Workshop on next-generation VLBI correlators
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Automatic VLBI data analysis for wide field/ high velocity dispersion VLBI observations

Development activity at Kagoshima University

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VLBI has ...

(K. Fujisawa 1994, in Summer School of Young Astronomers' Society)

- Surprisingly high angular resolution.
- Despairingly low sensitivity.

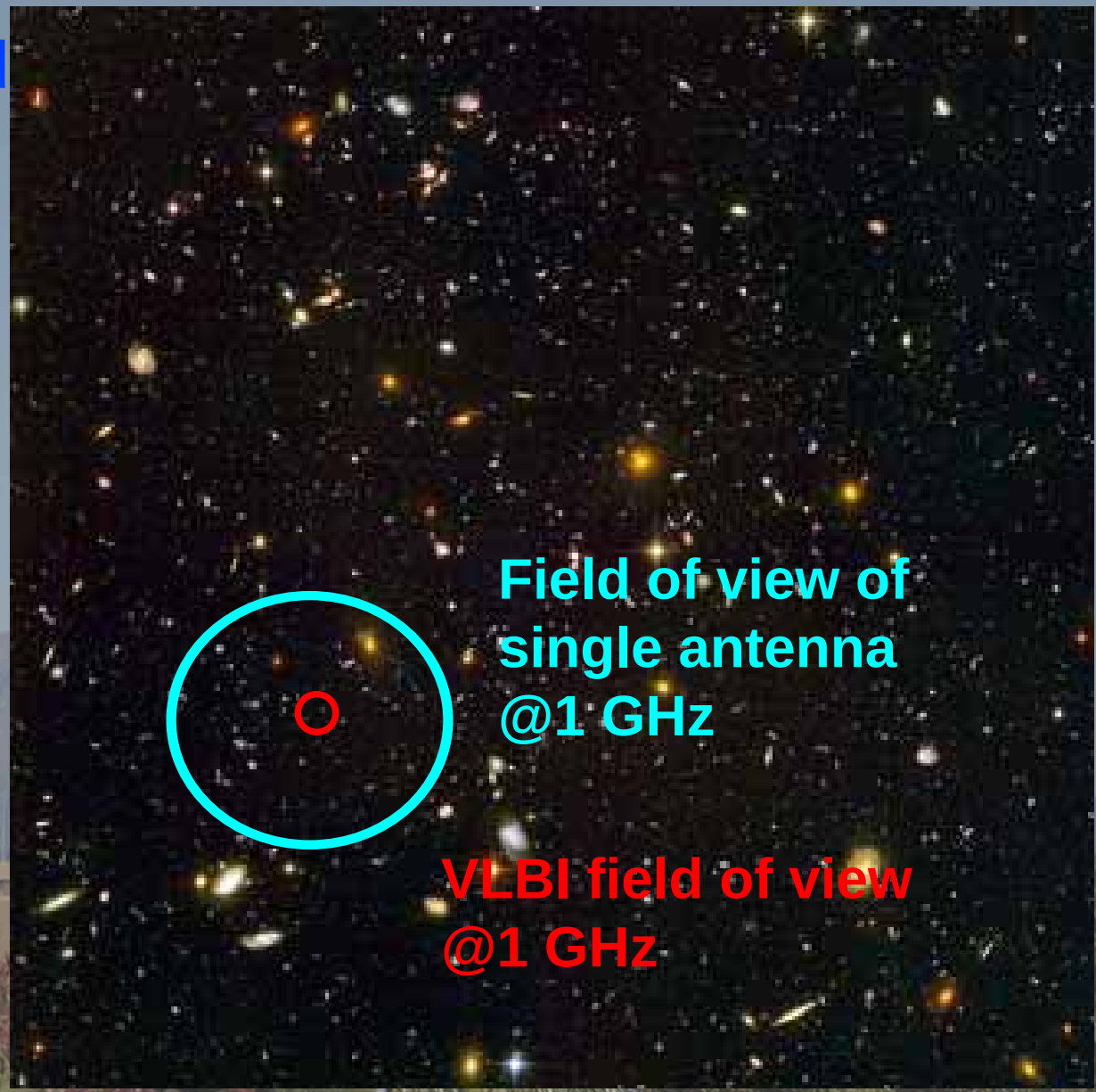
- Anachronistic tiny field-of view.
  - Band-width smearing
  - Time-averaging smearing
  - Limited by correlator performance

- VLBI had interestingly high velocity resolution.

VLBI's tiny field of view

Hubble Deep Field

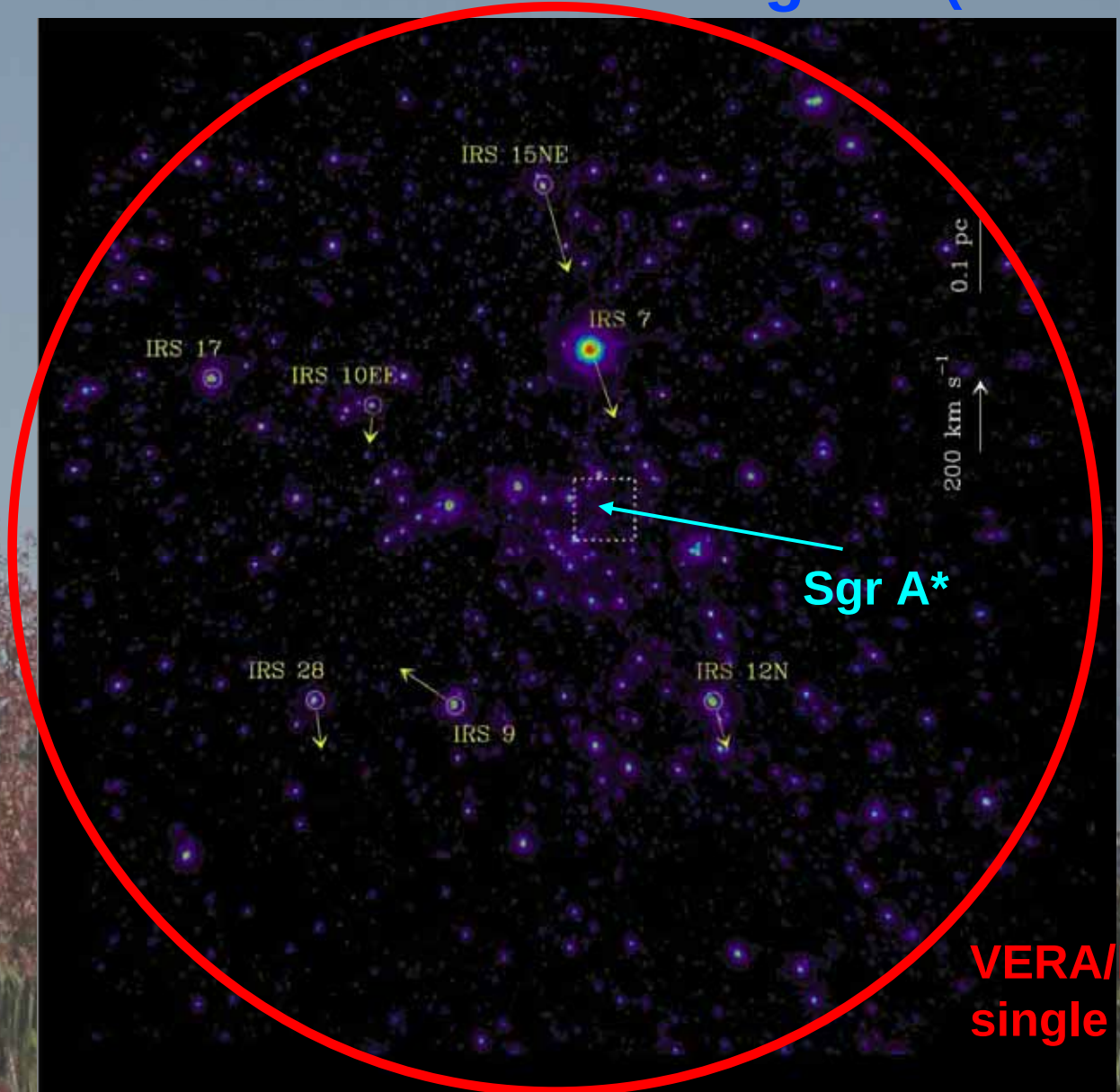
Many astronomers access to the same data.



Access to VLBI archival data might causes frictions between astronomers.

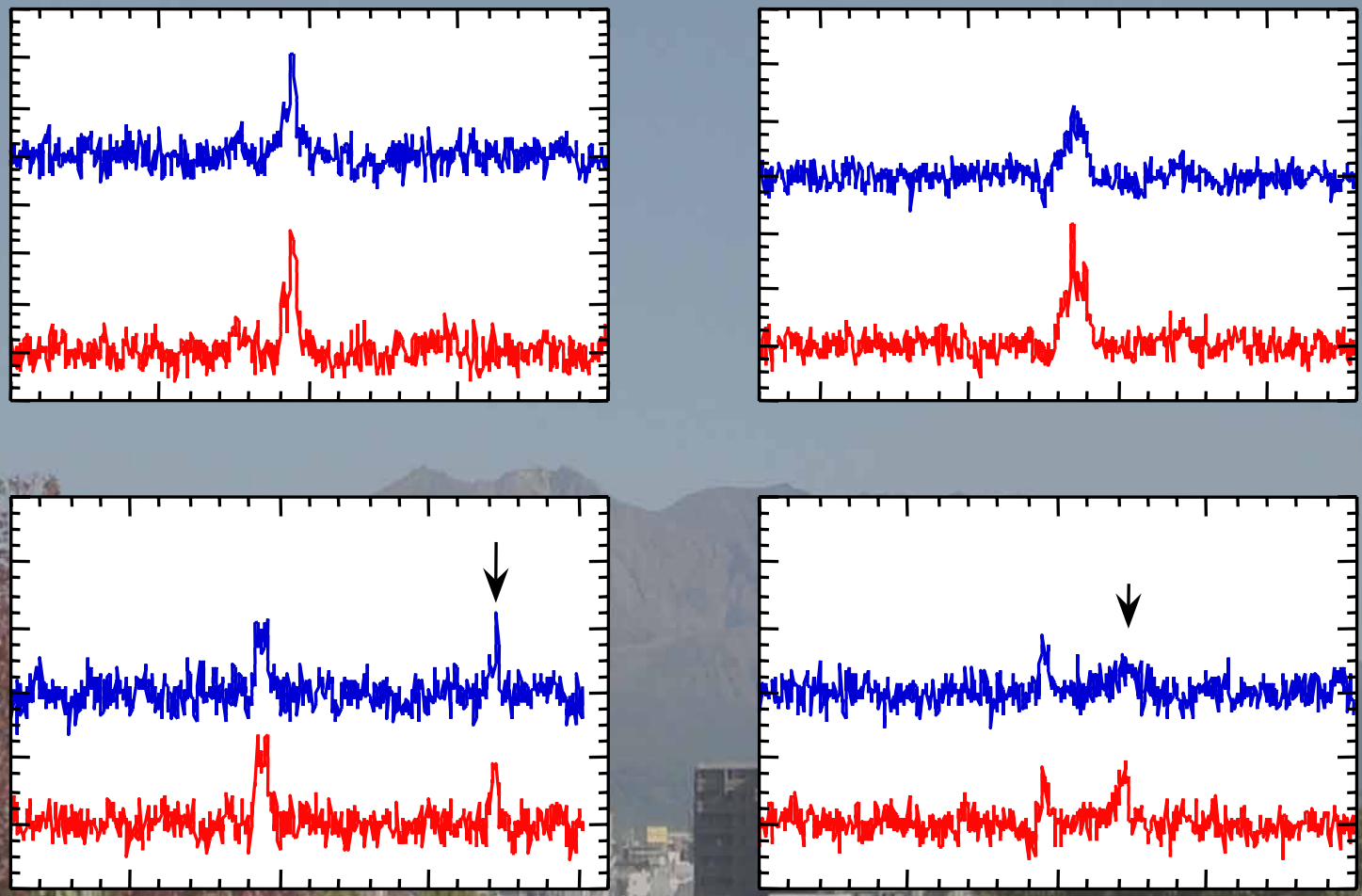
Multiple sources within a single antenna beam

10 SiO maser sources around Sgr A* (Reid et al. 2003)

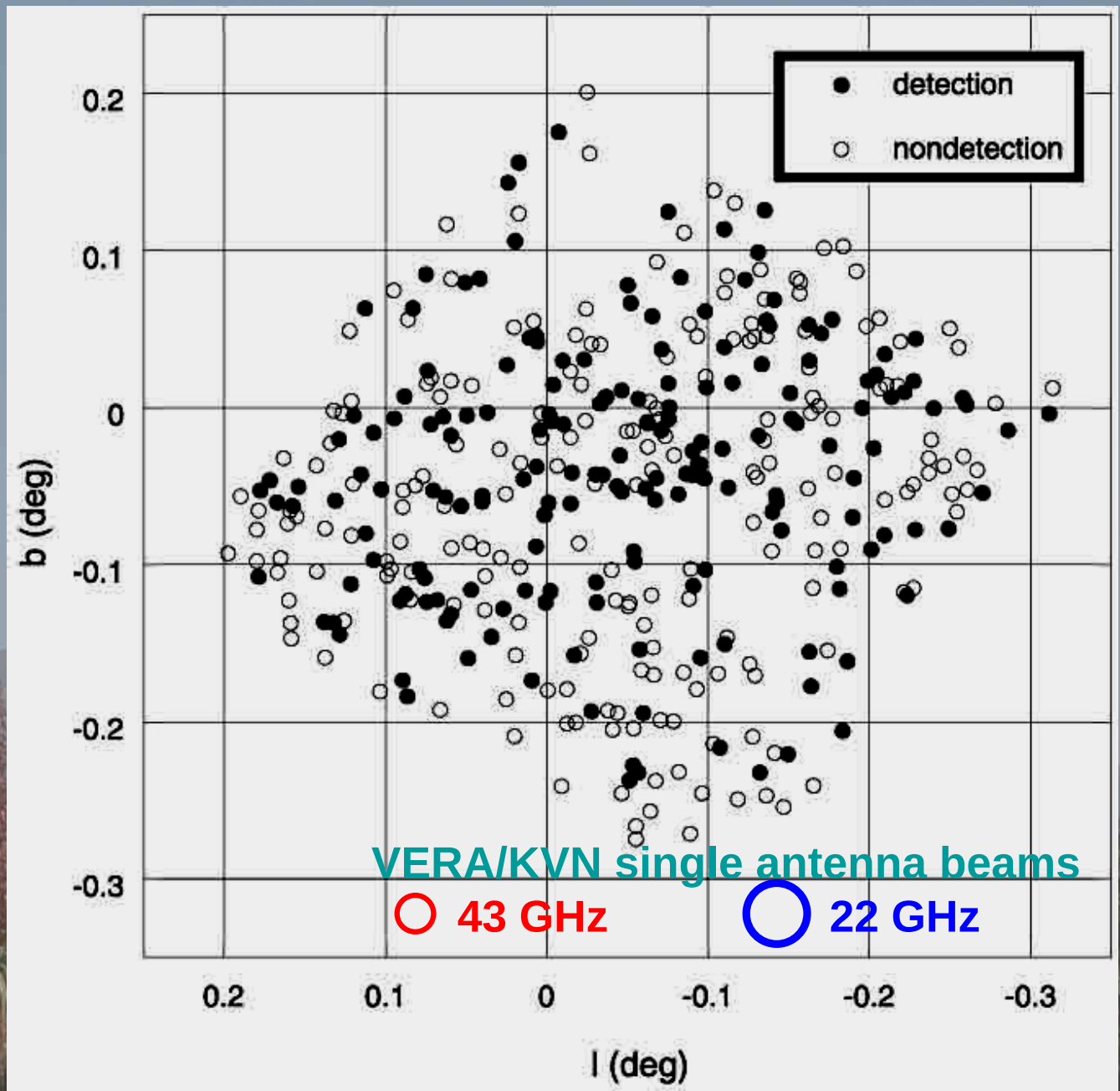


Multiple sources within a single antenna beam

SiO (J=1--0) maser sources around the Galactic center observed with NRO 45-m telescope (Imai et al. 2002; Deguchi et al. 2004)



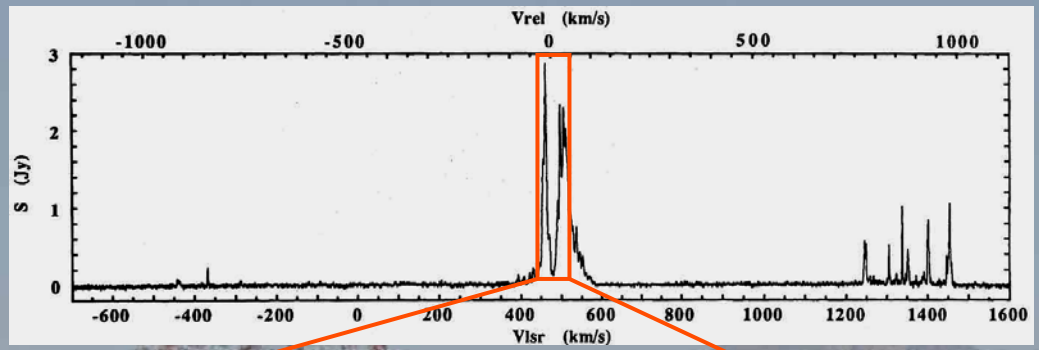
Multiple sources within a single antenna beam

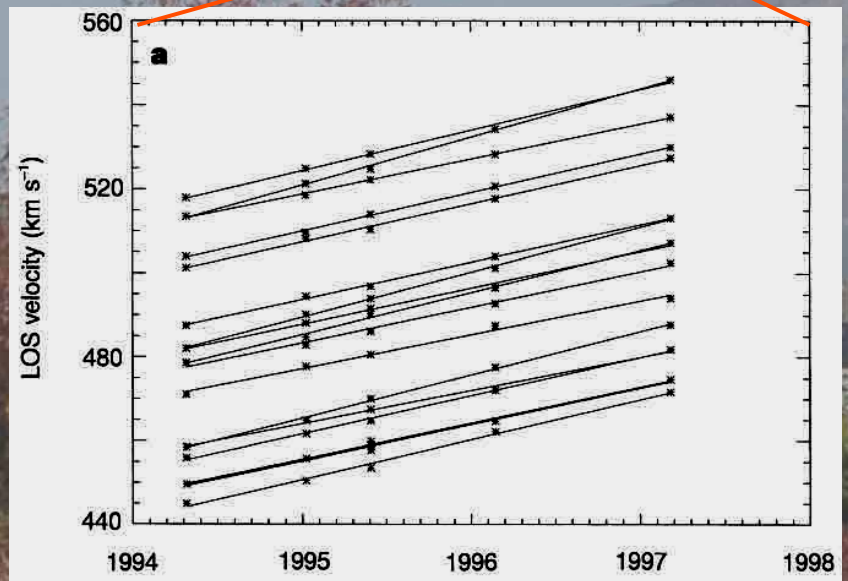


180 SiO (J=1--0) maser sources around the Galactic center (Imai et al. 2002; Deguchi et al. 2004)

High velocity resolution VLBI astronomy

- Velocity resolution requirement
  - 0.01 -- 0.1 km/s spacing
  - 10 -- 1000 km/s coverage
  - 1000 -- 10000 velocity channels are necessary.

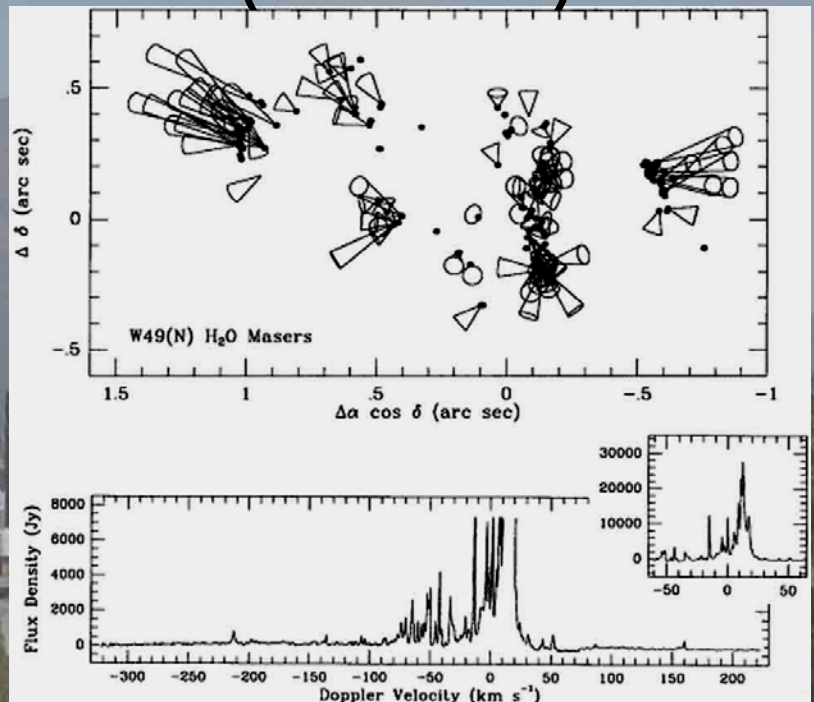




NGC4258

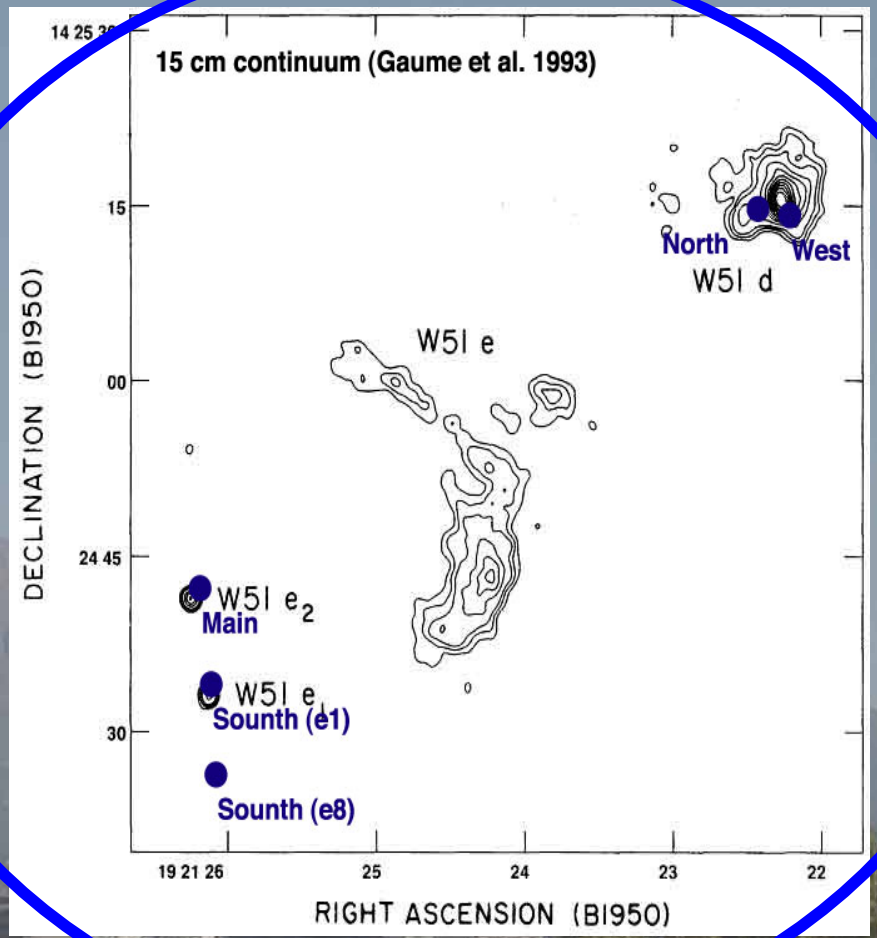
(Nakai et al. 1995;
Herrnstein et al. 1999)

W49N (Gwinn 1994)



Multiple sources within a single antenna beam

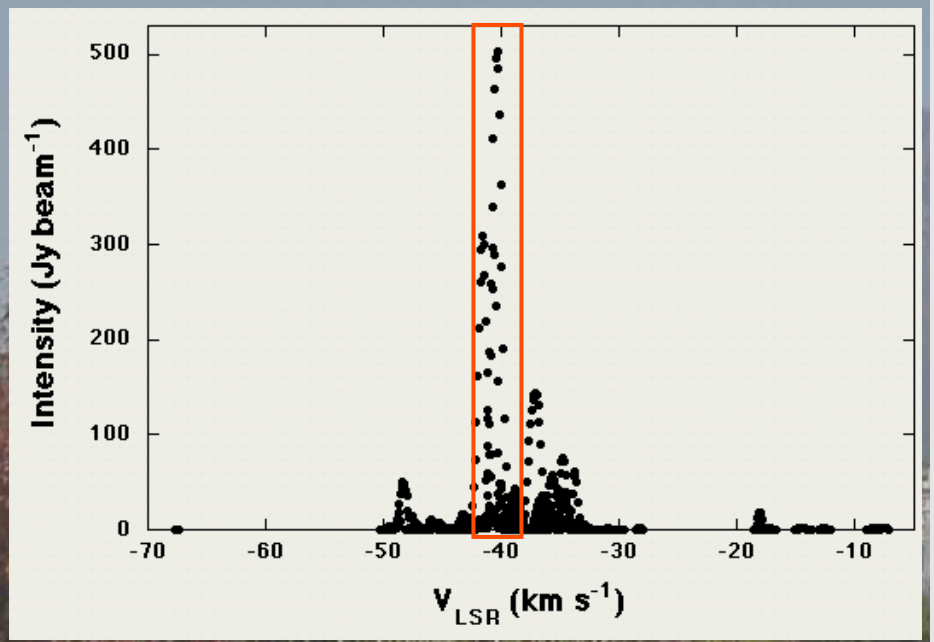
- Very famous H_2O masers
  - W51N/W/M/S
  - W49N
  - W3 IRS5/4
  - Orion KL
  - Sgr B2 N/M/S
  - NGC7538 IRS1/8
  - other famous star-forming regions

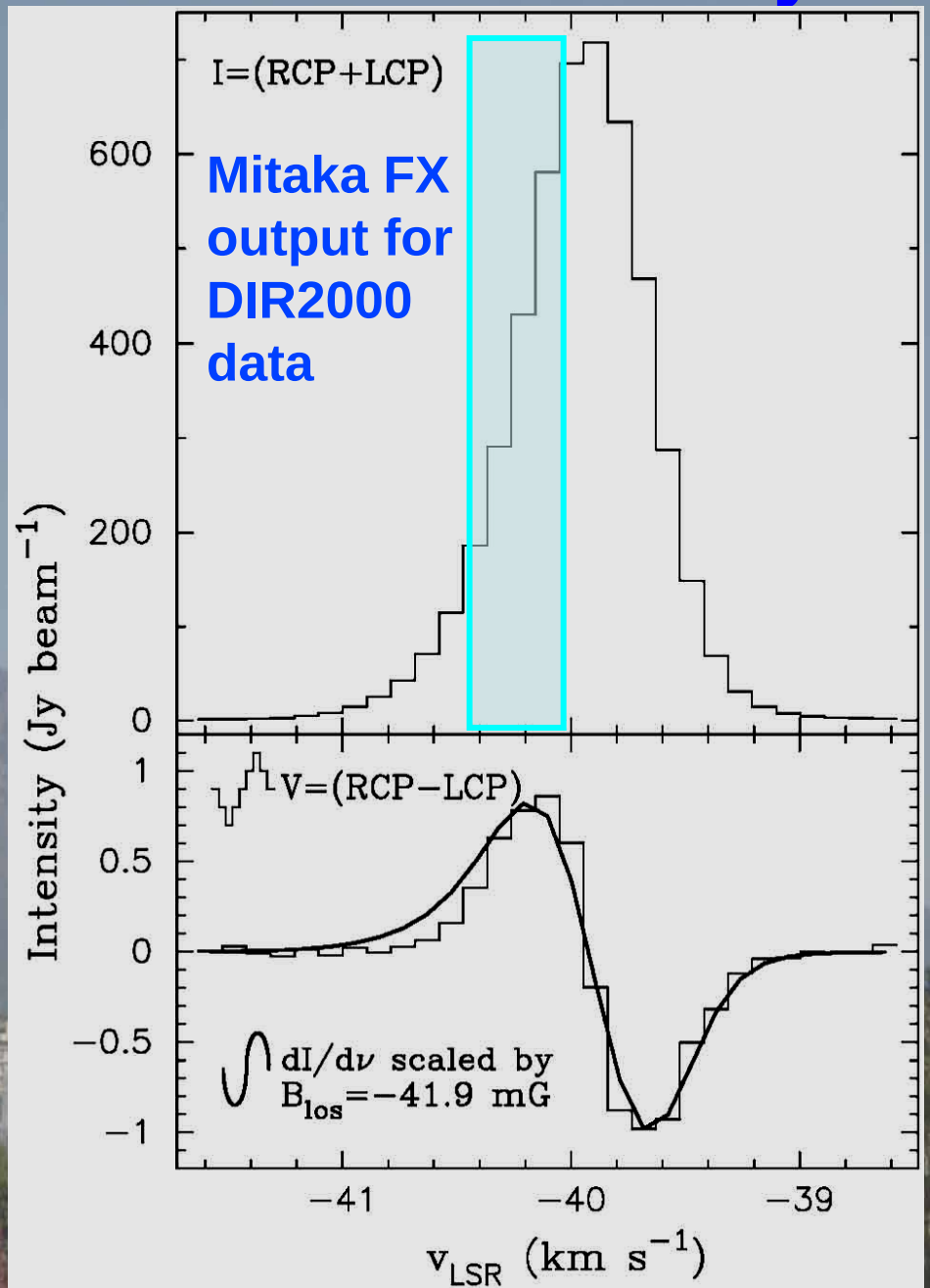


VERA/KVN single antenna beam

High velocity resolution VLBI astronomy

- Zeeman splitting of H_2O masers
  - 4 YSOs (Sarma et al. 2001, 2002)
  - S Per: evolved star (Vlemmings et al. 2001)





Development activity at Kagoshima University

- Development of a software correlator (K. Nishida)
  - Collaboration with NiCT Kashima group
  - Software digital auto-correlator
  - Software digital VLBI correlator
  - FITS conversion of correlator output

- Development of automatic pipeline for spectral-line VLBI data analysis (H. Imai)

Automatic data analysis with pipelines

- Quick and automatic process of fundamental data calibration and analysis
- Automatic creation of calibration tables for data archive
- Automatic creation of fundamental plots and reports for quick data evaluation
- Automatic imaging, source search and brightness model fitting

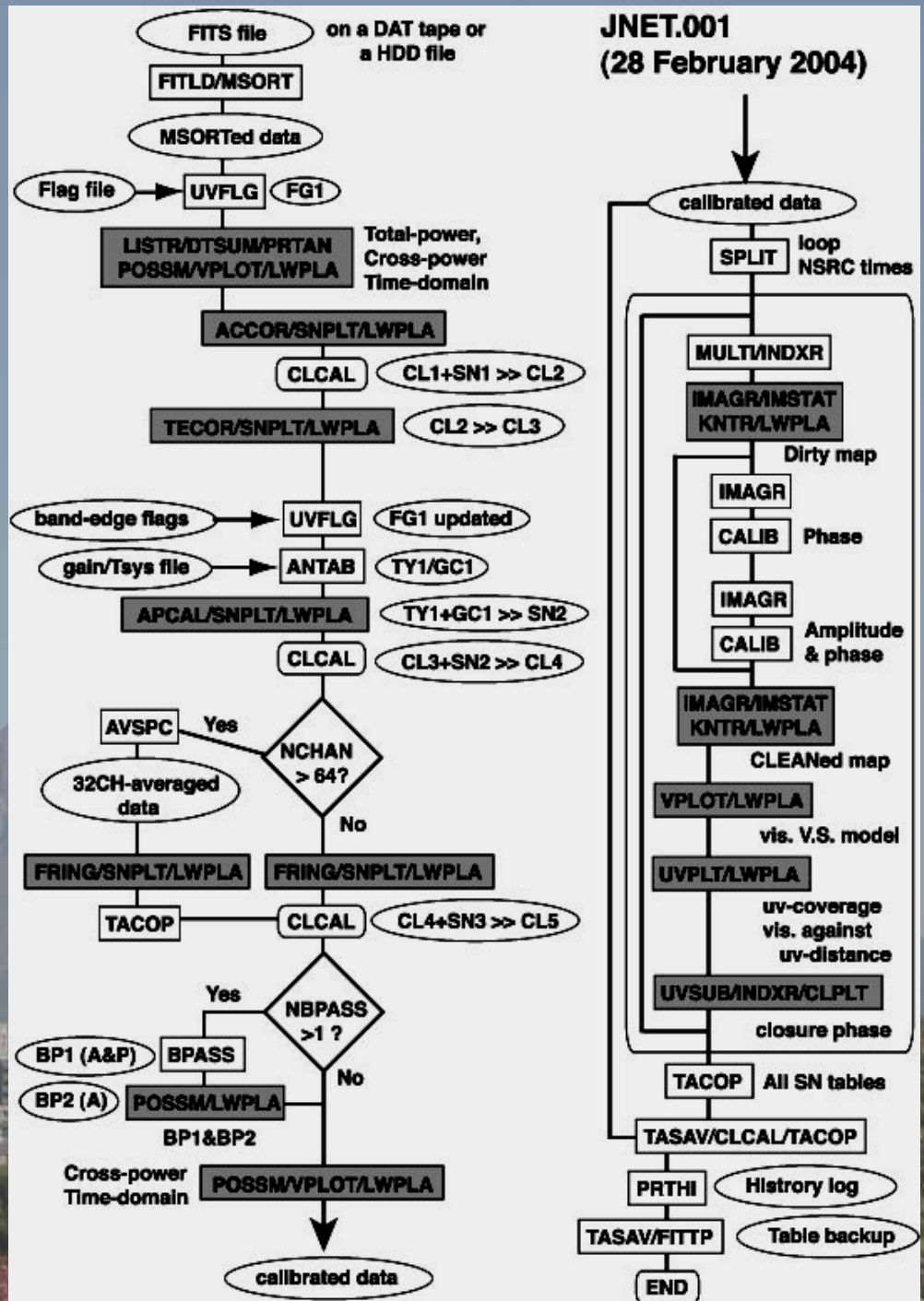
Automatic data analysis with pipelines

- Dramatically reduce man power
  for VLBI data analysis
  (1 month >>> 1 day, including other works)
- Freedom from masochistic works
- Creation of man power for
  pure astronomical actions
- Uniform and reliable data analysis
- Extension of VLBI users
- Education of VLBI beginners
  (e.g. bachelor students)

Current status of VLBI pipeline

- Working on classical AIPS (31DEC02 or later)
  - Based on an EVN pipeline script (Reynolds et al. 2002)
  - Improvement and new development for maser sources
  - Pipeline scripts for J-Net and VERA
  - JNET: Loading data to making trial images (for continuum sources)

JNET (RUN script)

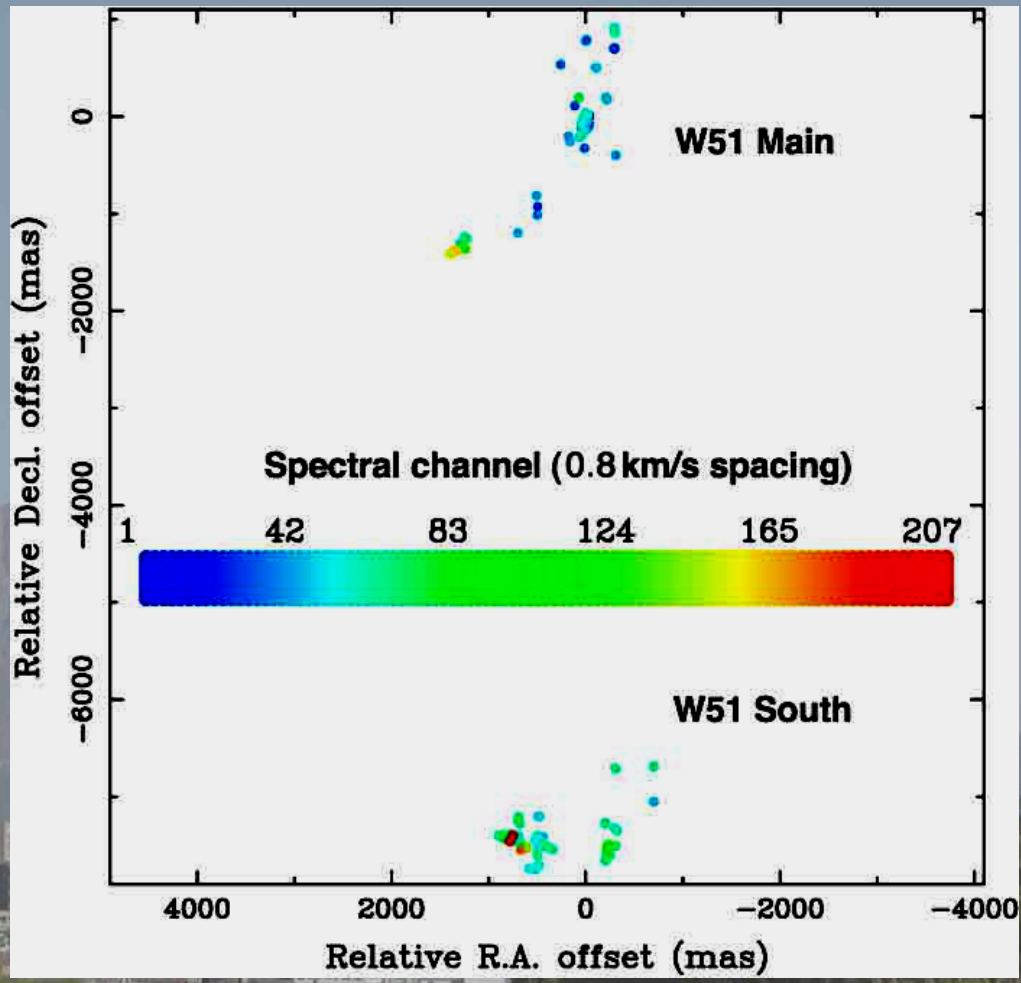


Current status of VLBI pipeline

- **Pipeline scripts for J-Net and VERA**
  - **JNET: Loading data to making trial images (for continuum sources)**
  - **MPLOT: Making several plots for supporting search for phase-reference velocity channel candidates**
  - **MCAL: Calibrating maser data with data in the phase-reference velocity channels**
  - **PKFND: Finding maser spot candidates in a huge map**
  - **MSAD: Automatic search for maser spots candidates from a wide map field and Gaussian fitting for searched spot candidates**

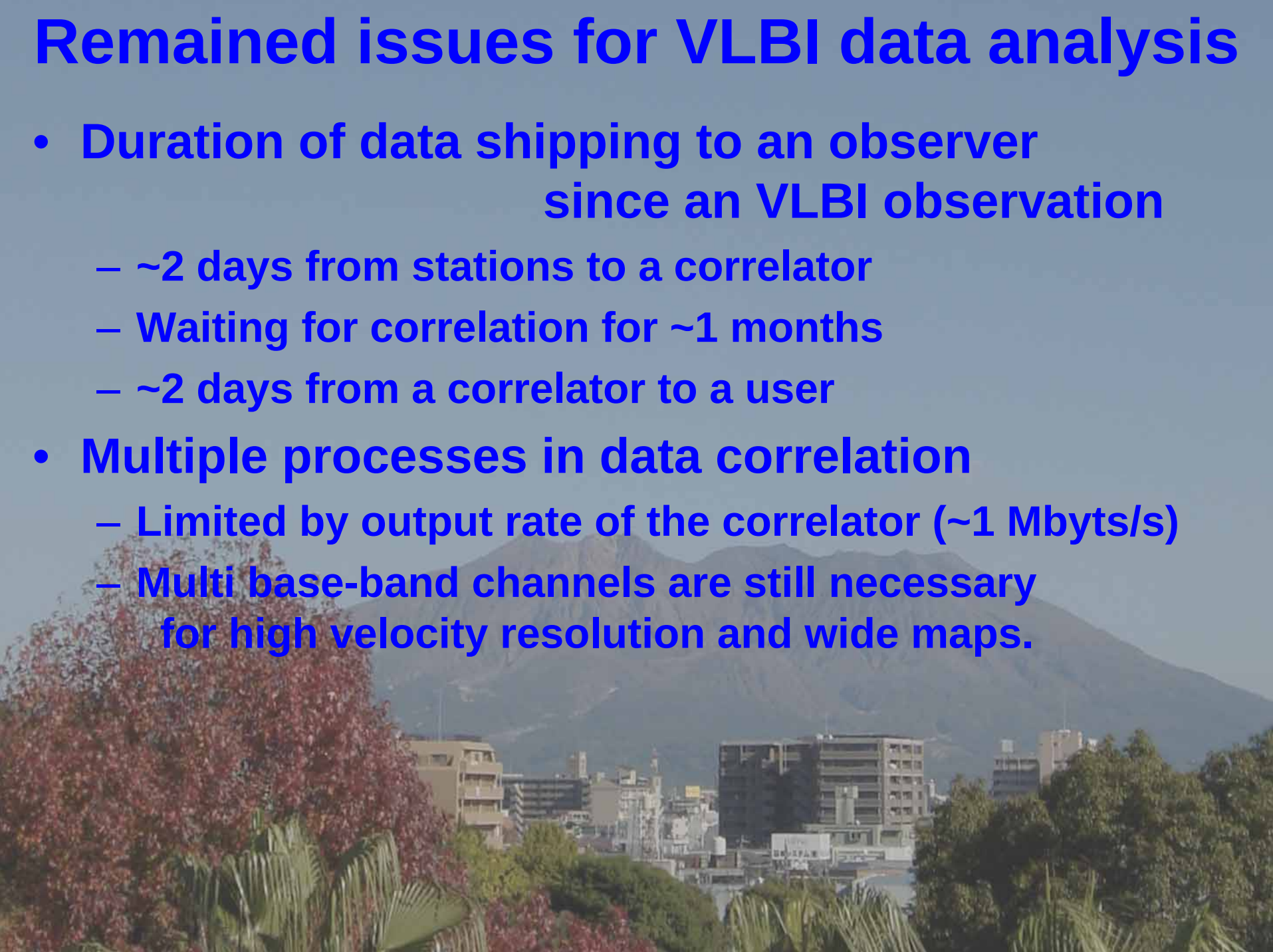
Automatic data analysis and maser spot search using VERA data

- W51M (P.I. Y. Kan-ya)
- Pipeline scripts: JNET, MPLOT, MCAL, PKFND
- ~200 spectral channels
- 6x 8000x8000-pixel cubes
- Data received on 1 May
- Map reported on 16 June
  - 5 observations analyzed
  - Other project analyzed (LkHα234 H_2O maser)
  - AIPS lecture (~1 week)
  - Lectures and preparations
  - Bachelor experiments
  - VERA VLBI operations
  - VERA single-dish observations



Remained issues for VLBI data analysis

- **Duration of data shipping to an observer since an VLBI observation**
  - **~2 days from stations to a correlator**
  - **Waiting for correlation for ~1 months**
  - **~2 days from a correlator to a user**
- **Multiple processes in data correlation**
  - **Limited by output rate of the correlator (~1 Mbyts/s)**
  - **Multi base-band channels are still necessary for high velocity resolution and wide maps.**



Remained issues for VLBI data analysis

- Automatic data flagging
  - Flagging by the observation scheduler
  - Clear flag criteria
- Image quality to find true maser spots
  - 4-station (depending on declination) maps are crucial.
- Saving huge image cubes
  - 8000x8000 pixels x 1000 velocity channels
  - Trial huge image cubes
    >>> compact cubes around true maser emission
- Astrometric correction
  - For unknown-position sources
  - For wide-field maps
  - VERA dual-beam calibration

Goals

- Quick/easy/reliable release of analyzed VLBI data
  - 0.5-day observation, real-time signal transportation
  - 0.5-day correlation, 0.1-day data transportation
  - 1.0--2.0 -day data analysis
  - Similar situation as that for
    Nobeyama Millimeter Array data / ALMA
- Enjoying VLBI astronomy
  - Increase in students/ researchers working on VLBI
  - Enterprise of new ideas in data analysis and astronomy