ESTEMA and HINOTORI

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On behalf of
ESTEMA (EAVN Synthesis of Stellar Maser Animations) Team
and
HINOTORI
(Hybrid Installation Project in Nobeyama, Triple-band Oriented) Team
Two large projects for circumstellar masers
(and wider new science cases)

**ESTEMA** (KaVA Large Program)
Long term (~2 stellar pulsation cycles) intensive (every 3—4 weeks)
VLBI monitoring of circumstellar H$_2$O and SiO (J=2→1 & 1→0) masers

**HINOTORI** (Two KAKENHI Programs)
Updating NRO 45 m telescope for triple-band simultaneous VLBI observation capability
Goal of ESTEMA
visualization of dynamic stellar mass loss

SiO maser region
H₂O maser region

Shock waves in C-rich envelope (Höfner et al. 1995)

SiO $v=1 \ J=1 \rightarrow 0$ masers around TX Cam (Gonidakis et al. 2013)
How are materials on the stellar surface lifted up outward in a circumstellar envelope?

Under periodic stellar pulsation and inhomogeneous mass ejection

Anthares In CO line center (2.31 μm) (Ohnaka et al. 2017)
Our challenges 1: simultaneous mapping of SiO maser transitions with H$_2$O masers

How to collocate these maser line regions throughout stellar pulsation cycles?

$$T_{\text{envelope}} = T_\star \left( \frac{R}{R_\star} \right)^{-2/5}$$

$T_\star \approx 3000$ K, $R_\star \approx 1 - 10$ AU

Are we really watching true physical gas motions in these maser lines?

SiO maser lines
$(J \rightarrow J-1, J=1,2,3, ...; \nu \approx 43 \times J [\text{GHz}])$

Line overlap excitation by Mid-IR H$_2$O radiation
Resolving different performances in SiO masers ($v=1$&$2$ $J=1\rightarrow0$)

Contracting only clumps hosting $v=2$ SiO masers while they may exist with clumps hosting $v=1$ SiO masers?

By M. Oyadomari
HINOTORI (Hybrid Installation Project in Nobeyama, Triple-band Oriented)チームは、2017年に続き2枚目の多孔板型周波数分離フィルタを開発し、復活したTZ受信機を合わせて2019年11月8日、3つの受信器を同時に使った22GHz/43GHz/86GHz帯同時観測を実現させました。このプロジェクトは、鹿児島大学、山口大学、大阪府立大学、茨城大学、国立天文台が共同で進めています。

HINOTORI’s four-year achievement

周波数分離フィルタを用いた3バンド同時観測

上) 22GHz帯H₂Oメーザー
中央) 43GHz帯SiOメーザー
下) 86GHz帯SiOメーザー

赤色巨星R Cas

主鏡からのビーム
旧系ビーム伝送系（ビーム切替部分）

多孔板型周波数分離フィルタ

86GHz帯受信機 (TZ)
22GHz帯受信機 (H22)
43GHz帯受信機 (H40)
Commissioning of K/Q-band quasi-optics in VERA

r19052b
(W Hya and VX Sgr)

Gain loss less than 10%(<uncertainty) by 20” beam offset (in Ishigakijima)

Source-frequency phase-referencing technique should be tested.

r19052a
(S Per)

\( \text{H}_2\text{O masers} \)

\( \text{SiO masers} \)
Our challenges 2: operating “hybrid” mode

Three vex files for one-day block

<table>
<thead>
<tr>
<th>Day 1</th>
<th>Day 2</th>
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<tbody>
<tr>
<td>VERA B–beam</td>
<td>VERA B–beam</td>
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<tr>
<td>VERA A–beam + CVN</td>
<td>VERA (A–beam +4Gbps) + CVN</td>
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<tr>
<td>KVN (4 Bands)</td>
<td>KVN (4 Bands)</td>
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<tr>
<td>NRO (K&amp;Q bands)</td>
<td>NRO (K&amp;Q bands)</td>
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<tr>
<td>LST(RA+)</td>
<td>LST(RA+)</td>
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Scan pattern (for 3hr) in 2018A and B
- BL Lac or J0019+7327
- NML Cyg or BX Cam
- Target masers
- Dummy source
- J2046+4106 or J0524+7034 (references for VERA)
- J2040+4527 or J0519+7133 (delay calibrators)
- BL Lac or J0019+7327 (fringe finder)
- Continuum calibrator (for KaVA maser band and VERA astrometry)

- KaVA/EAVN: mapping H$_2$O and SiO (43 GHz) masers → should be made in one day in future
- KVN: band-to-band phase transfer calibration for SiO masers (43/86/129 GHz)
- VERA: dual-beam astrometry and wide-band recording (for SiO $\nu=3$ and $\nu=0$ $J=1\rightarrow0$ masers)

Saved to a one-day session after installation of RF/IF signal switch modules supported by AGARC
Summary

• ESTEMA: one of key science cases with EAVN in a coming decade

→ For fully understanding the physics of astronomical masers and the dynamics of stellar mass loss

• HINOTORI: one of key projects yielding W-band VLBI in East Asia (NRO 45m + KVN + JMCT + GLT+ ···)

→ With higher flexibility and higher sensitivity for extended structures than GMVA

→ Enabling new science cases in W-band VLBI
My proposals

- Why don’t you make a more intensive synergy between Mizusawa and Nobeyama in JVN and EAVN?

  **Should be a key domestic VLBI array**

- When are K/Q-band simultaneous observations regularly operated with VERA?

  **Should be done before reducing the operation time**

- Astrometry for high accuracy measurement of space-time in the local universe

  **Only masers sources for targets of astrometry?**