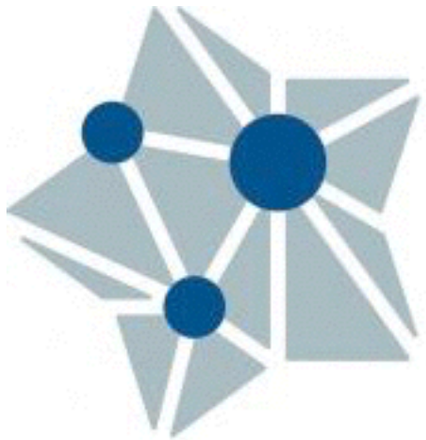

JIVE
Joint Institute for VLBI ERIC

Fringe-Fitting and VLBI Calibration in CASA

Mark Kettenis, Des Small,
Ilse van Bemmel (JIVE)
George Moellenbrock (NRAO)

European Research Council
Established by the European Commission

Black Hole Cam

Why CASA?

- Used by ALMA and VLA
- It's what young Astronomers learn to use
- Long-term future of AIPS isn't secure
- Benefit from new developments
- Data format shared with other software
  - MeqTrees, LOFAR software, SKA prototyping efforts

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EVN Pypeline Steps

1. Load and sort the data
2. A priori data flagging
3. Plot the raw data
4. Amplitude calibration and parallectic angle correction
5. Fringe fitting
6. Bandpass calibration

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Importing Data

- FITS-IDI data format
  - primary format for VLBA, EVN, LBA, GMVA
- AIPS: FITLD
- CASA: importfitsidi
  - Written by Dirk Petry @ESO
  - Converts to MeasurementSet
  - Can re-index to fix observation/scan IDs
  - Does not convert all meta-data yet:
    no Tsys, no gain curves, no WX, no antenna diameters

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Amplitude Calibration: Gain curves

- Two flavors:
  1. VLBI: DPFU (degrees per flux unit) × polynomial as function of elevation/zenith angle
  2. VLA: efficiency × $\sqrt{}$polynomial of zenith angle
- AIPS: ANTAB
- CASA: gencal(type='gc')
  - No support in MeasurementSet
  - Internal tables with VLA-type gain curves
- gc.py script converts ANTAB to VLA-type gain curves
- gencal modified to take external table

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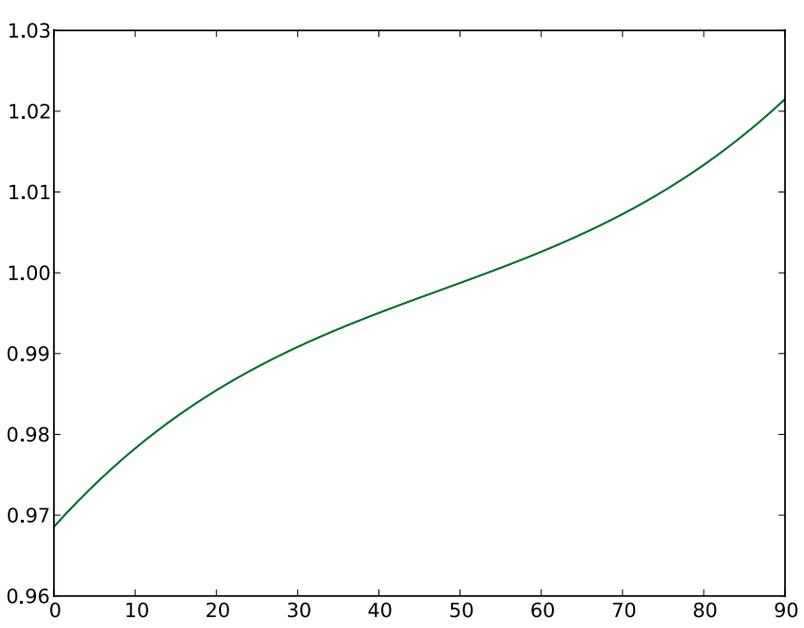
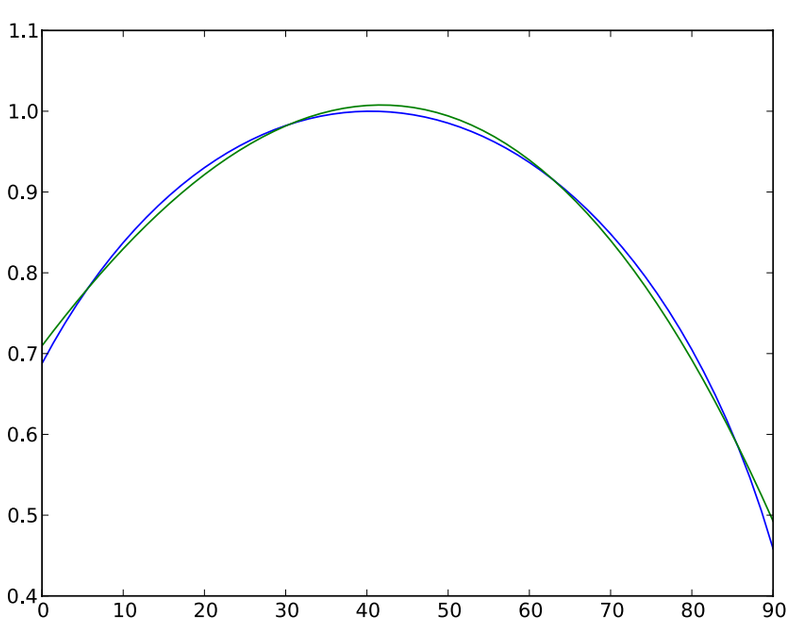
Gain curves

Third order polynomial fit of $f'(\phi) = \sqrt{f(90-\phi)}$

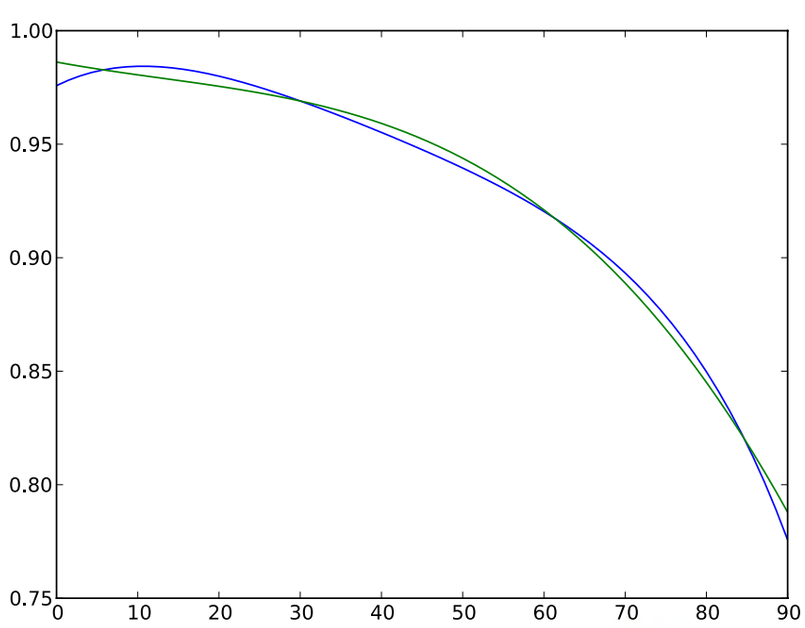
Ef



Jb



On



f'(ϕ)

polynomial fit

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Amplitude Calibration: Tsys measurements

- AIPS: ANTAB
- CASA: gencal(caltype='tsys')
- MeasurementSet SYSCAL table:
  - mandatory TSYS column
  - optional TSYS_SPECTRUM column
- gencal task only uses TSYS_SPECTRUM
- expects synchronous measurements for antennas
- tsys.py script reads ANTAB file inter/extrapolates

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JIVE

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JIVE

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- ~~expects synchronous measurements for antennas~~
- ~~tsys.py script reads ANTAB file inter/extrapolates~~

Import Tsys directly from FITS-IDI

X-AIPS TV-Screen-Server

PLOT FILE VERSION 0 CREATED
AMPLITUDE VS TIME FOR N14C1
IF 2 CHAN 4 - 61 STK RR

EF-ON (1-4) CH 4

JANSKYS

14 12 10 8 6 4 2 0

14 00 05 10 15 20 25 30 35 40
TIME (HOURS)

PlotMS

File Export Summary View Help

Plot | Flag | Tools | Annotate | Options

Data | Axes | Page

File

is/data/n14c1/n14c1.ms Browse...

Selection

field

spw 1:3~60

4:43:00

channels

seconds

Field

Antenna

Reload Plot

Amp:corrected vs. Time

Amp:corrected

14 12 10 8 6 4 2 0

13:53:20 14:01:40 14:10:00 14:18:20 14:26:40 14:35:00 14:43:20

Time (from 2014/03/04) (s)

Hold Drawing

Calibration script

```
importfitsidi(vis='n14c1.ms', fitsidifile=[
        '/scratch/kettenis/data/n14c1/n14c1_1_1.IDI1',
        '/scratch/kettenis/data/n14c1/n14c1_1_1.IDI2')

execfile('tsys.py')
gencal(vis='n14c1.ms', caltable='n14c1.tsys', caltype='tsys')
execfile('gc.py')
gencal(vis='n14c1.ms', caltype='gc', caltable='n14c1.gain',
        infile='EVN.gc')

applycal(vis='n14c1.ms', gaintable=['n14c1.tsys', 'n14c1.gain'])
plotms(vis='n14c1.ms', spw='1:3~60', antenna='EF&ON',
        correlation='RR', avgchannel='64', ydatacolumn='corrected')
```

Fringe Fitter

- Fit for instrumental/tropospheric (group) delay and (phase) rate
- Single-band, global fringe-fitting implemented
- Prototype in Python
- Implementation in C++
  essential for full integration in CASA

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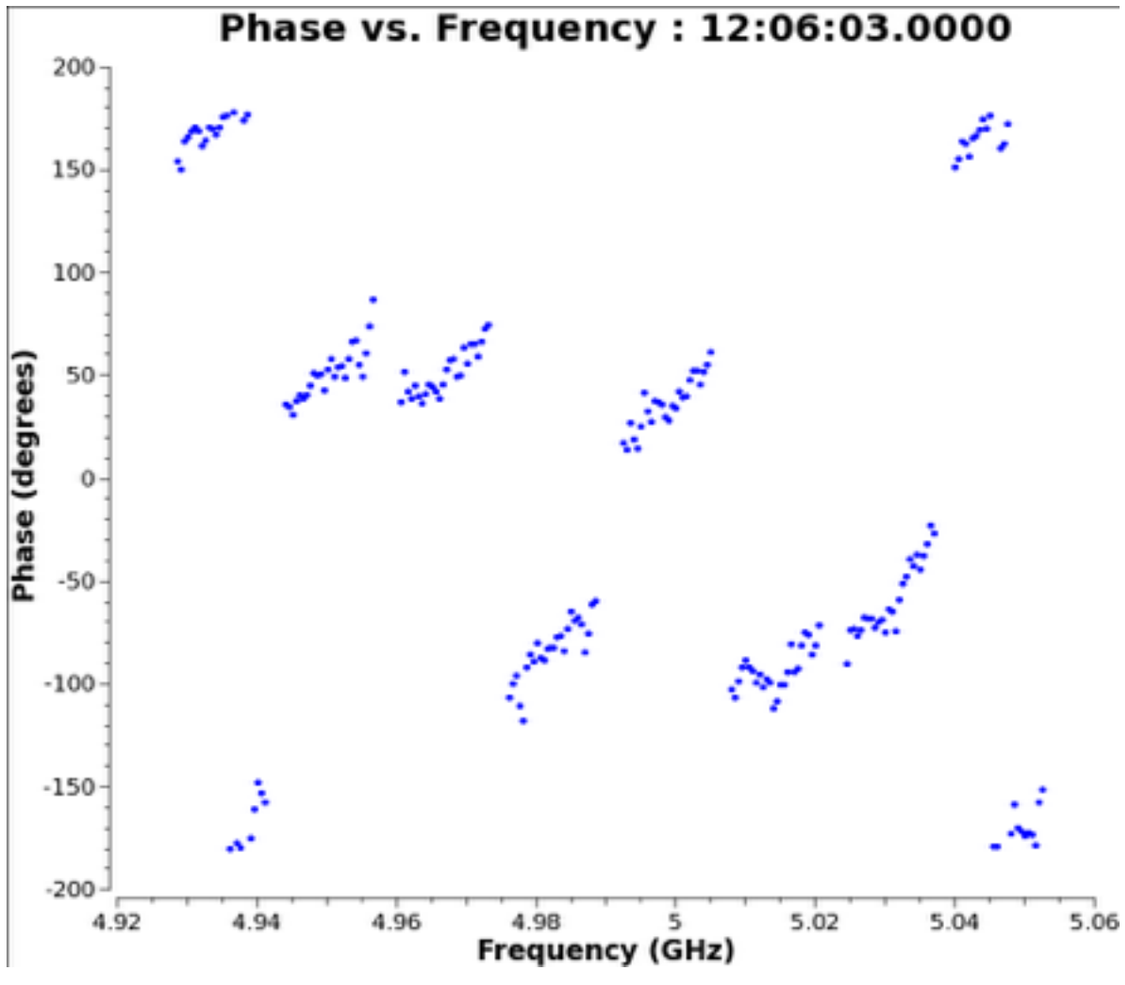
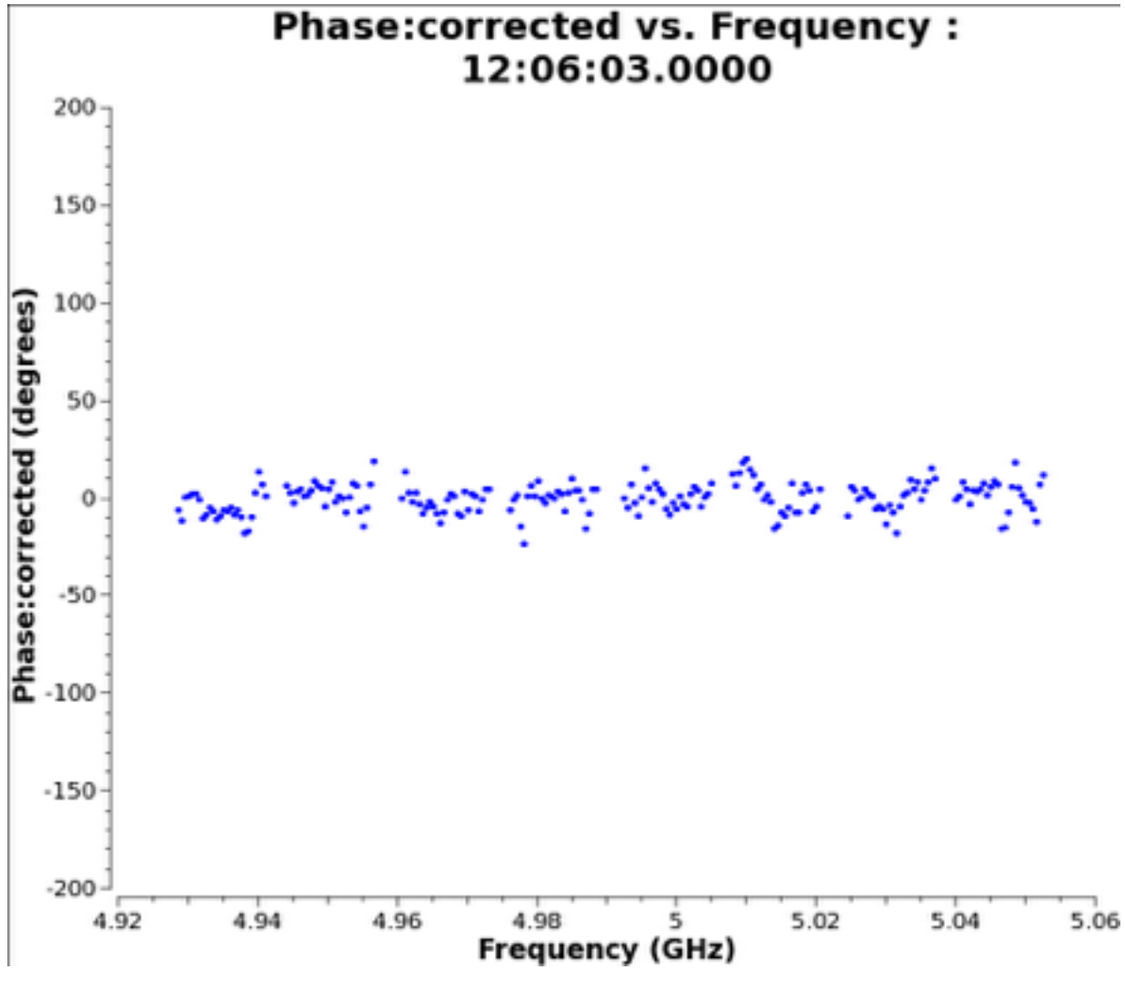
Fringe Fitter





Effelsberg-Badary baseline

CASA Cal Tables for Delay and Rate

- Prototype KRateJones C++ Class
  - Reference time handling TBD
  - Stores both delay and rate
  - Until Fringe Fitting code is finished:
    - Convert AIPS CL to CASA KRate

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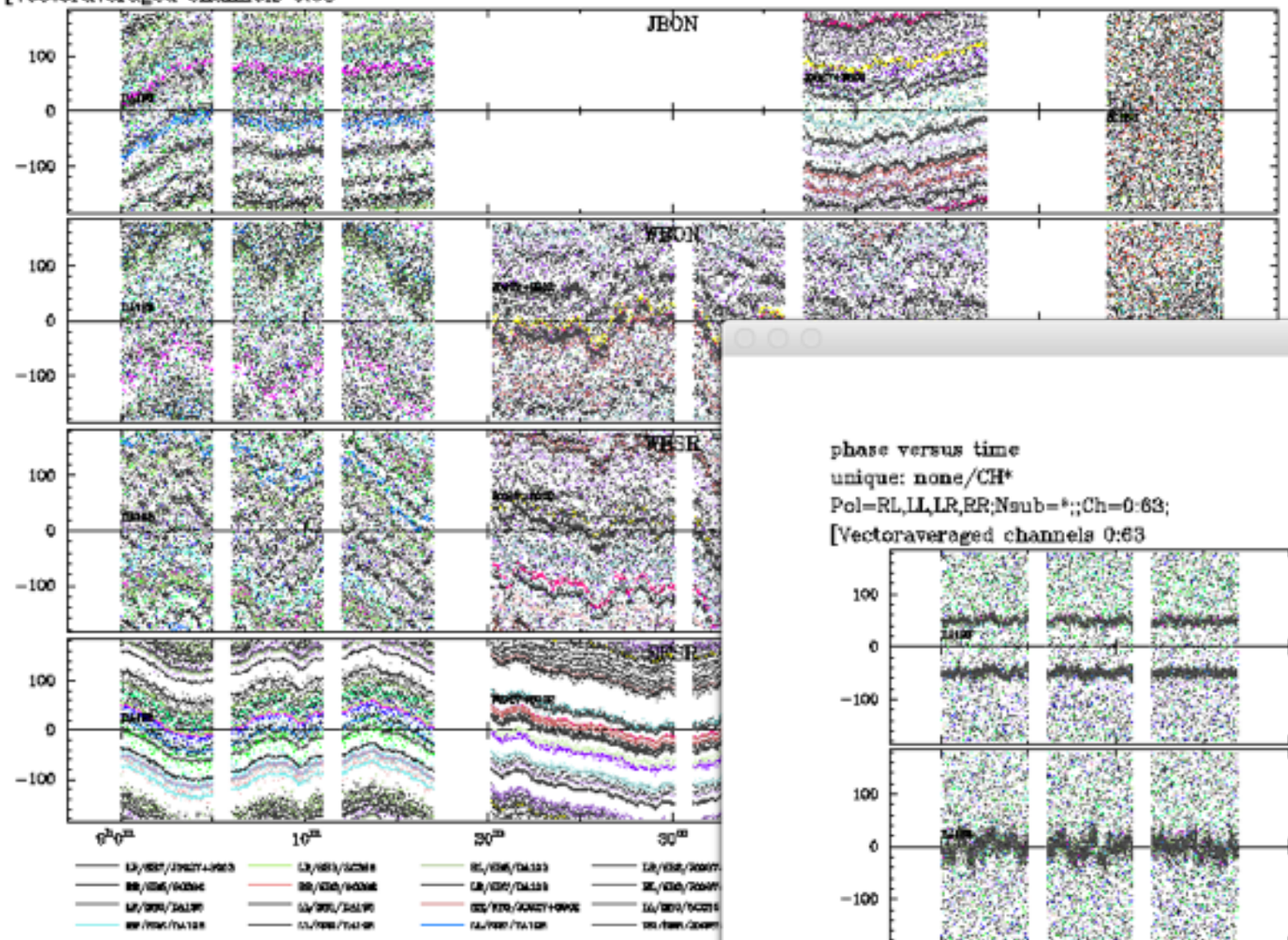
PGPLOT Window 42

N14M3

phase versus time
unique: none/CH*
Pol=RL,LL,LR,RR;Nsub=*;;Ch=0:63;
[Vectoraveraged channels 0:63

data: n14m3.ms
kettenis@<???> 2018-02-19T14:55:48
page: 1/7

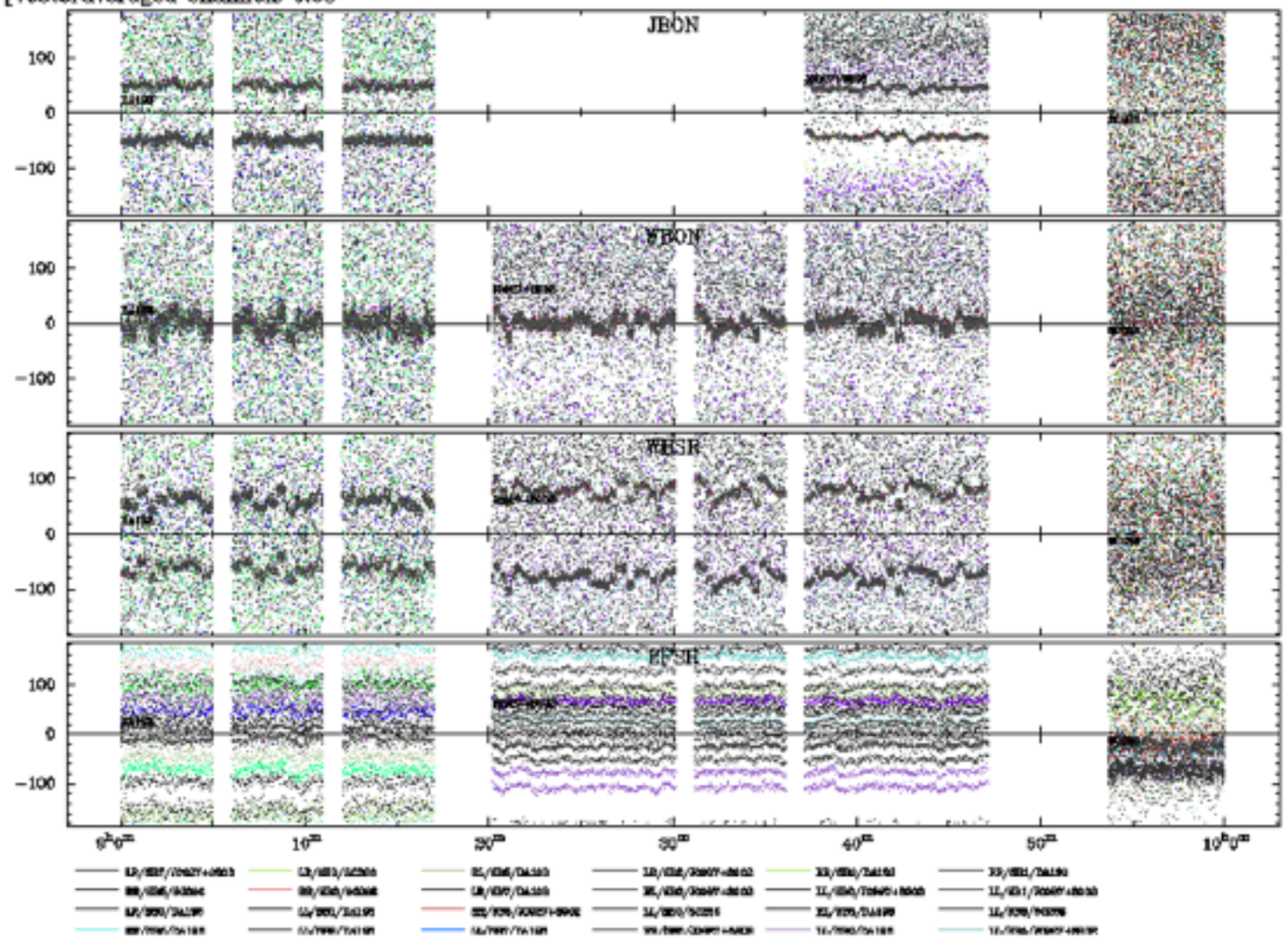


PGPLOT Window 43

N14M3

phase versus time
unique: none/CH*
Pol=RL,LL,LR,RR;Nsub=*;;Ch=0:63;
[Vectoraveraged channels 0:63

data: n14m3.ms
kettenis@<???> 2018-02-19T14:57:16
page: 1/7



CASA Cal Tables for Delay and Rate

- Prototype KRateJones C++ Class
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    - Convert AIPS CL to CASA KRate

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CASA Cal Tables for Phase, Delay and Rate

- Store phase, delay and rate
- Interpolation of phase should “integrate up” the rate
- Use center of band as reference frequency

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Bandpass Calibration

- AIPS: BPASS
- CASA: bandpass
- Solutions found for strong calibrators, except for longer baselines. Needs fringe fit!

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Collaboration with NRAO

- NRAO leads CASA development
- MOU has been drafted
- Implementation plan
- CASA tickets now exists for basic functionality
- Target: CASA 4.8

Projects

Current projects:

- BlackHoleCam
  - mm-VLBI calibration pipeline
- SKA-NL Roadmap
  - prepare for VLBI with SKA1-MID

Future projects:

- RadioNet H2020: RINGS (not yet funded)
  - include dispersive-delay in Fringe-Fitting
  - wide-band fringe-fitting

Additional calibration?

- Parallectic Angle Corrections
  - parang=true should work
- Opacity corrections
  - Ties in with gain curves
  - WVR
- Digital corrections
  - Correlator dependent

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Conclusions

- VLBI data reduction in CASA seems feasible
- Many details to be sorted out
- Beneficial for non-VLBI arrays as well: e-MERLIN, LOFAR, ngVLA, long baseline ALMA

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