Automated VLBI data reduction with rPICARD

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Why CASA?

- Future-proof software with scalability (MPI, ngCASA).
- Easy-to-use Python interface.
- Connect VLBI & connected element interferometer communities.

rPICARD installation

git clone https://bitbucket.org/M_Janssen/picard **or use singularity (see repo README)**
wget ftp://ftp.mpifr-bonn.mpg.de/outgoing/mjanssen/casa-CAS-13781-5-py3.6.tar.xz
tar xvJf casa-CAS-13781-5-py3.6.tar.xz
./picard/setup.py -p casa-CAS-13781-5-py3.6
printf '\nexport PATH=$PATH:"$(pwd)"/picard/picard\n' >> ~/.bashrc
printf '\nexport PYTHONPATH=$PYTHONPATH:"$(pwd)"/picard/picard\n' >> ~/.bashrc

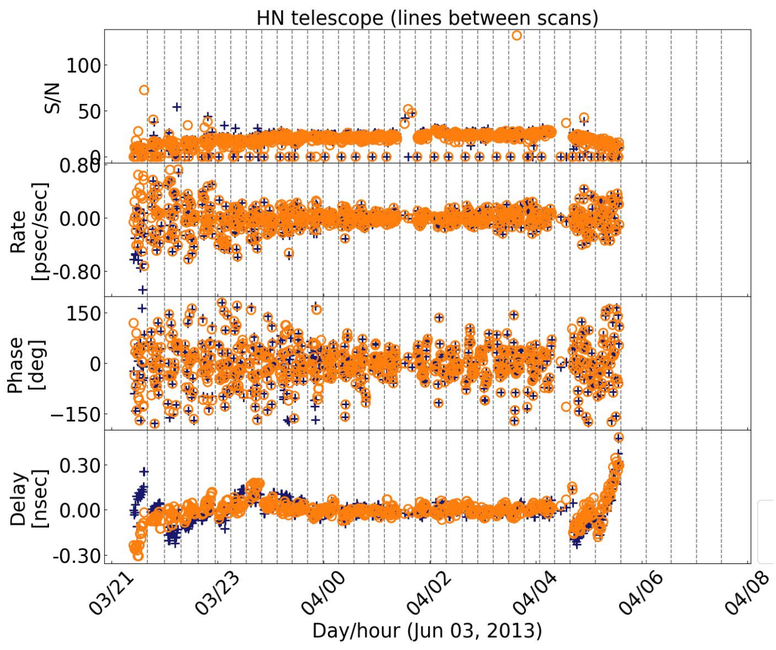
Running rPICARD

- `$ cd /path/to/your/working/directory`
- `$ cp -r /picard/installation/input_template/ input`
- Copy (`cp`) or create links (`ln -s`) to data:
  - FITS-IDIs, ANTAB, flag files, WX (weather) data
  - One experiment/observation per working directory
- Set a few non-default input parameters:
  - Name of science target(s) and calibrator(s) in `input/observation.inp`
  - *array_type* & *refant* in `input/array.inp`
- **`$ picard -p`**

Ongoing work

- New spectral line calibration mode:
  - Can set *spectral_line* = *search* in `input/observation.inp`
- Avinash Kumar (IA FORTH, SMILE project) work:
  - https://gitlab.ia.forth.gr/smile/vasco – sets **all** pipeline parameters automatically, incl. *science target & phaseref, calibrators, refant,* and *array_type* based on visibility and Tsys data.
  - https://github.com/avialxee/alfrd – automated picard execution and run tracking via google spreadsheets.
- Frequency-phase transfer.

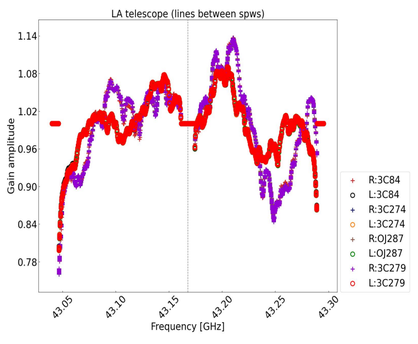
rPICARD special calibration steps & diagnostics



Example results from rPICARD based on Q-band VLBA data (BW0106) are shown here from automatically generated diagnostics.

Fig. 1 - Fringe-fit results for one telescope obtained at a short cadence.,

Fig. 2 - Phases and amplitudes of the calibrated data from one baseline.



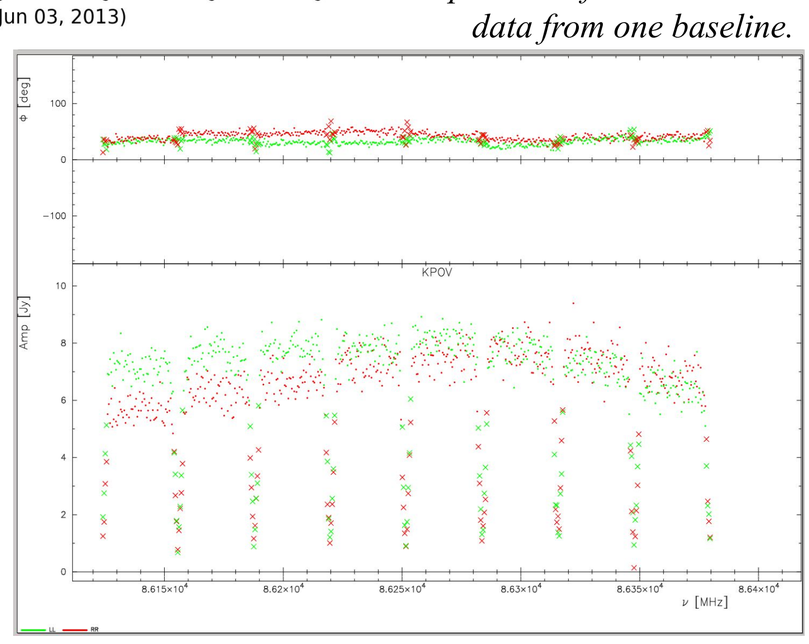


Fig. 3 - Scalar bandpass calibration solutions.

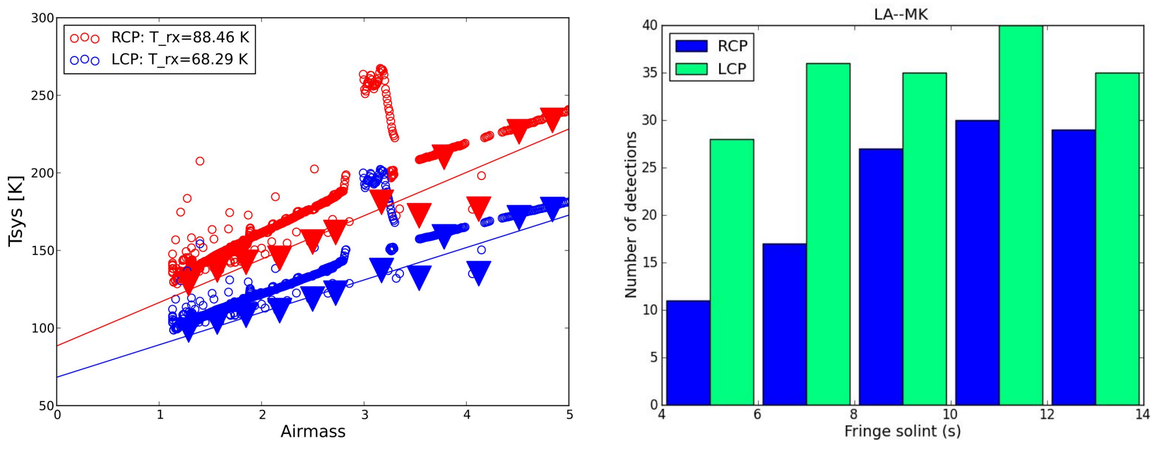
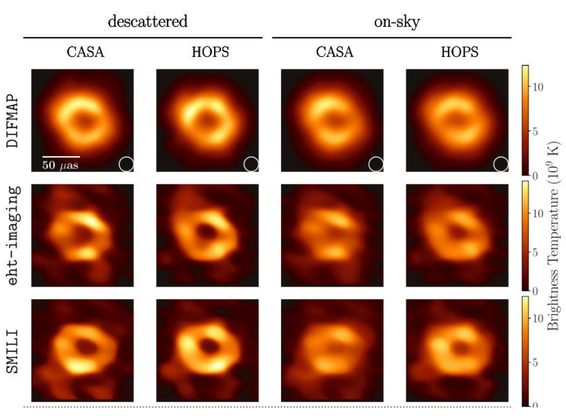


Fig. 3 - A fit for a receiver temperature used for a correction of atmospheric opacity (left) and a fringe-fit solution interval optimization that extends the coherences time and maximizes the number of source detections (right).

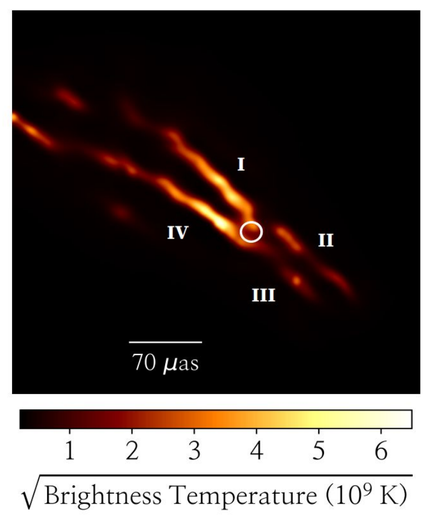
rPICARD: Pipeline-based VLBI data reduction

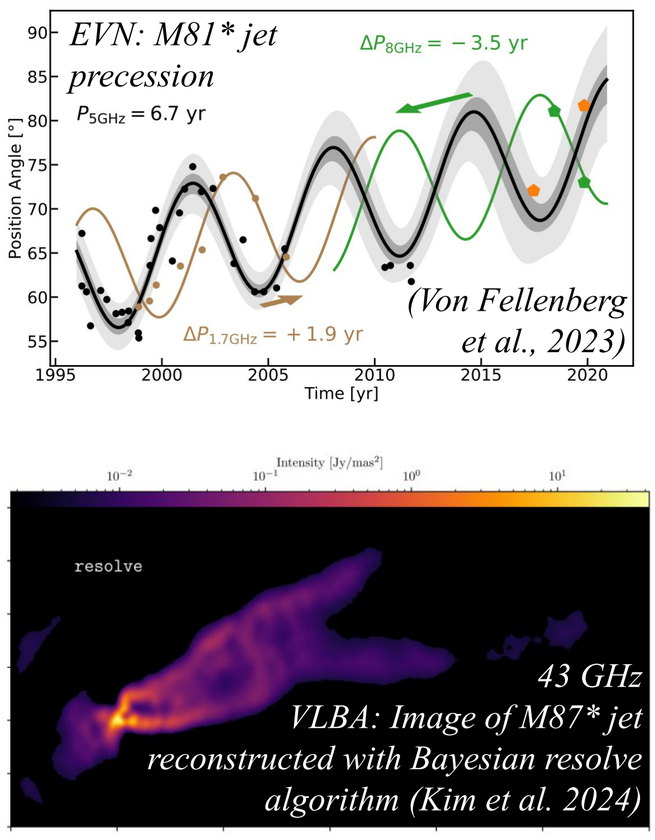
- Specify a set of input parameters and run the full data reduction automatically, skipping the tedious manual steps.
- Better diagnostics and improved calibration methods compared to standalone CASA.
- MPI speedup.
- Extensive documentation.
- Get reproducible results.
- Low barrier to entry.
- Able to restart at any point.
- Janssen et al. A&A, 626, A75.
- Philosophy
  - Let it run with the default parameters.
  - Inspect diagnostics.
  - Adjust input parameters accordingly, identify bad data, and run it again to produce science-ready data.

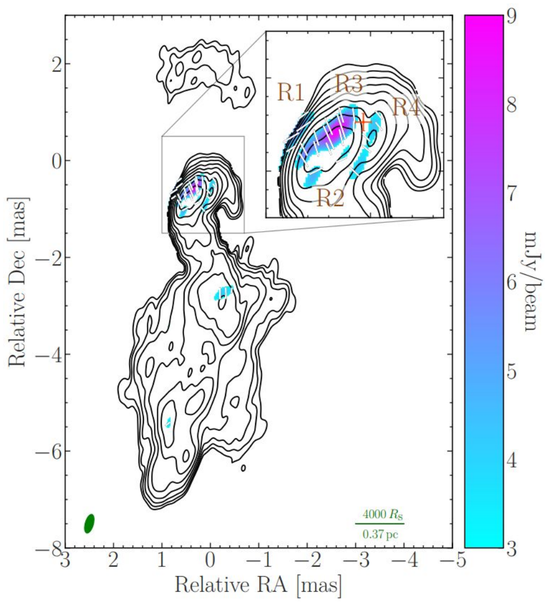
Example publications using rPICARD



Left: EHT Sgr A (EHT et al. 2022). Right: EHT Cen A (Janssen et al. 2021).*



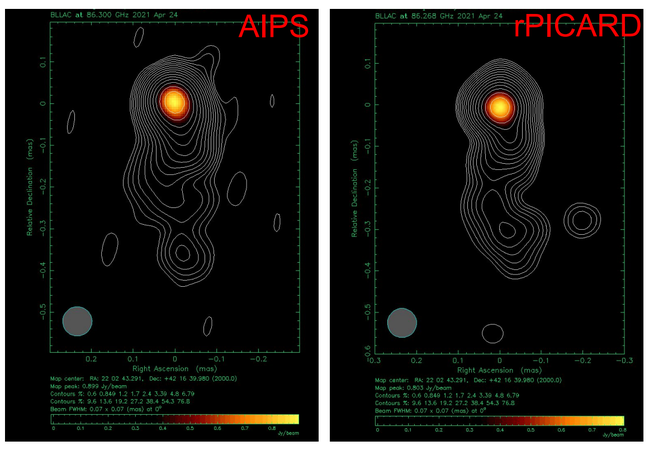


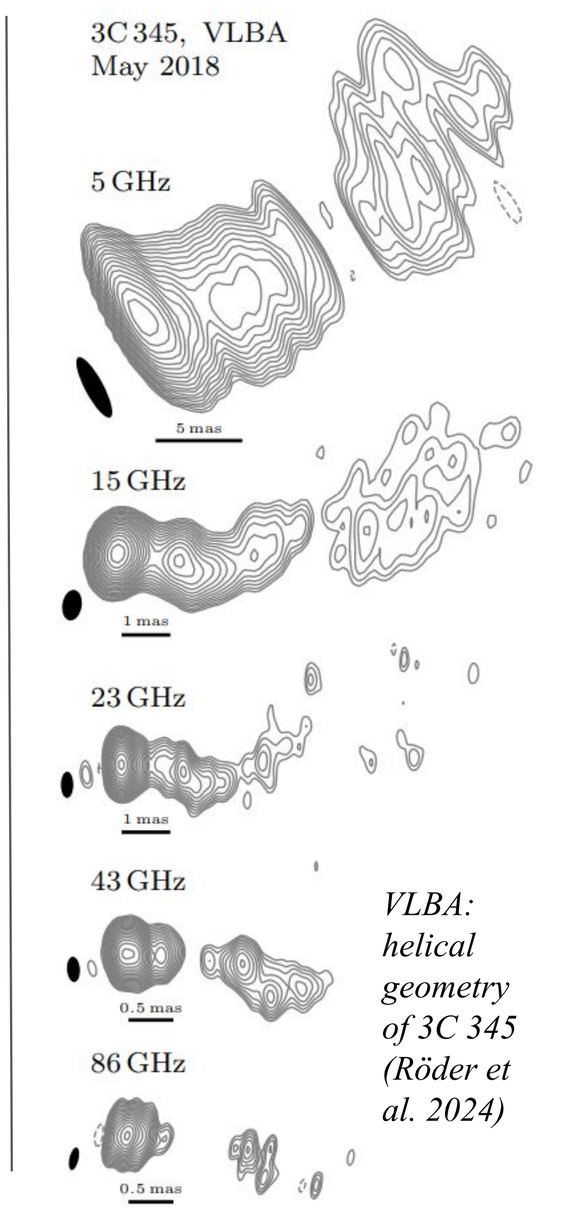


EVN: Toroidal magnetic fields in the core of 3C 84 (Paraschos et al. 2024)

43 GHz VLBA: Image of M87 jet reconstructed with Bayesian resolve algorithm (Kim et al. 2024)*

GMVA: BL Lac during γ-ray flare with rPICARD-AIPS comparison (Kim et al. 2023)





VLBA: helical geometry of 3C 345 (Röder et al. 2024)

How-to: reduce public EHT data with rPICARD

- Raw correlator output: "L1 Data" in https://eventhorizontelescope.org/for-astronomers/data
- Get *-fits.tgz and *.metadata-*.tgz files.
  Note sideband 1 = "lo" & sideband 2 = "hi" in 2017 data.
- Helpful scripts: https://bitbucket.org/M_Janssen/casaeht
  - `bin/process_eht & bin/singularity_data_production`