Ultra-wide band (16 Gbps) polarimetry using VERA

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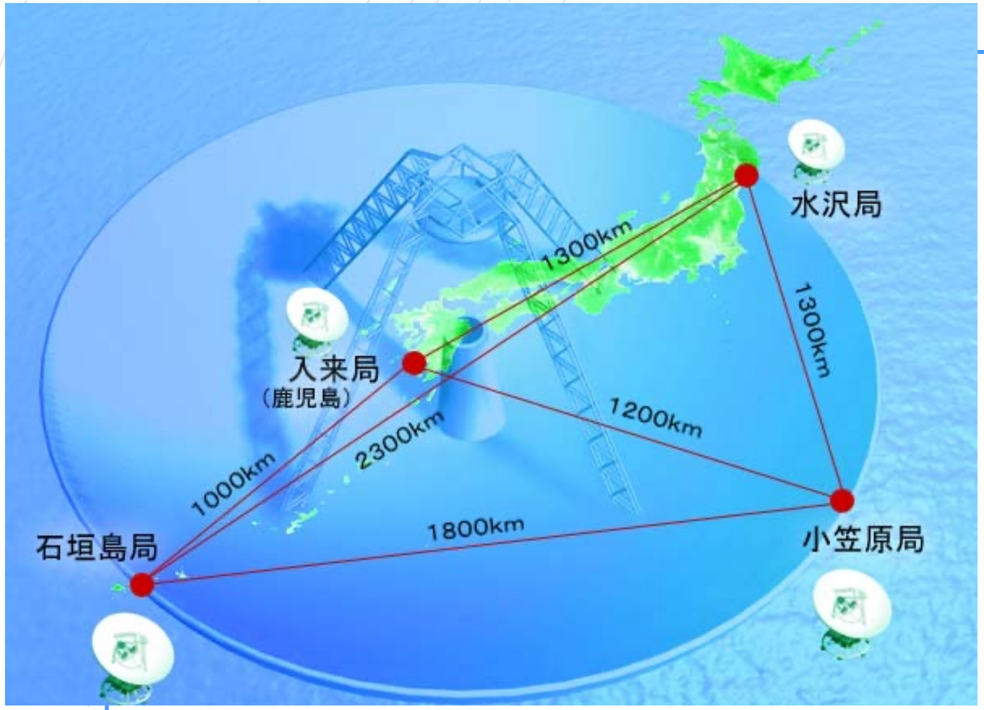
VERA - Recent Upgrade



- **Homogeneous array with four telescopes**
- **Installed RCP receivers at 22 and 43 GHz**

  => **This talk !**
- **New technology now enabled a significant increase in scientific capabilities**

  - New digital back-end (Sampler etc.)

  - Wider bandwidth data recorder (1, 4, 8, 16 Gbps)

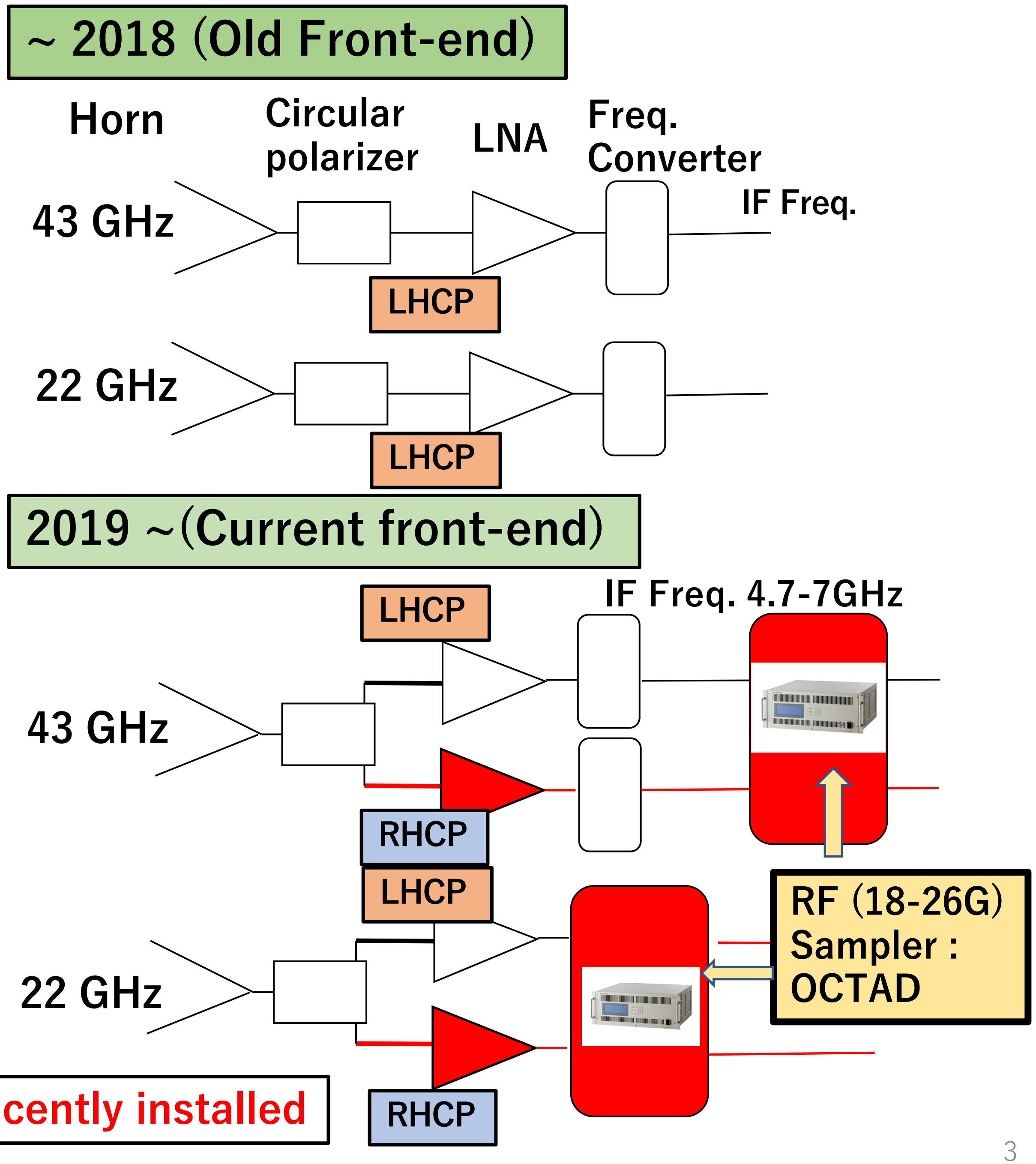
  - Software correlation

  - Better K/Q-bands low noise amplifier (LNA)

Current Status of the VERA Front-end

- 2019~ : **RHCP receivers installed at both 22/43 GHz front-ends**
  => Increase sensitivity for both continuum and line observing
  => Enable polarimetric observing

- **RF(18-26G) signal "Direct" samplers** (**OCTAD***) installed at back-ends



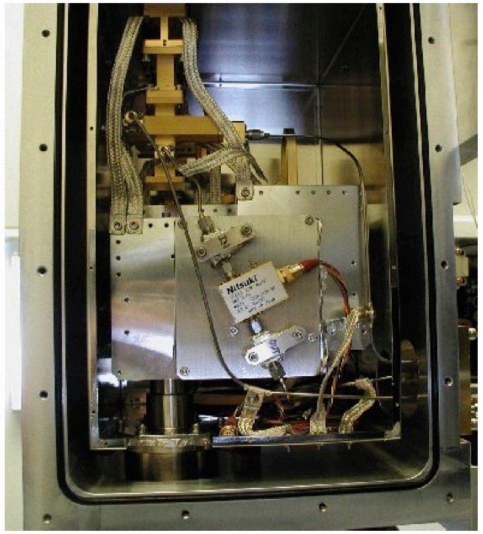
* Oyama et al. 2012 SPIE

Dual-polarization receivers (22G, 43 G) and OCTAD (22 G)

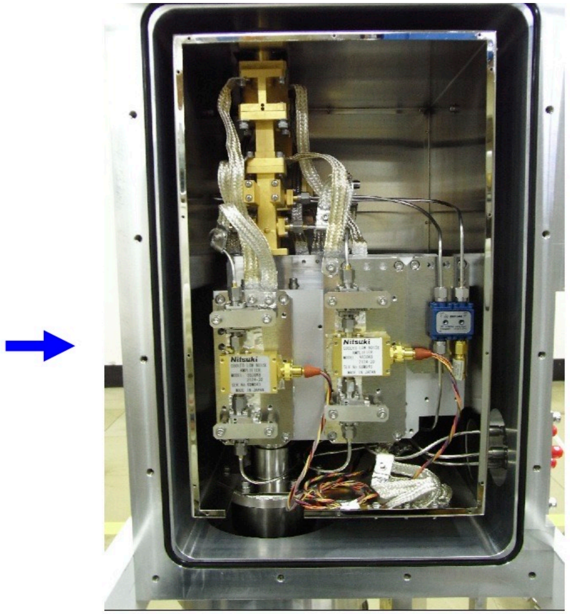
- **Dual-polarization receiver**

Single polarization LCP Receiver

Dual-polarization (LCP+RCP) Receiver



改修前

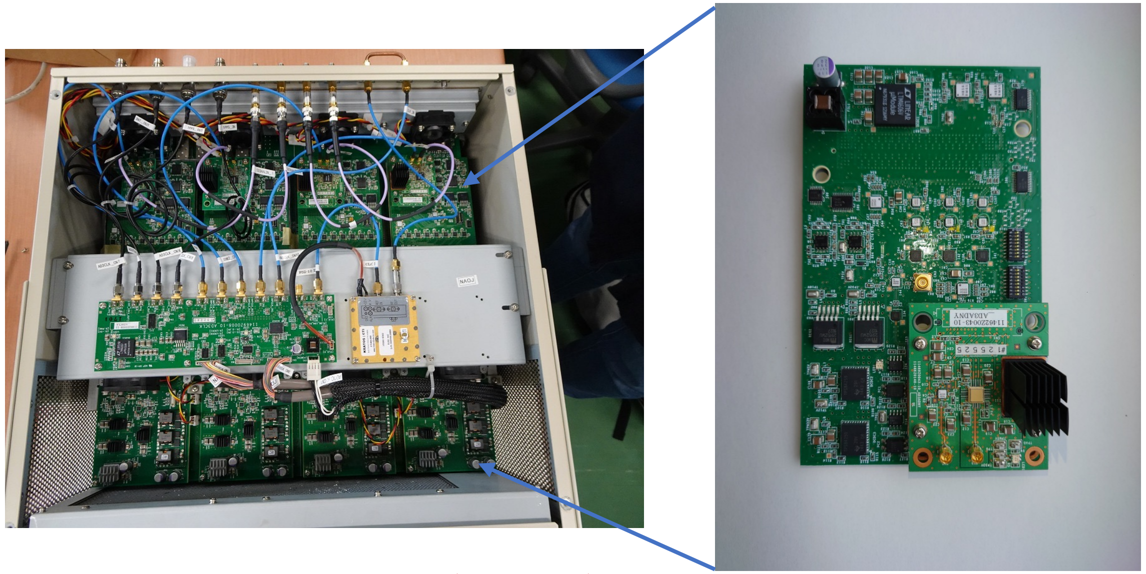


改修後

Interior Dewar **2019 ~**

- **18-26 GHz RF signal analog-to-digital sampler (OCTAD)**

  -OCTAD samples 4 analog RF(22 G) or IF(5-7G) signals of 512 MHz bandwidth (2bit)



Interior of OCTAD (4 x IF)

Performance evaluation experiments

◆ **Purposes**

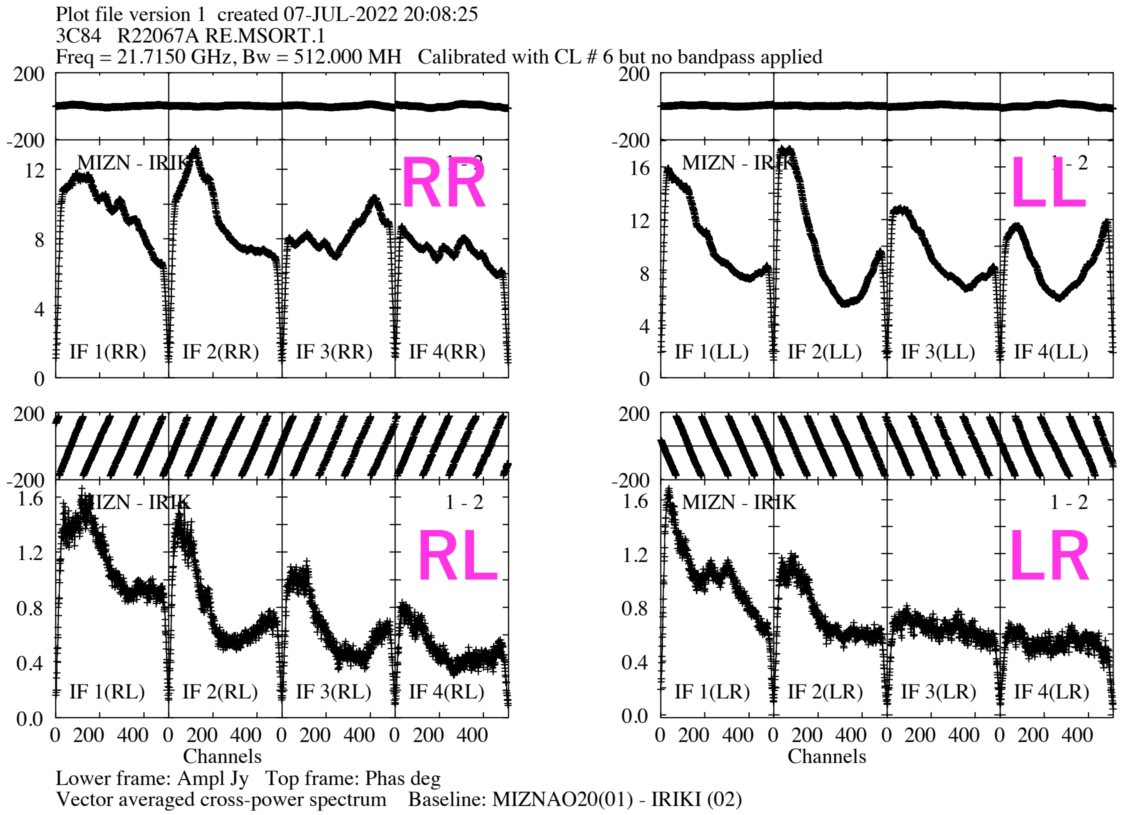
- **Obtaining the first polarized intensity map by VERA**
- **To solve D-terms (cross talk), full-track observations of as many as different sources conducted,** considering parallactic angles rotation

● **Observing specifications (March 9 and 14 2022)**

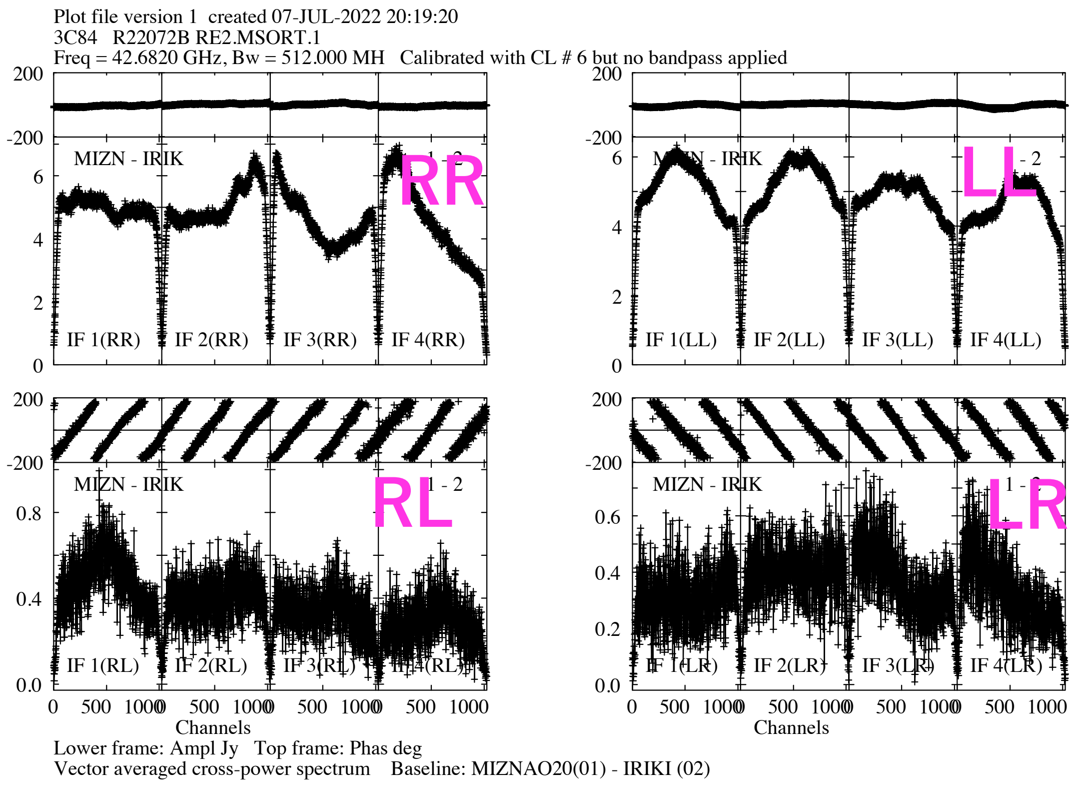
1. **2 x 19 hrs sessions at K-and Q-band each**
2. **Both continuum (3C273, OJ287, 3C84..) and spectral line (H_2O/SiO masers) sources observed**
3. **16 Gbps (4 x 512MHz x 2 pol) recording rate (2 bit)**
4. **NAOJ softcos (FX-type software correlator) correlation**

Results: possm plots (RR, LL, LR, RL) after running global FRING, 22/43 GHz, 3C84

22 GHz



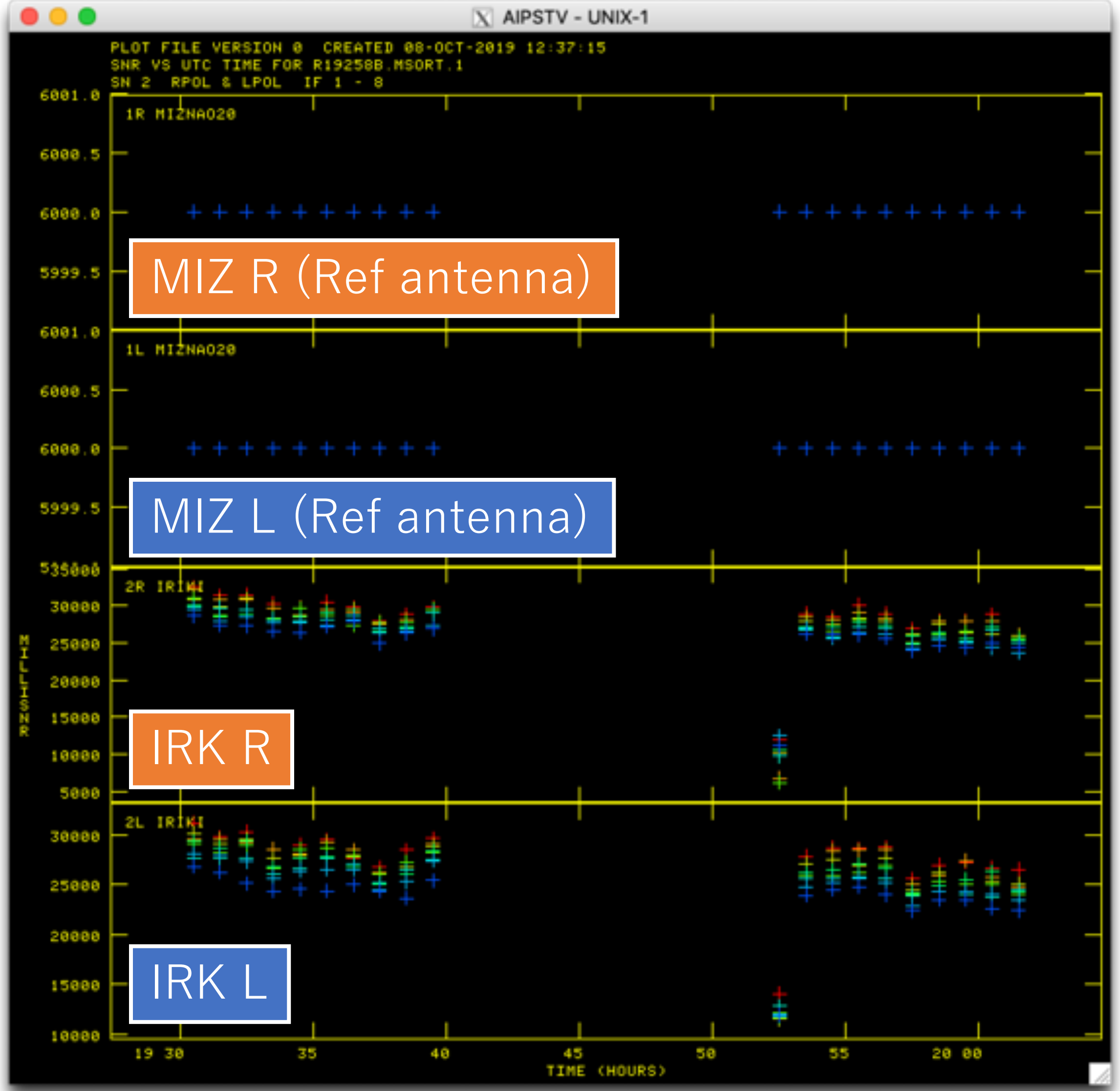
43 GHz

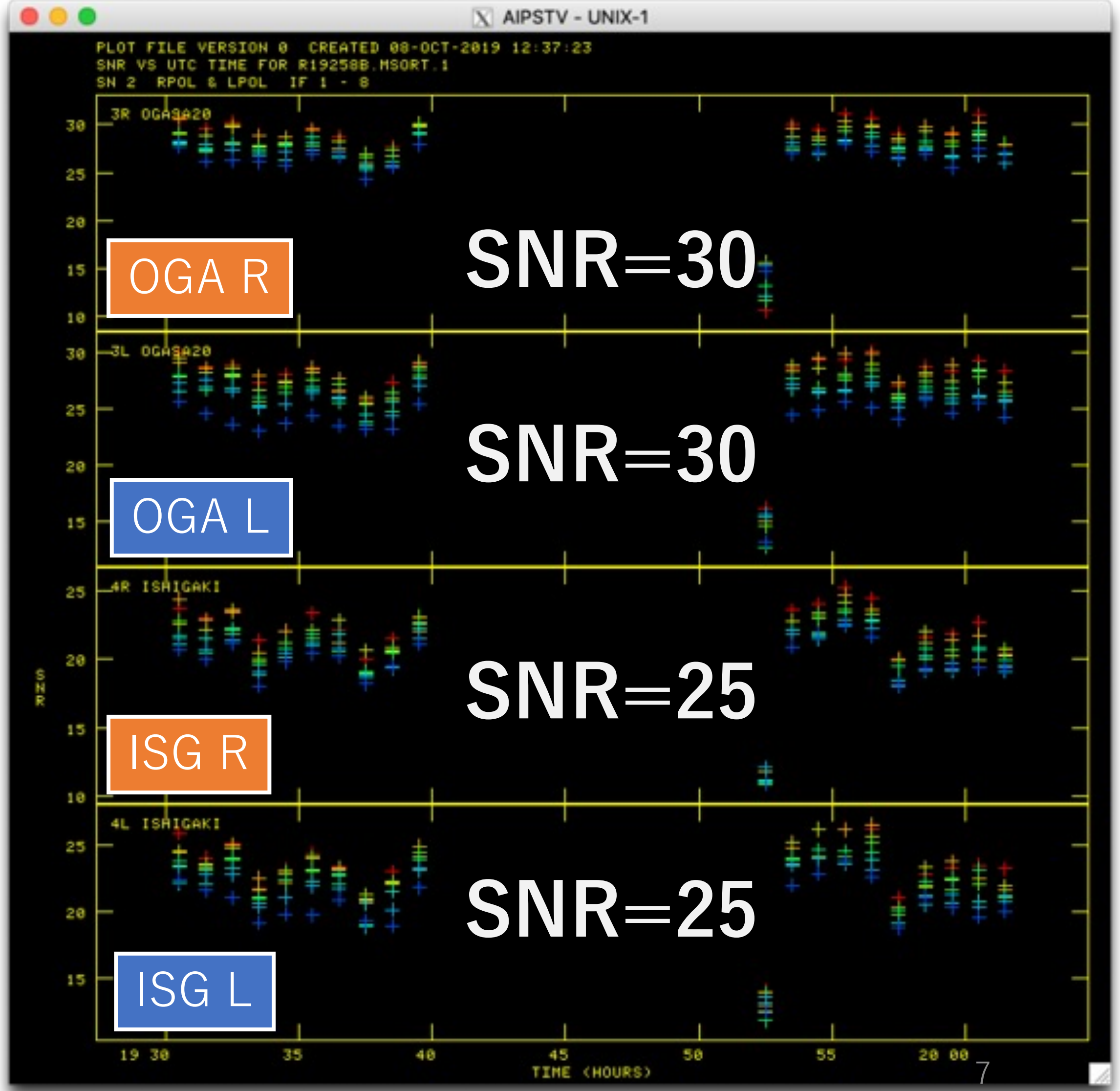


Analysis by Takamura, M.

FRING SNR: 22GHz, 3C84, 1 Gbps recording (2019)

Colors: different IFs, 16 MHz bandwidth each

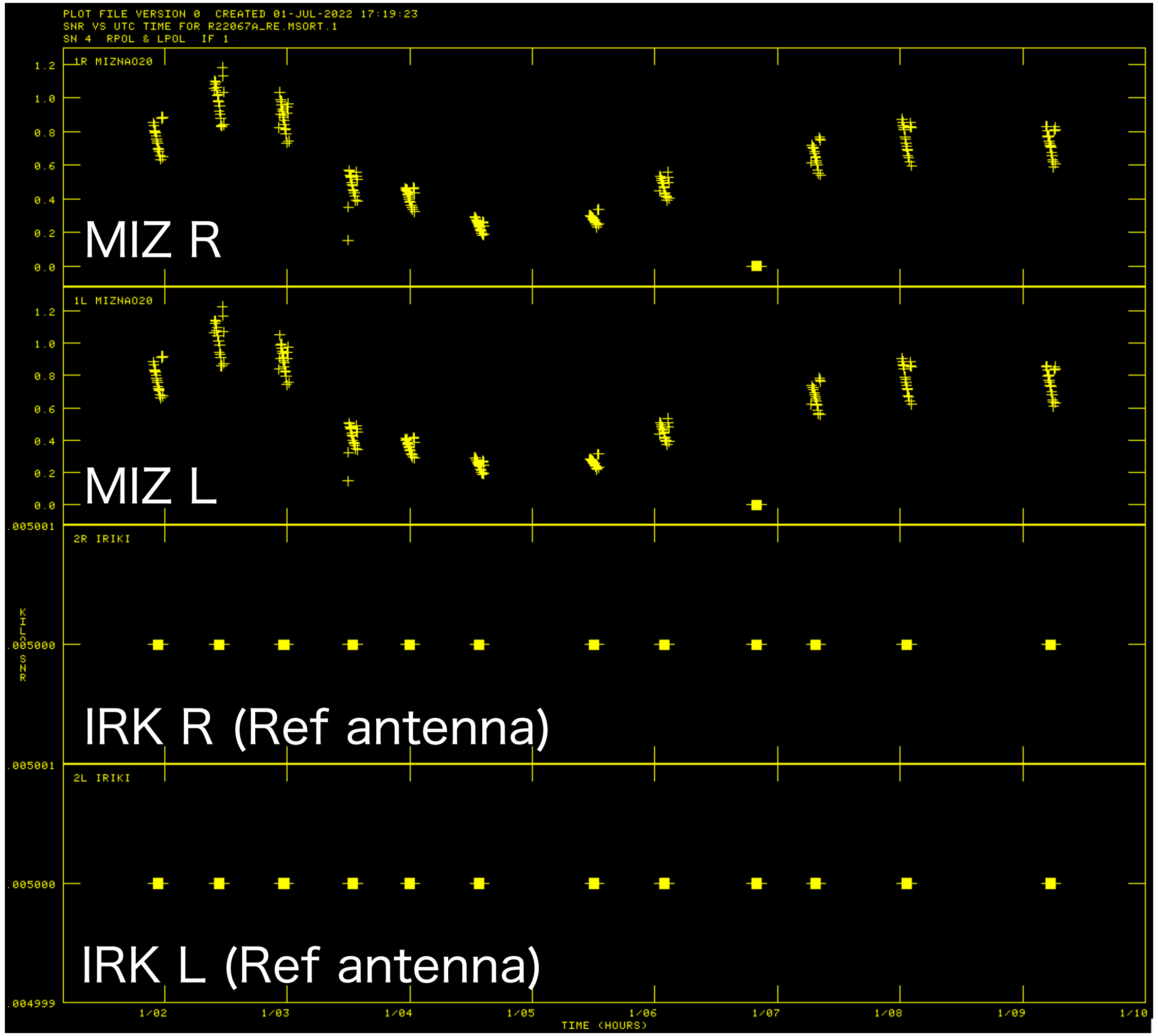


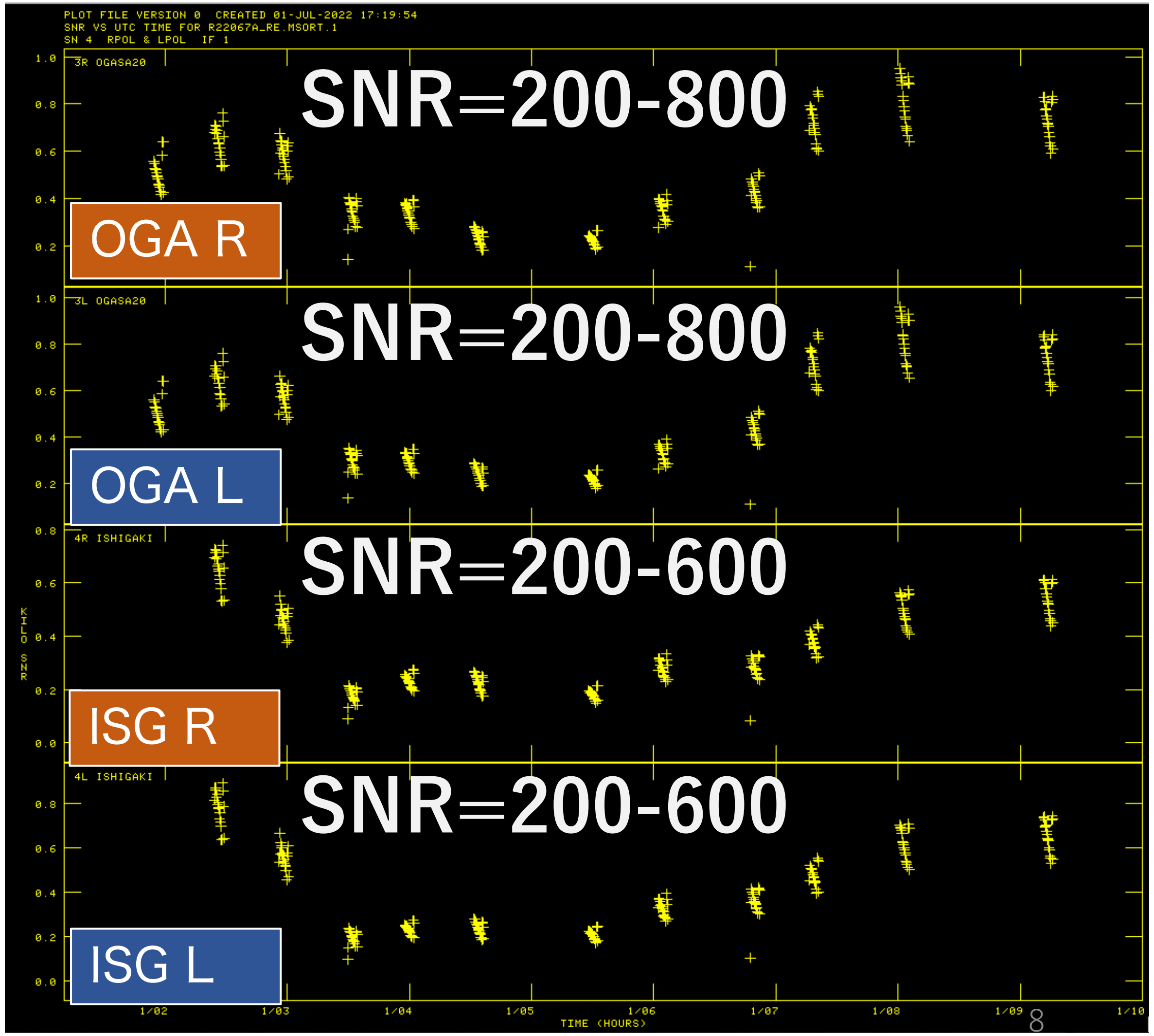


Analysis by Hada, K.

FRING SNR: 22 GHz, 3C84, 16 Gbps rec (2022)

All IFs combined : 4 x 512 MHz = 2048 MHz bandwidth
=> Sensitivity expected to increase by factor 11.3 compared to 16MHz

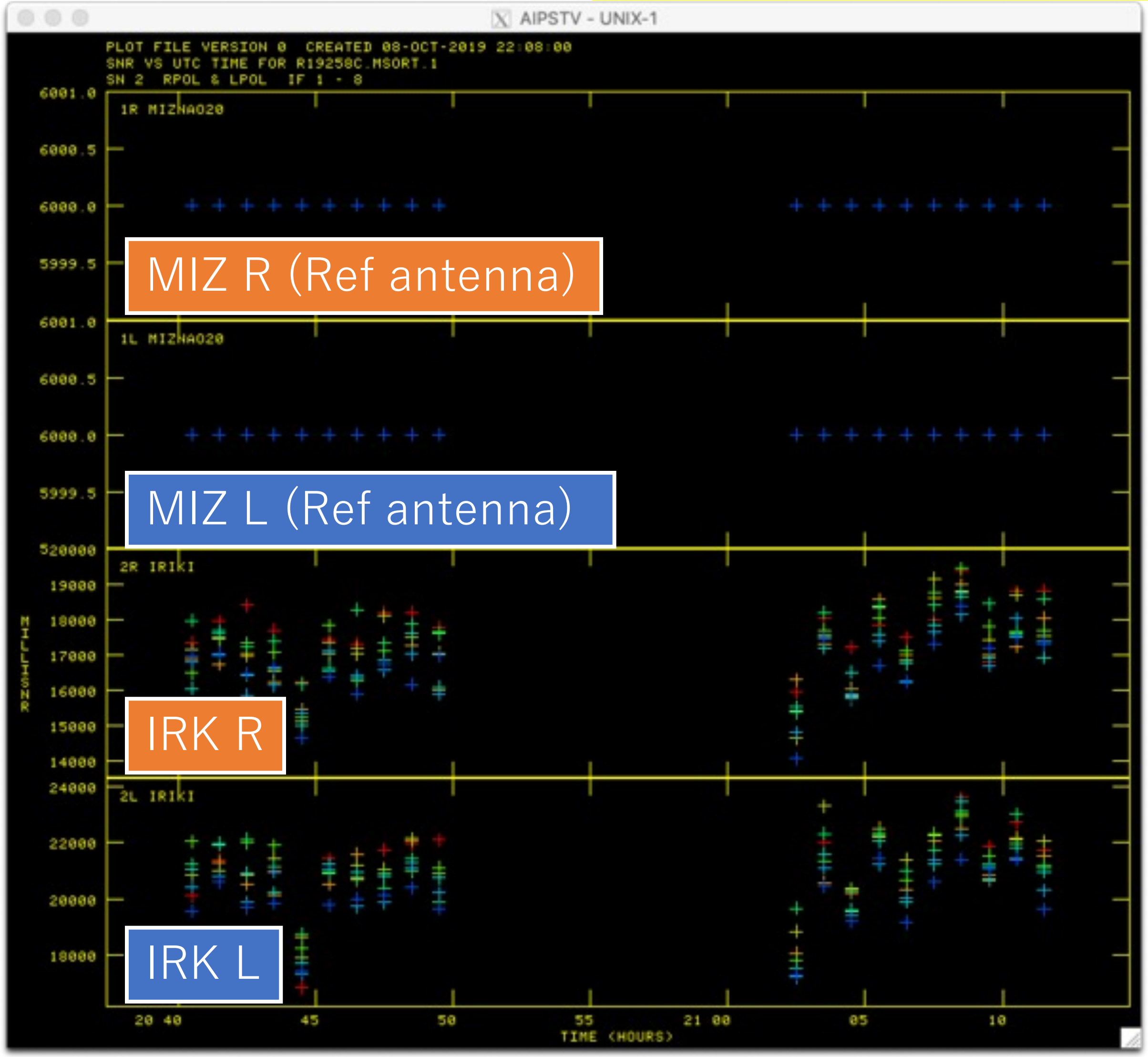


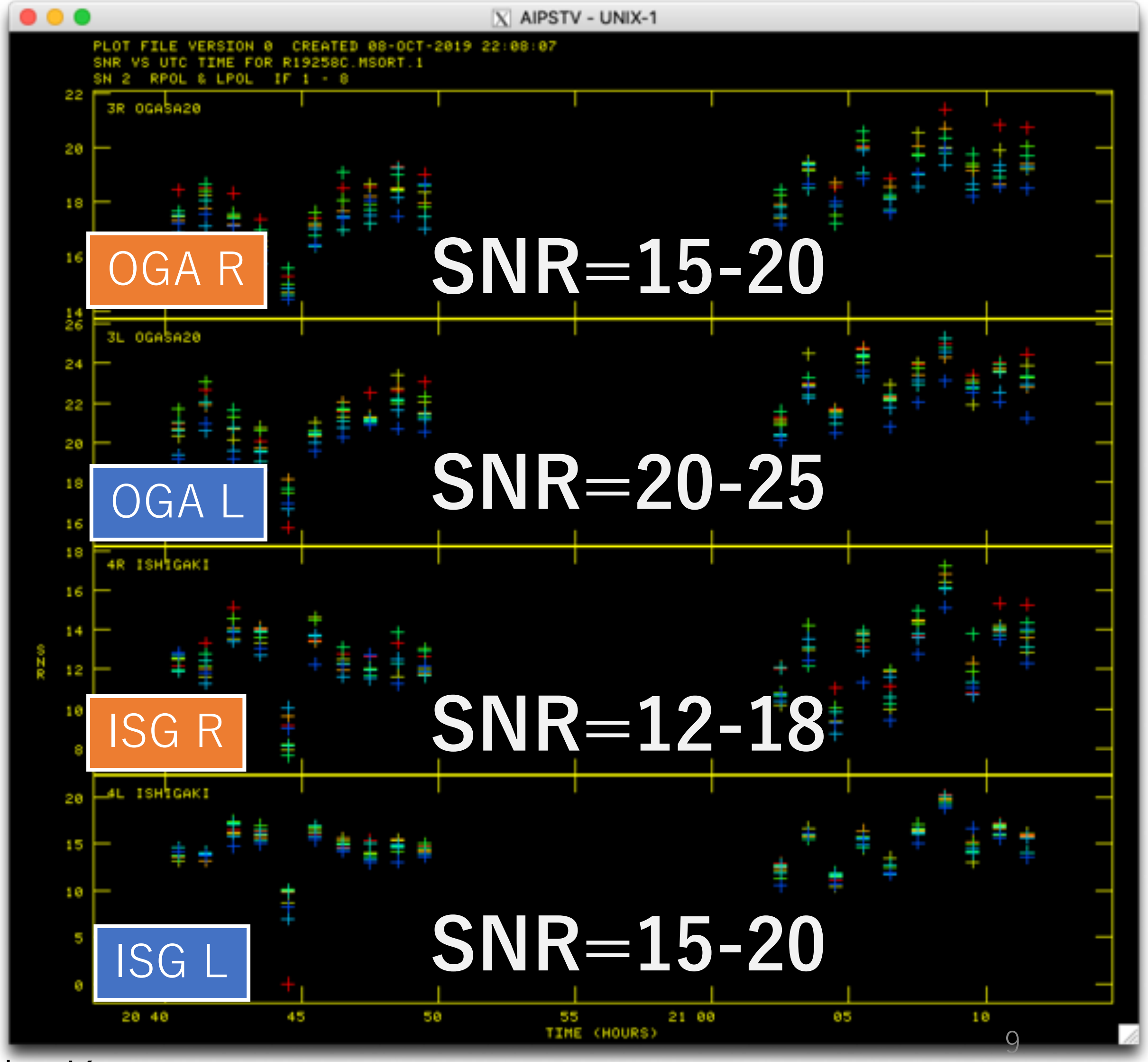


Analysis by Takamura, M.

FRING SNR: 43 GHz, 3C84, 1 Gbps (2019)

Colors: different IFs, 16 MHz bandwidth each

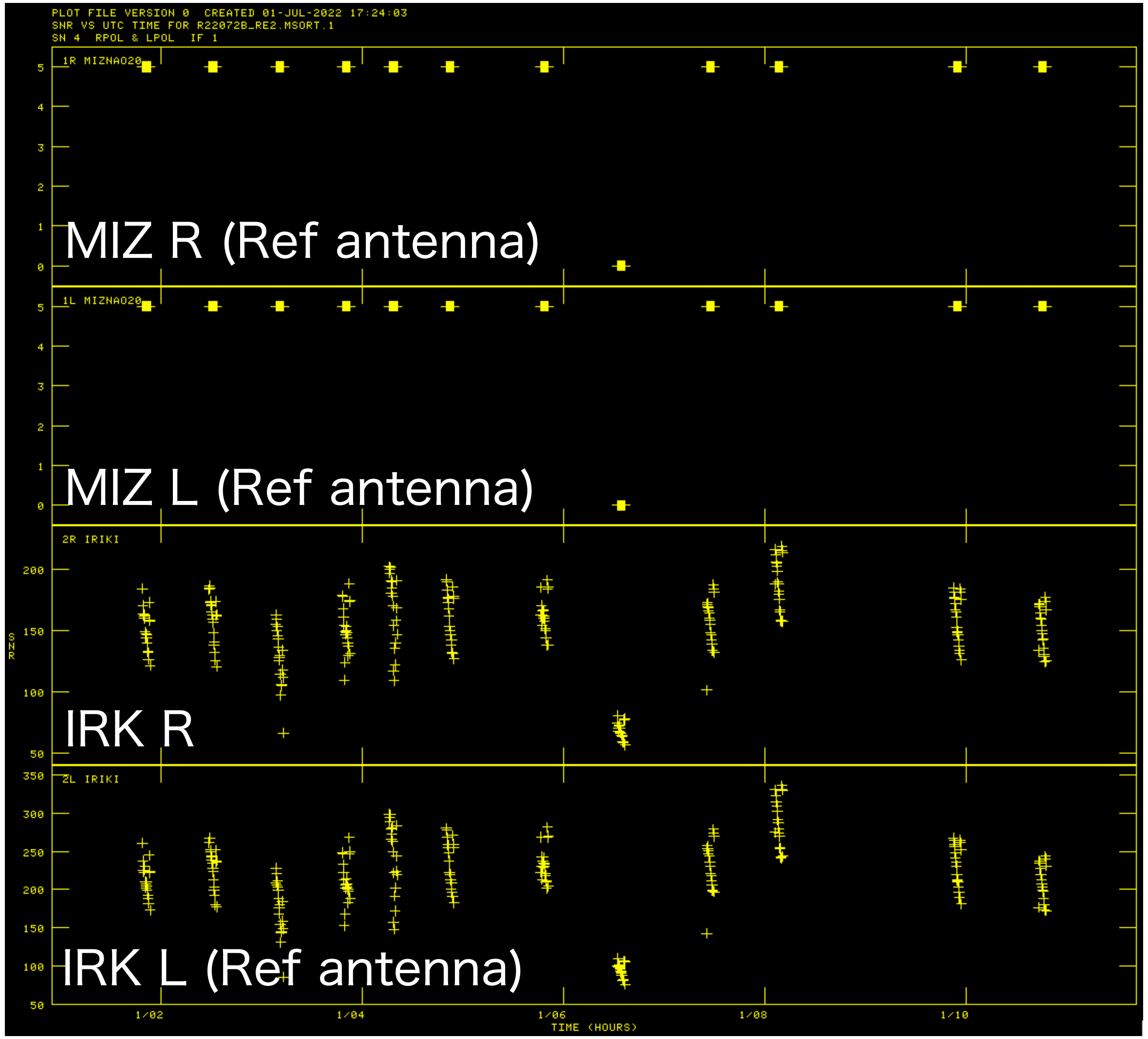


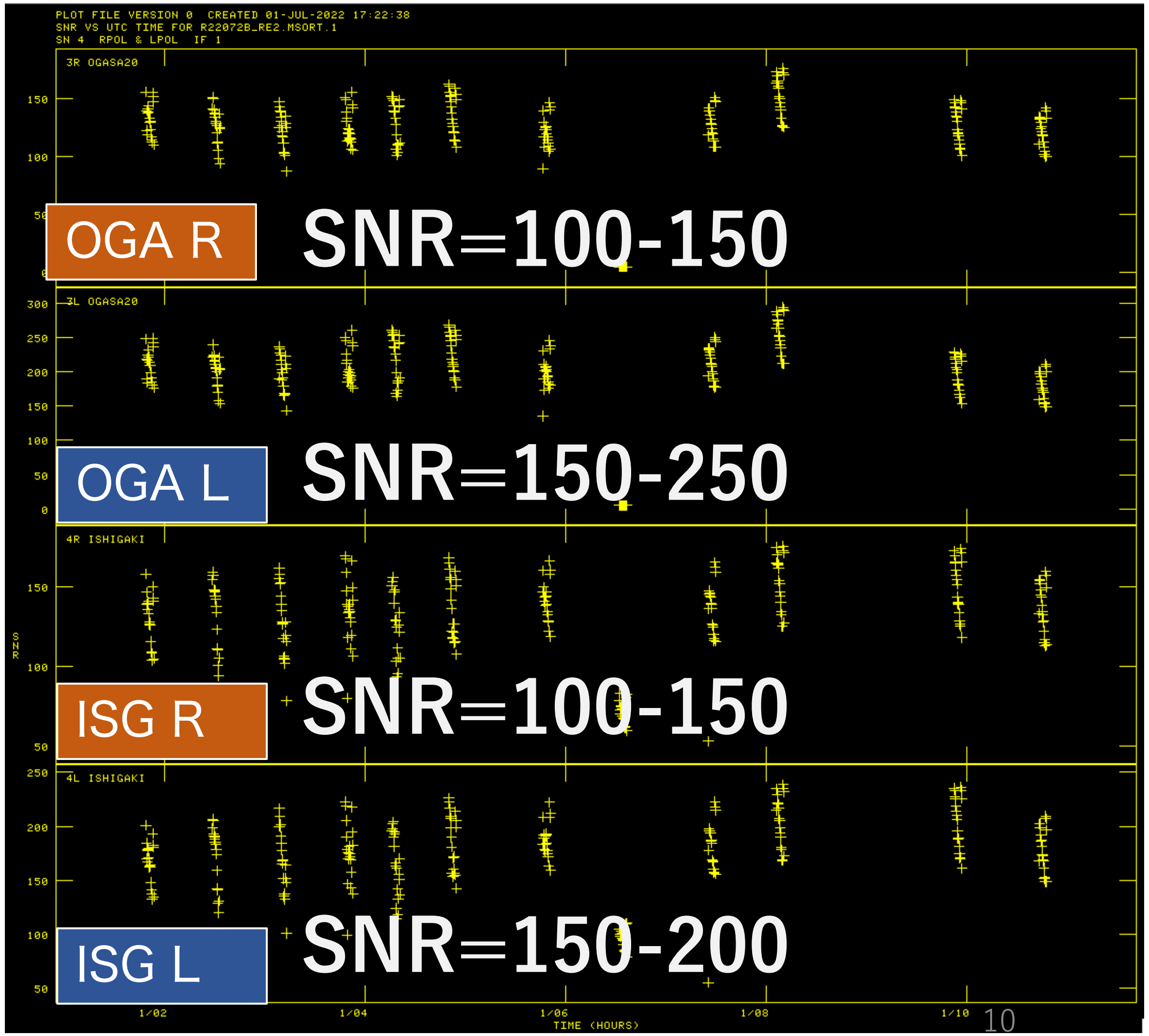


Analysis by Hada, K.

FRING SNR: 43 GHz, 3C84, 16 Gbps (2022)

Total 2048 MHz bandwidth
=> Sensitivity expected to increase by a factor 11.3 compared to 16 MHz

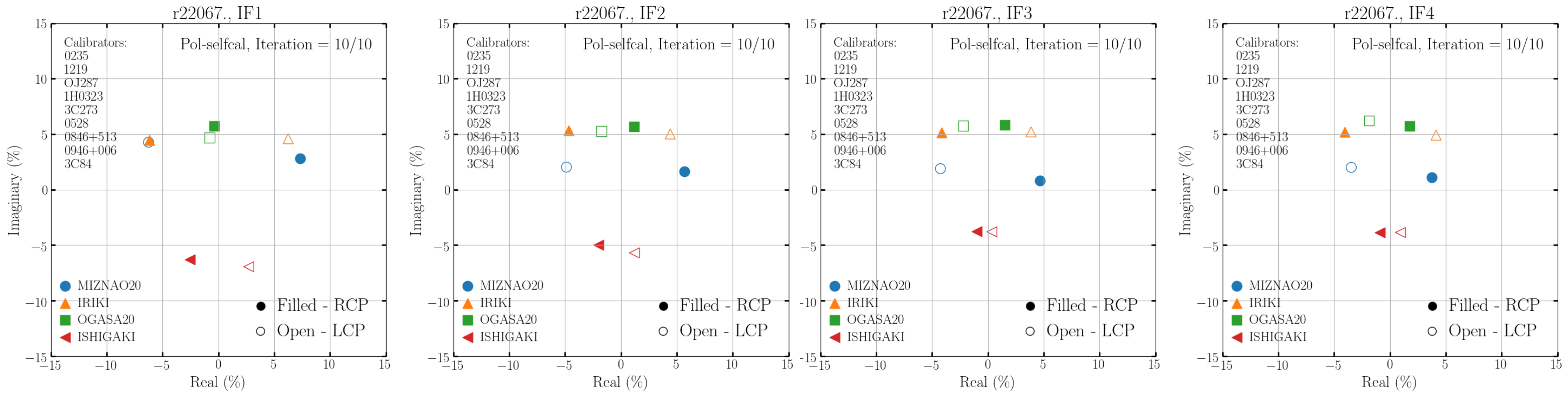




Analysis by Takamura, M.

Results : D-terms (22 GHz, 4 x 512 MHz IF)

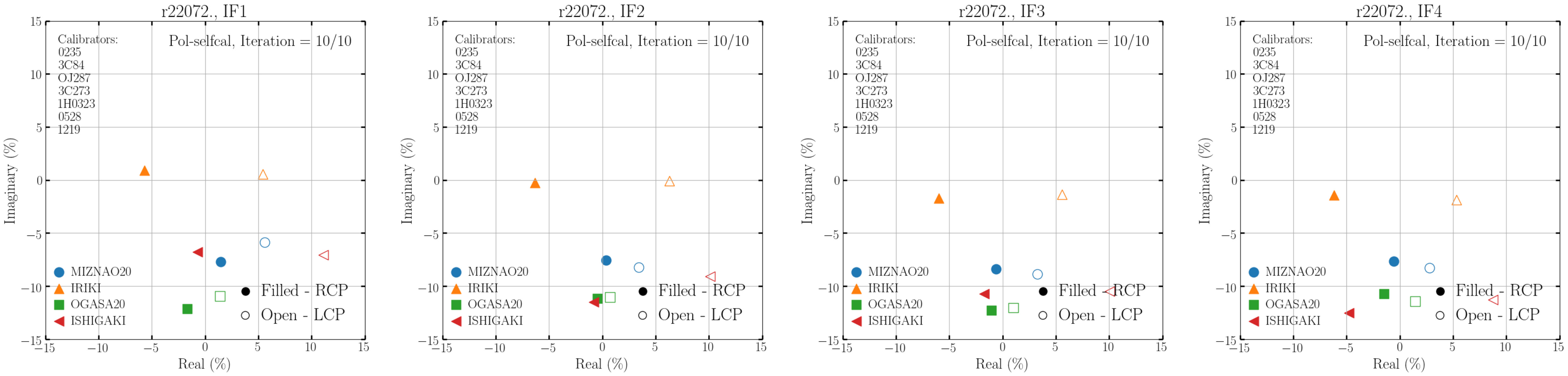
- D-terms (GPCAL) are converged to ~ 5 %



Takamura, Hada

Results : D-terms (43 GHz, 4 x 512 MHz IF)

- **D-terms (GPCAL) are converged within ~ 10%**



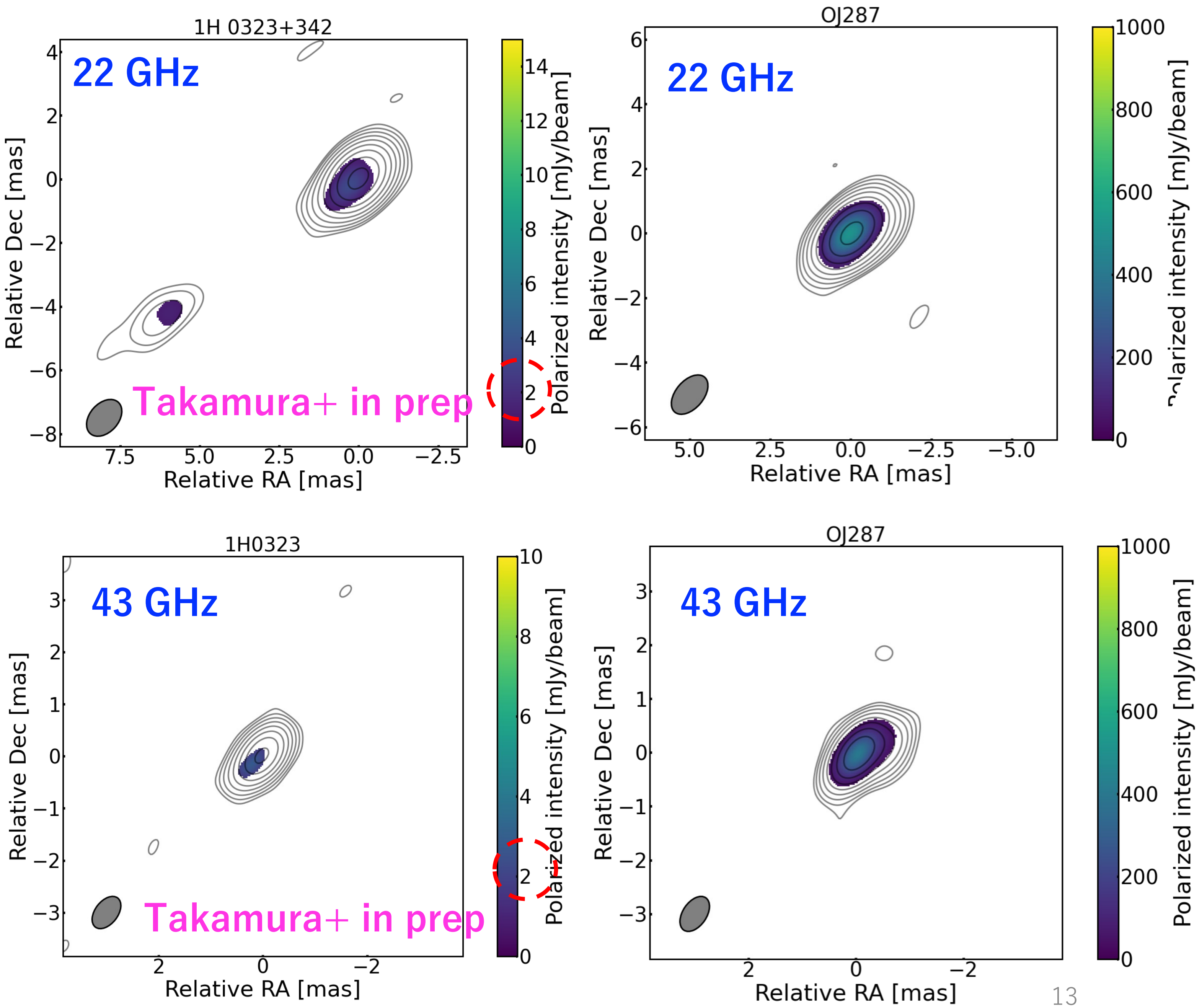
Takamura, Hada

First 16 Gbps Polarization intensity maps by VERA

- **3C 273, OJ 287**
  1H 0323+342 (NLS1)
  etc observed

- Polarized intensity of **~2 mJy/b detected in SNR of ~5**

- **EVPA** (electric-vector position angle) **calibration not executed**



Performance evaluation

- VERA is available for VLBI polarimetric imaging
  - Polarized intensity at mJy level detectable

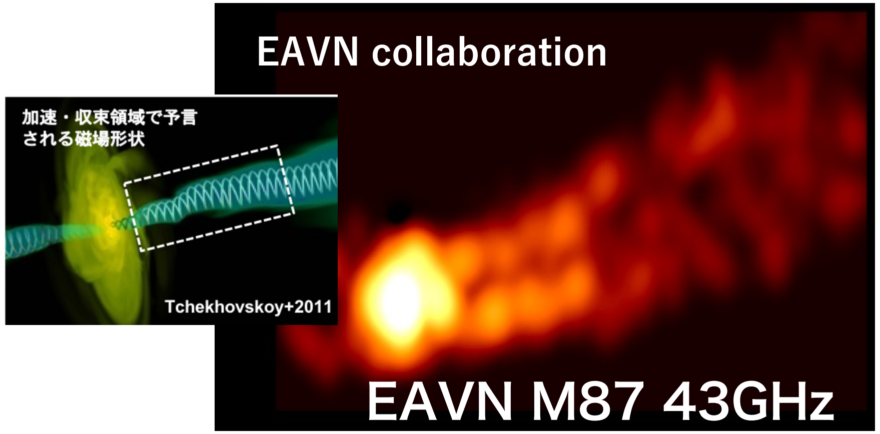
- Confirmed **that baseline sensitivities improved by 16 Gbps rec** (4 x **512 MHz = 2048 MHz**) observations, compared with 1 Gbps (8 x **16 MHz IF each**)
  >> Sensitivity increases by factor ~11.3 (= $\sqrt{2048/16}$)
  compared to 16 MHz, depending on observing conditions

- Evaluated **frequency dependency of D-terms**, based on the "**ultra-wide" band** (4 x 512 MHz = **2048 MHz**) polarimetry

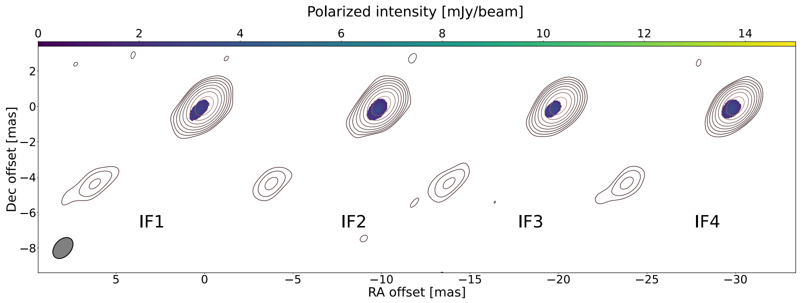
- EVPA calibration should be made, primarily by referencing to KVN (Korean VLBI Network)

What kinds of science enabled by the new capabilities?

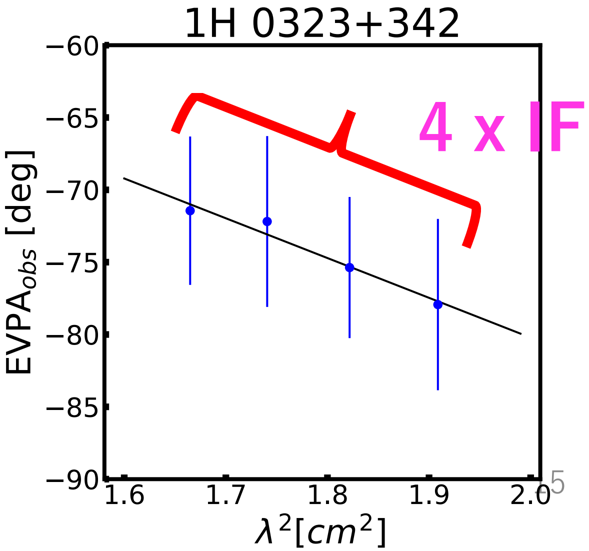
- **Larger Faraday Rotation (FR) measure in plasma jets, utilizing 2000MHz wide bandwidth - ”in-band” calibration enables FR measurement more accurate and sensitive**
- **Long-term monitoring magnetic fields to explore generation, acceleration, and convergence of jets in the vicinity of SMBH (e.g. M 87)**
- **Magnetic fields of stellar envelopes in late-type stars**



Polarized intensity of 1H0323+342



Takamura+ in prep



Future goals

■ Short-term goals

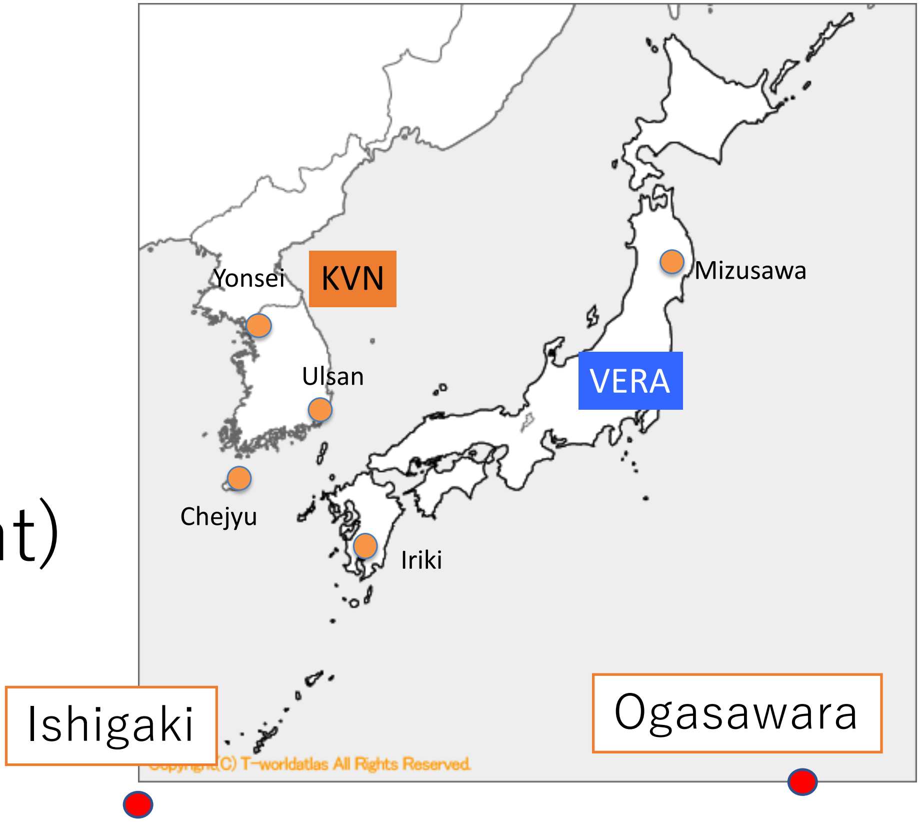
1. **First science with commissioning data（Takamura, M. in prep）**

2. **Joint polarimetric observing with Korean VLBI (KVN)**

3. Moving to **32 Gbps** (funding dependent)
   - **EAVN plans to 4 Gbps**
   - Any arrays to go beyond 16 Gbps?

KaVA (=VERA+ KVN)

KVN polarimetry operational at 22/43/86/129 GHz



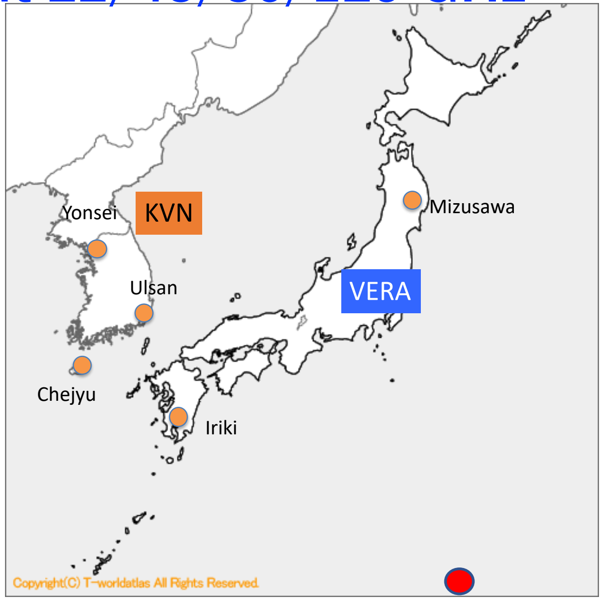
➢Long-term goals : “Global” connectivity

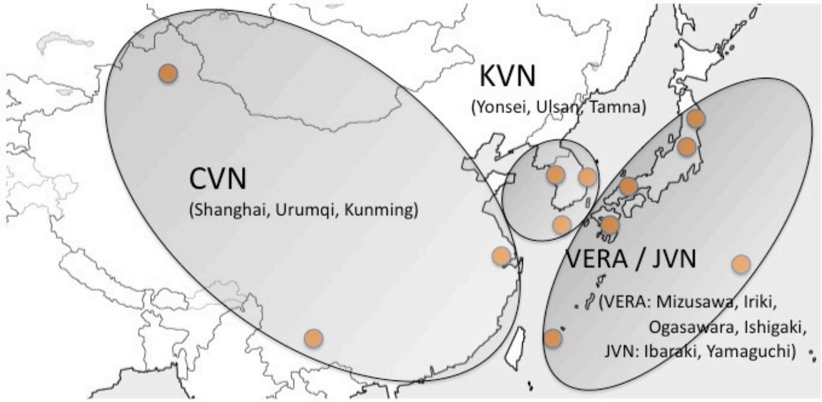
1. Efforts in expanding wide-band 22/43(/**86**) GHz VLBI polarimetry to **EVN, and Global-VLBI Alliance**

2. Complementary to EHT studies at > 230 GHz

KaVA (VERA+ KVN) → **EAVN** → **Global-VLBI Alliance**

KVN polarimetry operational at 22/43/86/129 GHz





Summary : "Ultra-wide" band VERA polarimetry

- **The first polarized intensity maps at 22/43 GHz obtained**
- **"Ultra-wide"** band (**16 Gbps**) **polarimetric observing enabled**
- **Polarized intensity at ~1 mJy/b level detectable with VERA**
- A short-term goal is to create polarimetric VLBI at higher frequencies, by connecting VERA to existing arrays, e.g. KVN or EVN
- Science cases with the given capabilities under consideration