Large European Array for Pulsars

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http://www.epta.eu.org

http://www.leap.eu.org

Large European Array for Pulsars

EPTA telescopes:

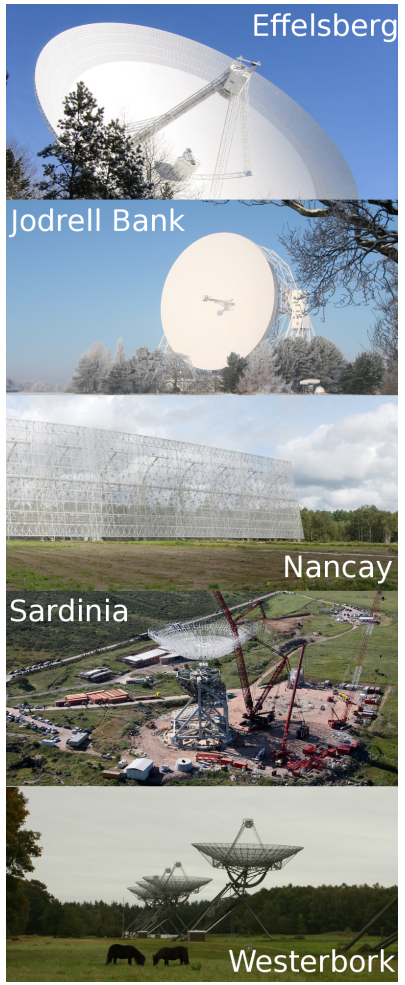
Germany | 100 m Effelsberg Telescope
MPIfR, Bonn

United Kingdom | 76 m Lovell Telescope
Jodrell Bank, Manchester

Netherlands | 14×25 m Westerbork Synthesis Radio Telescope (94 m equivalent diameter)
ASTRON, Dwingeloo

France | 94 m Nançay Radio Telescope
CNRS, Orléans

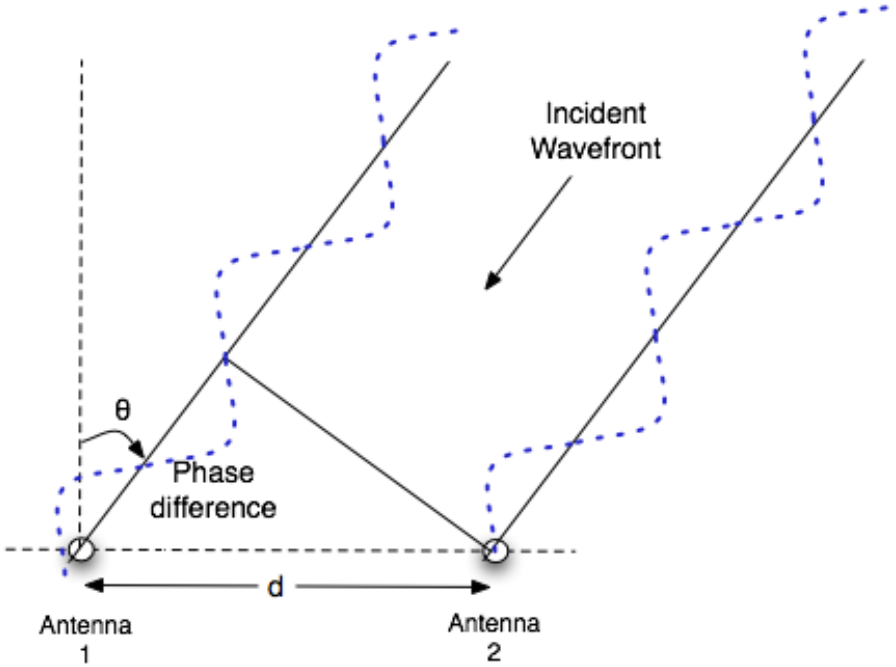
Italy | 64 m Sardinia Radio Telescope
INAF, Cagliari



LEAP Project: Coherently combine pulsar observations from the EPTA telescopes into a *tied array telescope*. Comparable in aperture to the illuminated Arecibo dish, but able to cover $-30° < \delta < 90°$.

Tied array telescope

In a *tied array telescope* signals from different telescopes are corrected for differences in time delay, then added in phase.



Time delays due to

- differences in geometry
- observatory clocks
- instruments (cable lengths)
- atmospheric conditions

Total time delay needs to be known to a fraction of a wavelength (21 cm = 0.7 ns)
→ observe phase calibrators

Advantages:

- Larger aperture will improve TOA accuracy
- Ability to time weaker pulsars
- Calibration of instrumental delays between telescopes

LEAP Plan

Observations:

- monthly 24 h sessions
- 20-30 millisecond pulsars
- simultaneously with all 5 EPTA telescopes
- observe pulsars and phase calibrators
- 128 MHz of bandwidth @ 1400 MHz, 8 bit sampling
- baseband data (raw voltages) recorded on disk

Processing:

- data transferred to Jodrell Bank
- correlate calibrator (pulsar) data to obtain time/phase offsets
- apply time/phase offsets to pulsar data and add coherently
- generate TOAs using standard software (*dspsr*, *psrchive*)

Status: pulsar backends

Upgraded existing backends at EPTA telescopes and developed new digital backends

- Storage capacity of PuMa II at WSRT upgraded to 80 TB to accommodate monthly 48 hours of EPTA timing and 24 hours of LEAP baseband data (8×20 MHz subbands for LEAP)
- ROACH based backends developed for Effelsberg and Jodrell Bank. Can observe 512 MHz of BW, 100 TB of storage (8×16 MHz subbands for LEAP) (see poster by Ramesh Karuppusamy)
- Presently upgrading disks of BON512 at Nançay (will use 8×16 MHz subbands)
- Intend to use APSR mode on Sardinia DFB. May acquire a ROACH as well.

Status: storage and processing

Storage/processing hardware:

- 24 hour session @ 128 MHz BW → 40 TB of data per telescope
- Storage servers at each telescope with 100 TB of storage (in place for Westerbork/Effelsberg/Jodrell Bank)
- Jodrell Bank gets another 4 storage servers to match remote observatories
- Data transfer by shipping disks between storage servers or copy over internet (presently @ 80 MB s^{-1} for Eff-JB, WSRT-JB)
- 400 CPU HPC cluster is in place at Jodrell Bank for processing

Correlation/tied array software:

- Developed from scratch (see poster by Roy Smits)
- Fringe fitting of closure phase (after Schwab & Cotton 1983)
- Uses *CALC* model for geometric delays (also used by VLBI)
- Ability for pulsar binning (necessary to calibrate phases on pulsars)

Status: Observing

Observations:
Monthly observations since June 2011

June/July 2011 6 h with WSRT/Eff @ 5×20 MHz

Aug-Dec 2011 12 h with WSRT/Eff @ 5×20 MHz

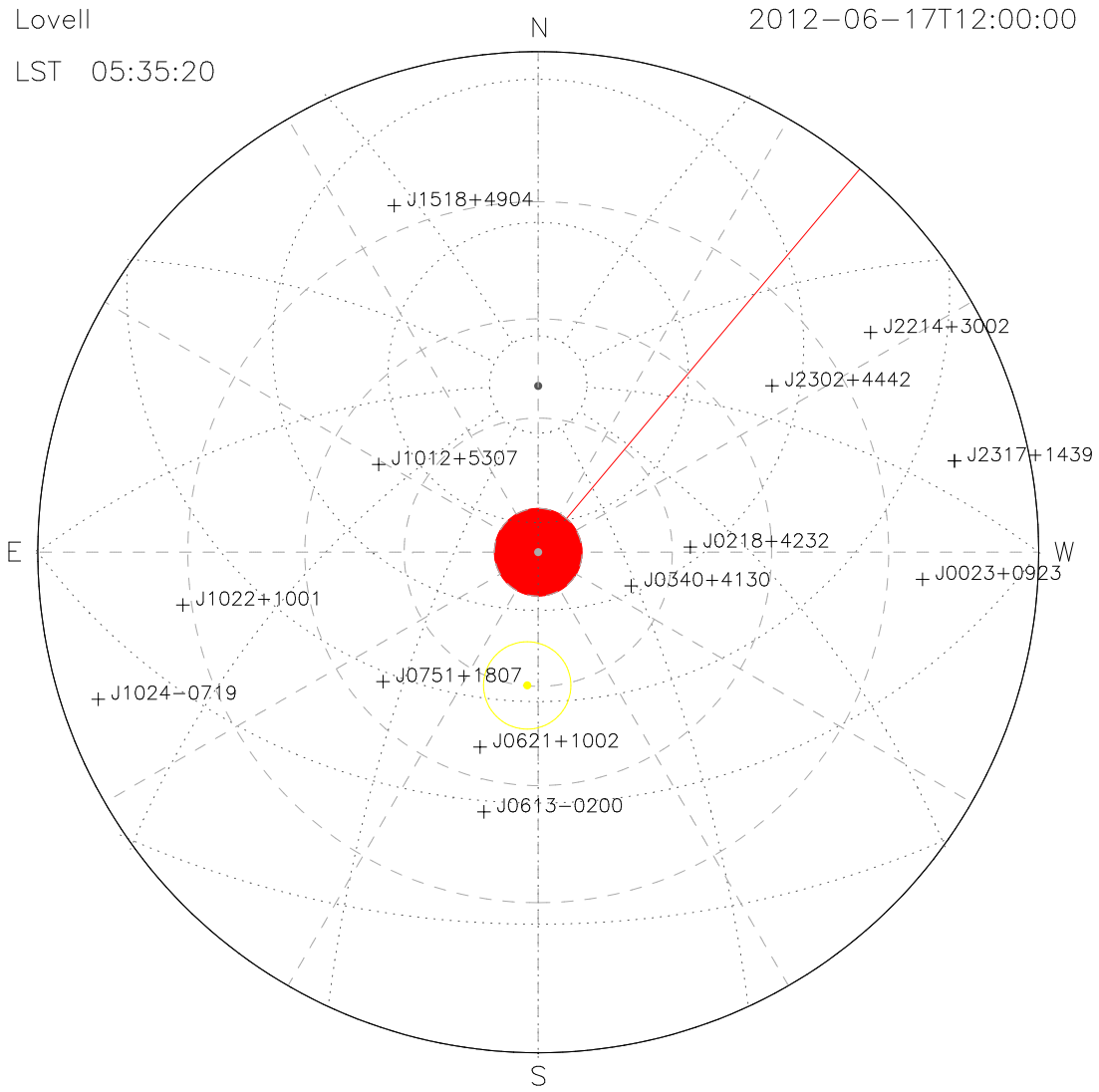
Jan-Feb 2012 12 h with WSRT/Eff(JB) @ 8×16 MHz

March-July 2012 24 h with WSRT/Eff/JB @ 8×16 MHz

Constraints on scheduling:

- Telescope specific slew speeds, elevation constraints, cable wraps
- Minimum slew/integration times
- Phase calibrators in between pulsars (cal+psr+cal+psr+cal)
- Atmosphere coherence time limits integration times

Scheduling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LST 05:35:20
2012−06−17T12:00:00
N
E
W
S
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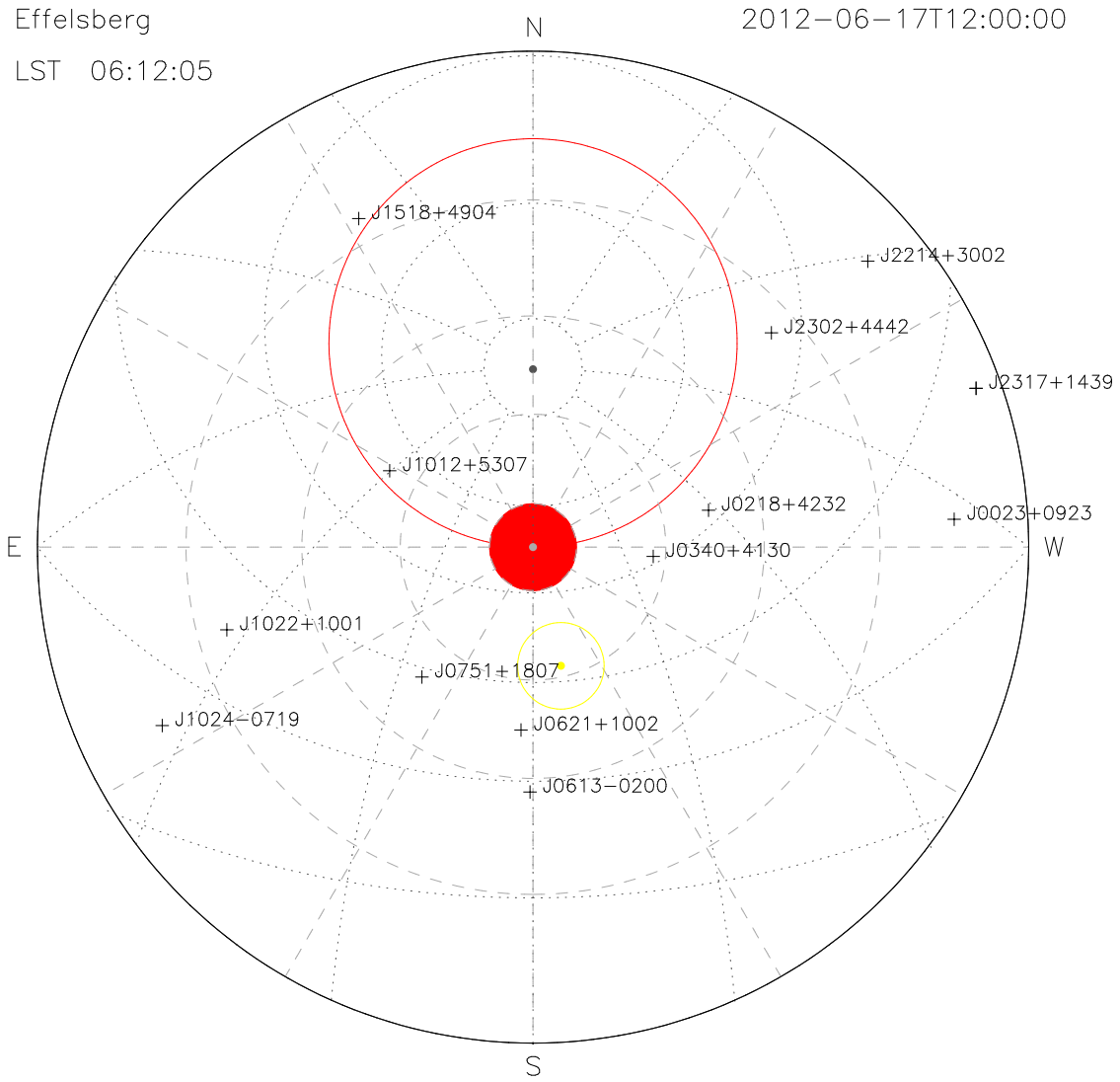
J2214+3002
J2302+4442
J1012+5307
J2317+1439
J0218+4232
J0340+4130
J0023+0923
J1022+1001
J0751+1807
J1024−0719
J0621+1002
J0613−0200

Scheduling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N
E
W
S
J1518+4904
J2214+3002
J2302+4442
J2317+1439
J1012+5307
J0218+4232
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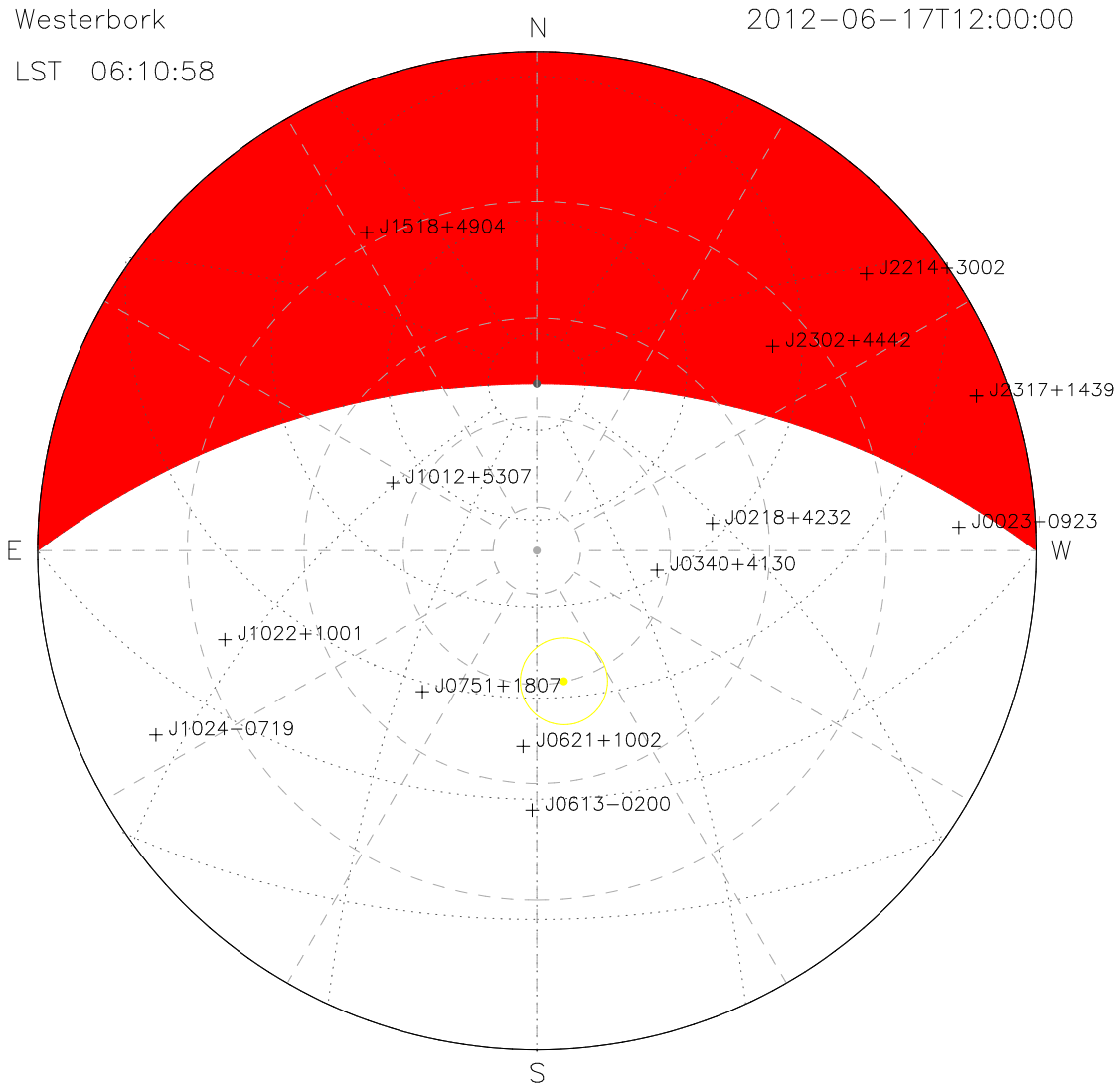
Scheduling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J2214+3002
J2302+4442
J2317+1439
J1012+5307
J0218+4232
J0023+0923
J0340+4130
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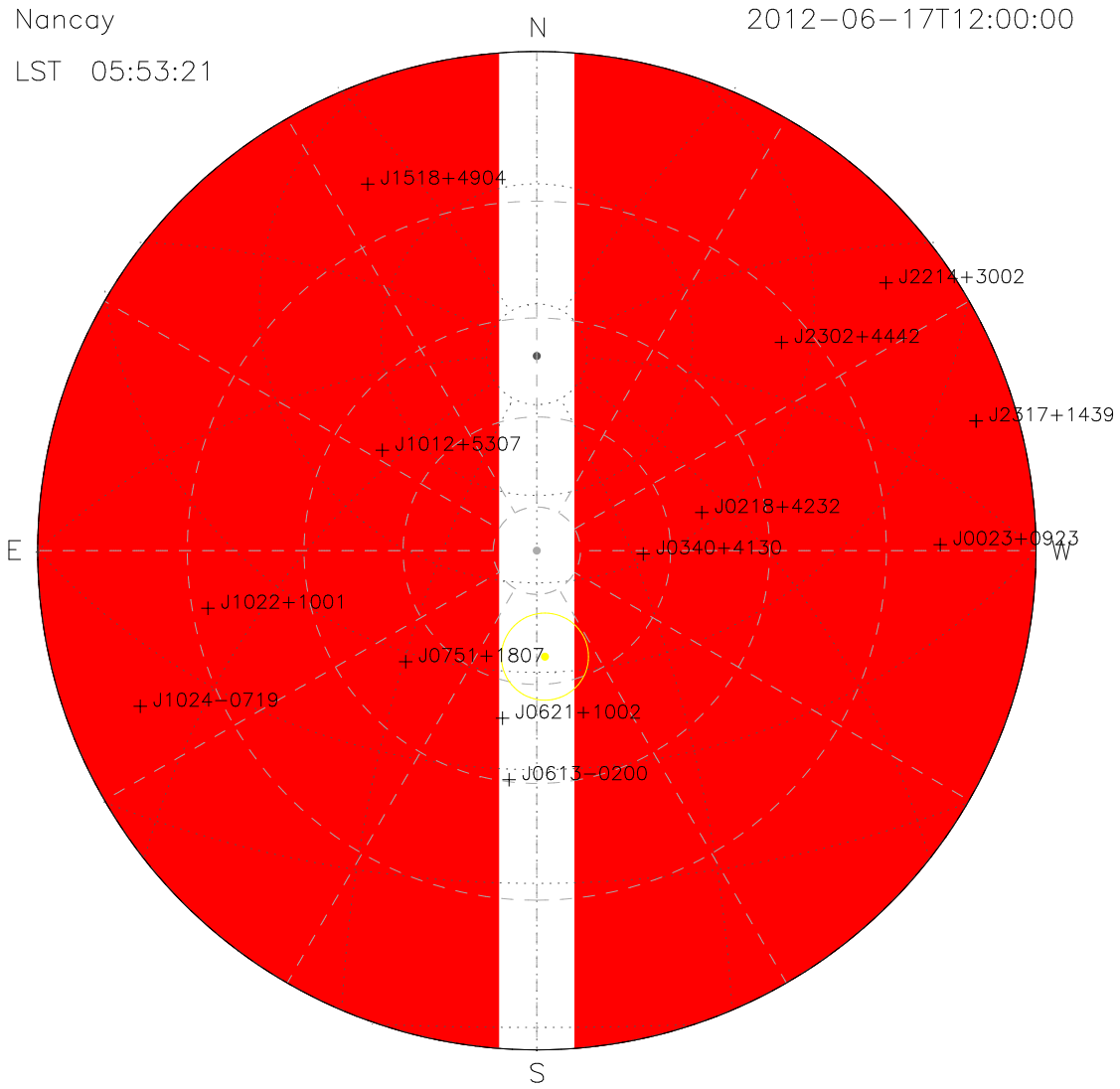
J0613−0200

Scheduling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J2317+1439
J1012+5307
J0218+4232
J0340+4130
J0023+0923
J1022+1001
J0751+1807
J1024−0719
J0621+1002
J0613−0200

Preliminary results

Dataset:

- 600 s of baseband data on PSR B1937+21
- Simultaneous with Effelsberg, Jodrell Bank and Westerbork
- 128 MHz of BW (1332 MHz to 1460 MHz)

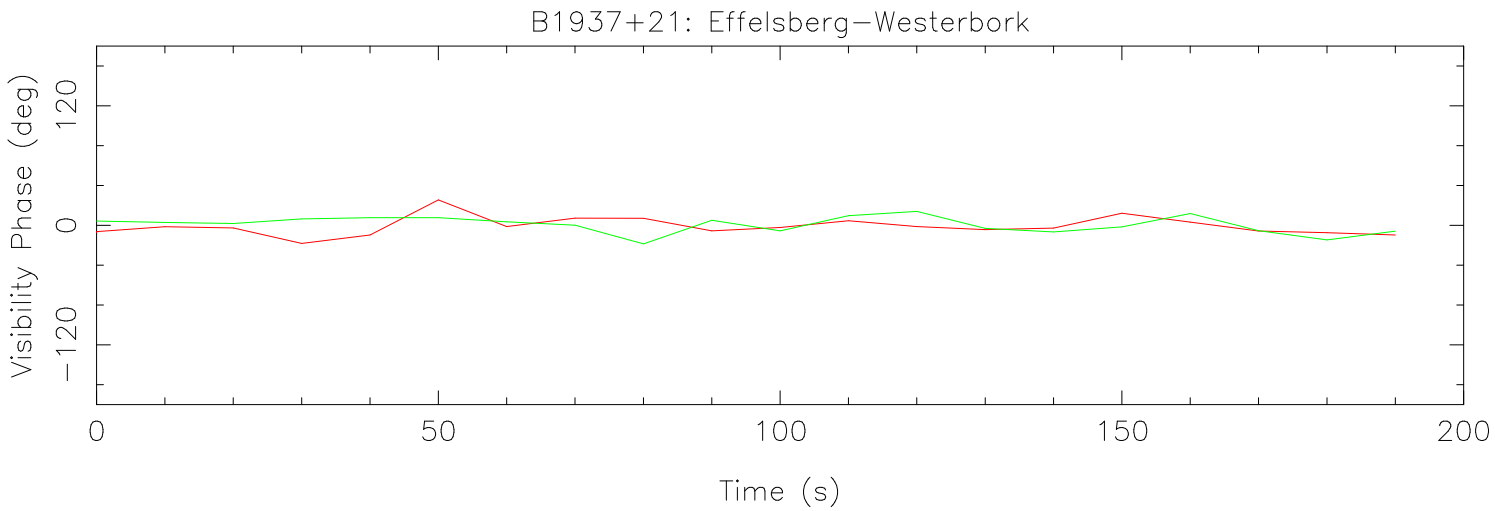
Processing:

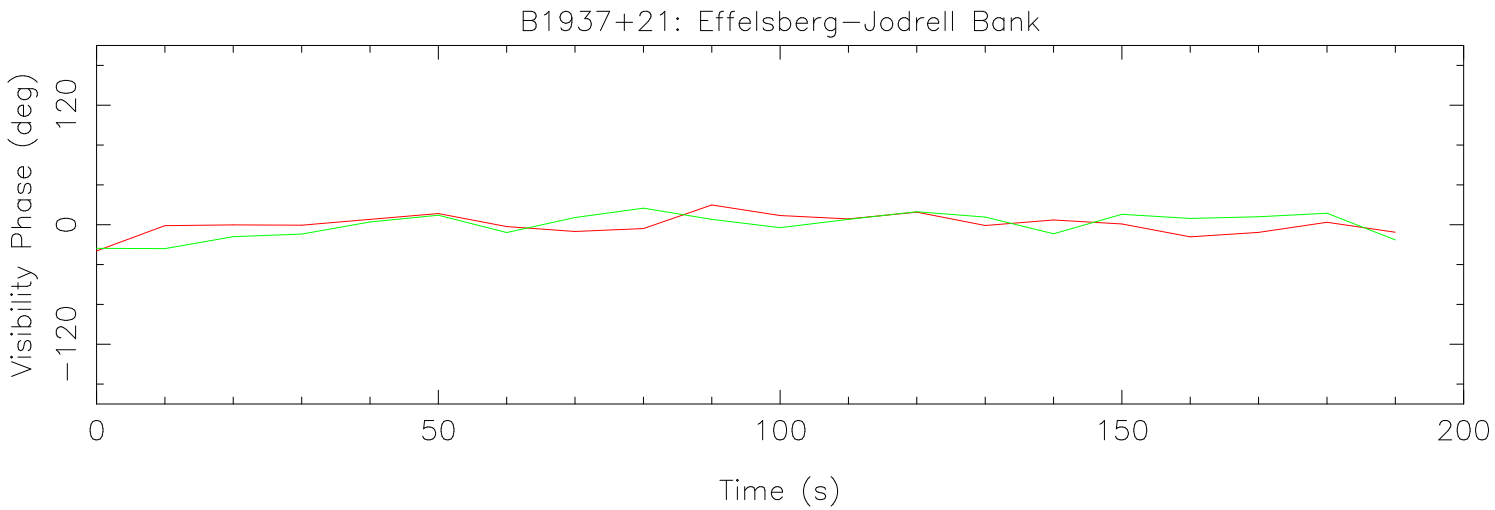
- Phases calibrated on the pulsar
- All data dedispersed and folded using same ephemeris/software

Issues:

- Preliminary scaling of telescopes before adding (not optimal)
- Bad RFI and packet loss in some bands of Jodrell Bank
- Not yet flux and polarization calibrated (signal losses in cross terms)

Preliminary results: Phase calibrating on pulsars





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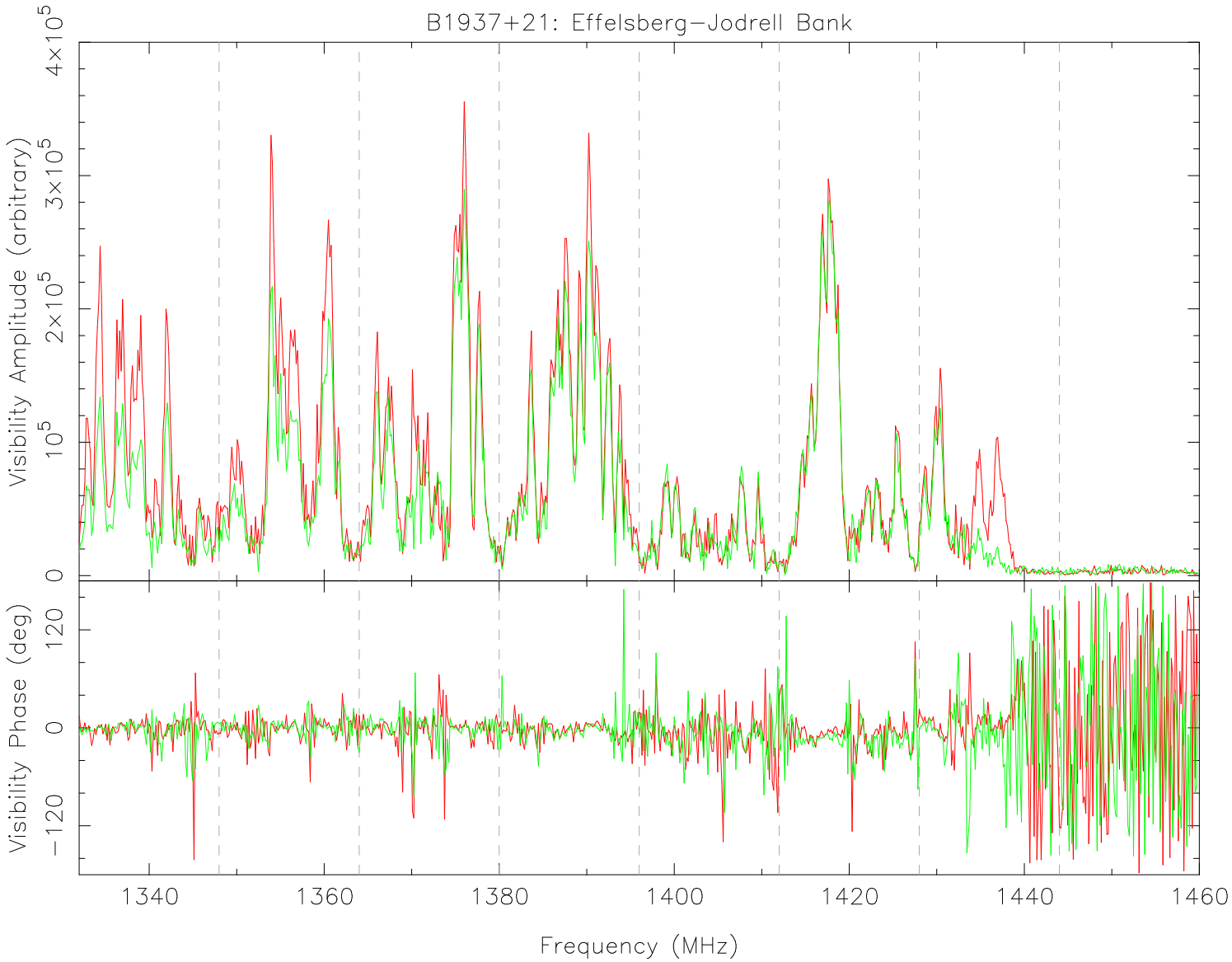

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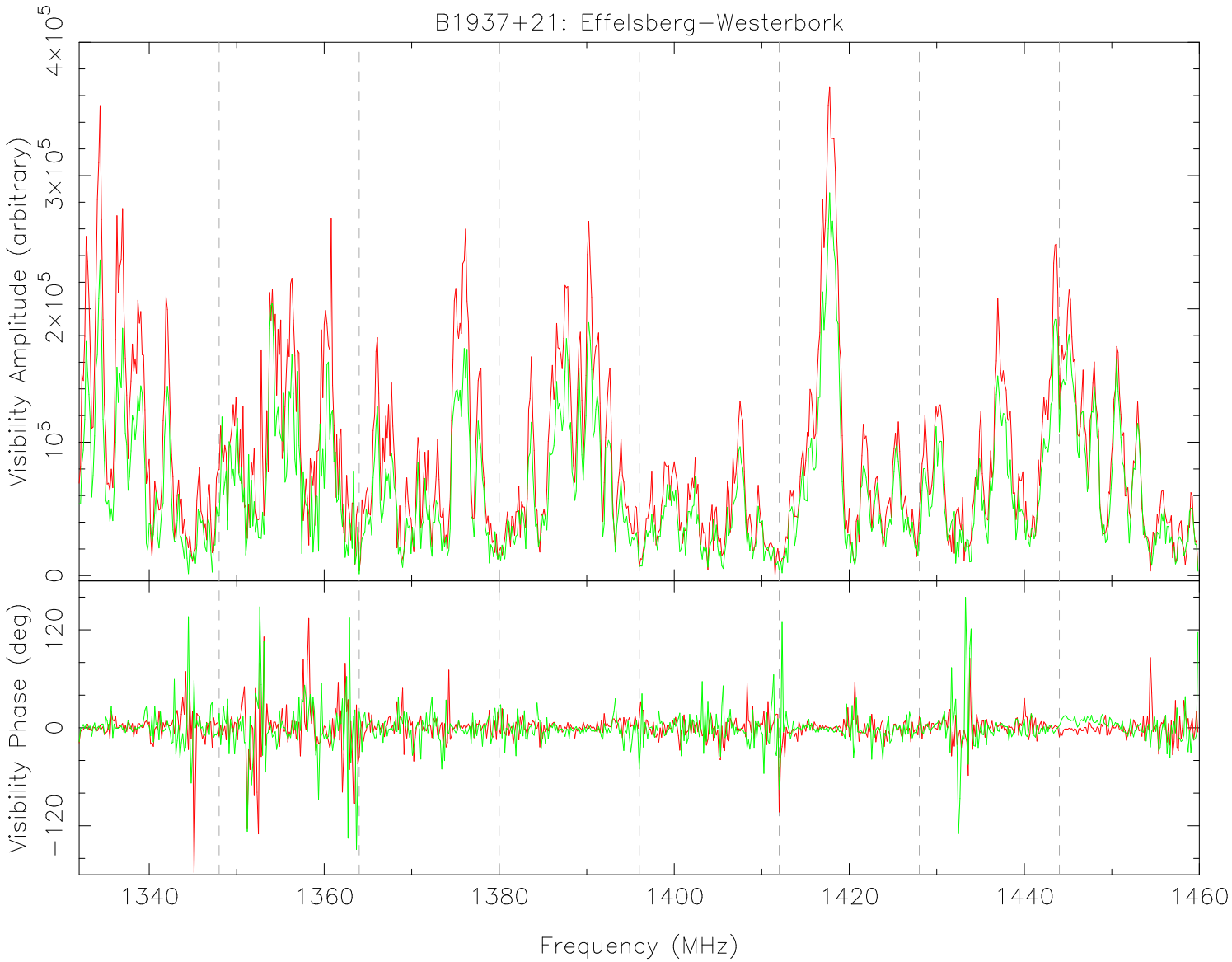
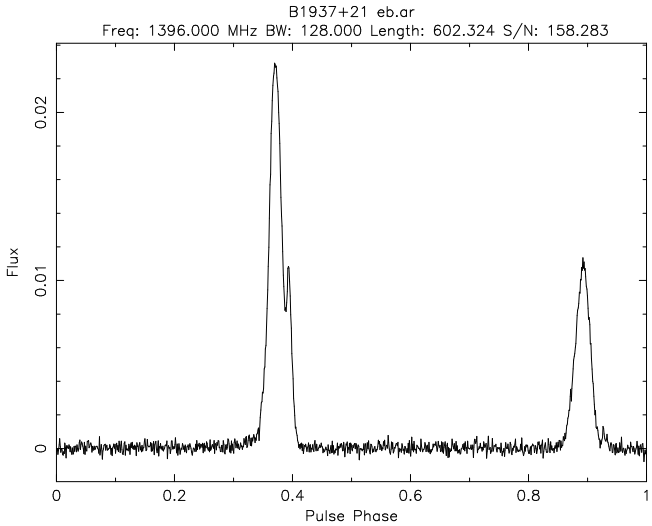
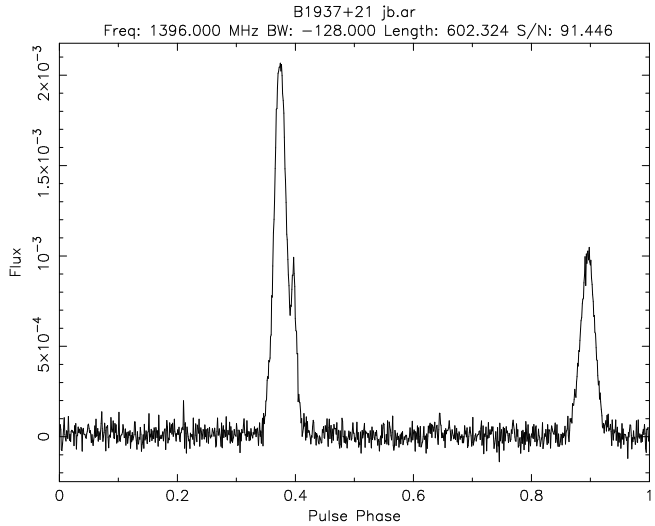
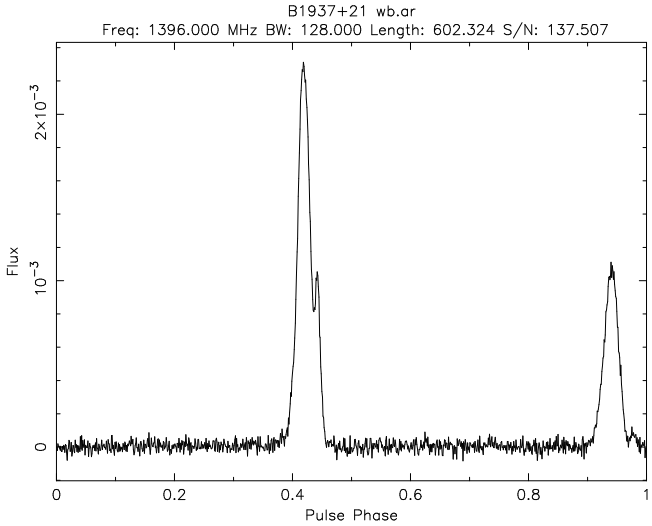
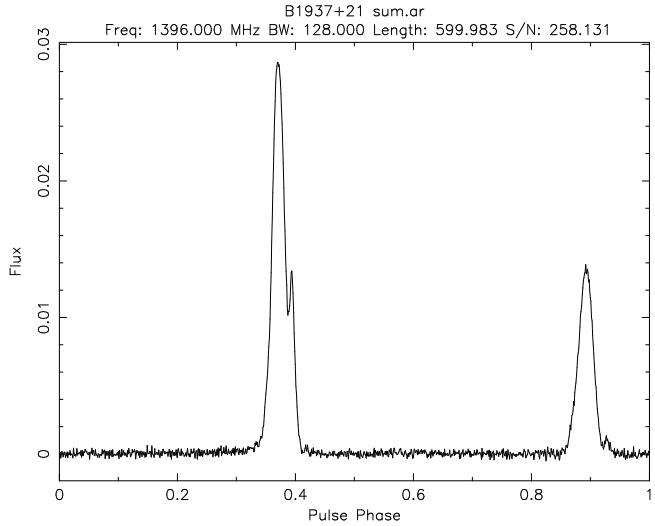


Preliminary results: Profiles









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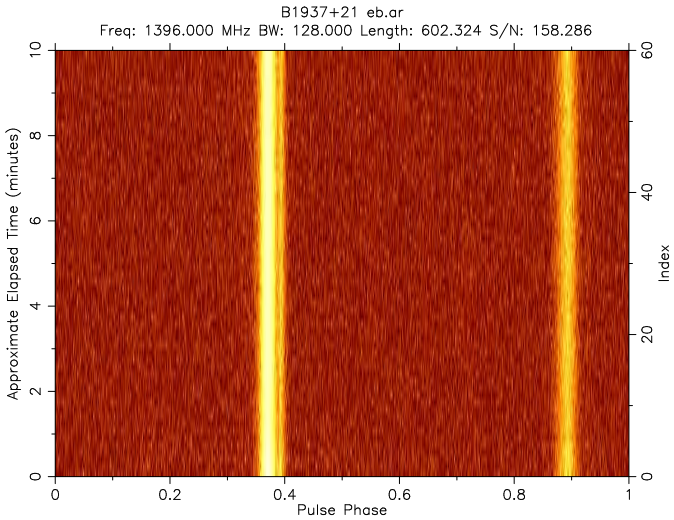
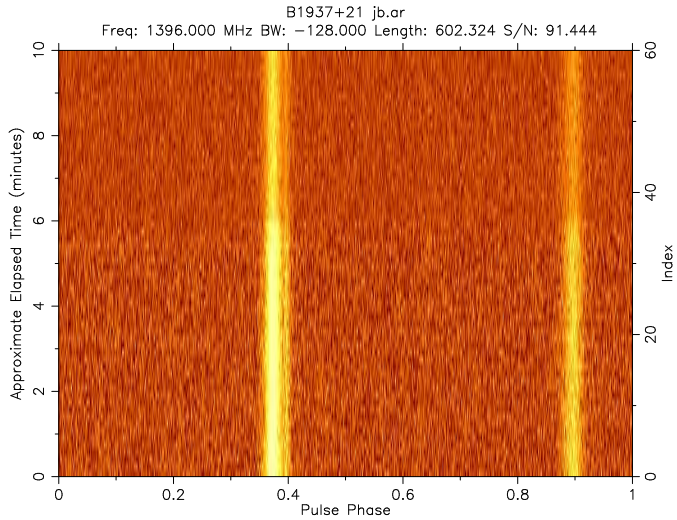
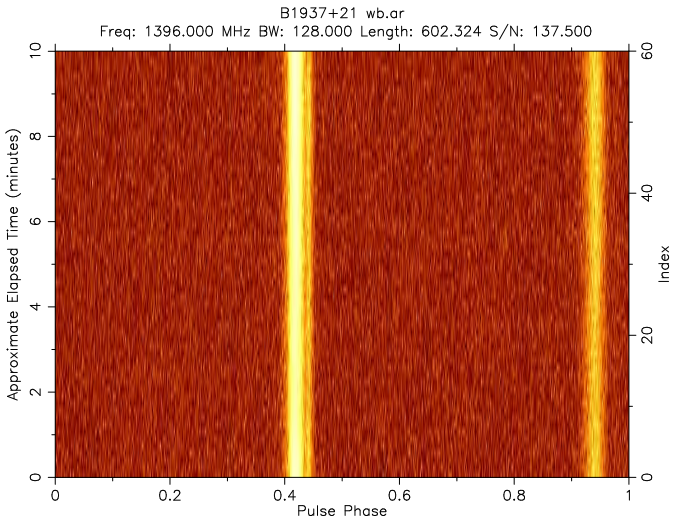
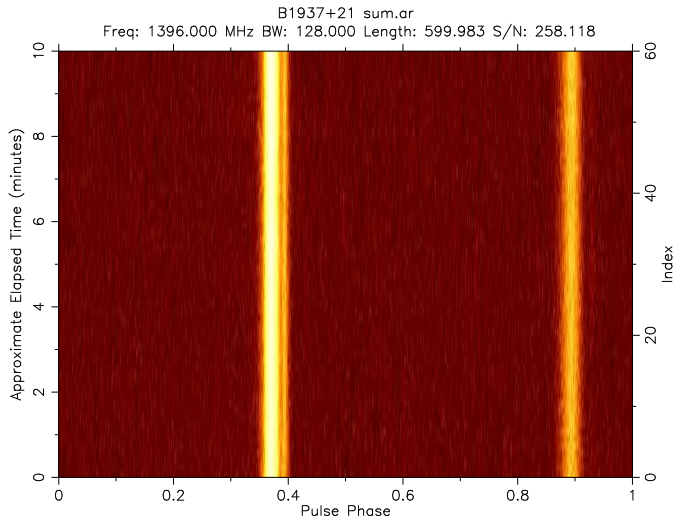
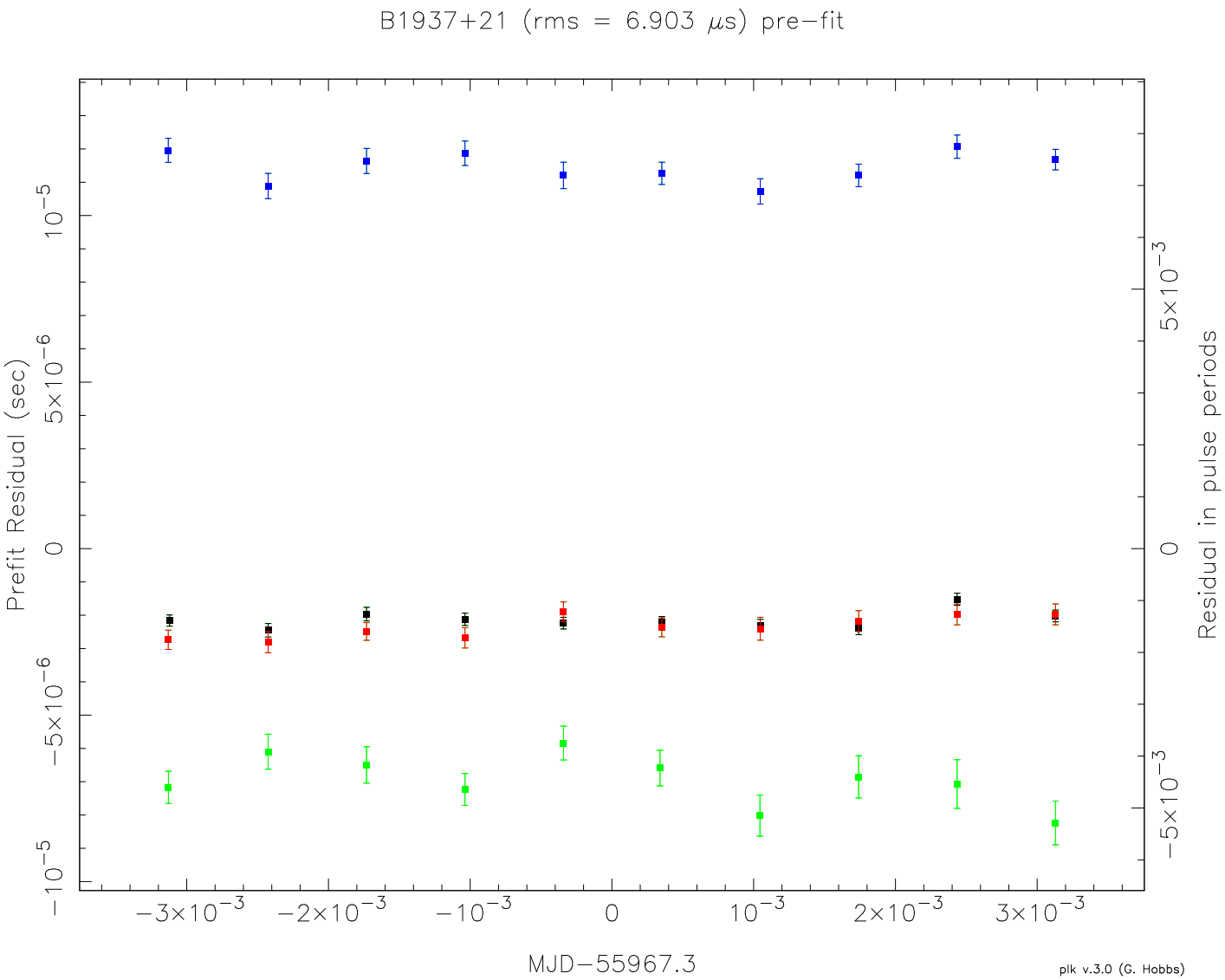








Preliminary results: TOAs



SUM/EB/JB/WB

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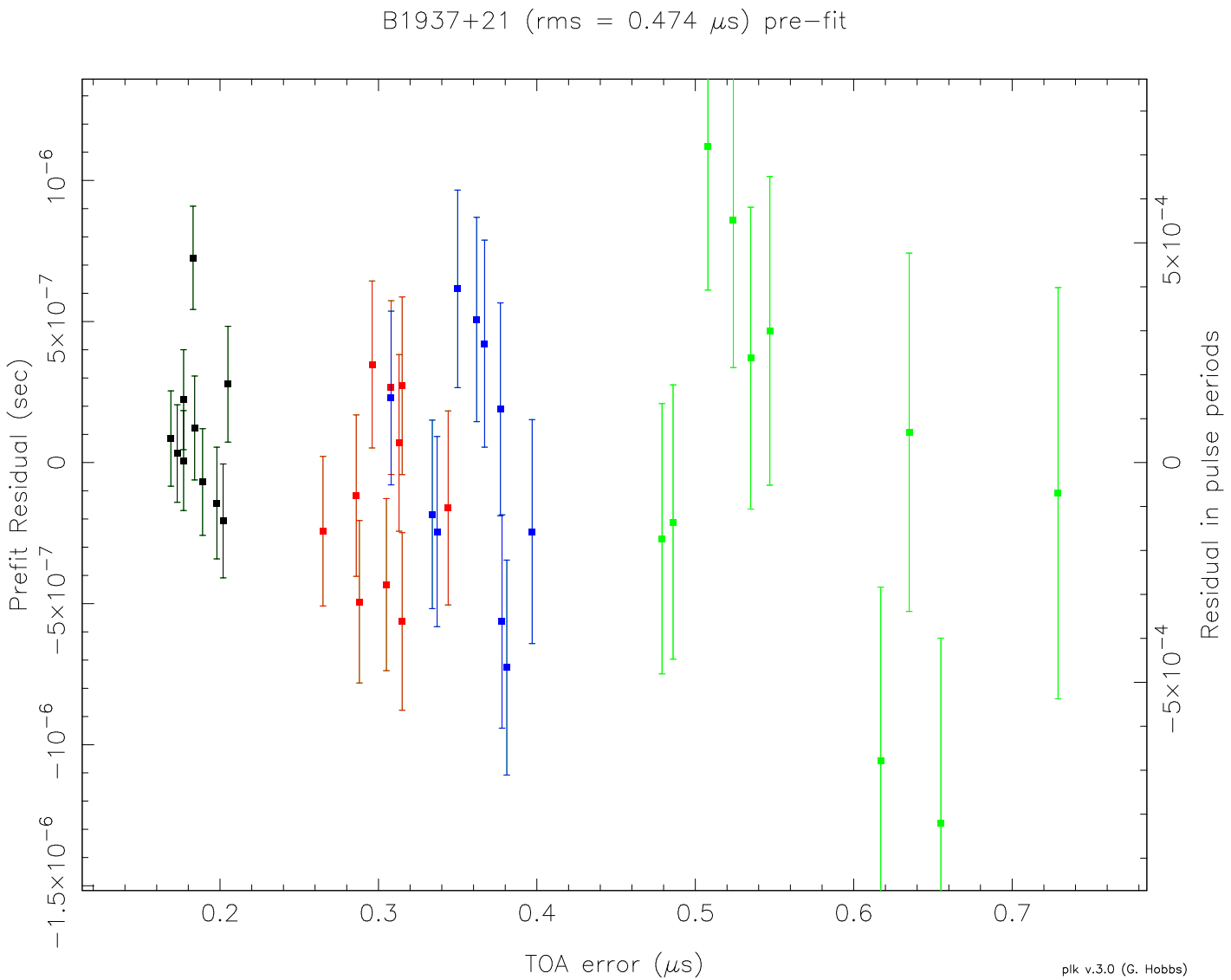

SUM/EB/JB/WB

Summary

Realizing LEAP will:

- increase TOA accuracy
- provide high signal-to-noise data
  (studies of noise characteristics)
- help understanding of timing systematics between telescopes
- calibrate instrumental delays between EPTA telescopes
- allow observations of fainter pulsars

Thank you!

Summary

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