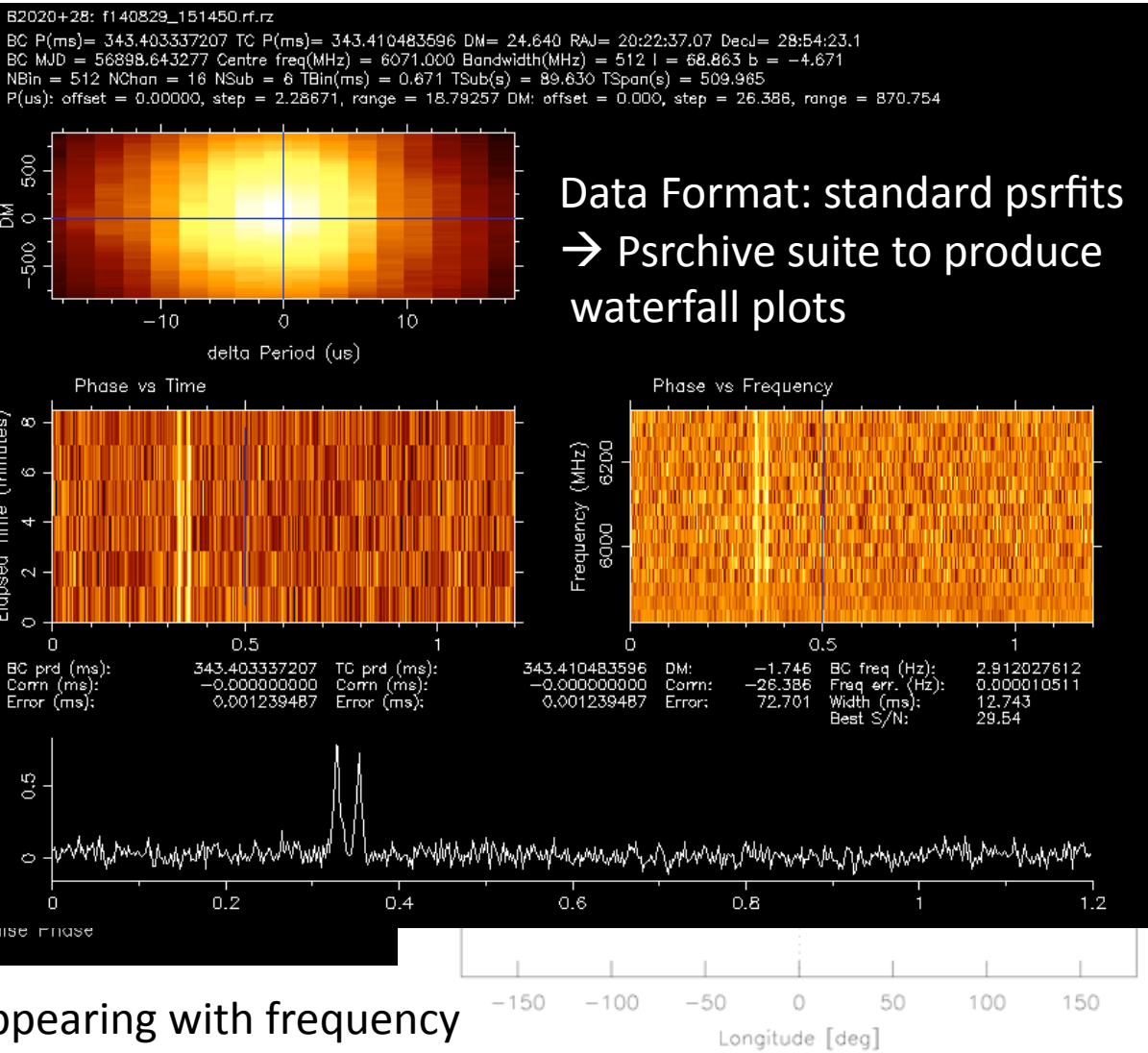
AV – PULSARS: SD (DFB)

Credits: M. Burgay + Pulsar Group

PSR J1713+0747

Effelsberg

SRT: **6.1 GHz** (400 MHz BW, 512
 → one of highest frequency det



Intrinsic profile asymmetry disappearing with frequency
 J1713+0747: one of the best for timing arrays (regular pulses)

SUMMARY

VALIDATED - CLOSE TO VALIDATION:

- ✓ **VLBI Operations:** ready from technical point of view (EVN+RadioAstron) L, C, K
- ✓ **LEAP Operations:** L-band/Roach (close to ready)
- ✓ **Single Dish:** Pulsar C-band Observations: TP and DFP folding mode
Continuum TP Observations: C-band, incl. imaging; K-band-single

IN PROGRESS I:

CAVEAT: Logistics, technical support (shifts), man power

- ✓ **Single Dish K-band-multifeed/imaging:** Continuum TP
- ✓ **Single Dish Spectroscopy:** single/multi-feed: XARCOS
- ✓ **Single Dish Pulsar search mode**

IN PROGRESS II:

- * **Single Dish L/P Band** → spectropolarimetry with DFB or ROACH
- * eVLBI → 1-1.5 years (optic fibre)
- * mm-VLBI → 86 GHz + 43 GHz (under design); metrology

ToO → limited time available as DDT (see eg Magnetar)