Status Reports on EAVN Evolved Stars Science Working Group and ESTEMA

Hiroshi Imai

(Center for General Education/All-over Galactic Astronomy Research Center, Kagoshima University)

On Behalf of EAVN Evolved Stars SWG and ESTEMA team

Members

- **EAVN Evolved Stars Science Working Group**

  Hiroshi Imai, Se-Hyung Cho, Bo Zhang, Youngjoo Yun, Dong-Hwan Yoon, Cheuhong Min, Jaeheon Kim, Haneul Yang, D.-J. Kim, Lang Cui, J. Zhou, G. Wu, Gabor Orosz, Miyako Oyadomari, Akiharu Nakagawa, Ross Burns, Richard Dodson, Maria Rioja, James Chibueze Okwe, Yuanwei, Wu, Shuangjin Xu, Tomoaki Oyama, Yoshiaki Asaki, Naoko Matsumoto

- **ESTEMA (EAVN Synthesis of Stellar Maser Animations)**

  (order appeared in the original proposal)

  Hiroshi Imai, Youngjoo Yun, Bo Zhang, Se-Hyung Cho, Dong-Hwan Yoon, Cheuhong Min, Jaeheon Kim, Haneul Yang, D.-J. Kim, Lang Cui, J. Zhou, G. Wu, Gabor Orosz, Miyako Oyadomari, Akiharu Nakagawa, Ross Burns, Richard Dodson, Maria Rioja, James Chibueze Okwe, Shuangjin Xu, Tomoaki Oyama, Yoshiaki Asaki, Jun-ichi Nakashima, Andrey M. Sobolev

Co-chars of EAVN Evolved Stars Science Working Group Co-P.I. of ESTEMA

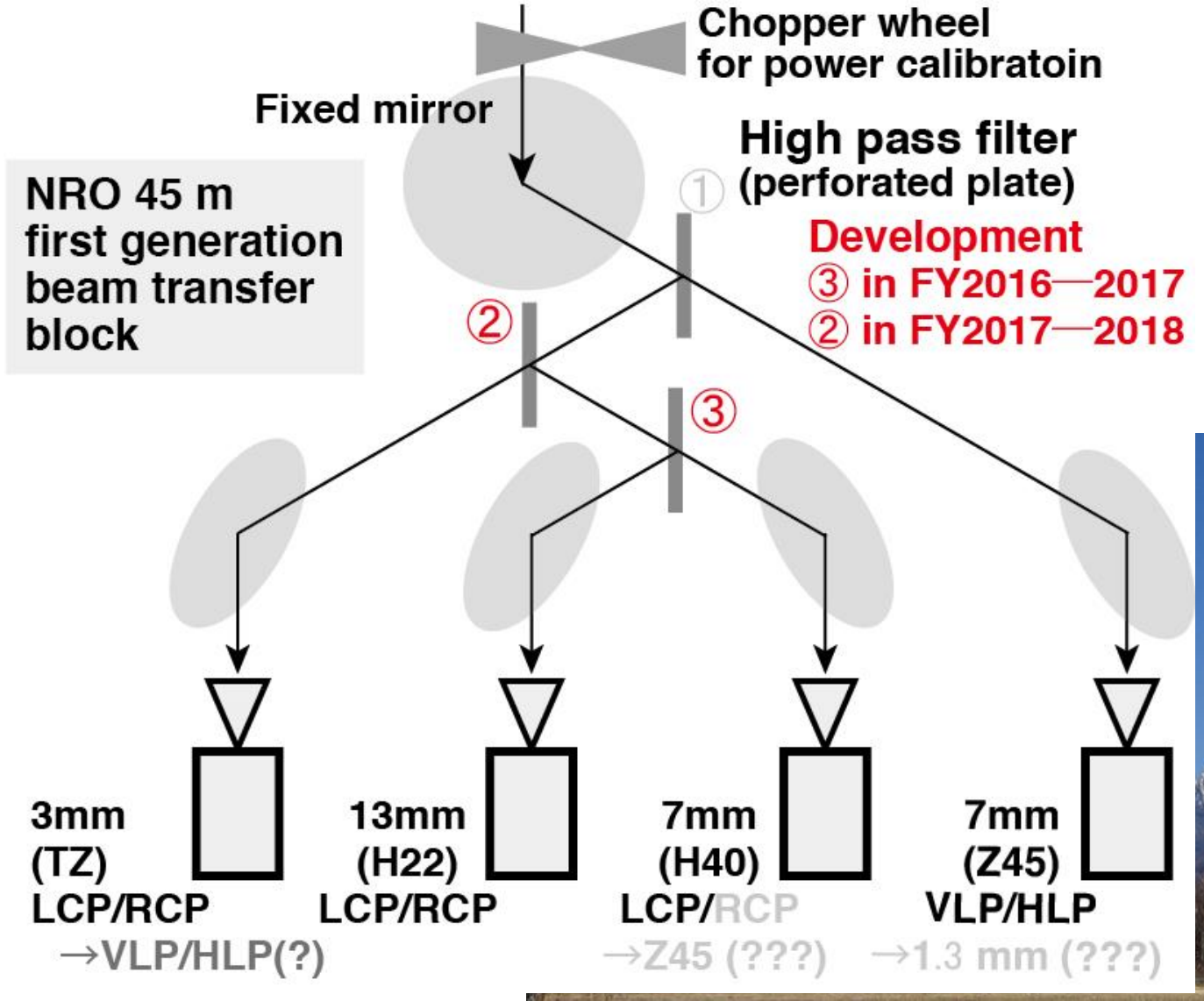
New members since last F2F meeting

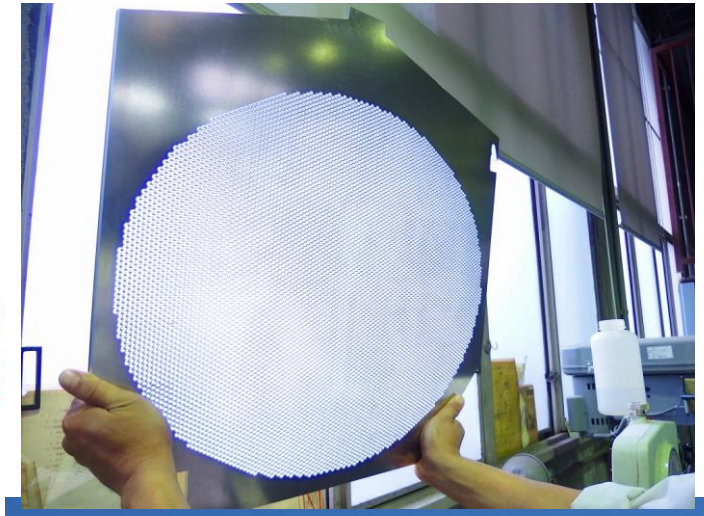
Member activities

- **Commissioning works in EAVN Evolved Stars SWG**
  - ✓EAVN imaging/animation demonstrations using SiO masers around VX Sgr and H_2O masers around RT Vir (data provided by AGN SWG)
  - ✓HINOTORI (Hybrid Installation Project in Nobeyama, Triple-band Oriented)
  - ✓Dual polarization mapping (forthcoming commissioning)
- **KaVA ESTEMA (Expanded Study on Stellar Masers)**
  - ✓2015 November—2017 March
  - ✓Snapshot imaging of ~40 stellar maser sources successfully detected
- **ESTEMA (EAVN Synthesis of Stellar Maser Animations)**
  - ✓From 2018 May
  - ✓Targeting 6 stars with different stellar pulsation period

Status of Nobeyama 45 m telescope for VLBI

HINOTORI (Hybrid Installation Project in Nobeyama, Triple-band Oriented)



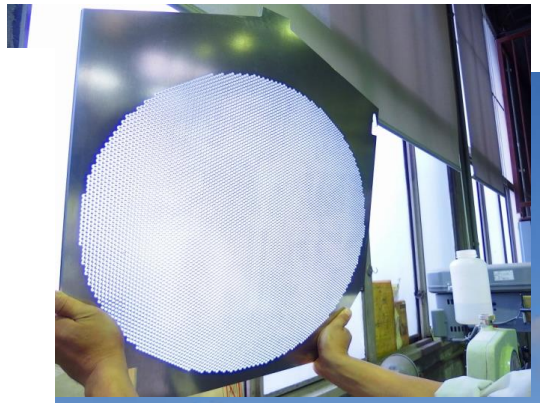


Perforated high-pass plate @Osaka Pref. Univ.

Status of Nobeyama 45 m telescope for VLBI

HINOTORI (Hybrid Installation Project in Nobeyama, Triple-band Oriented)

- Approved by NRO Development Proposal (2018—2019)
- Acceptance Review for K/Q-band simultaneous *single-dish* observation system (2018/09/13)
- TZ (W-band) receiver repair ongoing @Osaka Prefecture University
  - ✓Reinstallation planned in this autumn
- Installing new VLBI Backends
  - ✓OCTAD-V1(FY2017) & OCTAD-V2 (FY2018)
  - ✓OCTADISK2 (FY2018)
- EAVN commissioning delayed
  - ✓Commissioning in spectral lines
  - → X-corr bw 2 and 4 Gbps recording @KJCC
  - ✓Commissioning in K-band (continuum)
    →AGN SWG

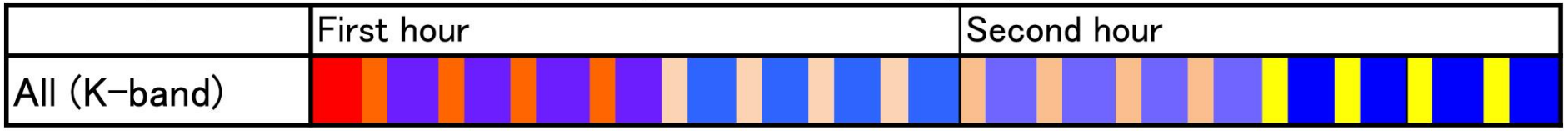


Status of KaVA ESTEMA (Expended Study on Stellar Masers)

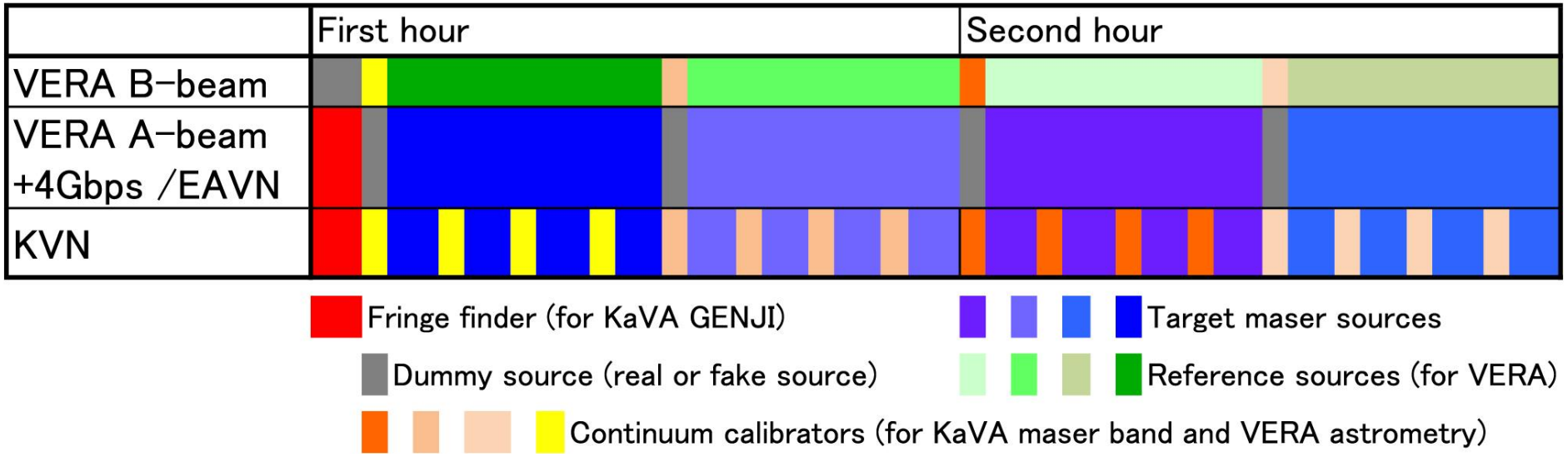
- **Image cube synthesis in progress**
  - ✓Jaeheon Kim @SHAO → Pilot manual processing
    Tests for automatic processing
  - ✓Ross Burns @JIVE → sequential data calibration processing
    Shell script development for first step procedures
  - ✓Miyako Oyadomari @Kagoshima → automatic pipeline processing
    Several issues tacking …..
- **Technical issues in data handling**
  - ✓Pipeline scripts should accept all the KaVA/EAVN data sets, but ……
    - ✓Antenna ID changing from session to session when one of telescopes missing
    - →additional manual data handling when combining KaVA and KVN data
  - ✓Full automation impossible
    - ✓Selecting phase-reference channels → Several manual trials
  - ✓Handling hybrid data set: VERA dual-beams, KVN 4 bands, ….

First 2 hr scan patterns in ESTEMA session (3—9 hr/day)

First day (with K-/Q-bands quasi-optics in VERA single-beam for SFPR)



Second day (Q-band in dual beams in VERA)



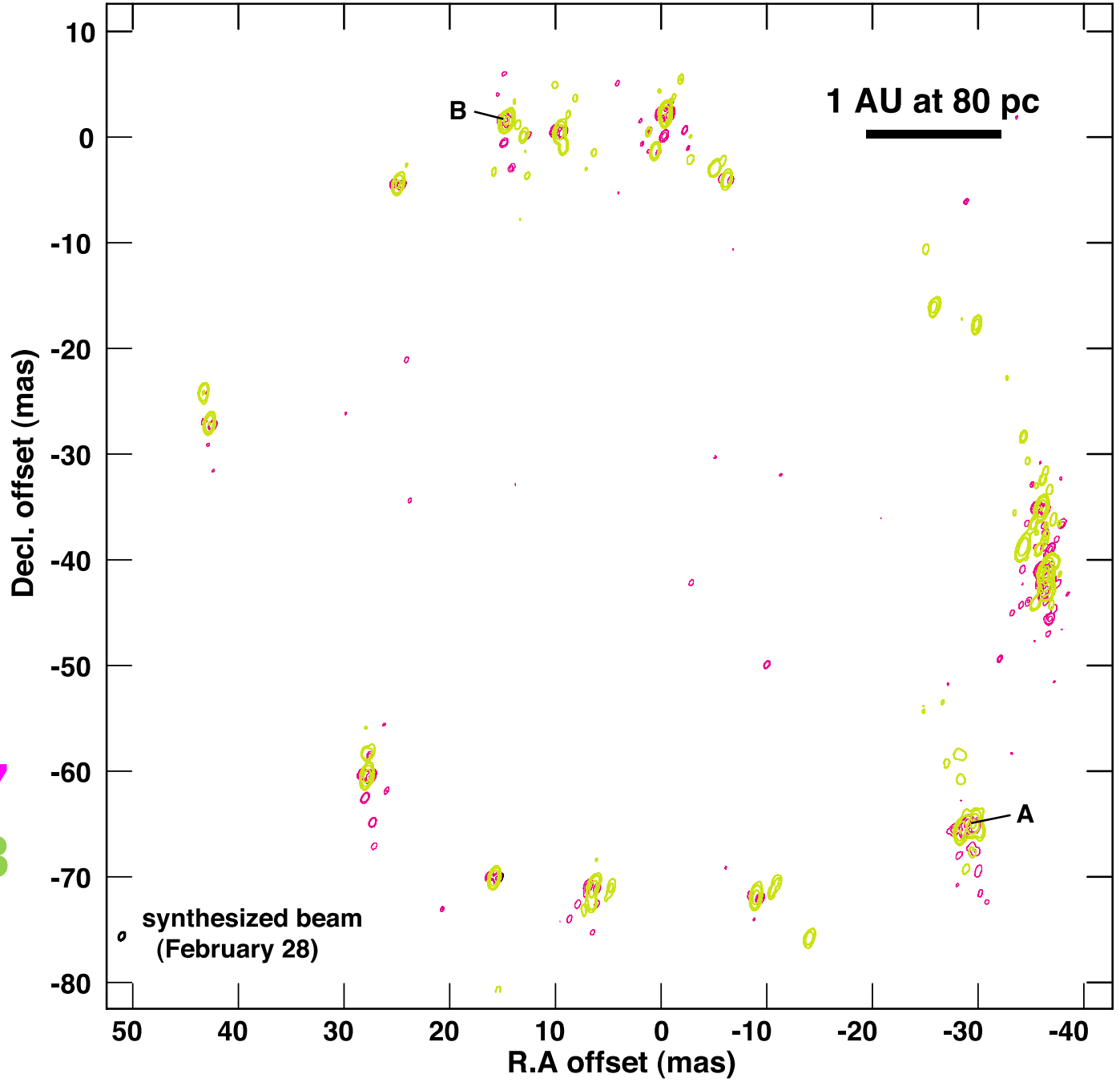
- Requested observation time (down to ~2/3) saved by adopting
  - only the first day session with 1(or 2) + 4 Gbps recording or K-/Q-bands
    - using two independent down-conversion signal generators in VERA
  - only the second day session with K-/Q-band QO with 1(or 2) + 4 Gbps
- Chinese telescopes will join each session in single band (K or Q).

Stability of circumstellar SiO masers

Intraday variability due to

- Intrinsic variability of the SiO masers
- Change in array performance

2009/02/27
2009/02/28



W Hya SiO v=2 J=1→0 masers (Imai et al. (2010)

Status of ESTEMA (EAVN Synthesis of Stellar Maser Animations)

- **Launch from 2018**
  - ✓**With 2 targets (BX Cam and NML Cyg)**
  - ✓**Starting with KaVA**
  - ✓**Adding telescopes**
    - **Tianma (2018 September?), Nanshan (2018 November?), Nobeyama (2019 March?)**
- **Current issues**
  - **More efficient VLBI operation**
    - **Pair of K/Q band sessions (for 2 days) → One-day K+Q session**
    - **K/Q-band quasi-optics in VERA (commissioning)**
    - **K/Q-band + wide-band recording → Installation of unified RF/IF switch module**
    - **K/Q & K/Q/W-band quasi-optics in NRO (see previous slide)**
  - **Development of scientific tools**
    - **eDAMS (**The Extensive Database of Astrophysical Maser Sources , Nakashima et al. 2018**)**

Target sources of ESTEMA

	Source name (order of priori	reference	Coordinates (J2000) R.A.			Decl.			*Approx. flux density (Jy/b)		Source category	Cadence
Target maser sources (order of priority)										Period (d)		
1	omicron Cet	symbiotic star	02	19	20.7921	−02	58	39.496	5 (K) / 1303 (Q)	333	A1	15 d
2	U Her	Mira	16	25	47.4520	18	53	32.660	27 (K) / 9 (Q)	406	A2	15 d
3	BX Cam	Mira	05	46	44.2900	69	58	24.200	78 (K) / 77 (Q)	486	B1	20 d
7	Y Cas	Mira	00	03	21.4700	55	40	51.800	3.9(K) / 17.2(Q)	414	B2	20 d
9	IW Hya	Mira or OH/IR	09	45	15.2400	−22	01	45.300	8 (K) / 41 (Q)	650	C2	30 d
10	NML Cyg	red supergiant	20	46	25.5444	40	6	59.383	45 (K) /3 (Q)	~1000	D2	60 d
Delay calibrator/phase-reference sources									(Jy/beam)	Sep. (deg)		
1	J0215−0222	VLBA Cal.	2	15	42.0173	−2	22	56.752	0.14 at K band	1.08	Ref. A1	
2	J1620+1736	VCS	16	20	21.8186	17	36	23.951	0.07 at K band	1.82	Ref. A2	
3	J0524+7034	Oyama in prep.	5	24	13.4334	70	34	52.906	0.16 at Q-band	1.99	Ref. B1	
7	J2353+5518	rfc_2017b	23	53	42.2997	55	18	40.666	0.24 at X band	1.42	Ref. B2	
9	J0921−2618	VLBA Cal.	9	21	29.3539	−26	18	43.386	1.22 at X band	6.91	Ref. C2	
10	J2046+4106	Zhang et al. 2012	20	46	21.8414	41	6	1.107	0.017 at Q-band	1.00	Ref. D2	

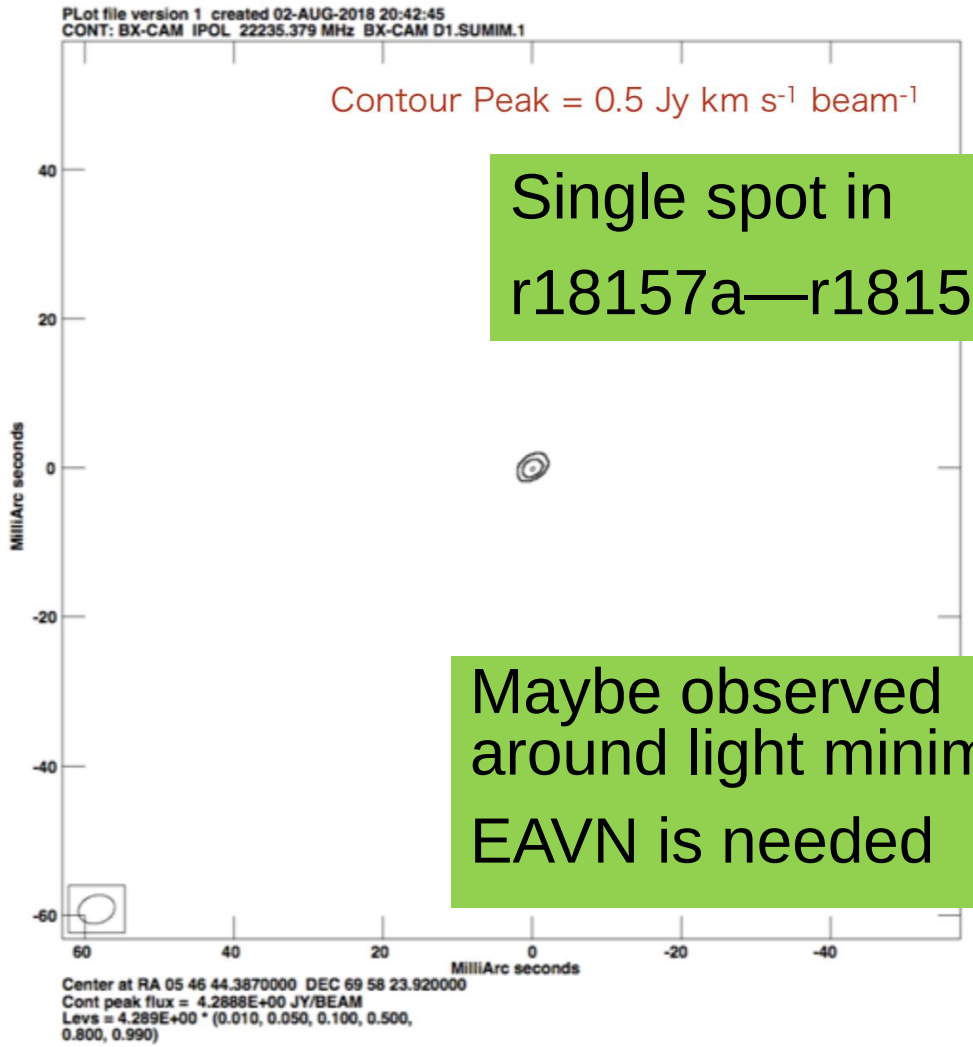
~550 hours/yr, ~2600 hours in total, observable in 24 hours

Note: Most famous sources monitored in KVN KSP

First output of ESTEMA (EAVN synthesis of Stellar Maser Animations)

H_2O masers around BX Cam

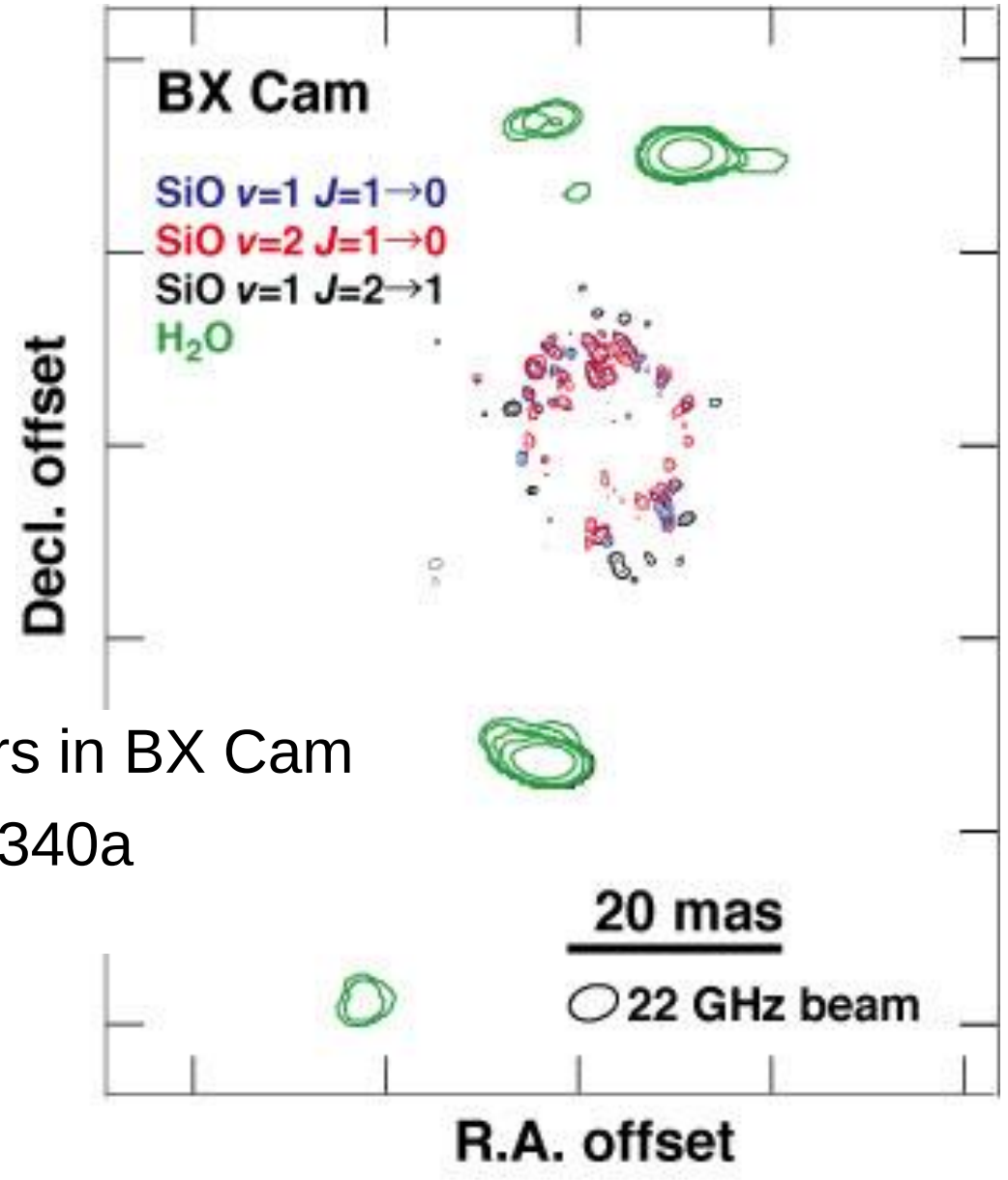
in r18144a-r18145a (ESTEMA)



Single spot in r18157a—r18158a

Maybe observed around light minimum

EAVN is needed

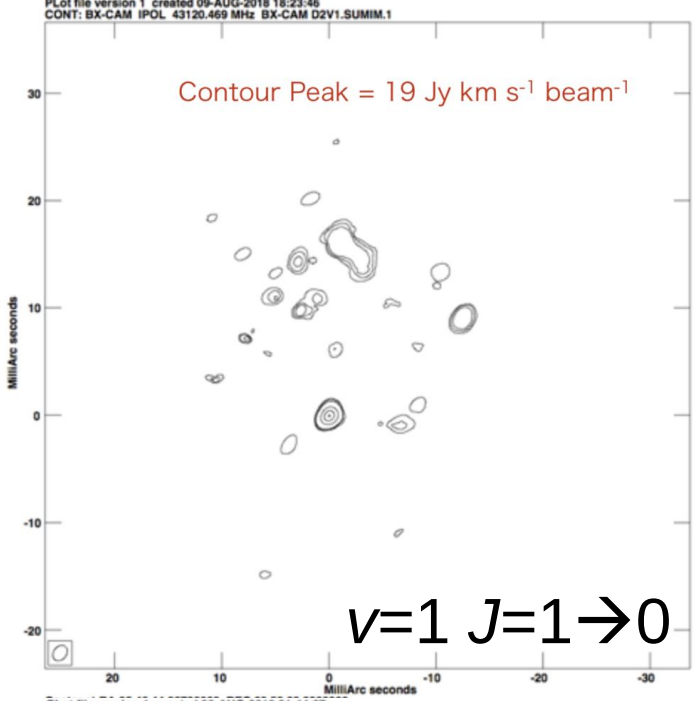


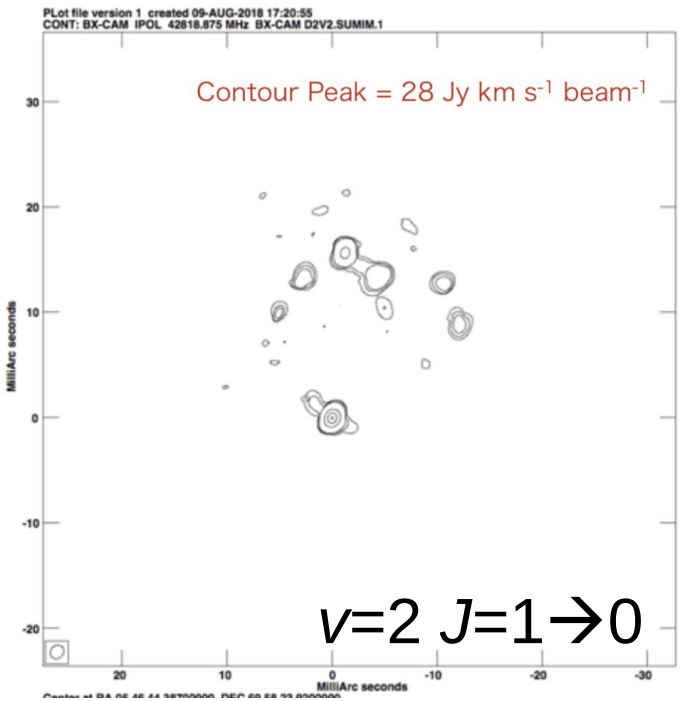
Masers in BX Cam

In r13340a

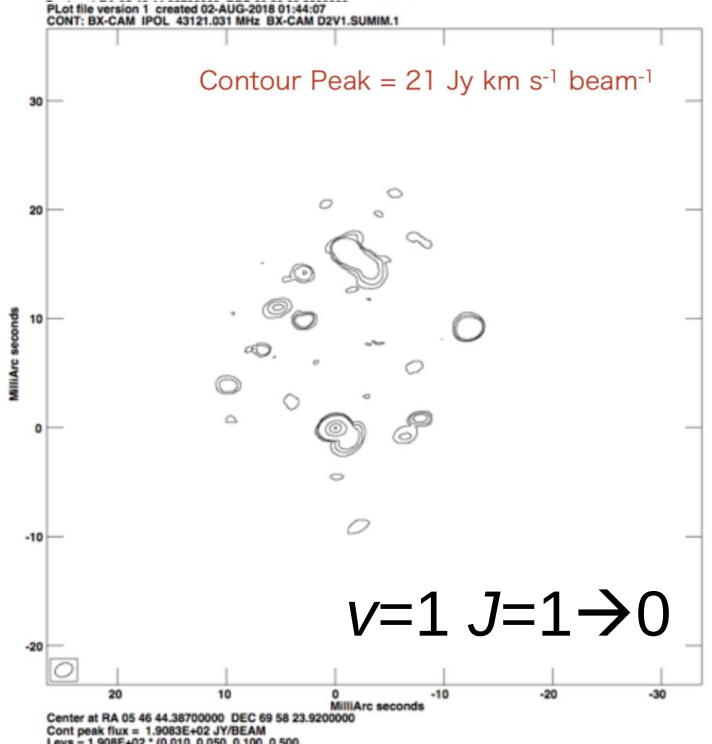
“Two frames” movies of SiO *v*=1 and *v*=2 masers

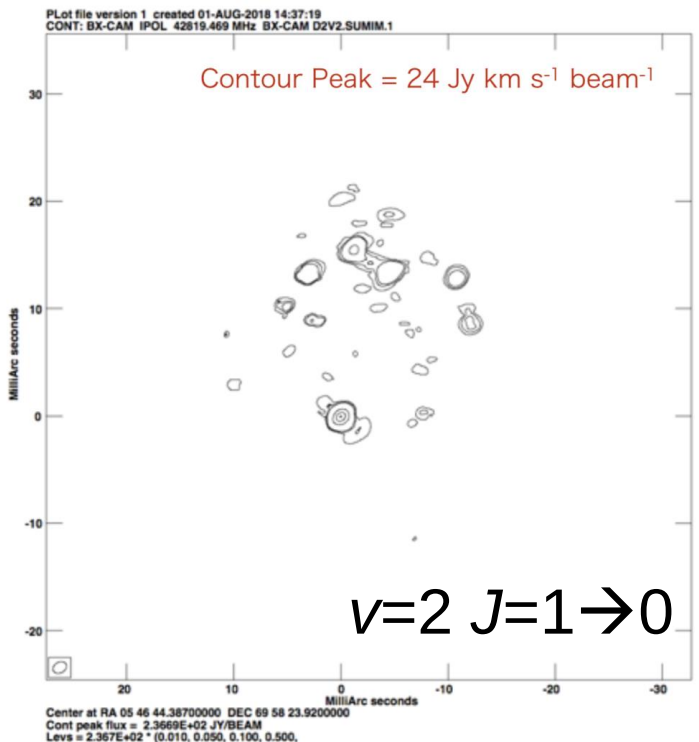
r18144a—r18145a





r18157a—r18158a





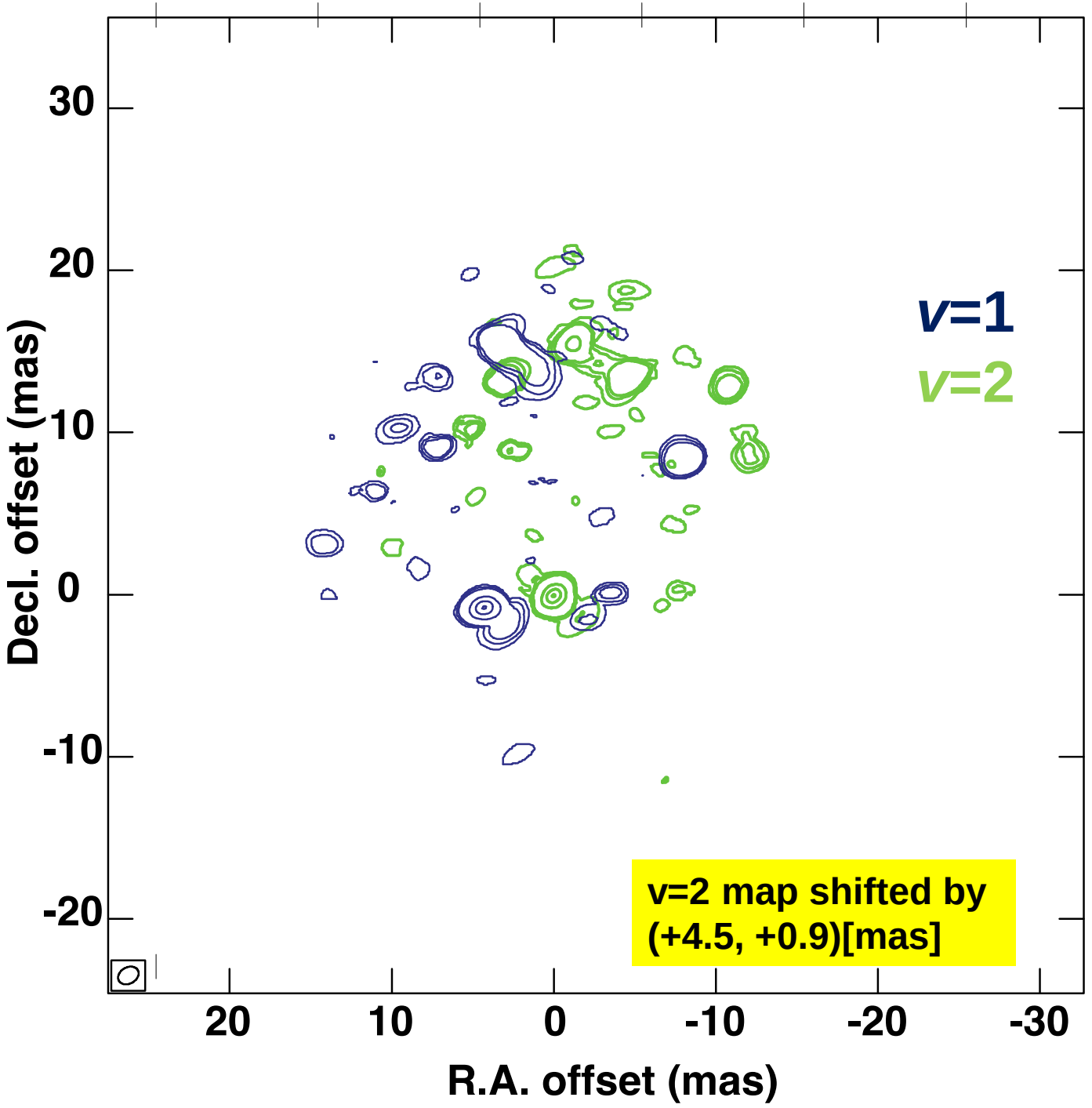
Map registration for SiO *v*=1 and *v*=2 masers

Toward BX Cam
in r18144a—r18145a

Poor accuracy in the SIMBAD coordinates for BX Cam?
Astrometry is crucial

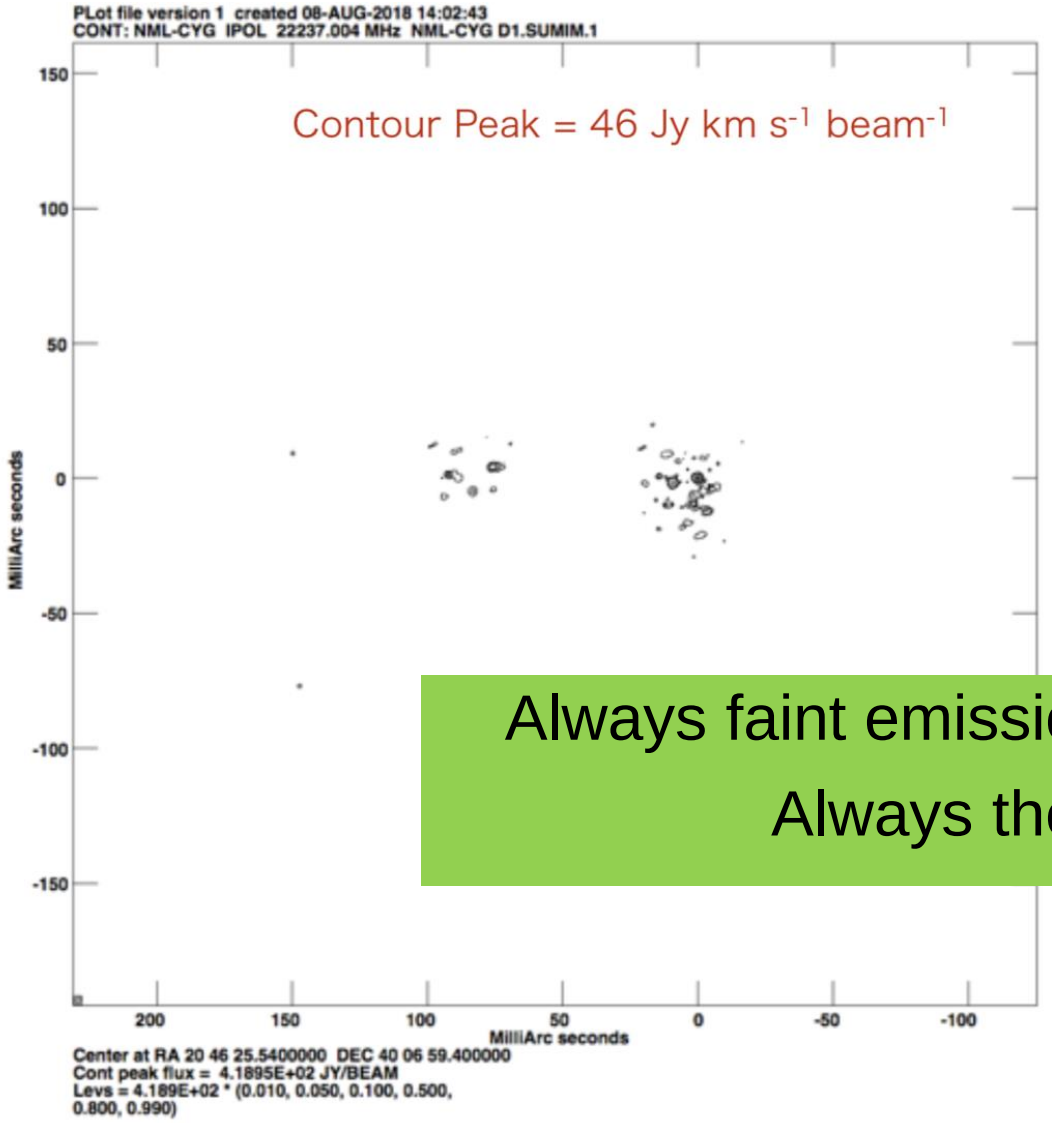
- Antenna slow nodding
- VERA's dual beam

Imperfect phase compensation at present

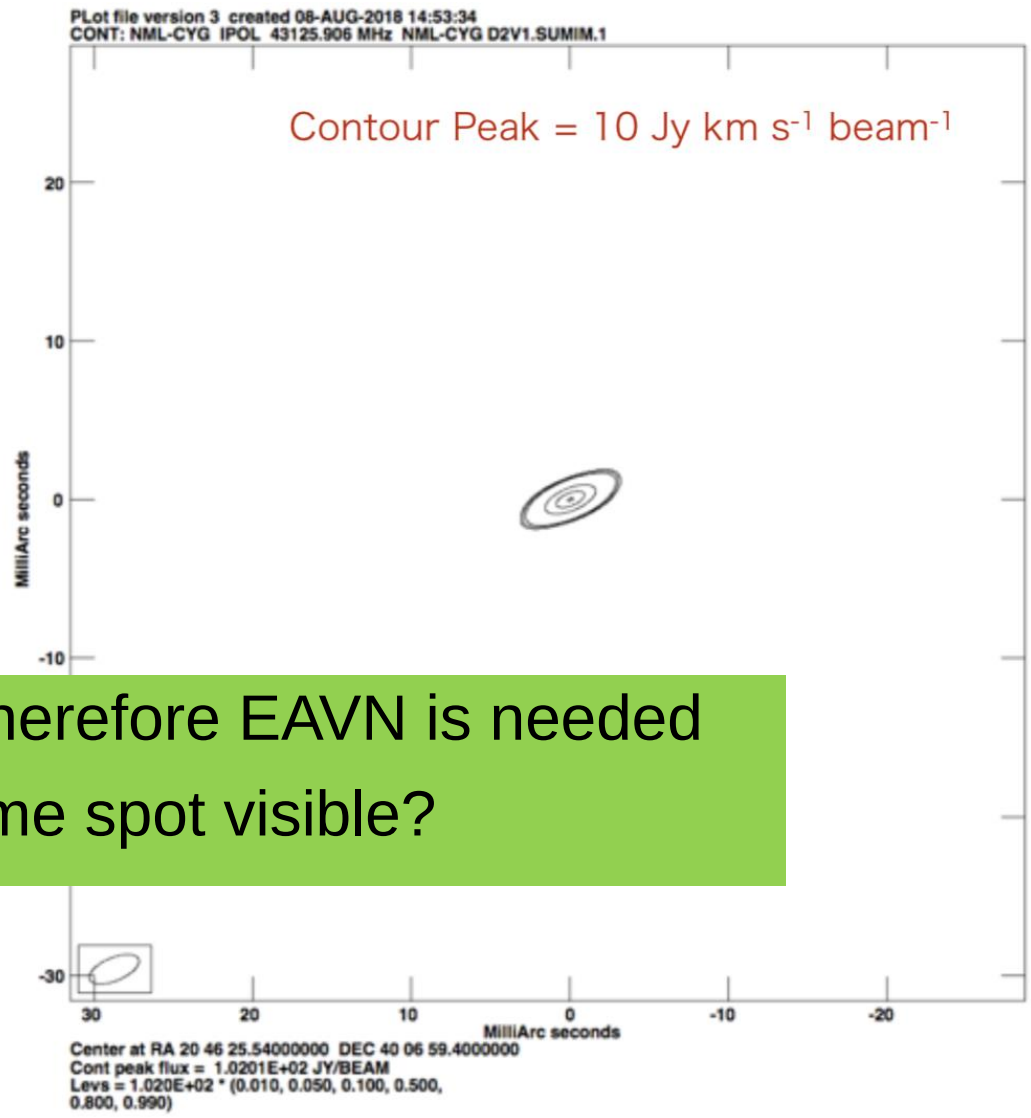


Masers in NML Cyg in r18157c—r18158c

H_2O masers



SiO v=1 J=1→0 masers



Always faint emission, therefore EAVN is needed

Always the same spot visible?

Summary and future perspectives

- **ESTEMA is a decadal project for multiple circumstellar maser lines.**
  - ✓How to secure sustainable project operation?
  - ✓How to develop the database with scientific analysis tools and science-ready maser image cubes?
- **Opened issues: development of theoretical models of circumstellar masers and circumstellar envelopes**
  - ✓Strong constraints on maser excitation

H_2O, SiO (v=0, 1, 2, 3, J=1→0 / v=1 J=2→1, J=3→2 / ^{29}SiO v=0, J=1→0)

- ✓More precise estimate of mass-loss rates of evolved stars generating pulsation-driven shock waves