The Extended KVN (x-KVN): Adding Global baselines to the KVN array

Global baselines with Simultaneous KVN-Style VLBI

International Centre for Radio Astronomy Research

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Jamie Stevens: ATNF/CSIRO
Mareki Honma: NAOJ
Taehyun Jung: KVN/KASI
Bong Won Sohn: KVN/KASI
Pablo de Vicente: OAN/IGN

Curtin University

The University of Western Australia

Australian Government
Department of Foreign Affairs and Trade

Firenze 2015: ERATec Workshop

What is KVN-Style VLBI?

KVN-Style is NOT:

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What is KVN-Style VLBI

KVN VLBI receiver system can co-observe multiple frequency bands: *Han etal 2008 Int. J. of mm & IR*

Any system which can co-observe multiple frequency bands is KVN compatible

Whether it is:

- **Quasi-Optics (with high performance gratings)**
- **Traditional QO**
- **Co-axial feeds**
- **Sub-arraying**

Fast-Switching is semi-compatible (i.e. some of the time)

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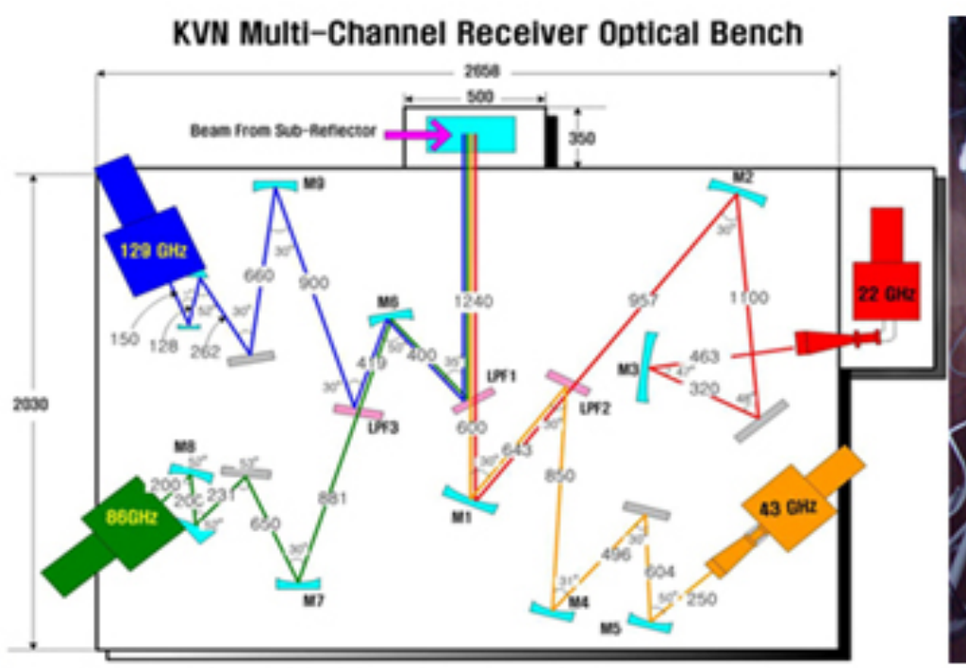

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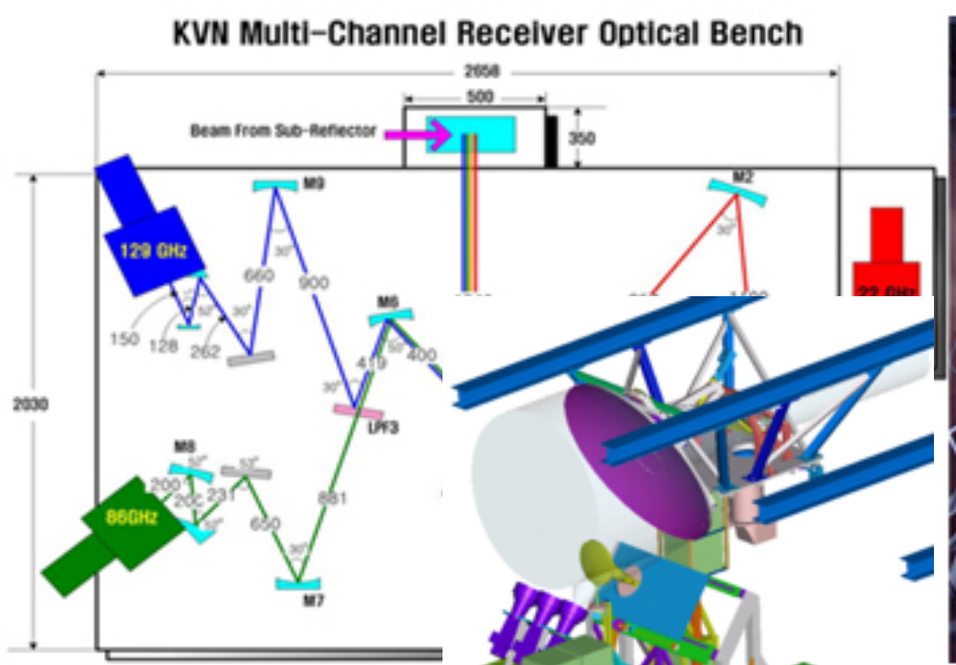

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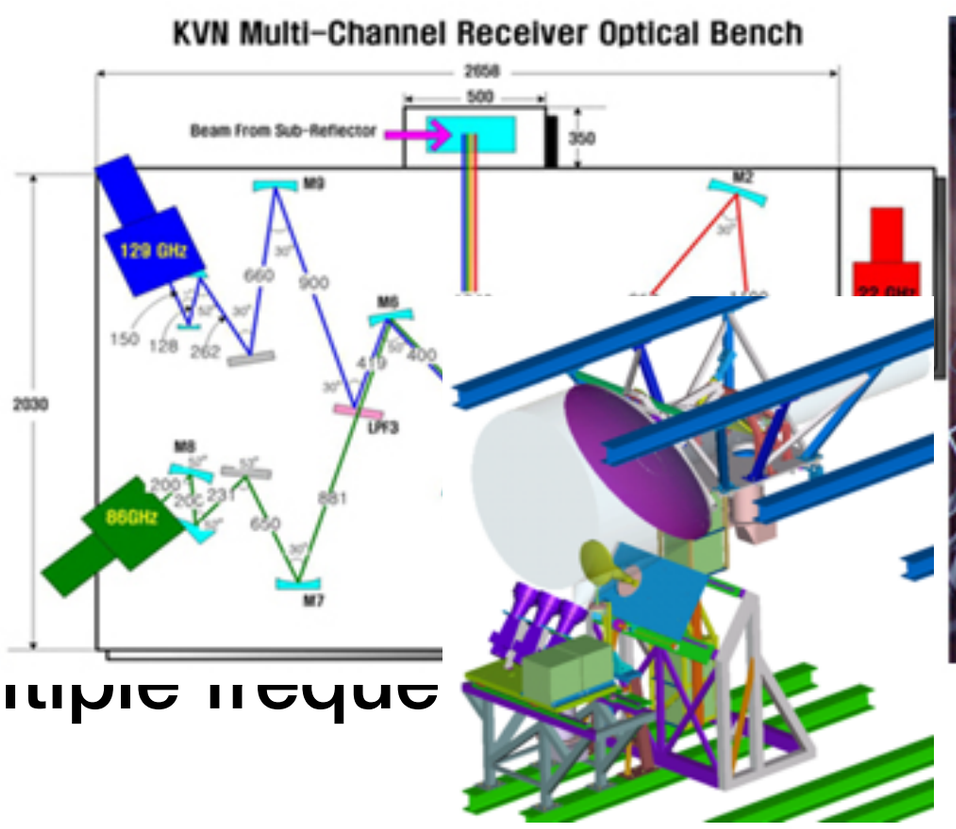

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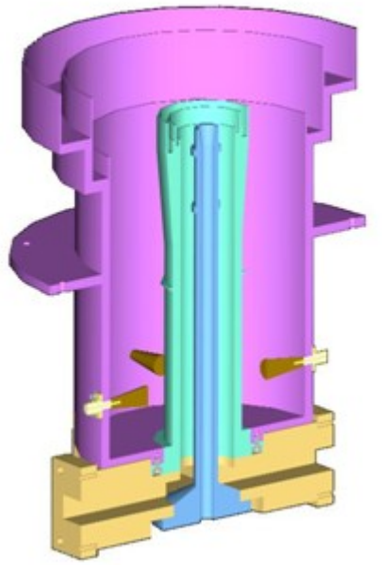

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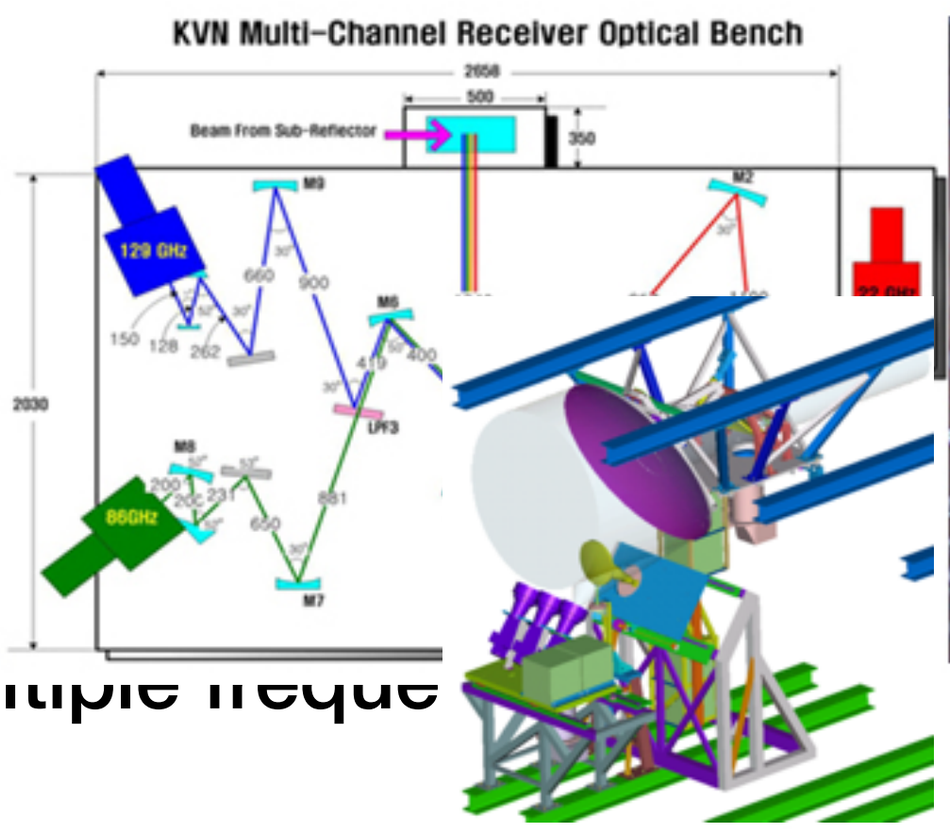

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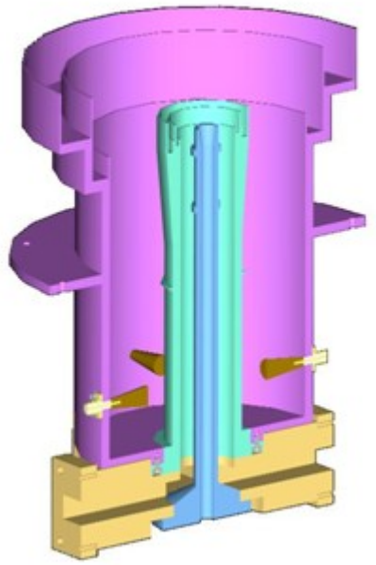

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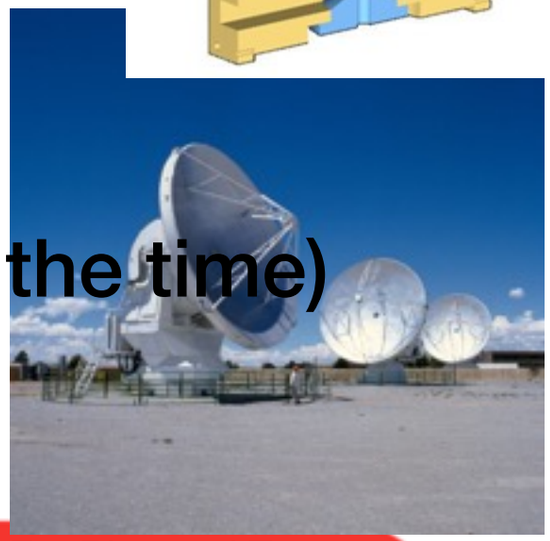

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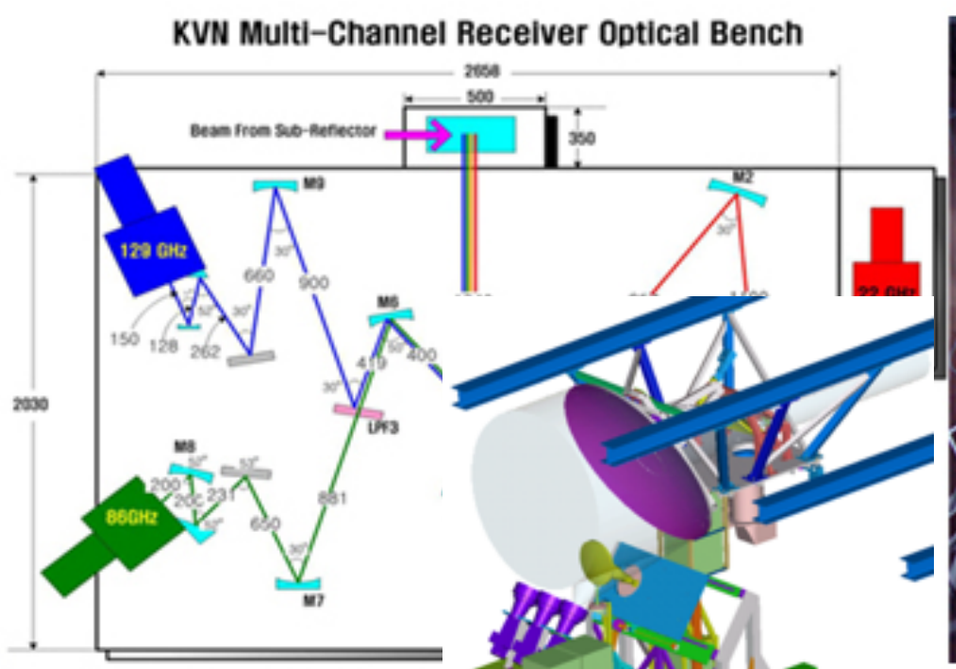

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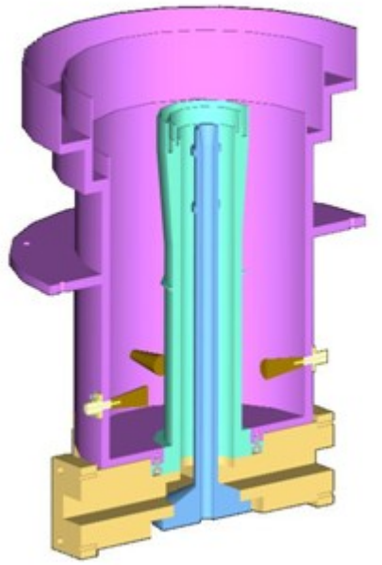


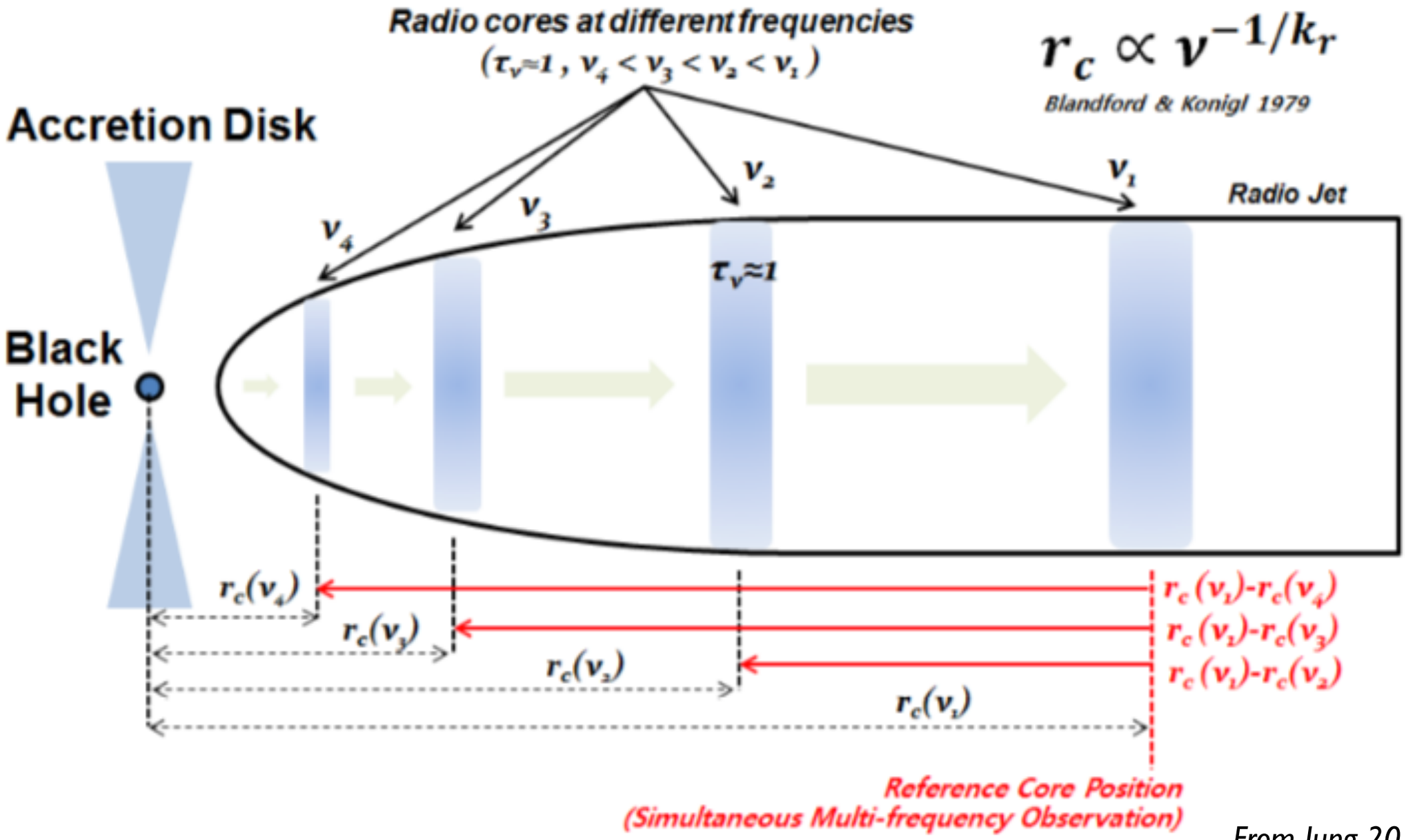
Fast-Switching is semi-compatible (i.e. some of the time)

i.e. the VLBA.

Even just one freq. could be said to be `semi-compatible'

KVN Challenge:

The Multifrequency capability of the KVN is well suited for **core-shift studies**



From Jung 2015

KVN Challenge:

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But Core Shifts are at milli-as or micro-as scale

KVN resolution is about milli-as scale

Frequency	KVN
22GHz	6mas
43GHz	3mas
86GHz	1.2mas
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Frequency	KVN	Global
22GHz	6mas	400μ as
43GHz	3mas	200μ as
86GHz	1.2mas	90μ as
130GHz	0.8mas	60μ as

Global baselines are required for micro-as scale

KVN `Challenging the Future' (Pilot) Project:

A Korean Government scheme, managed via KASI, for innovative ground breaking investigations.

Annually renewed (on review) for maximum of three years, funded upto ~$200K* p.y.

Dr Jung, was successful in landing one, in the face of strong competition, in 2014. The partners were:
KASI, NAOJ, CSIRO, NRAO, IGN-OAN

The Goal was to investigate providing global baselines for simultaneous multifrequency VLBI (x-KVN)

*This pilot project has not received this amount!

A Global multi-Freq. mm-VLBI

KVN 13/7/3/2mm VLBI

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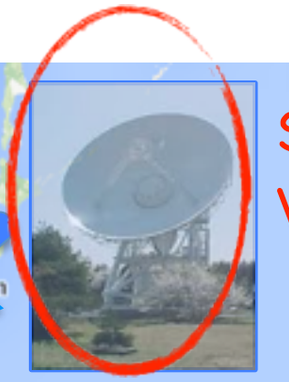
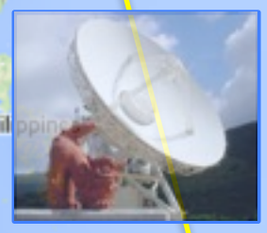
Simultaneous VLBI with KVN:



2,300km



7,900km

Simultaneous 7/3mm mode

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KVN 13/7/3/2mm VLBI

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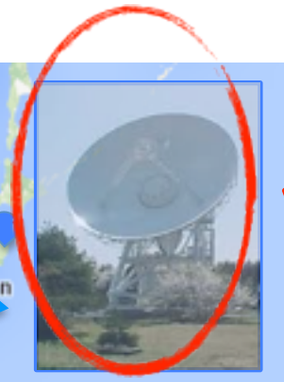
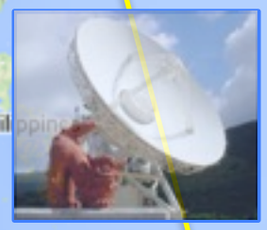


Simultaneous VLBI with KVN:



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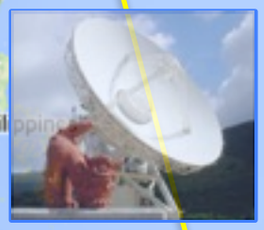
Simultaneous VLBI with KVN:

Installed KVN-QO for Simultaneous 13/7&3mm VLBI



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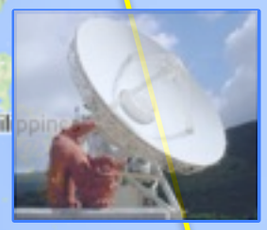

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Observations with KVN 2014/2015

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2016?:
Tests with MK

7,900km

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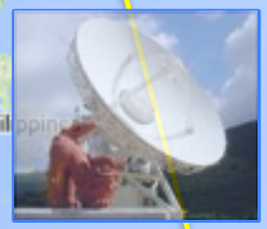


Simultaneous 7/3mm mode

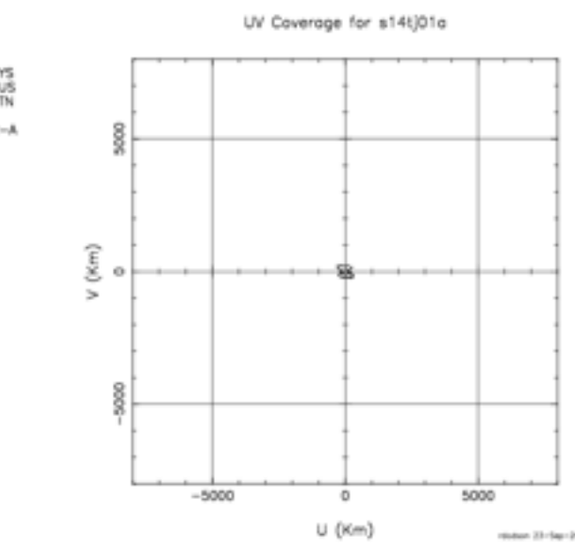
KVN Phase 1 Pilot Project Partners

VERA:

Yebes:

ATCA:

KVN Phase 1 Pilot Project Par



VERA:

Four VERA stations improve KVN coverage. AKA KaVA

Baseline lengths increase to ~2400km

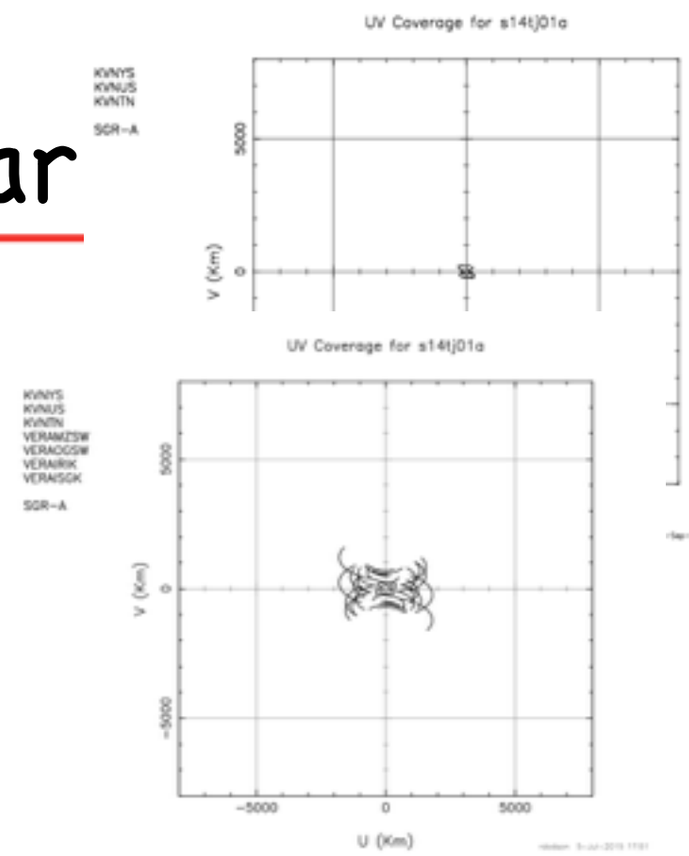
but

Matching capabilities at both arrays would maximise use

To that end KASI developed a QO system for VERA.

VLBI Fringes have been obtained. second QO system built

KVN Phase 1 Pilot Project Par



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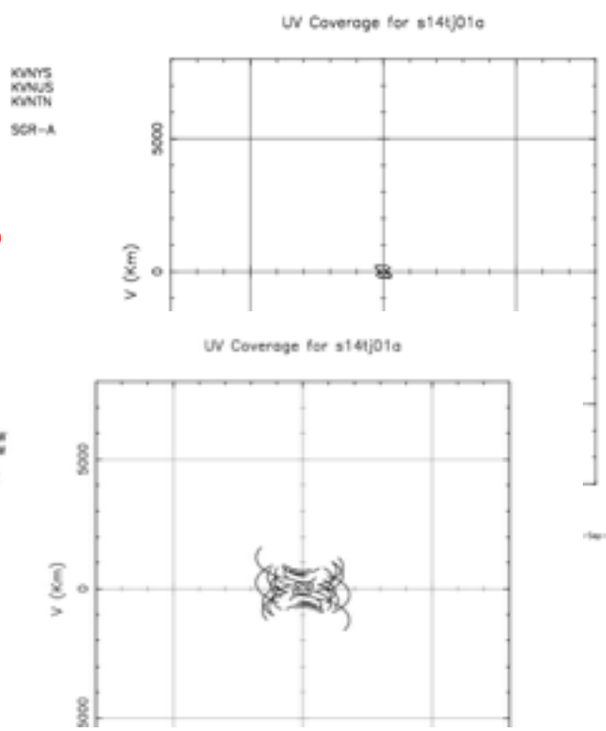

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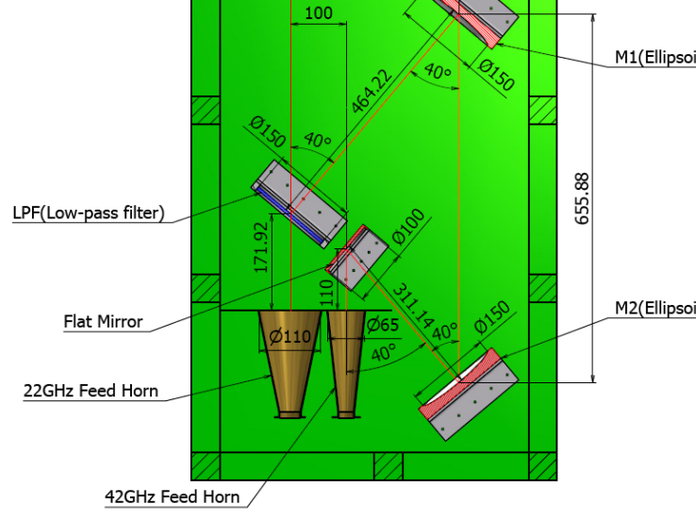

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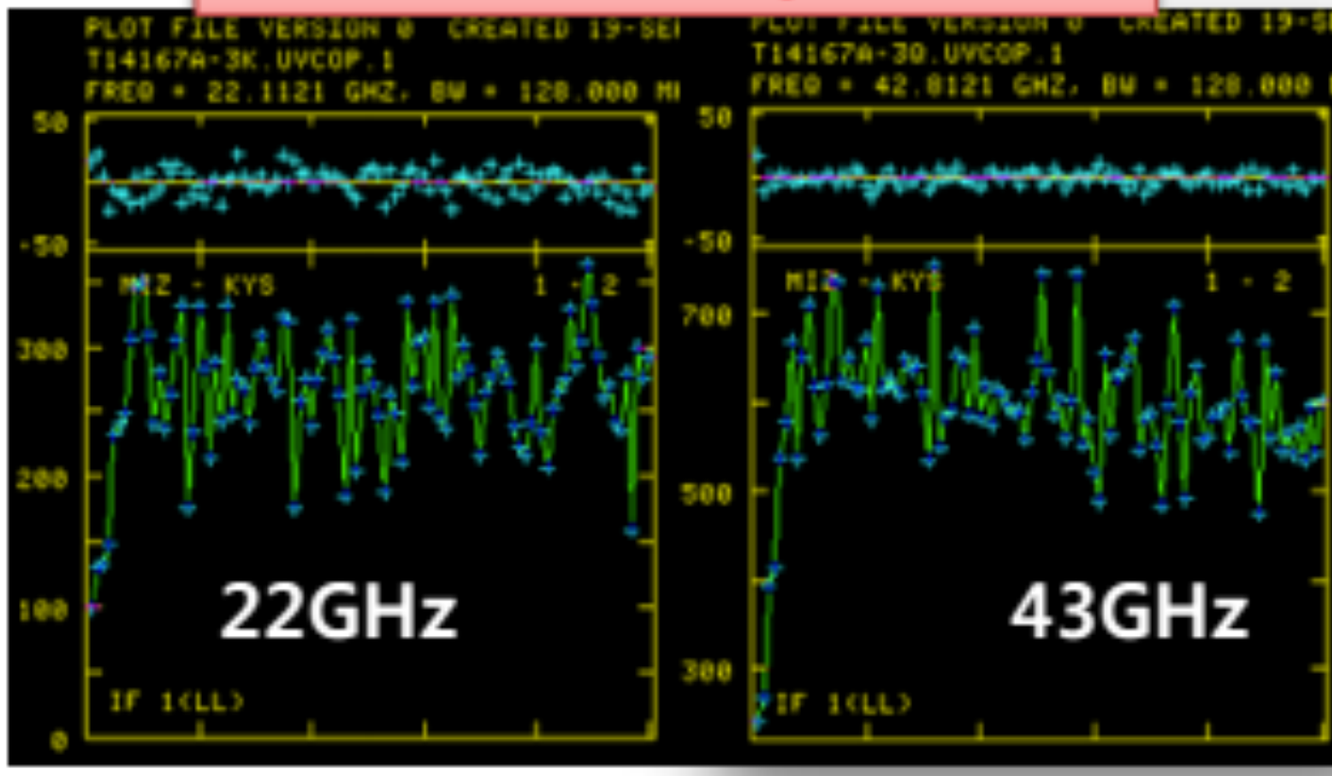
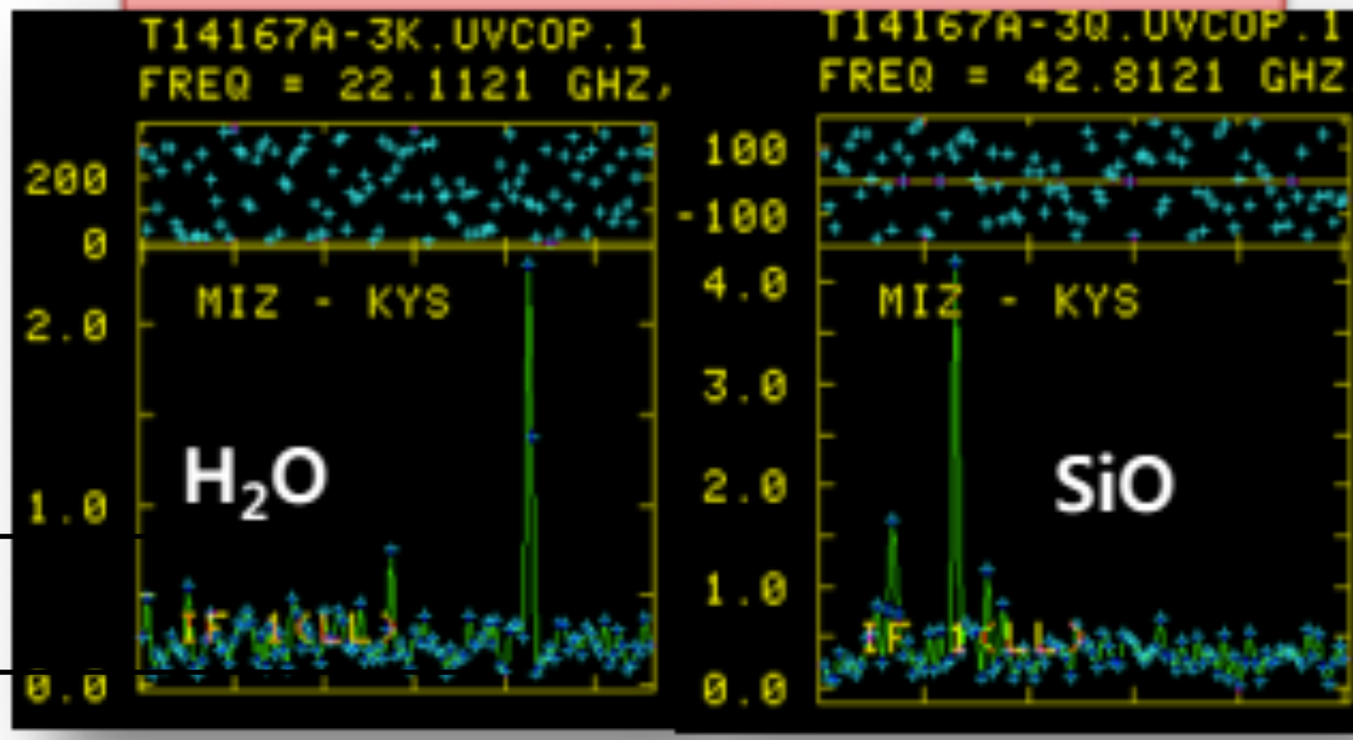
K/Q simultaneous fringes of OJ287



H_2O/SiO Simultaneous fringes of ORION-KL



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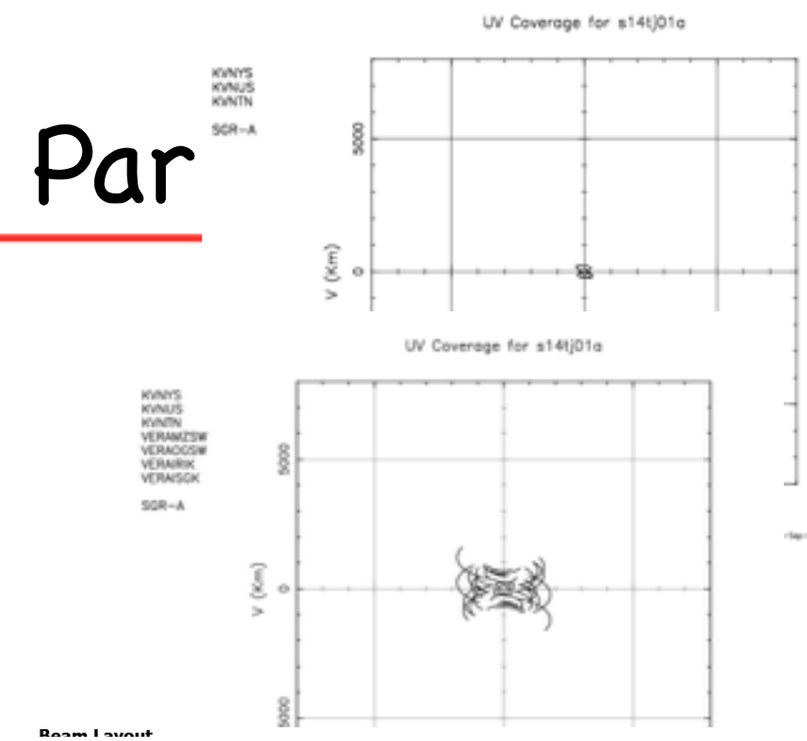
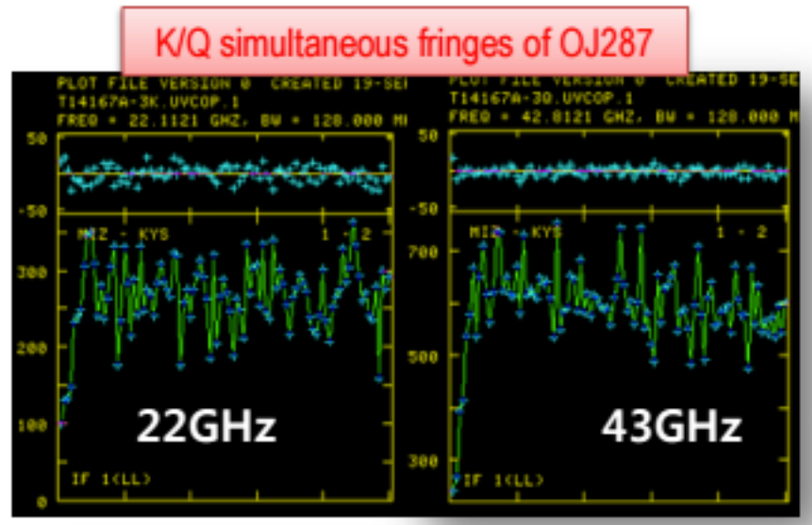
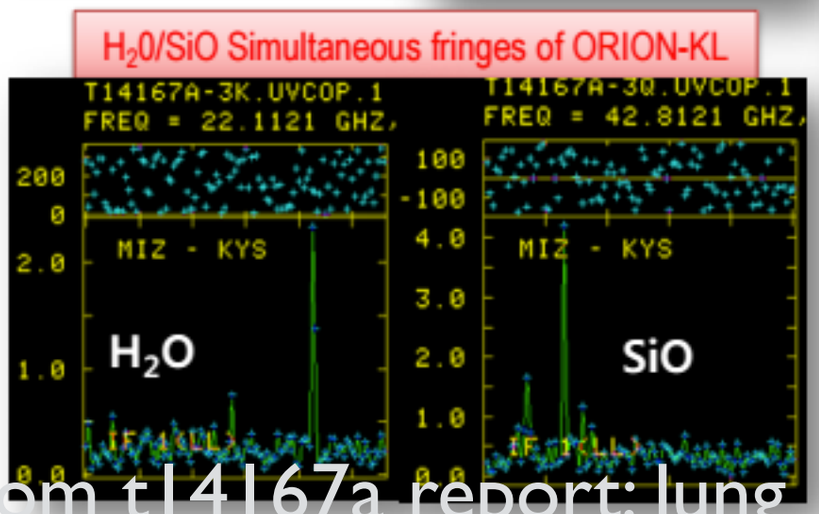




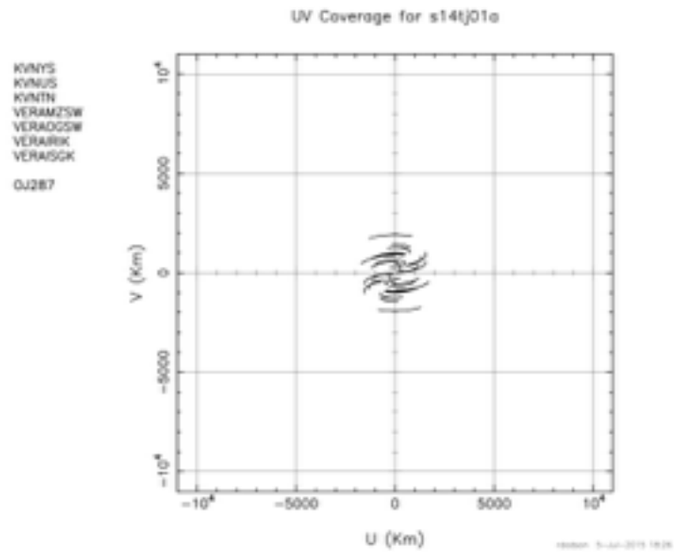


From t14167a report: Jung

KVN Phase 1 Pilot Project Partners

Yebes:

Baseline lengths KVN to Yebes are ~9000km



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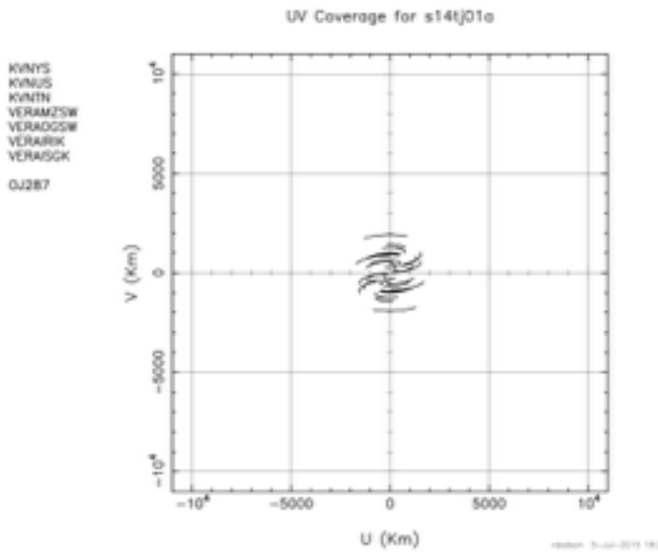

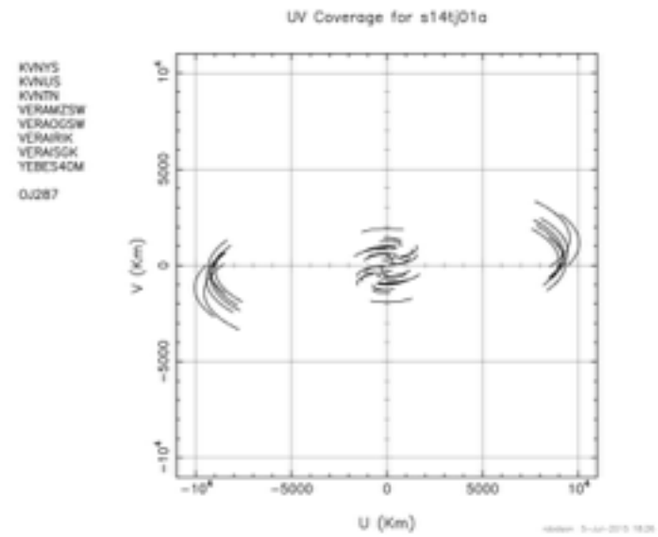

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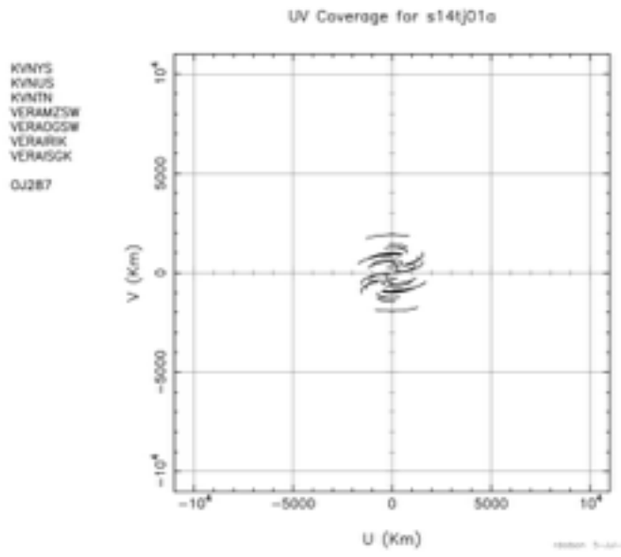

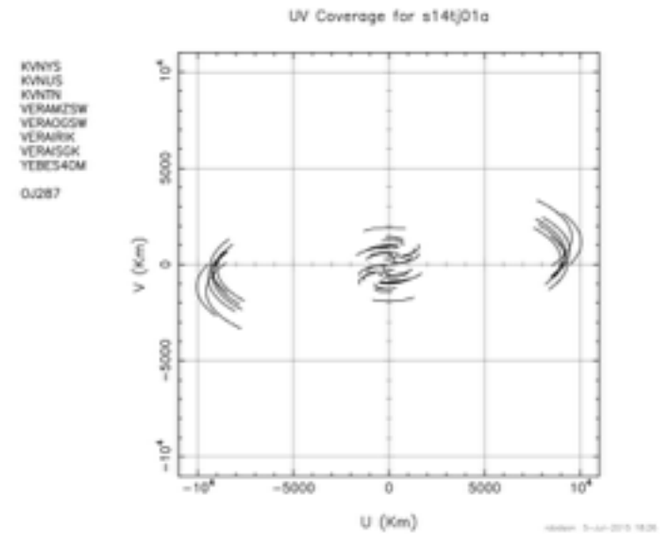

KVN Phase 1 Pilot Project Partners

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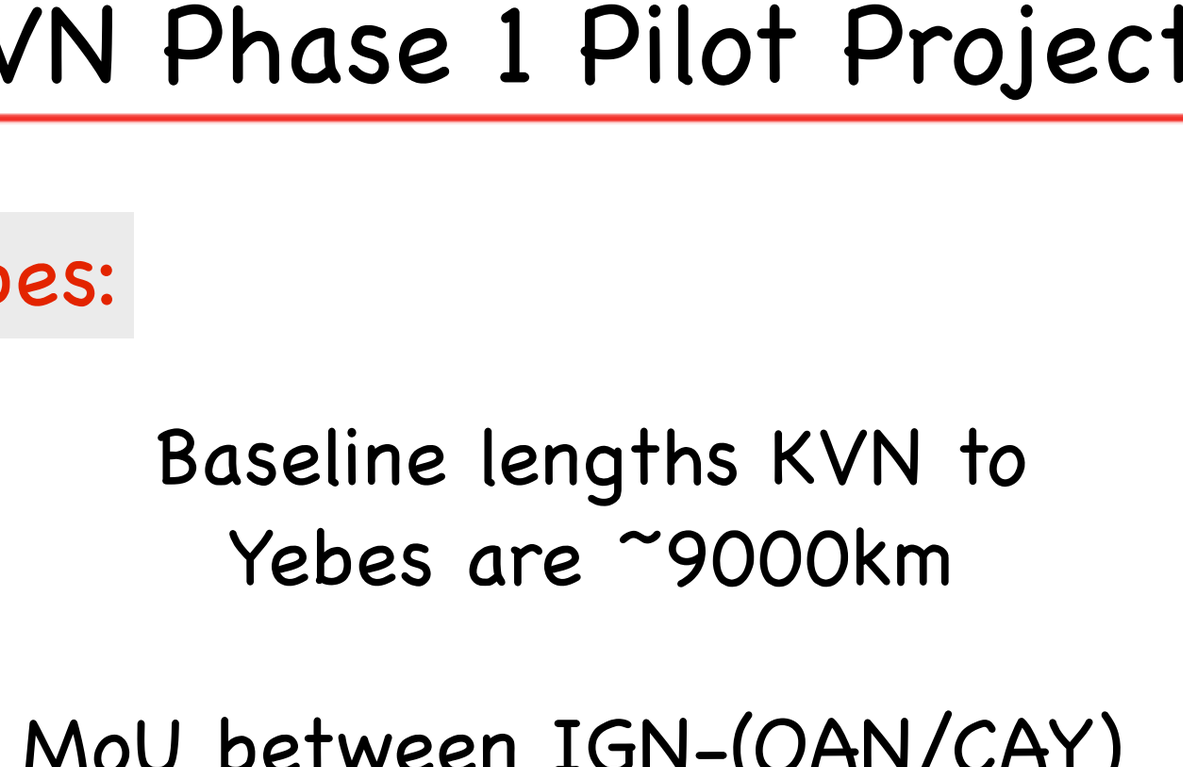
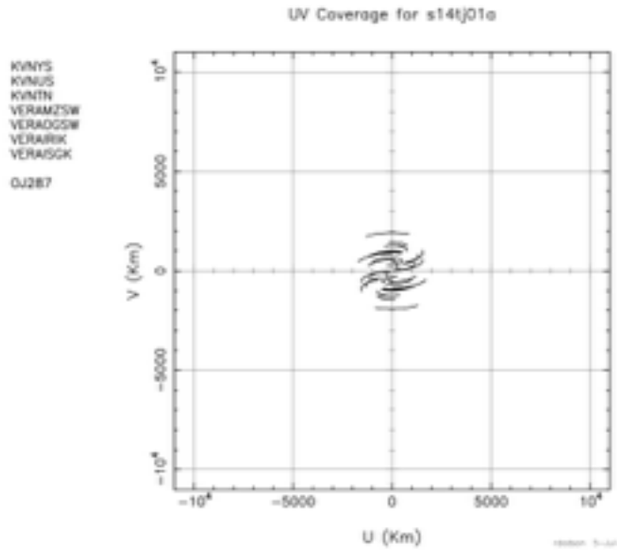
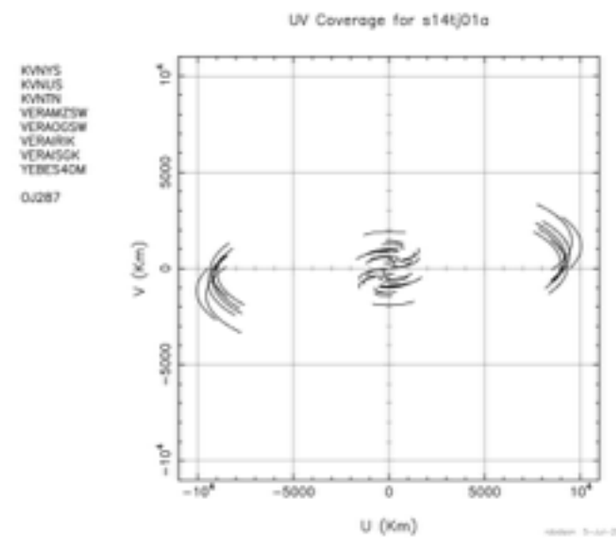
KASI developed a QO system for Yebes (under pilot-project).







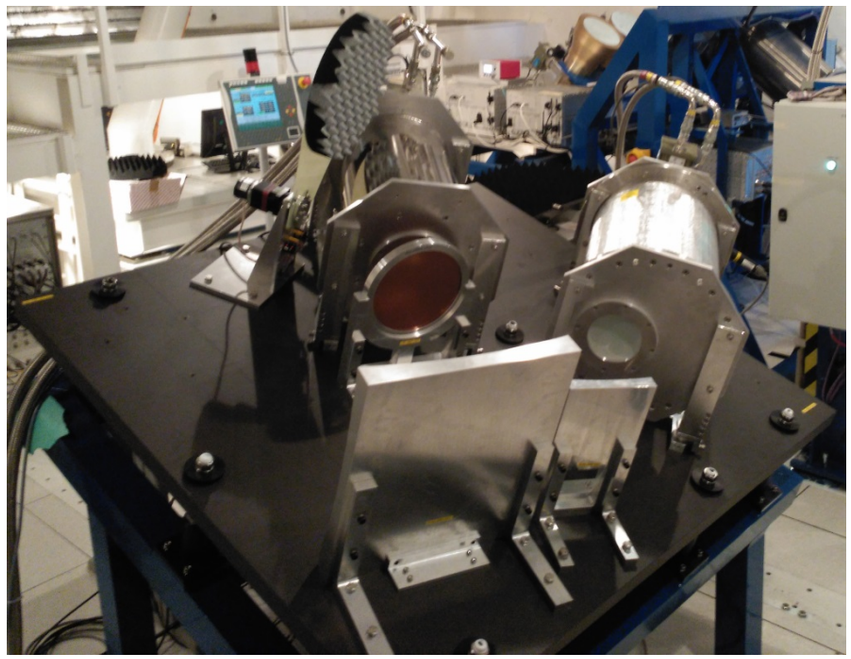
KVN Phase 1 Pilot Project Partners

Yebes:

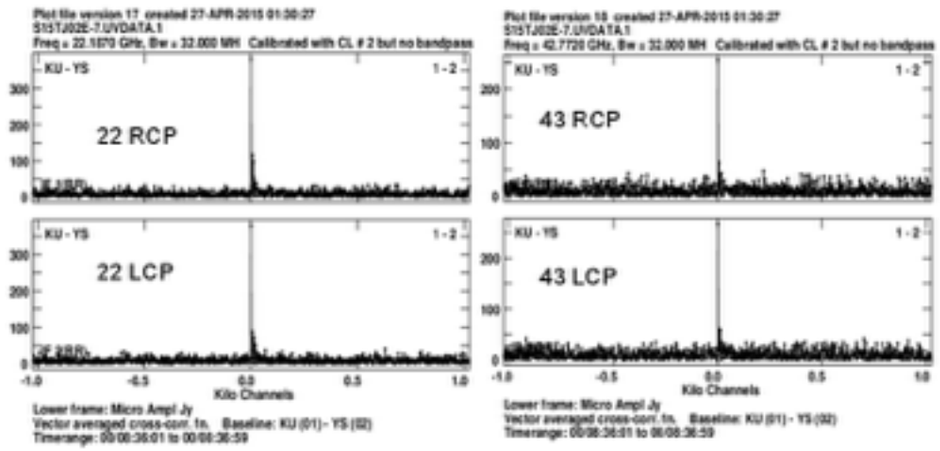
KASI has designed a proto-type for Yebes

K-Q only at the moment, but space for W

VLBI Fringes have been recently obtained. (April)



First Simultaneous K/Q-band Fringes between KVN – Yebes



KVN Phase 1 Pilot Project Partners

ATCA:

Australian Compact Array Telescope

Funded by DFAT Australia/Korea Foundation grant

Australian Government
Department of Foreign Affairs and Trade

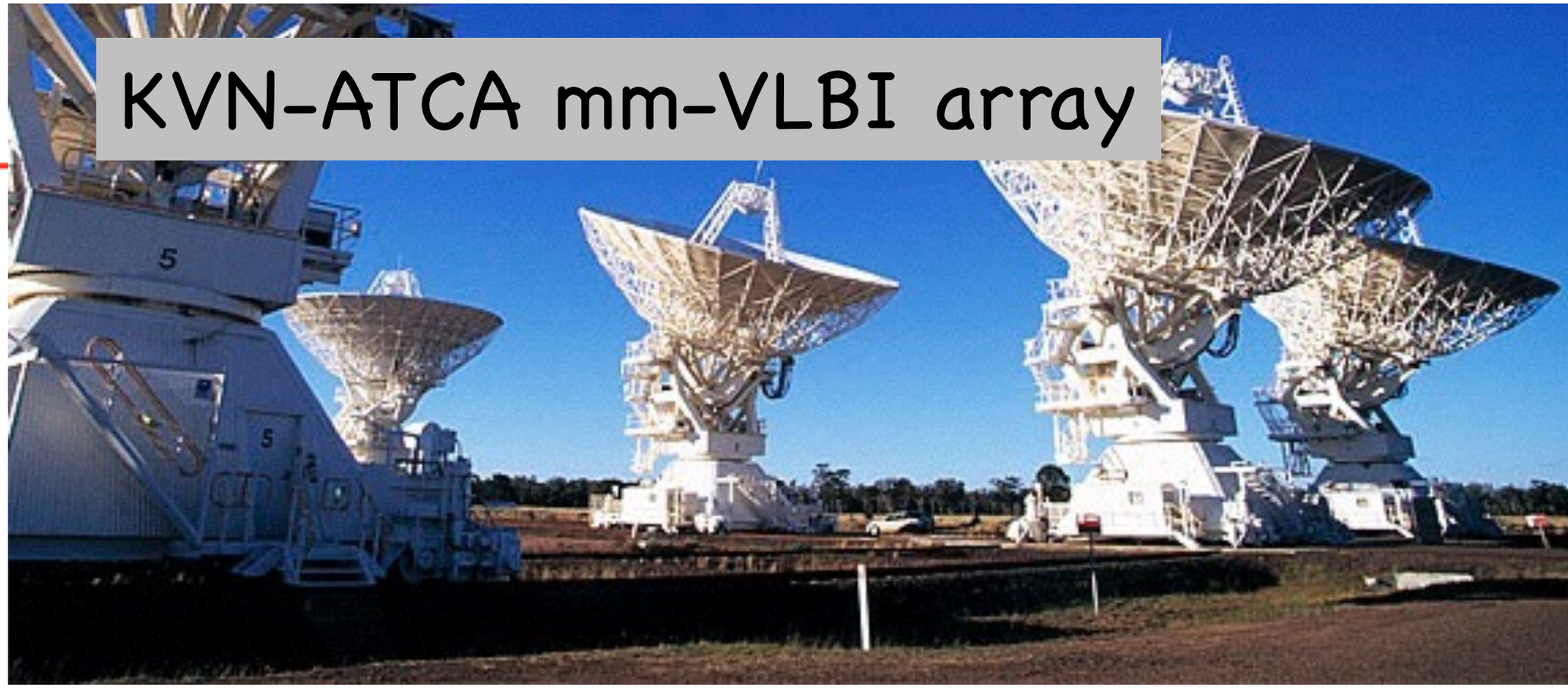
6 antennas on a 6km EW baseline, movable

pre-2006: fitted with 1.4GHz to 22GHz

now: fitted with 1.3GHz to 105GHz

(NB only 5, closer, antennas have ν >50GHz)

KVN-ATCA mm-VLBI array



ATCA is an important part of Australian **L**ong **B**aseline **A**rray

ATCA as part of LBA:

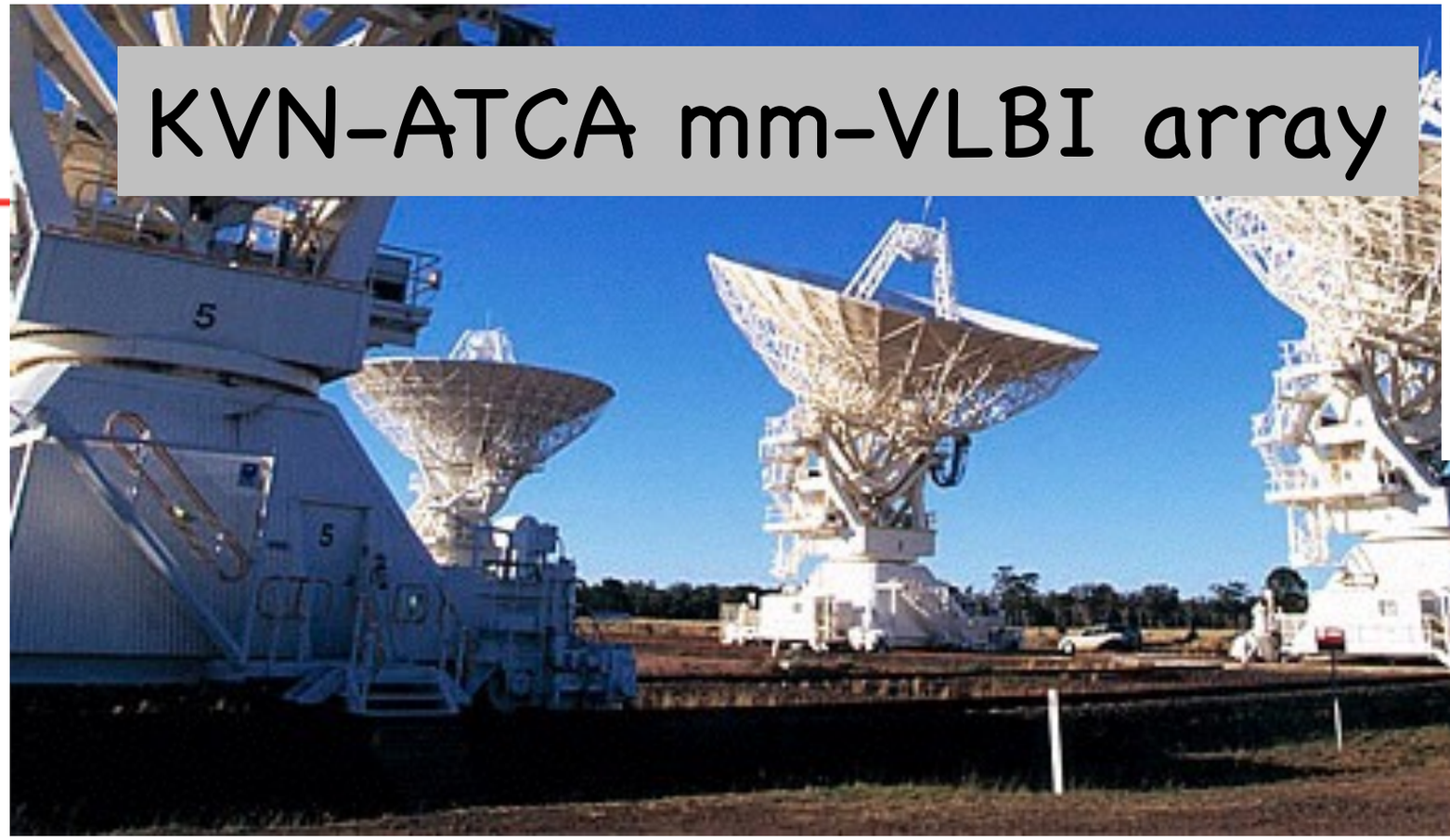
LBA (usually) scheduled when 5 antennas are close:

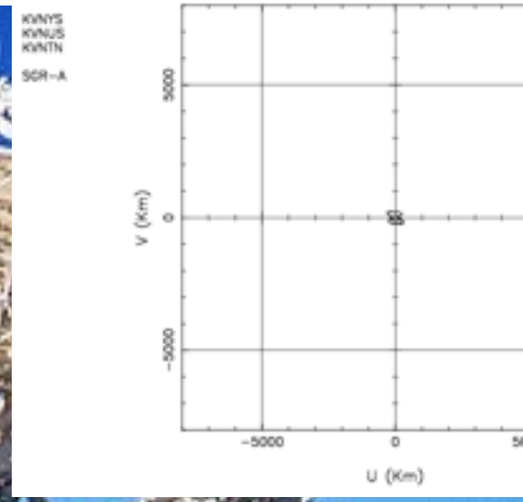
Antennas phased together to get equivalent of 45m dish

As the array is calibrated one expects accurate SEFD and accurate D-terms (~0)

2*2IFs of 64MHz recorded on dual recording systems

KVN-ATCA mm-VLBI array





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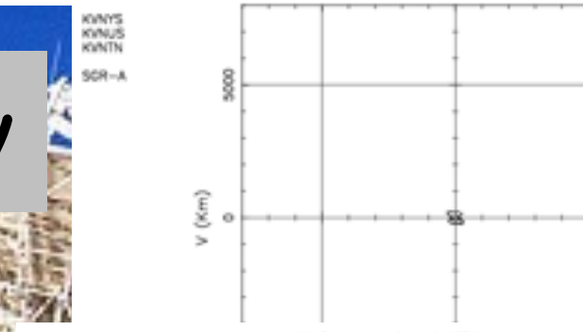

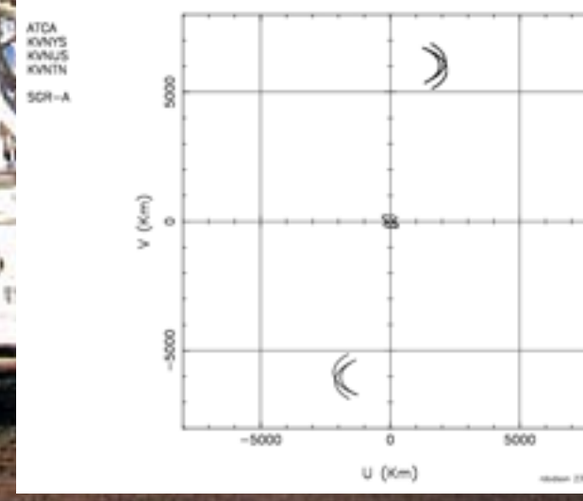

ATCA is an important part of Australian **L**ong **B**aseline **A**rray

ATCA as part of LBA:

LBA (usually) scheduled when 5 antennas are close:

Antennas phased together to get equivalent of 45m dish

As the array is calibrated one expects accurate SEFD and accurate D-terms (~0)

2*2IFs of 64MHz recorded on dual recording systems

uv-coverage with KVN (big gap)

& with KaVA (not so bad)

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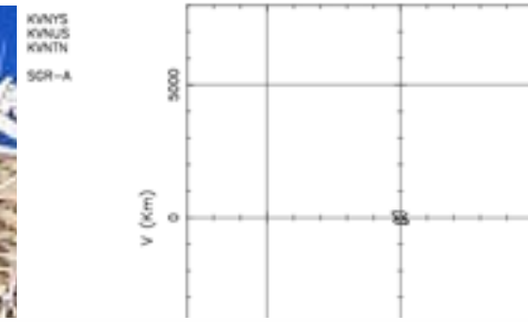

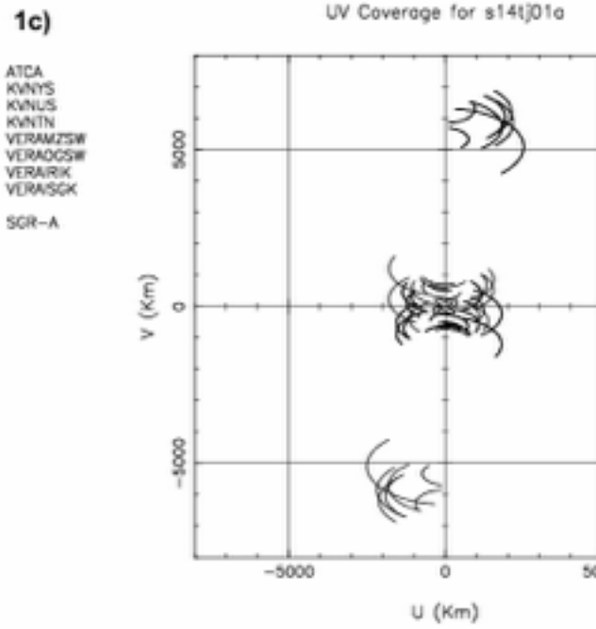

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KVN-ATCA mm-VLBI array

KVN-ATCA mm-VLBI array

Split Array in to two parts

Sub-array 1 — IF1 — 43GHz

Sub-array 2 — IF2 — 86GHz

Single band observing at K, Q and W possible

Only K/Q and Q/W pairs possible

Limited freq range - does not cover SiO (could change)

Does not cover current K/Q range at KVN

I will focus on Q/W Continuum for now

See http://www.narrabri.atnf.csiro.au/people/ste616/mm_simultaneous/

KVN-ATCA single Band mm-VLBI array

On November 2013 we observed s13tj03a @ 43 & 86GHz

First mm-VLBI in Australia

KVN-ATCA single Band mm-VLBI array

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because ATNF staff did not believe it would work

22GHz (1.2cm) had been highest freq. till this point

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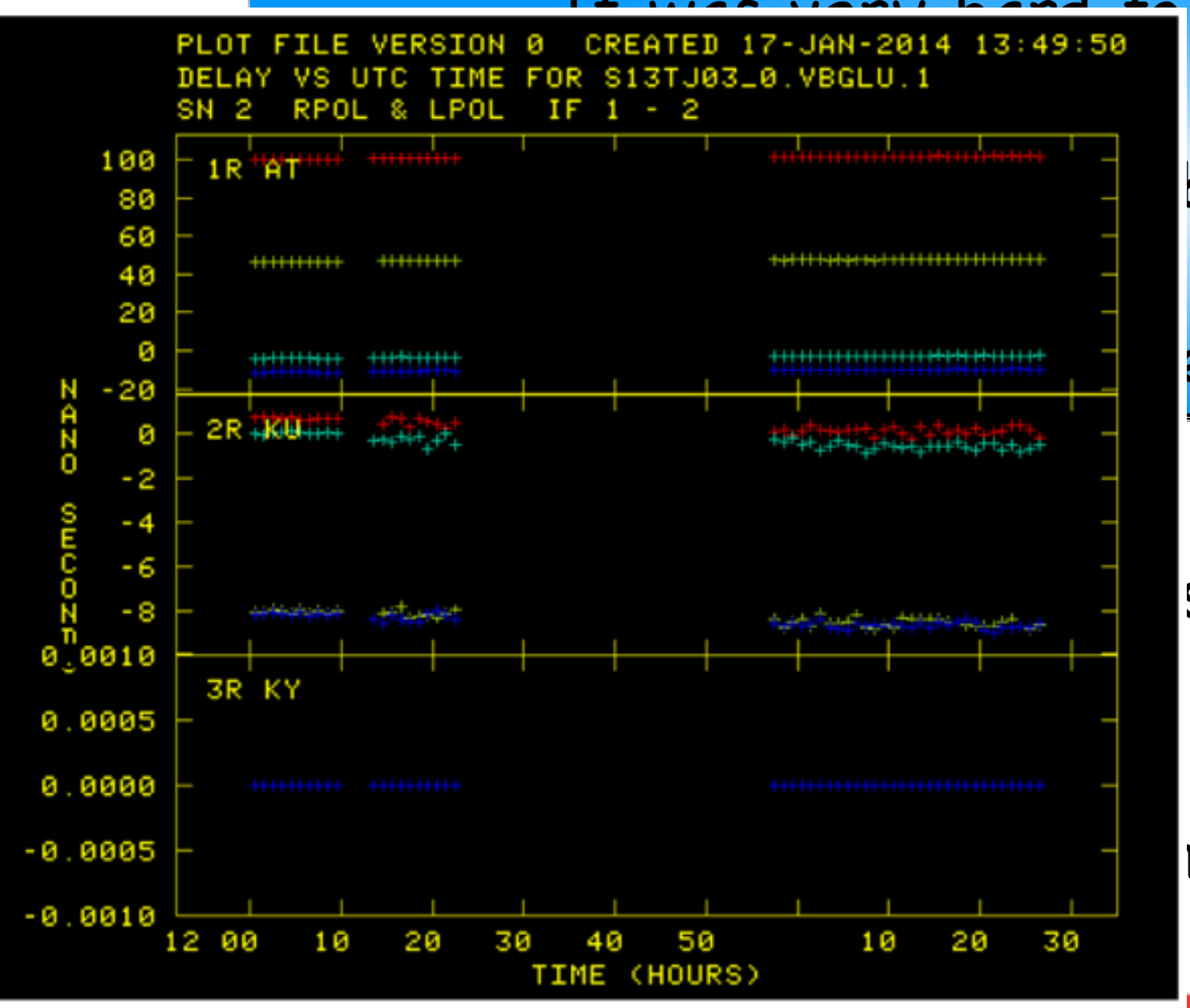
The major problem was the `phased' array was anti-phased. Only single dish data had strong signals.

Also the polarisations are linear

KVN-ATCA single Band mm-VLBI array

On November 2013 we observed s13tj03a @ 43 & 86GHz

First mm-VLBI in Australia



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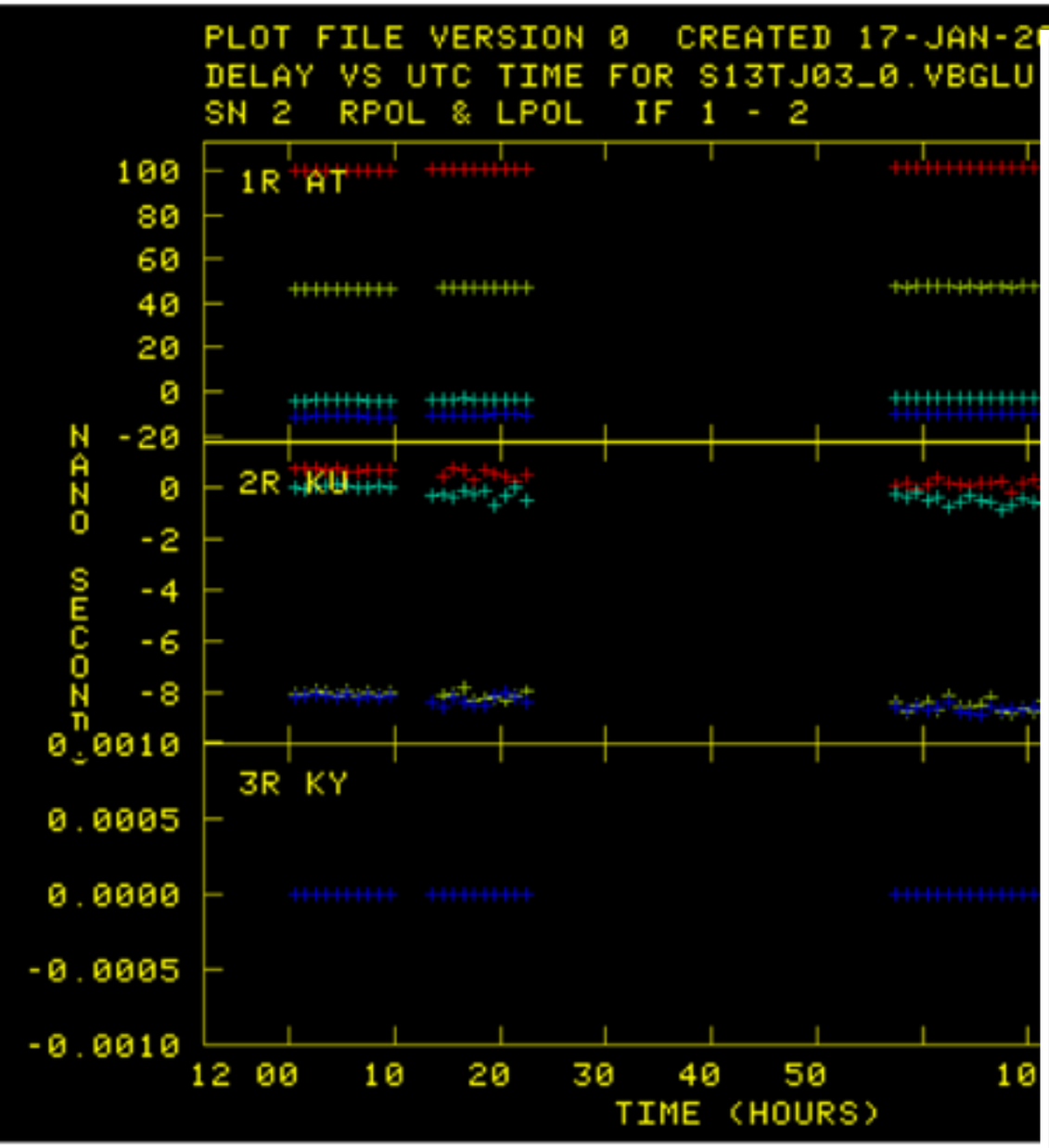
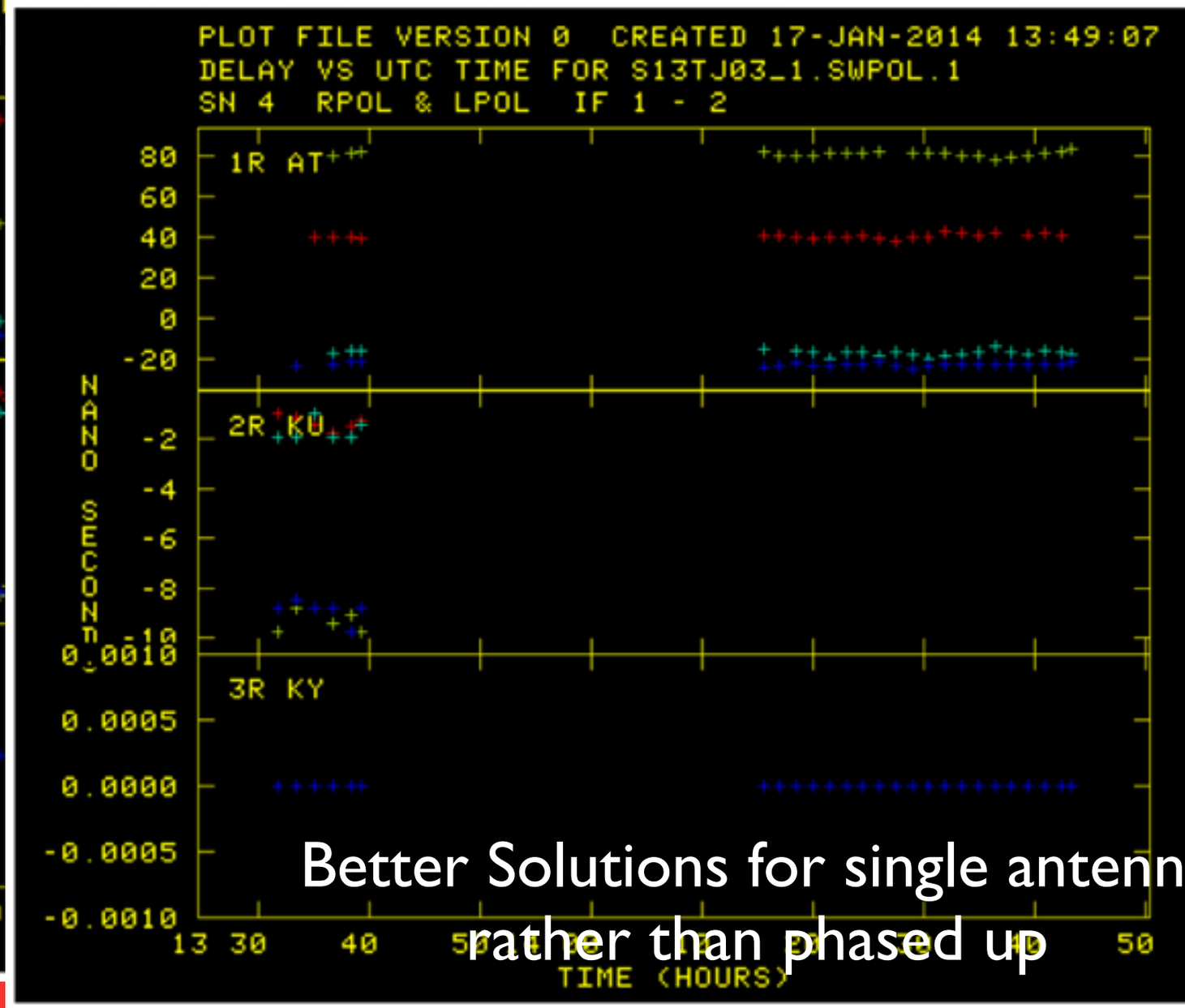
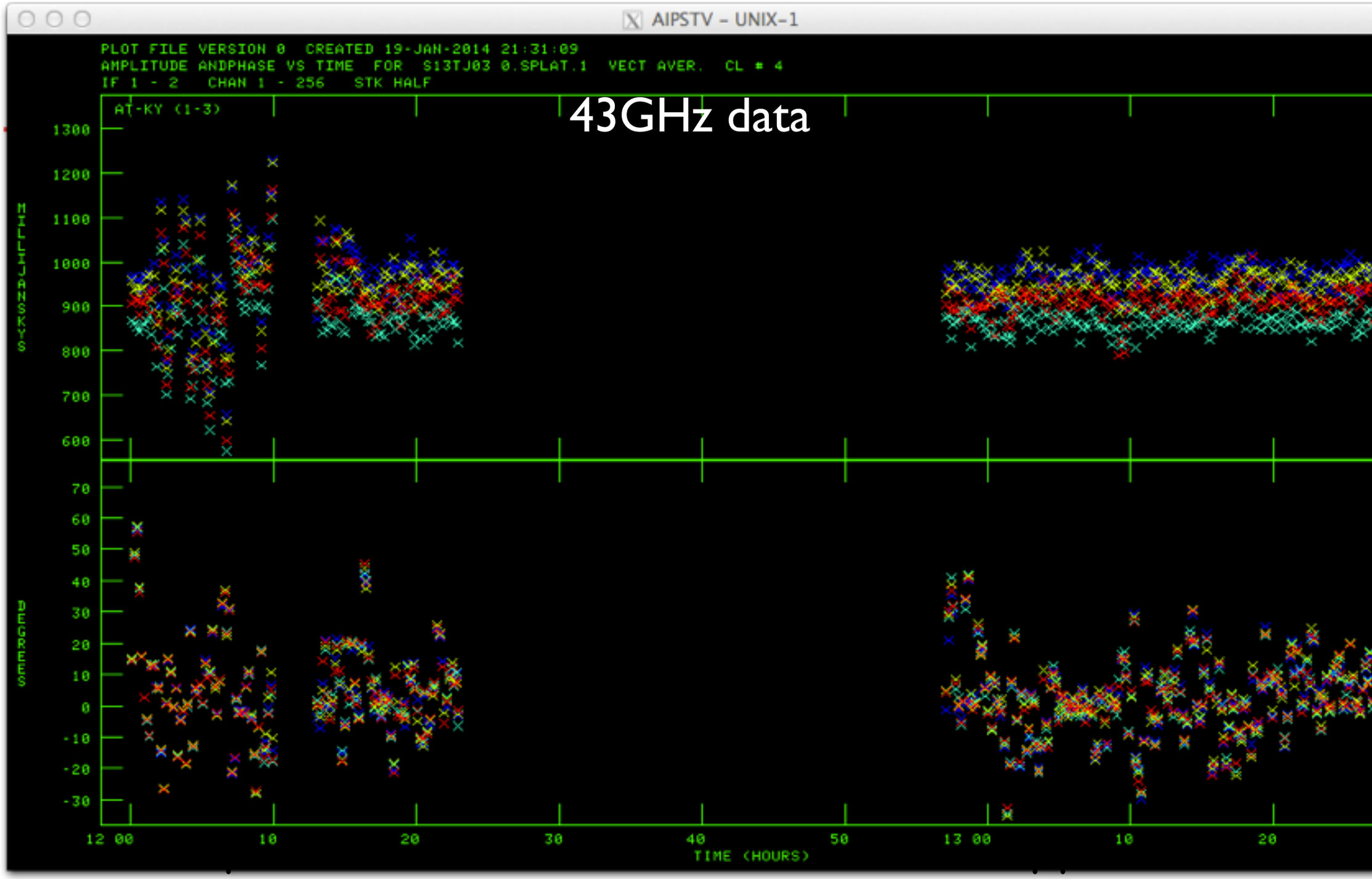
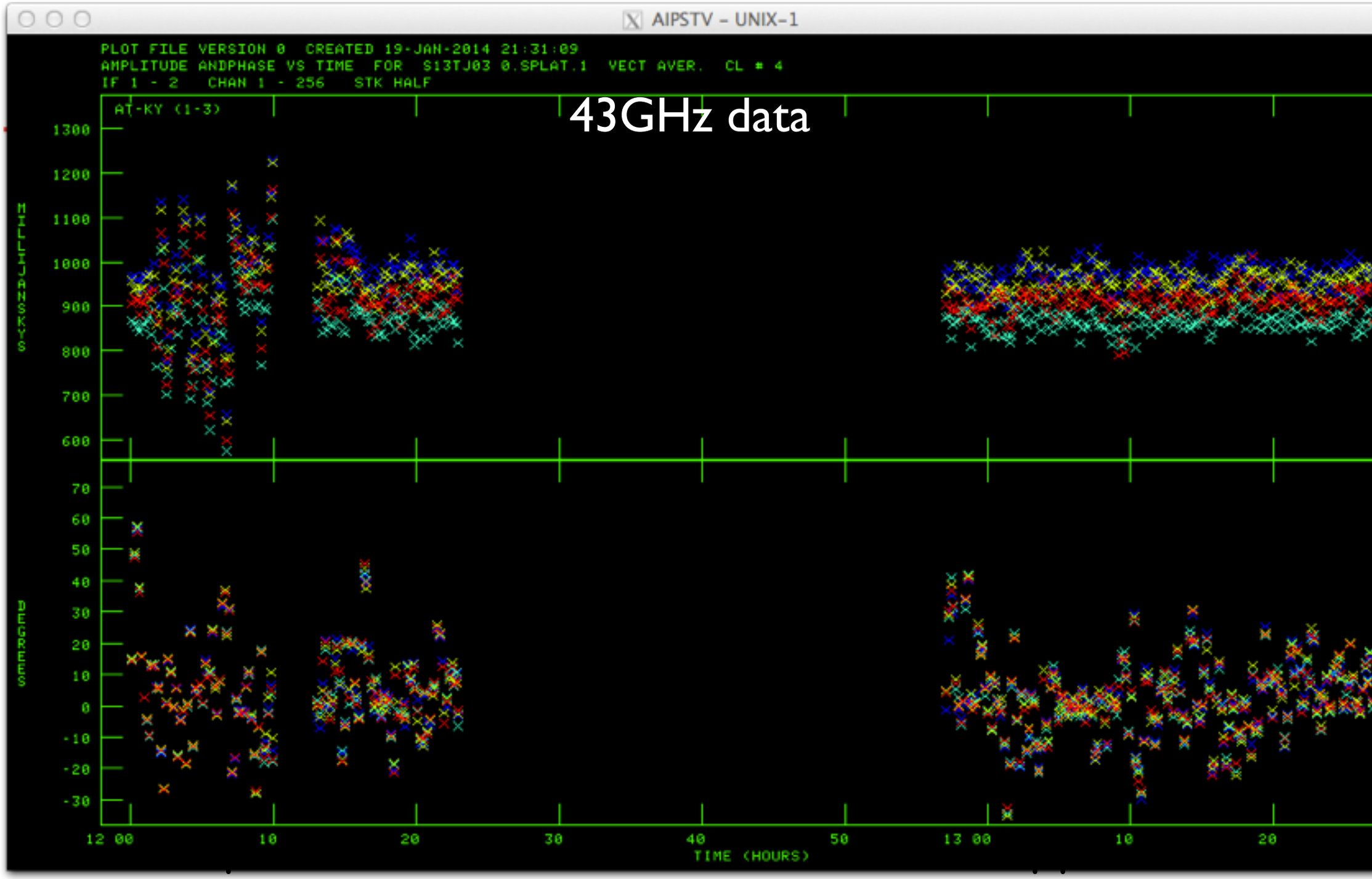




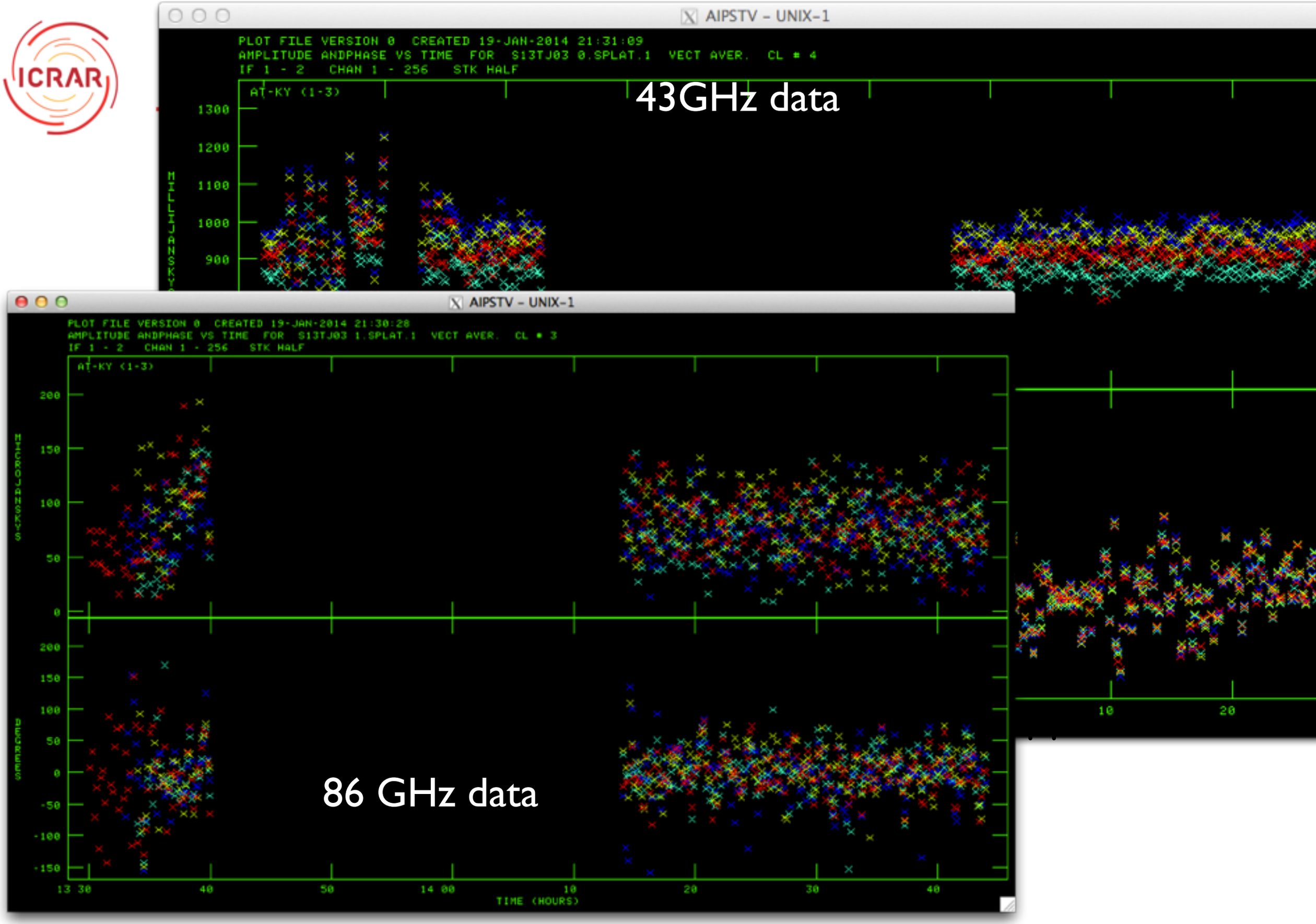
Better Solutions for single antenn

rather than phased up


AIPSTV – UNIX-1
PLOT FILE VERSION 0 CREATED 19-JAN-2014 21:31:09
AMPLITUDE ANDPHASE VS TIME FOR S13TJ03 0.SPLAT.1 VECT AVER. CL # 4
IF 1 - 2 CHAN 1 - 256 STK HALF
AT-KY (1-3)
43GHz data
MILLIJANSKYS
1300
1200
1100
1000
900
800
700
600
DEGREES
70
60
50
40
30
20
10
0
-10
-20
-30
12 00
10
20
30
40
50
13 00
10
20
TIME (HOURS)



But Eventually we succeeded!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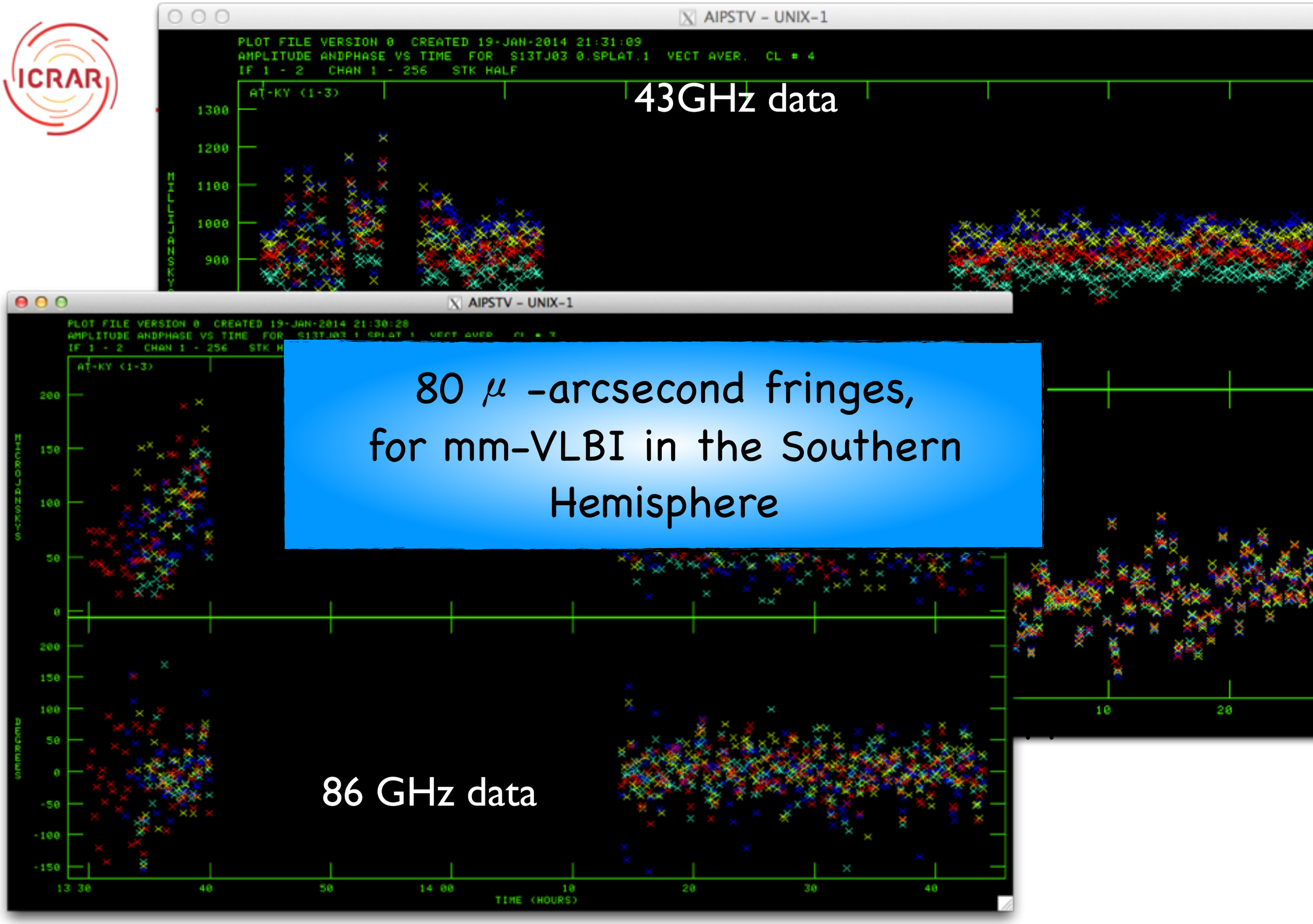
AT-KY (1-3)
1300
1200
1100
1000
900
MILLIJANSKYS
43GHz data
AIPSTV – UNIX-1
PLOT FILE VERSION 0 CREATED 19-JAN-2014 21:30:28
AMPLITUDE ANDPHASE VS TIME FOR S13TJ03 1.SPLAT.1 VECT AVER. CL # 3
IF 1 - 2 CHAN 1 - 256 STK HALF
AT-KY (1-3)
200
150
100
50
0
MICROJANSKYS
200
150
100
50
0
-50
-100
-150
DEGREES
13 30
40
50
14 00
10
20
30
40
TIME (HOURS)
86 GHz data
10
20



80 μ -arcsecond fringes, for mm-VLBI in the Southern Hemisphere

KVN-ATCA dual freq mm-VLBI array

New features of ATCA added to support pilot project:

KVN-ATCA dual freq mm-VLBI array

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1) Independent Feed Rotation

KVN-ATCA dual freq mm-VLBI array

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2) Independent LO setting

KVN-ATCA dual freq mm-VLBI array

New features of ATCA added to support pilot project:

1) Independent Feed Rotation

2) Independent LO setting

3) Sub arraying at different frequencies

KVN-ATCA dual freq mm-VLBI array

On March 2014 we observed KVN + ATCA
Test Experiment s14rd01a

with Simultaneous Multiple Frequencies ....
But we lost the data (lets not talk about it)

On Sept we observed KVN + ATCA
Test Experiment s14rd01b (~2hours)

with Simultaneous Multiple Frequencies
Correlation details are important, but boring

- Selfcal on Scan#1 (Q&W)
- Selfcal on Q (all scan)
- Double phase and apply to W

KVN-ATCA dual fr

On March 2014 we obse
Test Experimen

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Test Experiment s14r

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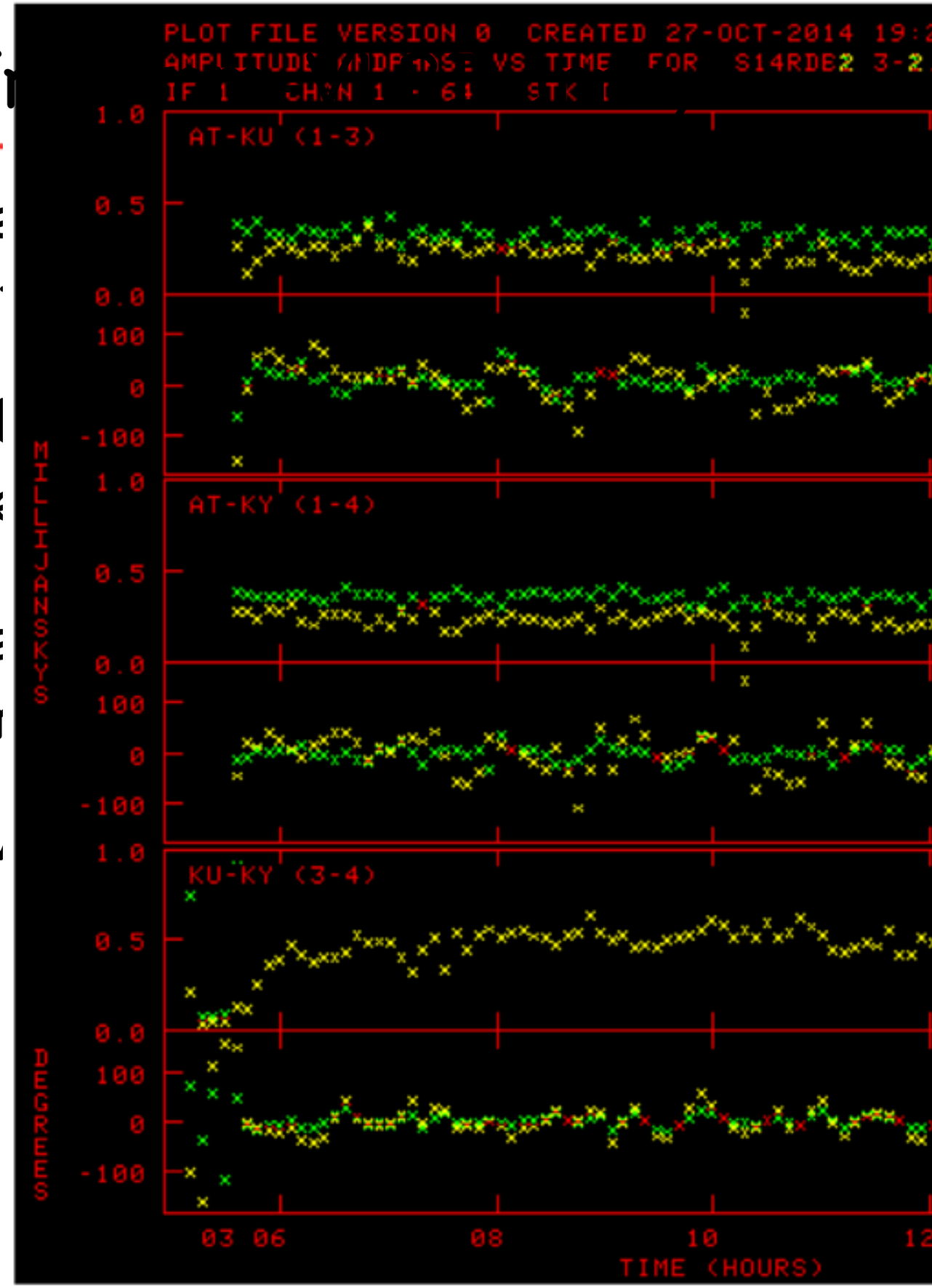

KVN-ATCA dual freq mm-VLBI array

On Sept we observed KVN + ATCA
Test Experiment s14rd01b (~2hours)

The previous plot was 3C273. 3C273 was also prime calibrator (and only source strong enough to see phases in VPLOT).

Target was M87. Results `not so good'

Phases must be coherent as calibrated data produces an image, but not at centre

~0.5mas offset from centre

KVN-ATCA dual freq mm-VLBI array

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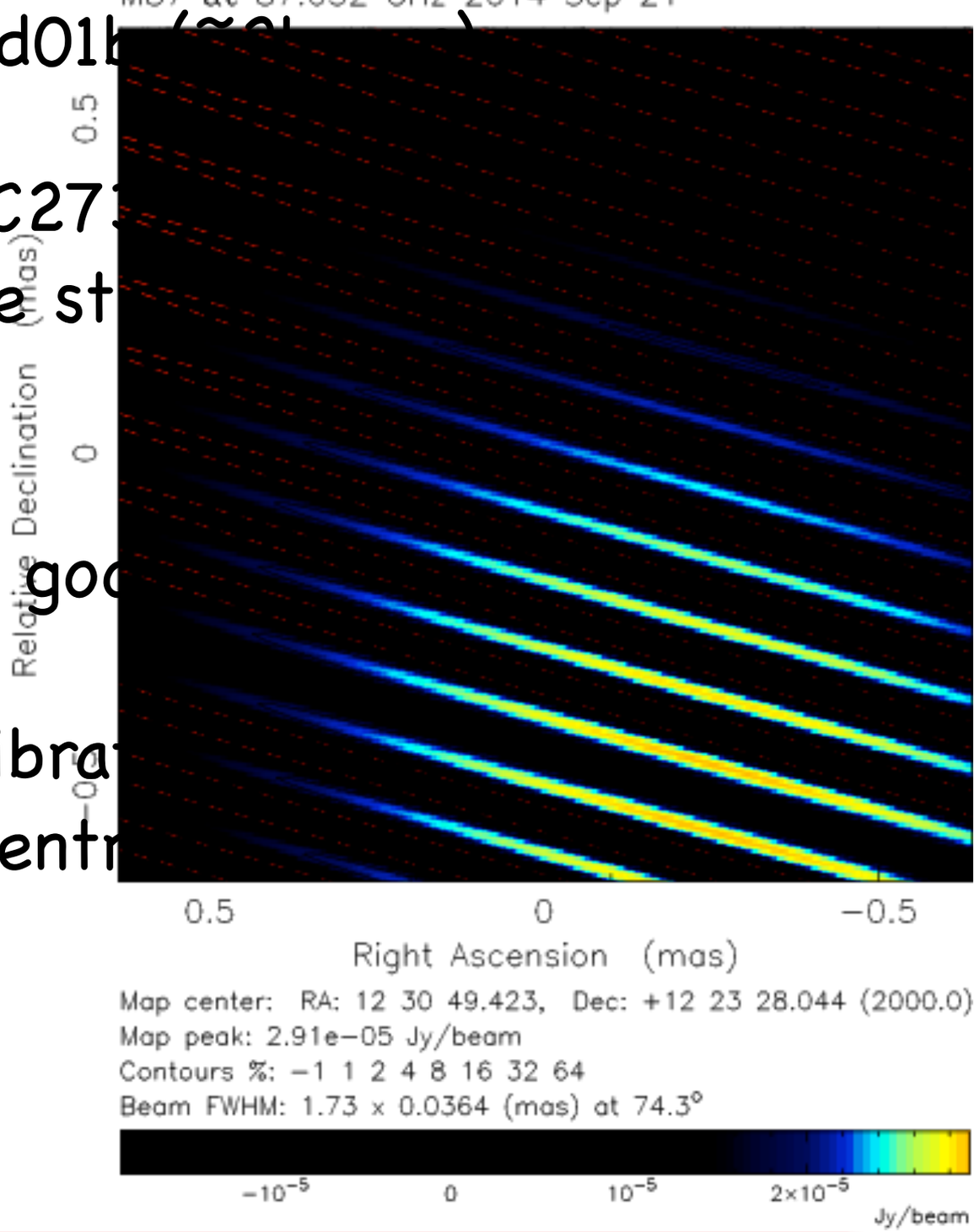

KVN-ATCA dual freq mm-VLBI array

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Test Experiment s14rd01b (~9h)

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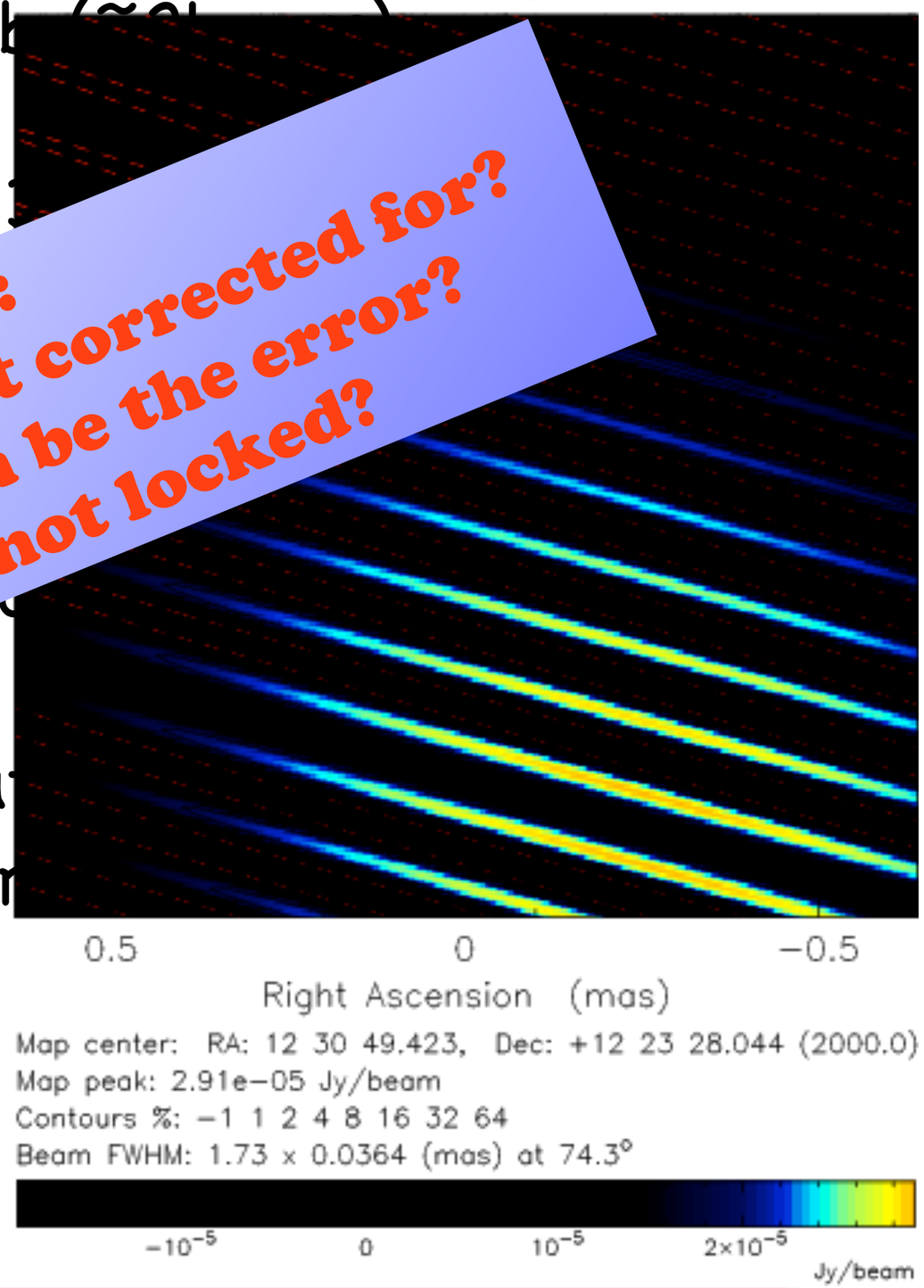


Questions:
Instrumental terms not corrected for?
Could Feed Rotation be the error?
Or Q/W phases not locked?

KVN-ATCA dual freq mm-VLBI array

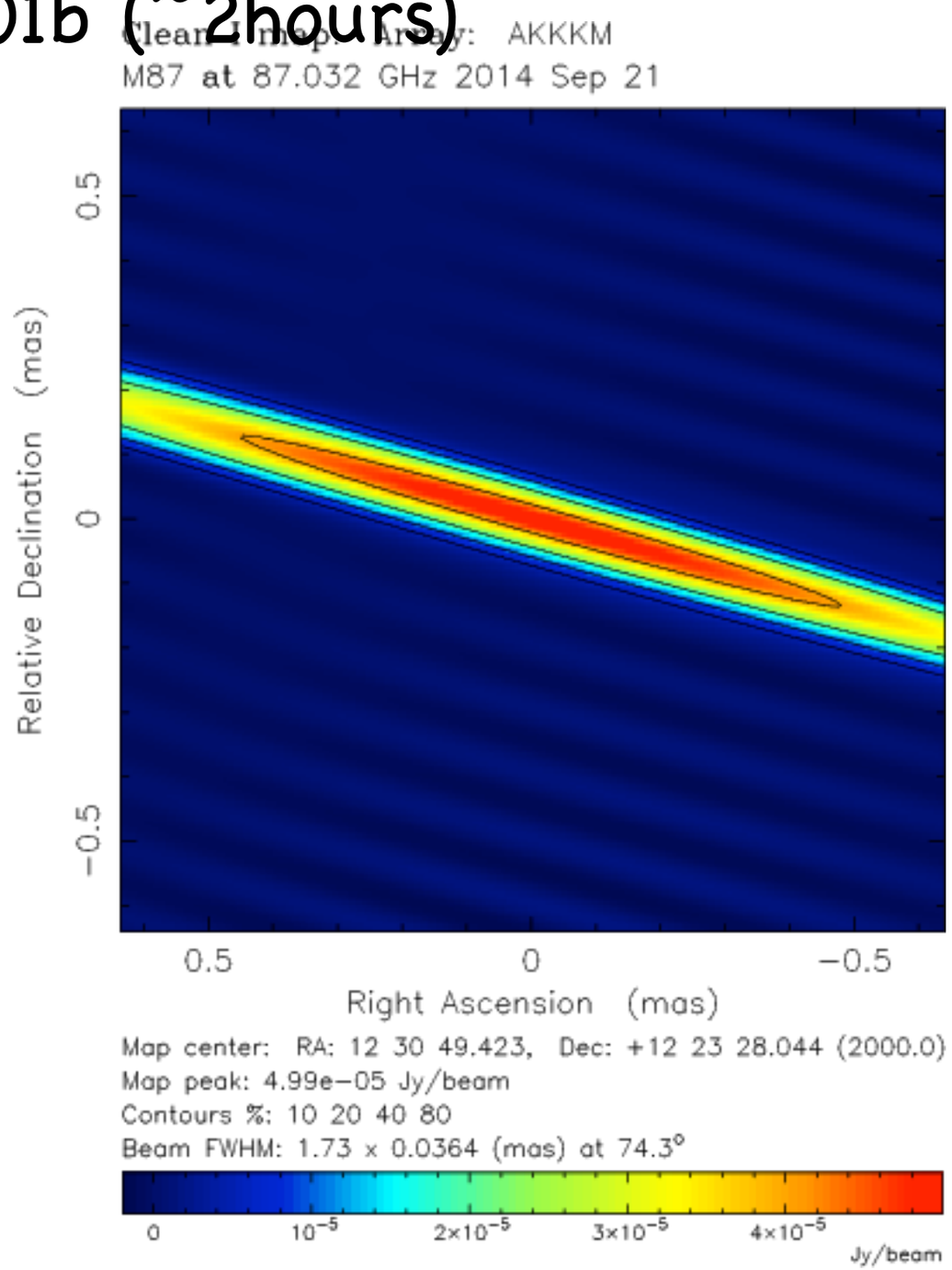
On Sept we observed KVN + ATCA
Test Experiment s14rd01b (~2hours)

However selfcalibration works and produces a believable, resolving source.

Long test required, with better calibration strategy

aka s14rd01c, March 2015

……



KVN-ATCA dual freq mm-VLBI array

On March 2015 we observed KVN + ATCA
Test Experiment s14rd01c (~8hours)

Expectations High. Better Calibration
Fringes found …

Then problems …
  Delays right, but phases not.

Discovered that no phase lock was made between ATCA antennas.

 Reportedly `Not possible'
 Which means `we must try harder'

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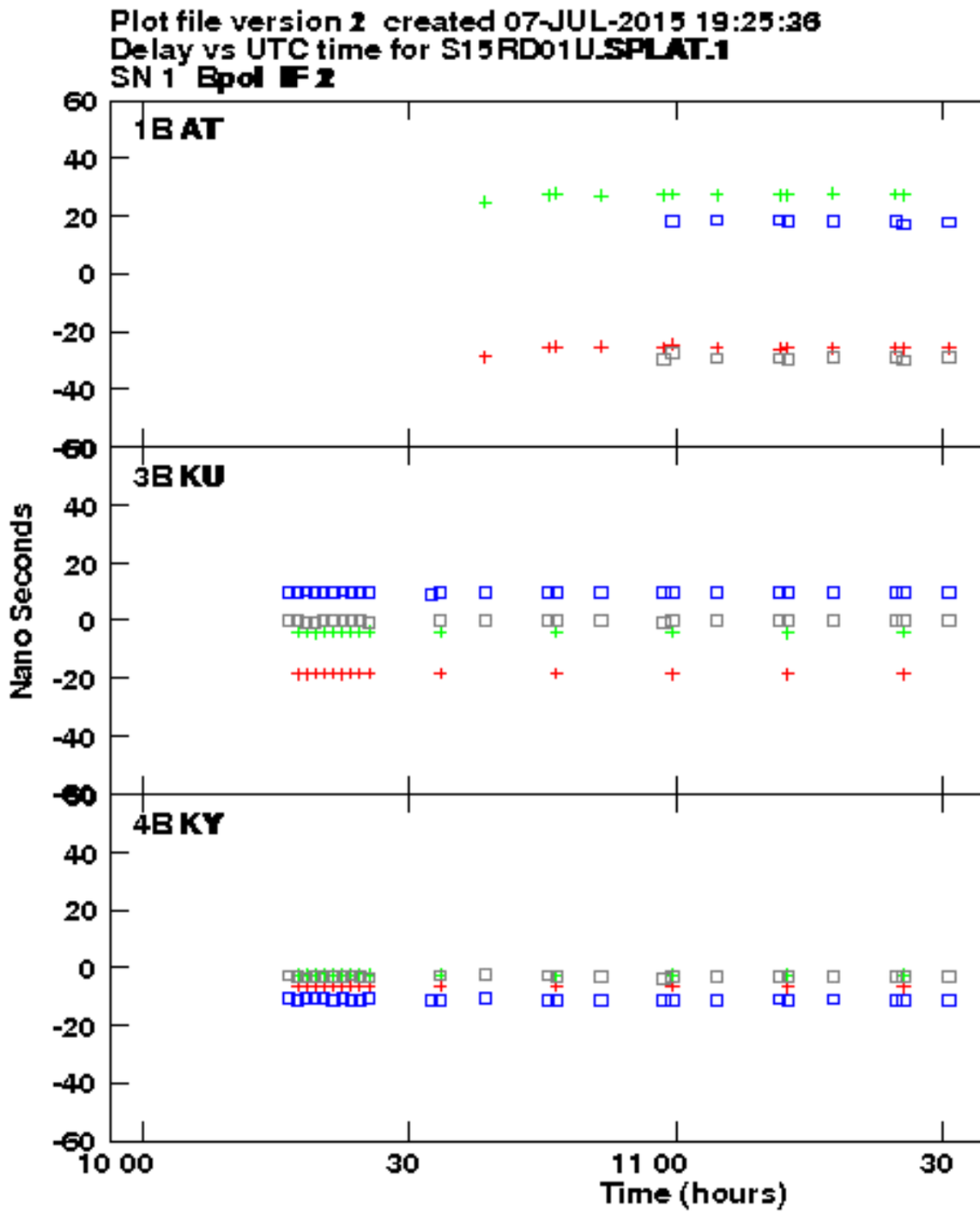

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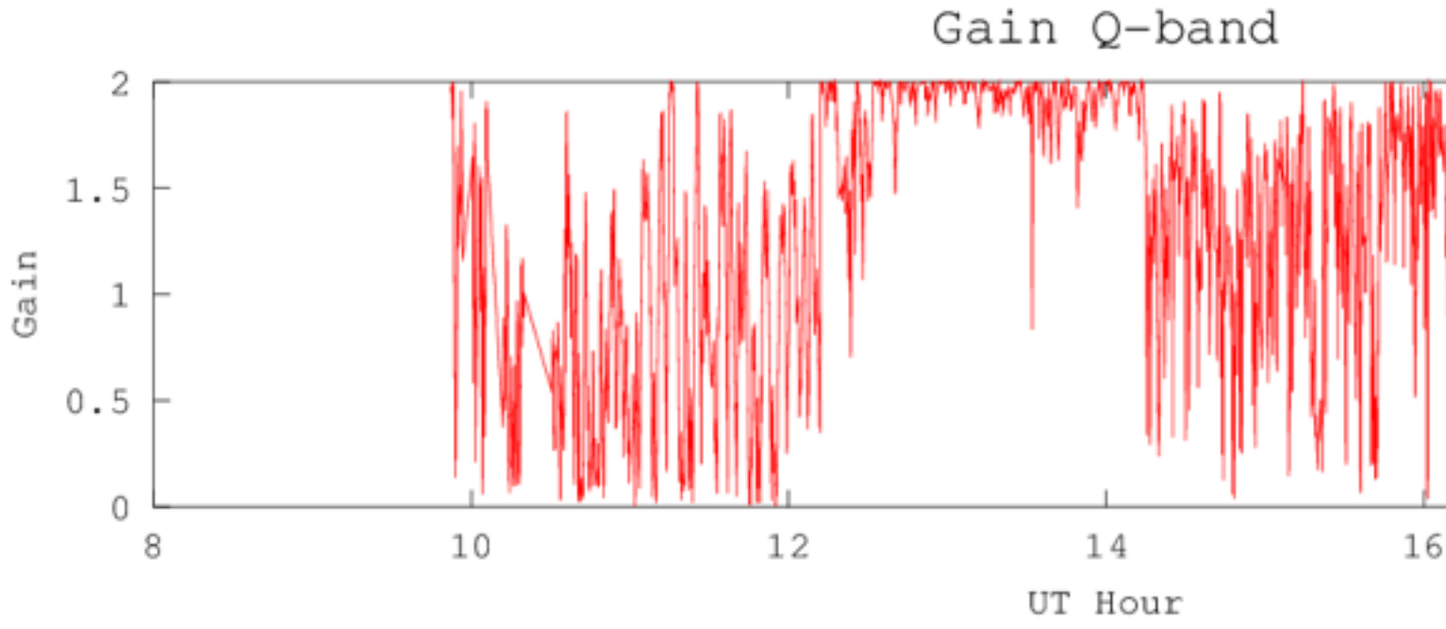

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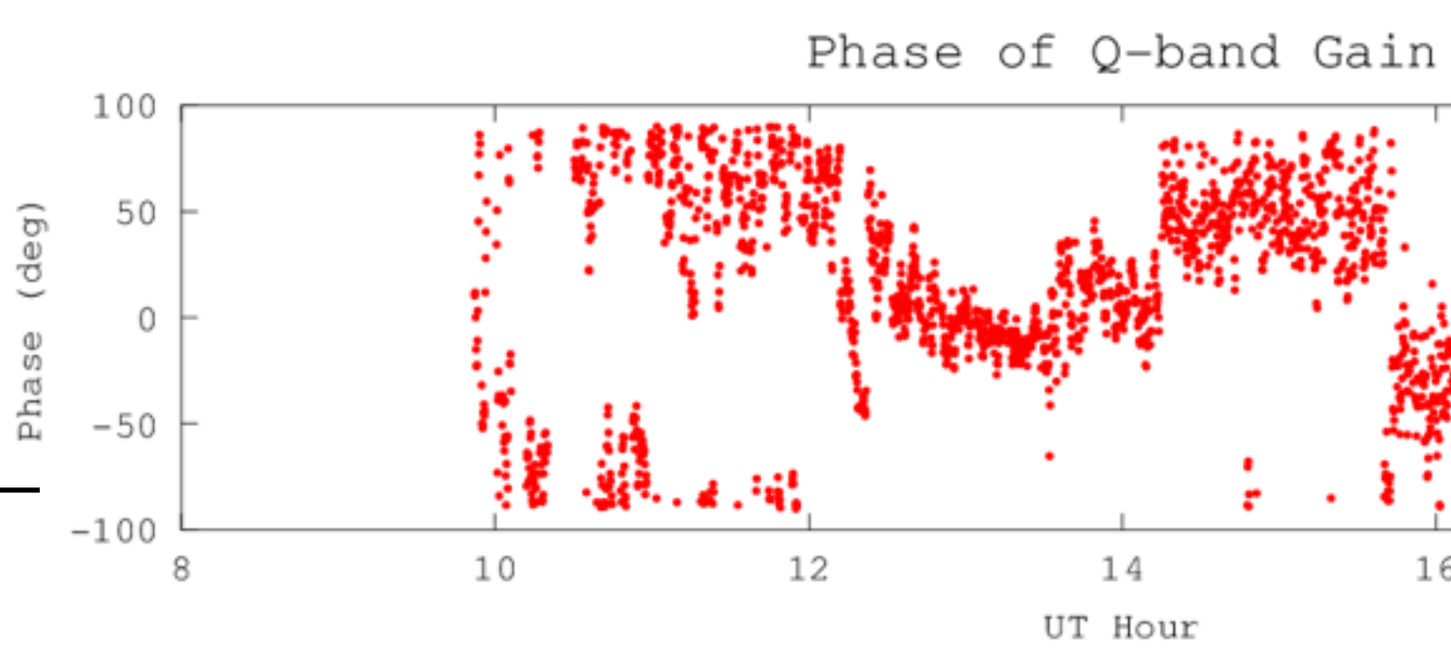

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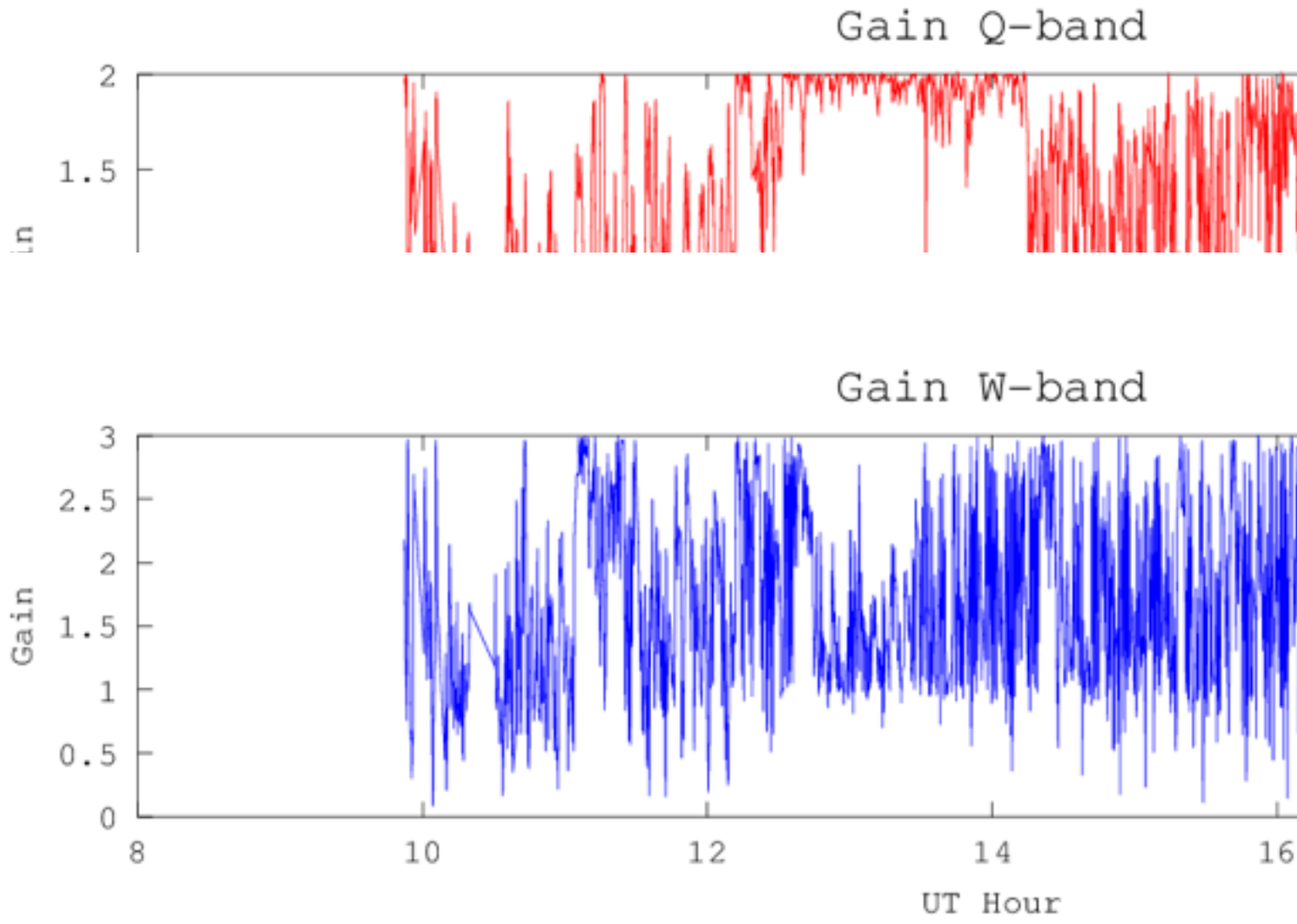

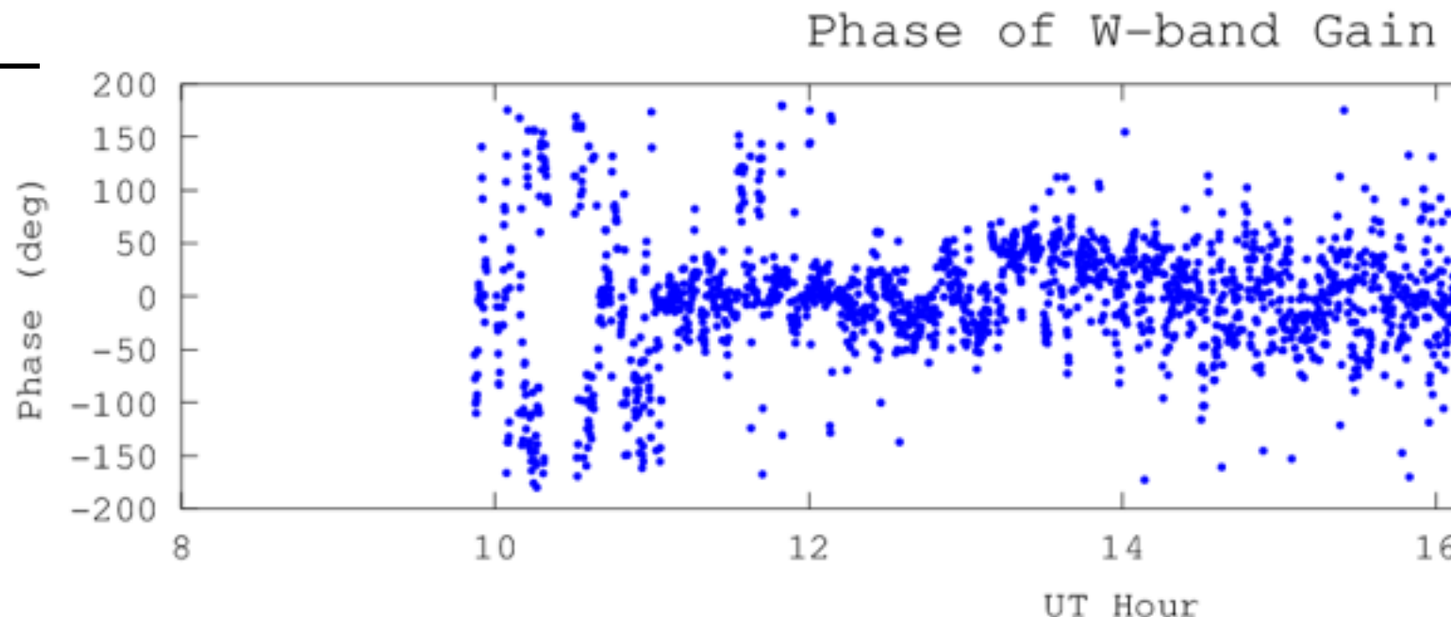

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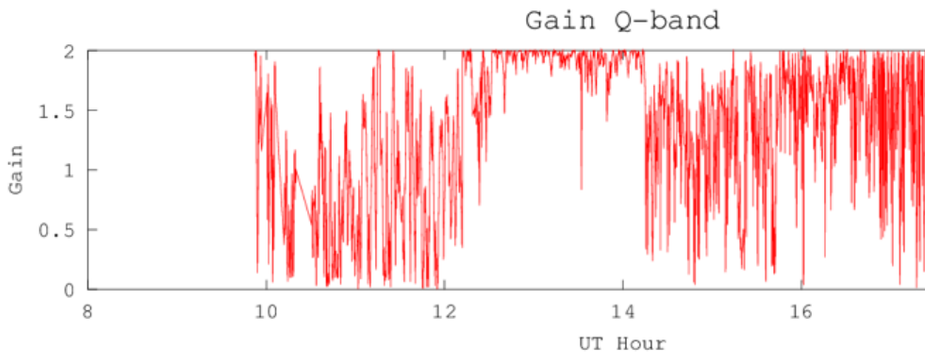
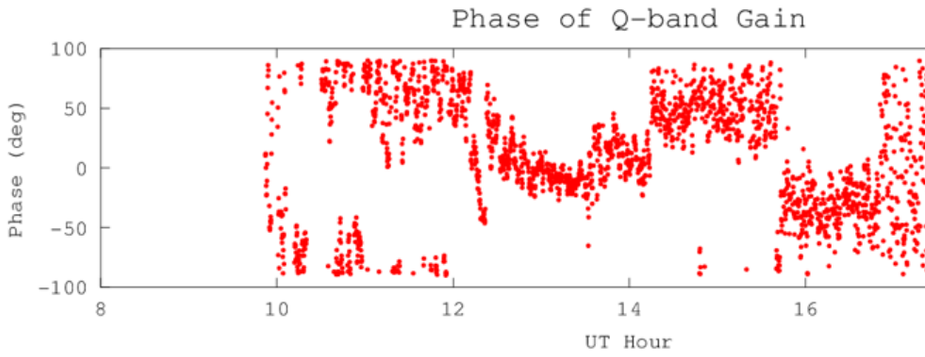
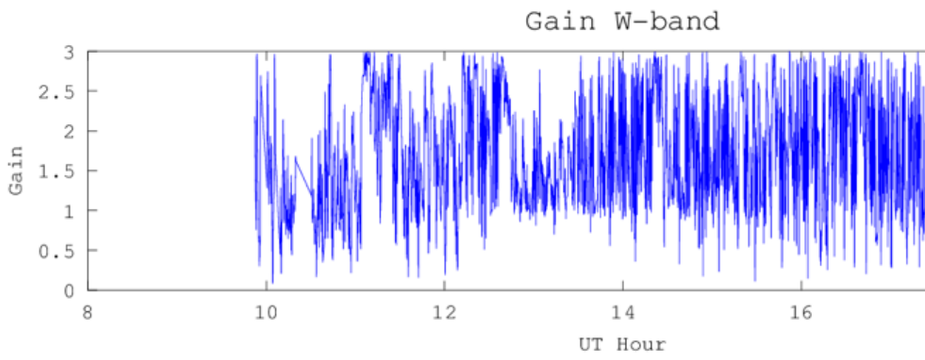
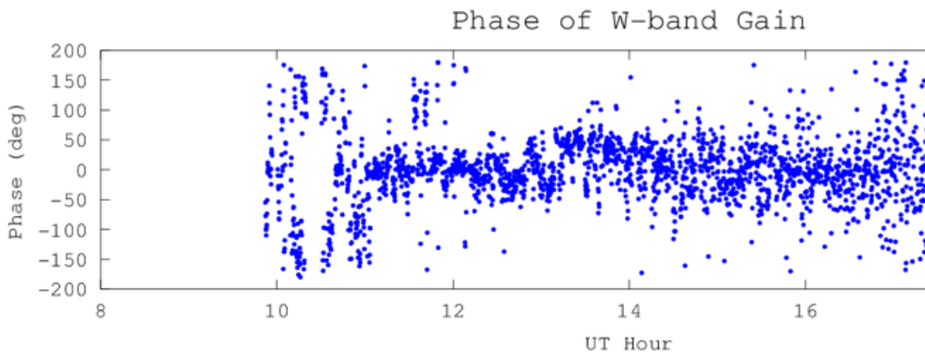




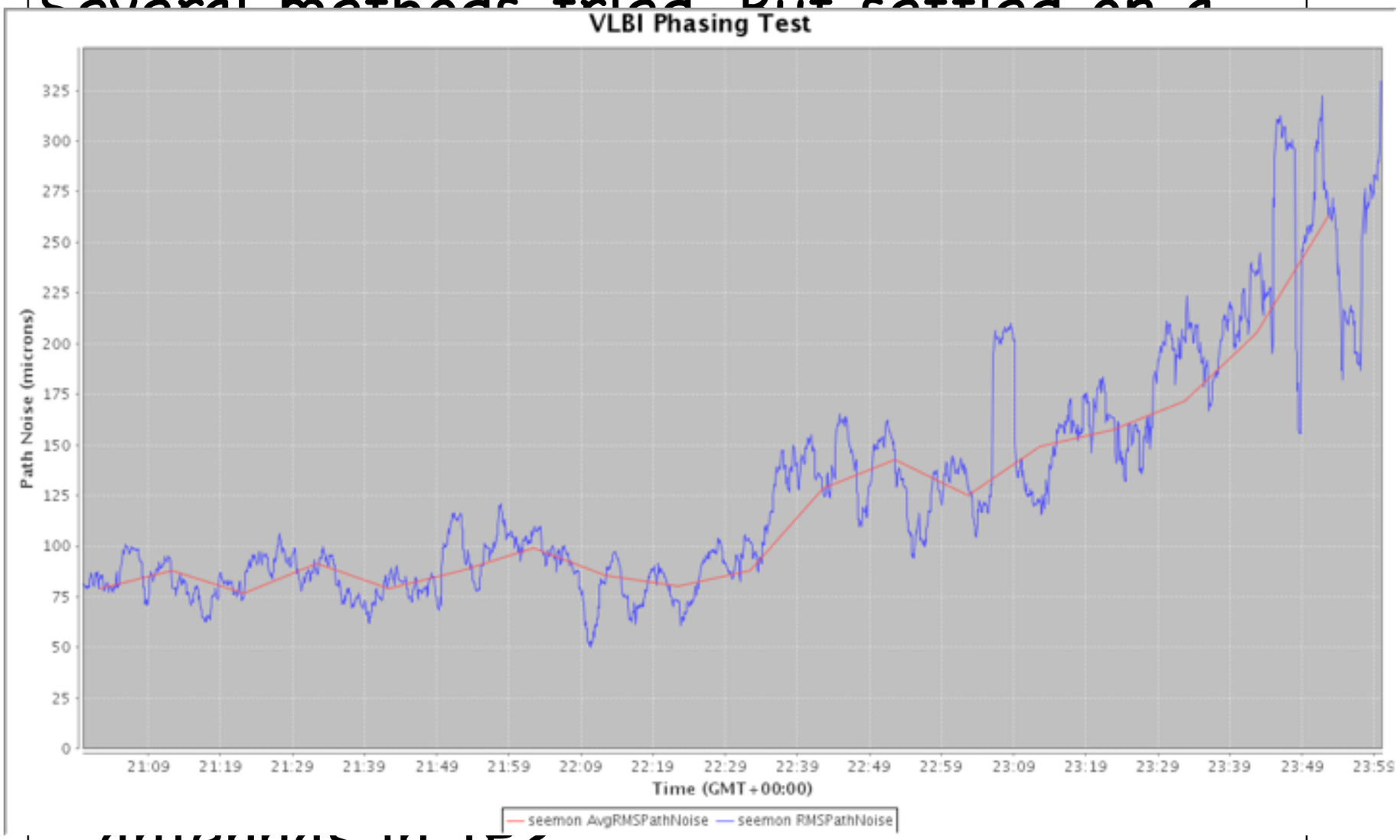




KVN-ATCA dual freq mm-VLBI array

On Sept 12 we did some ATCA tests to try various approaches for phasing the 750C array

Several methods tried. But settled on a



antennas in 1+2.

KVN-ATCA dual freq mm-VLBI array

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Several methods tried. But settled on a simple solution which worked well:

In mixed freq. mode:

- Use 'detach' to isolate antennas in other freq.
- PhaseCal (pcal) only on the 1st set of antennas in IF1.
- `retach' & 'detach' others
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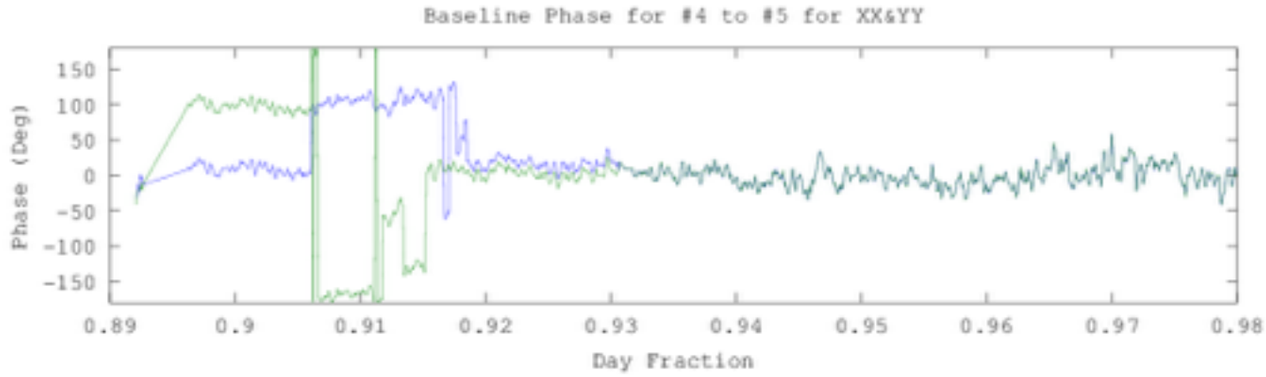

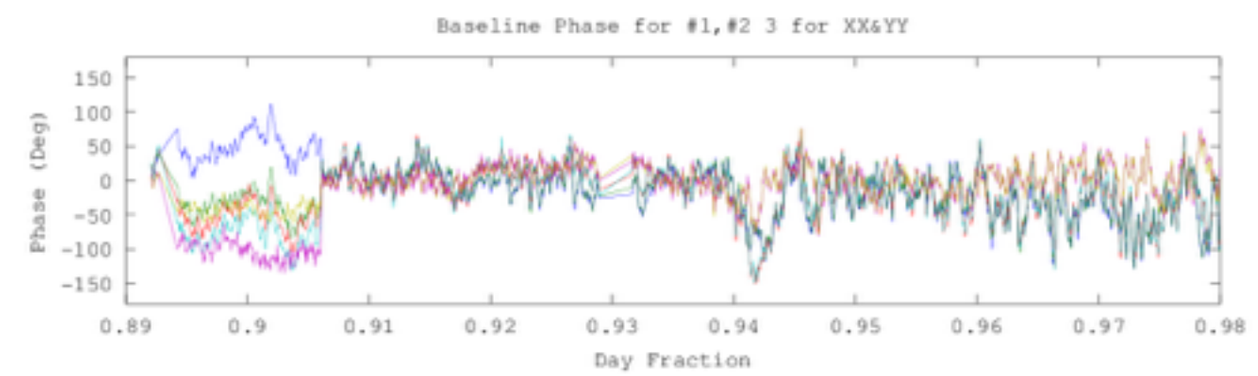

KVN-ATCA dual freq mm-VLBI array

Global simultaneous multi-frequency mm-VLBI to ATCA is now possible!

Phase coherence within the array with new strategy should work. Demonstration Oct 8th

Many thanks are due to the ATNF staff (Jamie and Mark) who made great efforts to bring this about!

Can this be approach be used for ALMA or Plateau de Bure?

Conclusions

Extending Simultaneous Multi-frequency VLBI internationally

Australia can now join mm-VLBI.

Extending SFPR to ATCA has been demonstrated.

Sub-array mode is now demonstrated on ATCA
Can support different frequencies.

By sub-arraying we can join with KVN
And demonstrate SFPR on global baselines

Race is still open to be the first to deliver science results.

These will come soon ...

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uv coverage "with the lot"