The relationship between the 46-year acceleration in the H_2O maser spectrum of the long-period OH/IR star NSV17351 and the recent detection of its OH maser emission

-Examining circumstellar mass transfer and acceleration through radio observations-

Akiharu Nakagawa (Kagoshima university)

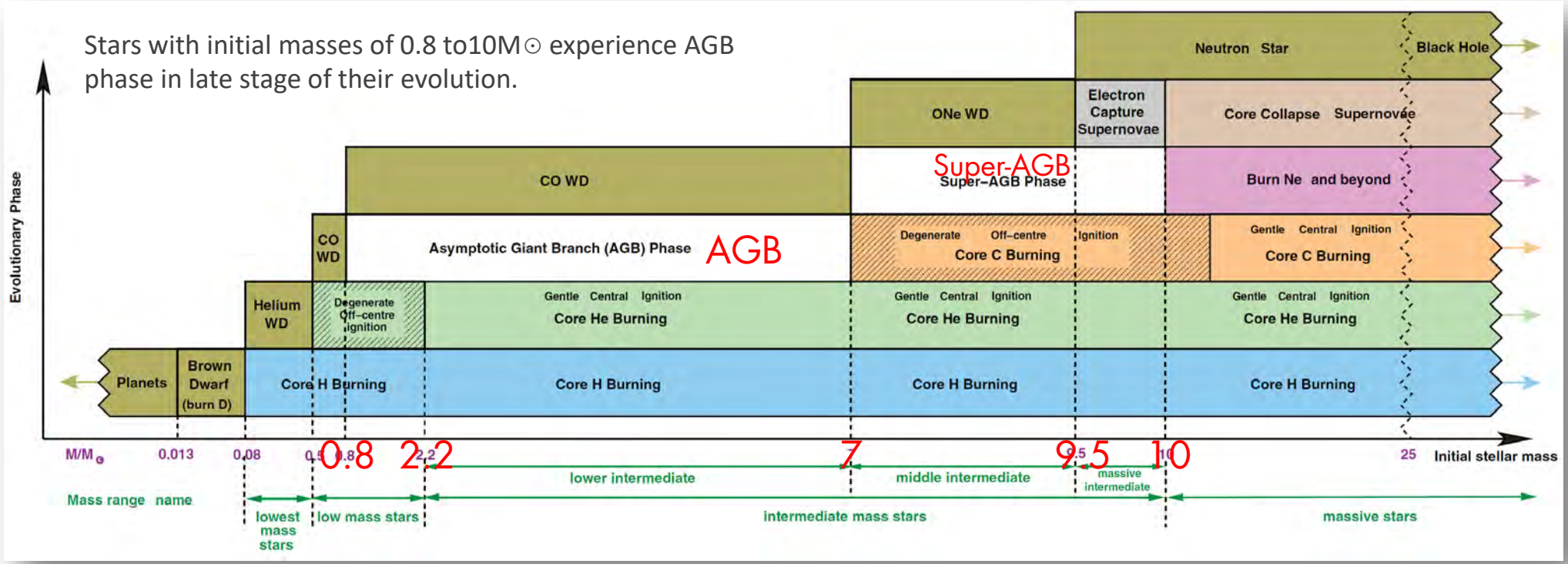
Tomoharu Kurayama(Teikyo University of Science), Hiroshi Sudou(National Institute of Technology, Sendai College), Gabor Orosz(JIVE), Nobuyuki Sakai(NARIT/NAOJ), Hiroshi Imai(Kagoshima university), Dieter Engels(Hamburger Sternwarte), Sandra Etoka(JBCA-Manchester University), Takafumi Kamizuka(Univerisy. of Tokyo), Tamaki Matsuo(Kagoshima univerisy)

Topics:

- AGB star and OH/IR star
- Large mass-loss and time variation
- Importance of VLBI astrometry (Comparison between VLBI & DR3)
- 22GHz astrometric VLBI observations with VERA
- Individual source : Dust-enshrouded OH/IR star NSV17351

AGB stars with various initial mass

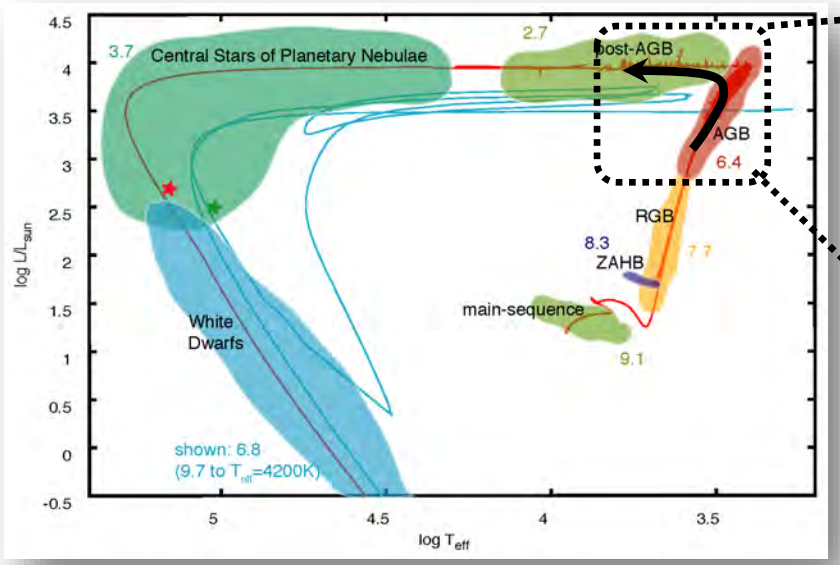
- AGB stars : Late stage of stars with masses of $0.8M_{\odot}-8M_{\odot}(-10M_{\odot})$
  - Large mass loss rate : dM/dt $(\sim 10^{-7}M_{\odot}/yr)$
  - Extreme-OH/IR star : dM/dt ($>10^{-4}M_{\odot}/yr$), intermediate mass ($>5M_{\odot}$) (Justtanont+ 2015)
  - Period-luminosity relation as a standard candle
  - Possible contributor to the problem of dust abundance in the early universe



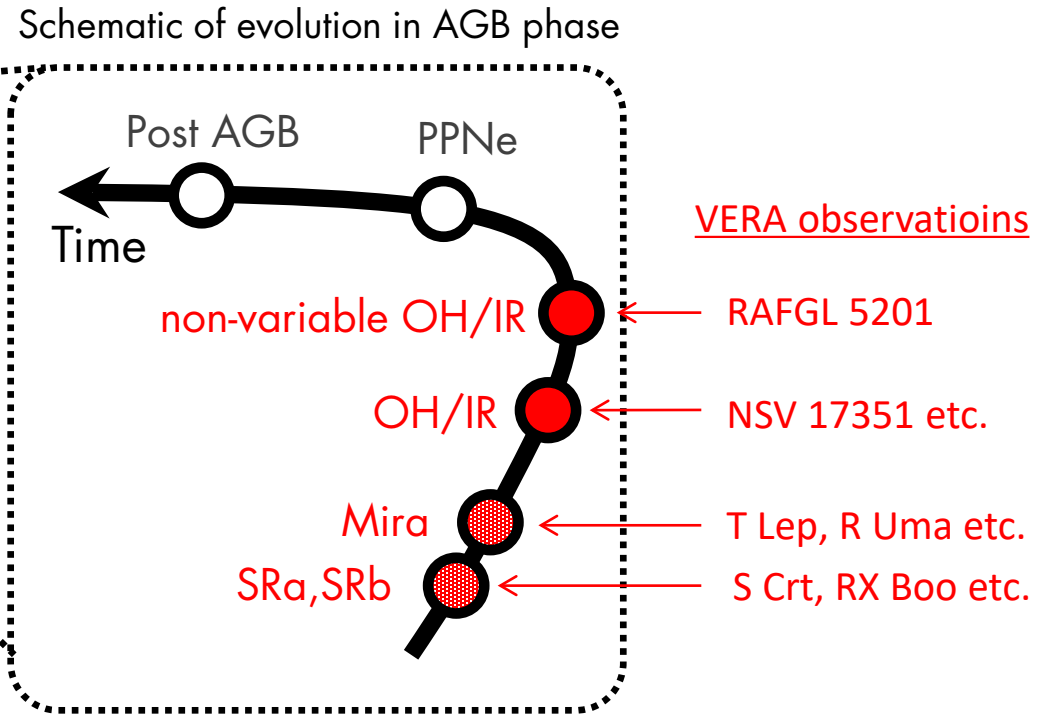
Karakas & Lattanzio (2014)

AGB stars with various initial mass

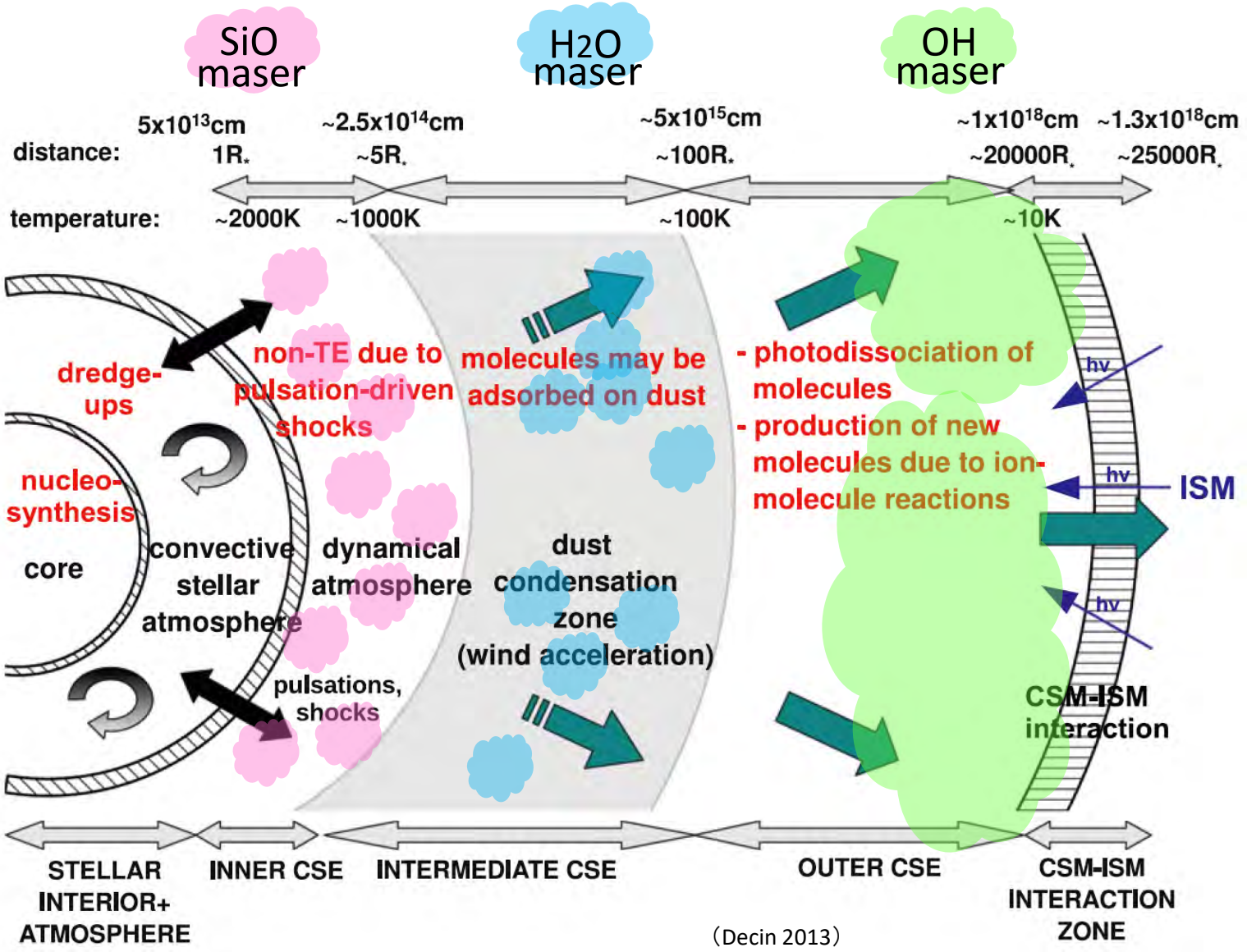
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HR diagram 2M⊙ evolution track (Herwig 2005)



Circumstellar masers around AGB star



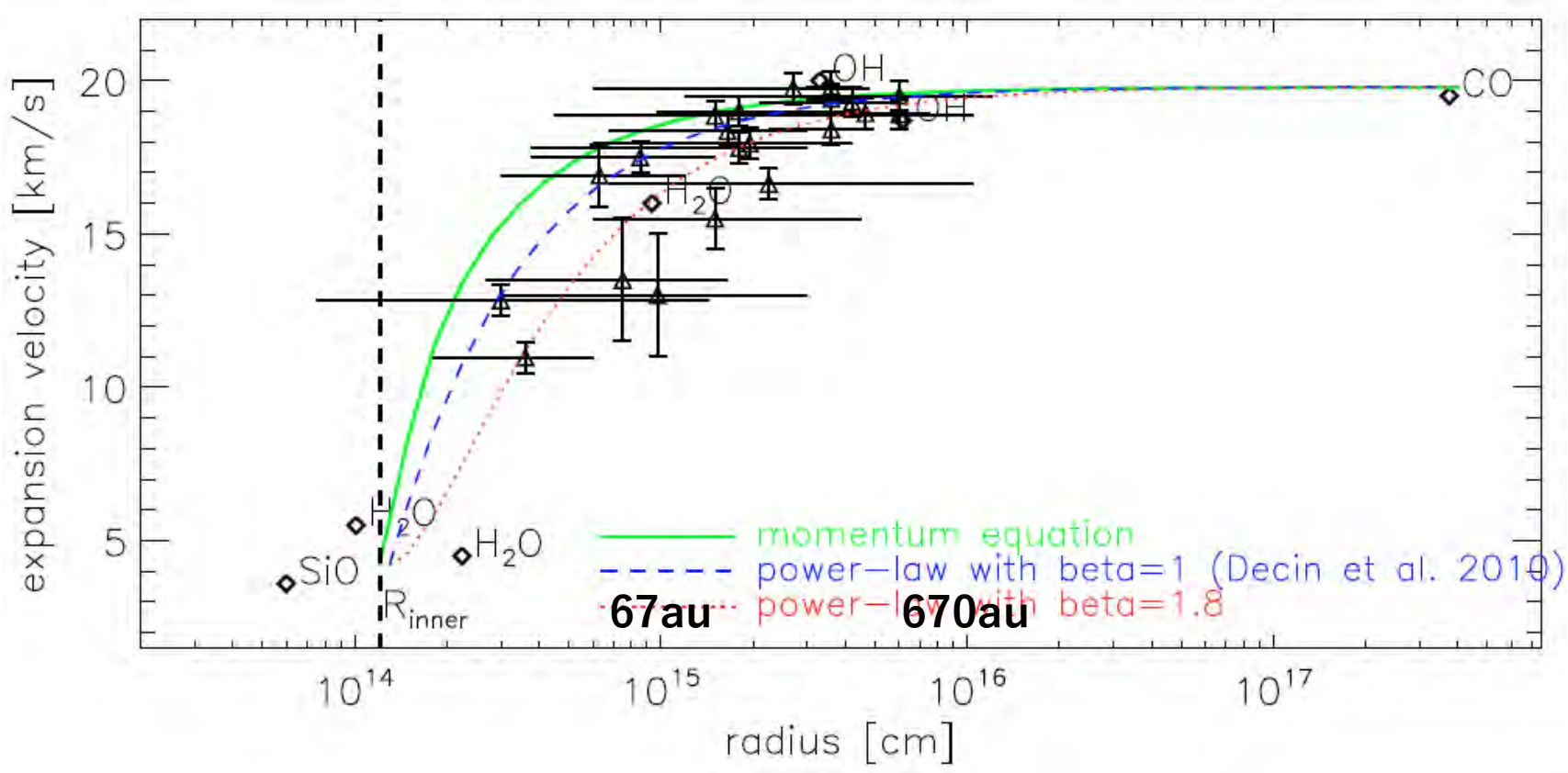
(Decin 2013)

Maers are good target of VLBI

Maers can be used to study distribution and kinematics of circumstellar matters(CSM).

Mass transfer and acceleration of circumstellar matter

- CSM are accelerated and transferred to outer region
- OH maser is exited in the outermost region due to photodissociation of H_2O molecule

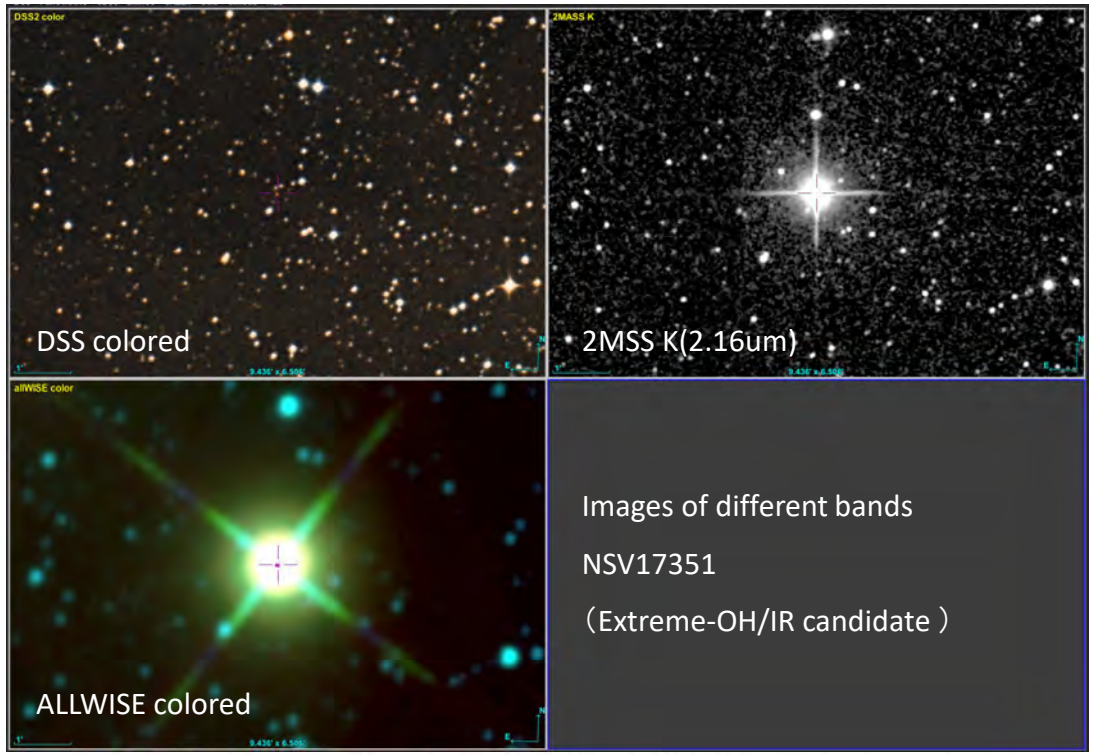


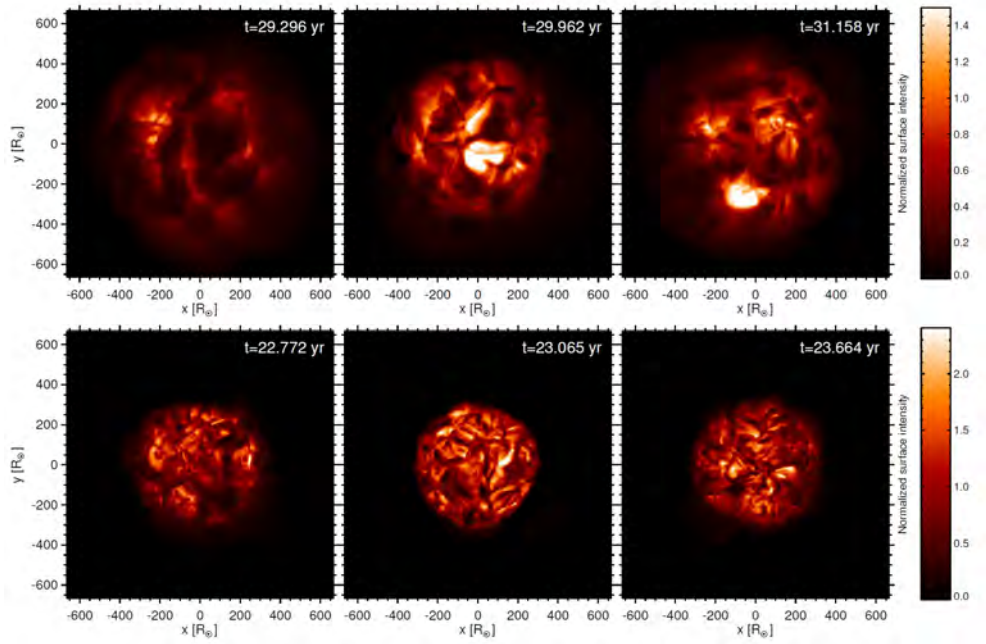
Acceleration of circumstellar matter (Decin et al. 2010) in an AGB star IK Tau. Radius of 10^{15} cm corresponds to 67 au.

Why are VLBI observations important ?

Advantage of VLBI on parallax measurements of AGB and OH/IR stars

- Distance is crucial for understanding of stellar properties.
- Difficulty in Gaia measurements for dust-obscured stars like OH/IR stars.
- VLBI is a promising method of parallax measurements, especially for, dust-obscured AGB stars.

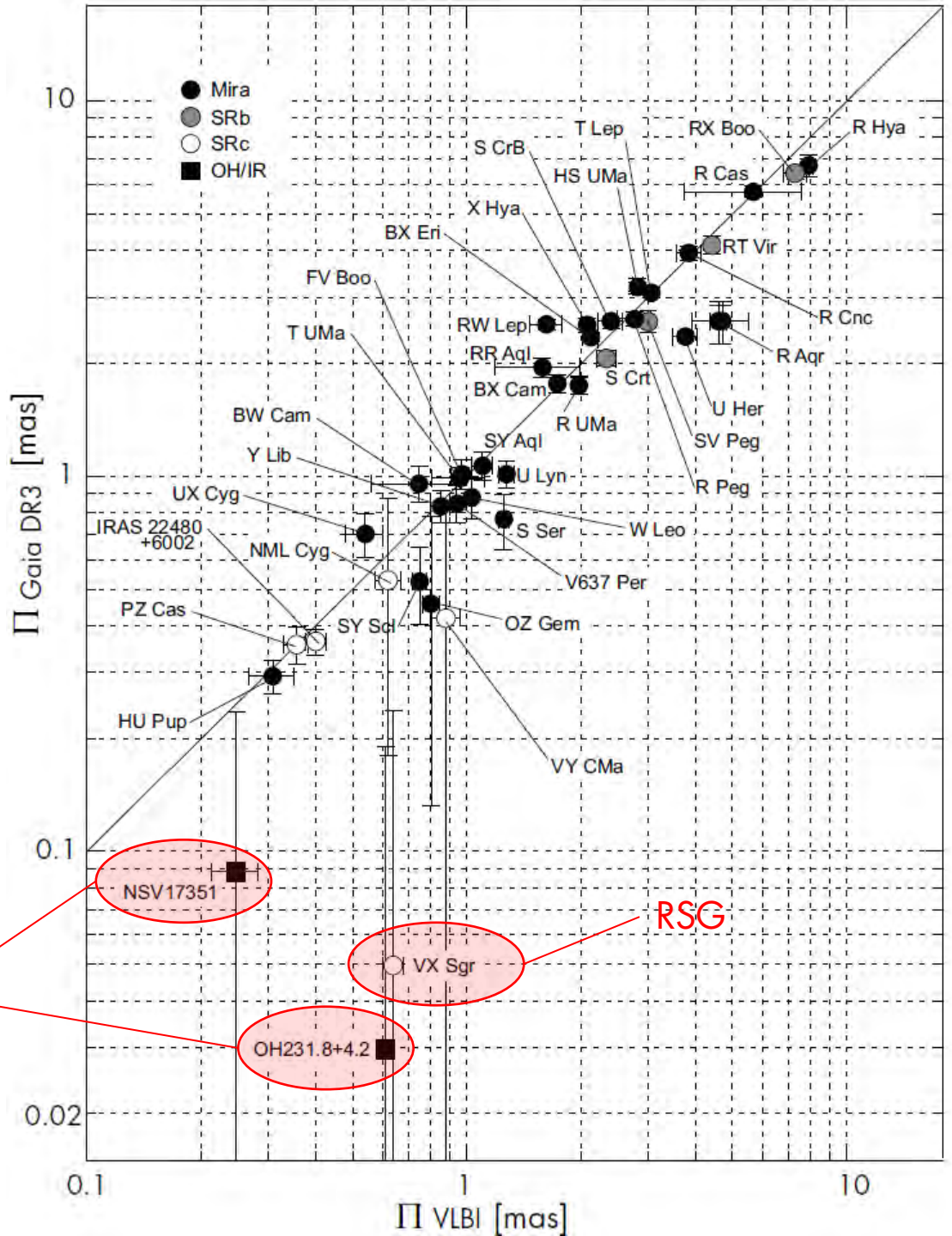




Fluctuation of surface brightness
(Freytag and Hofner 2023)

Parallaxes from VLBI and DR3

VLBI ●
DR3 ○



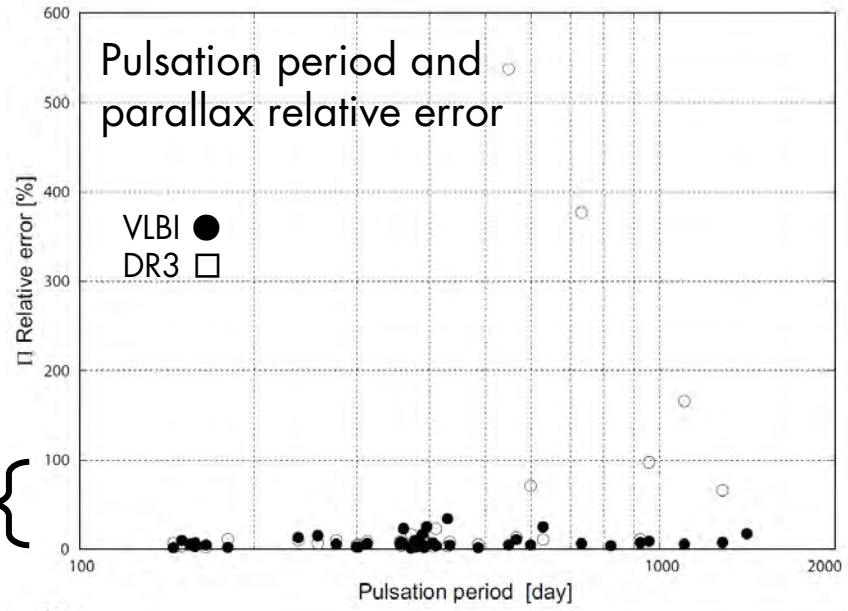
OH/IR star

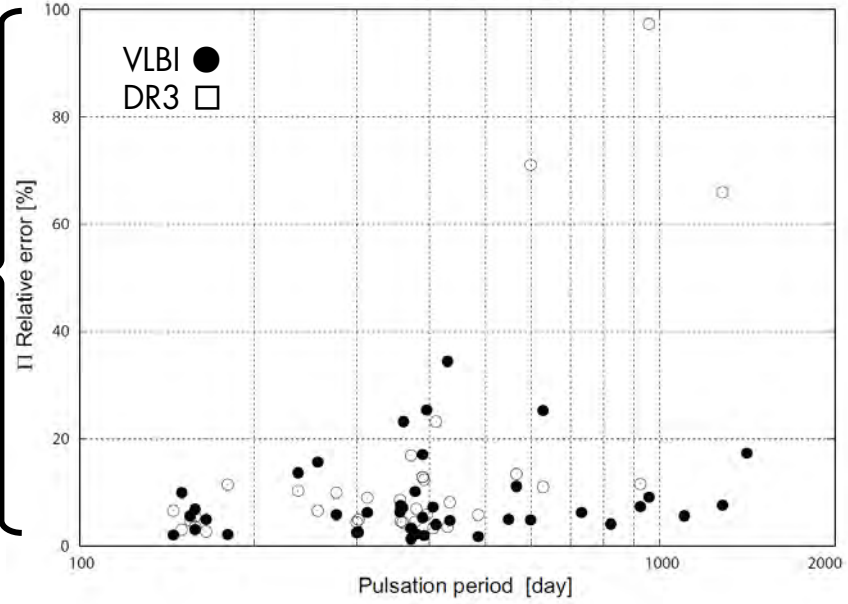
RSG

Nakagawa et al. (in prep.)

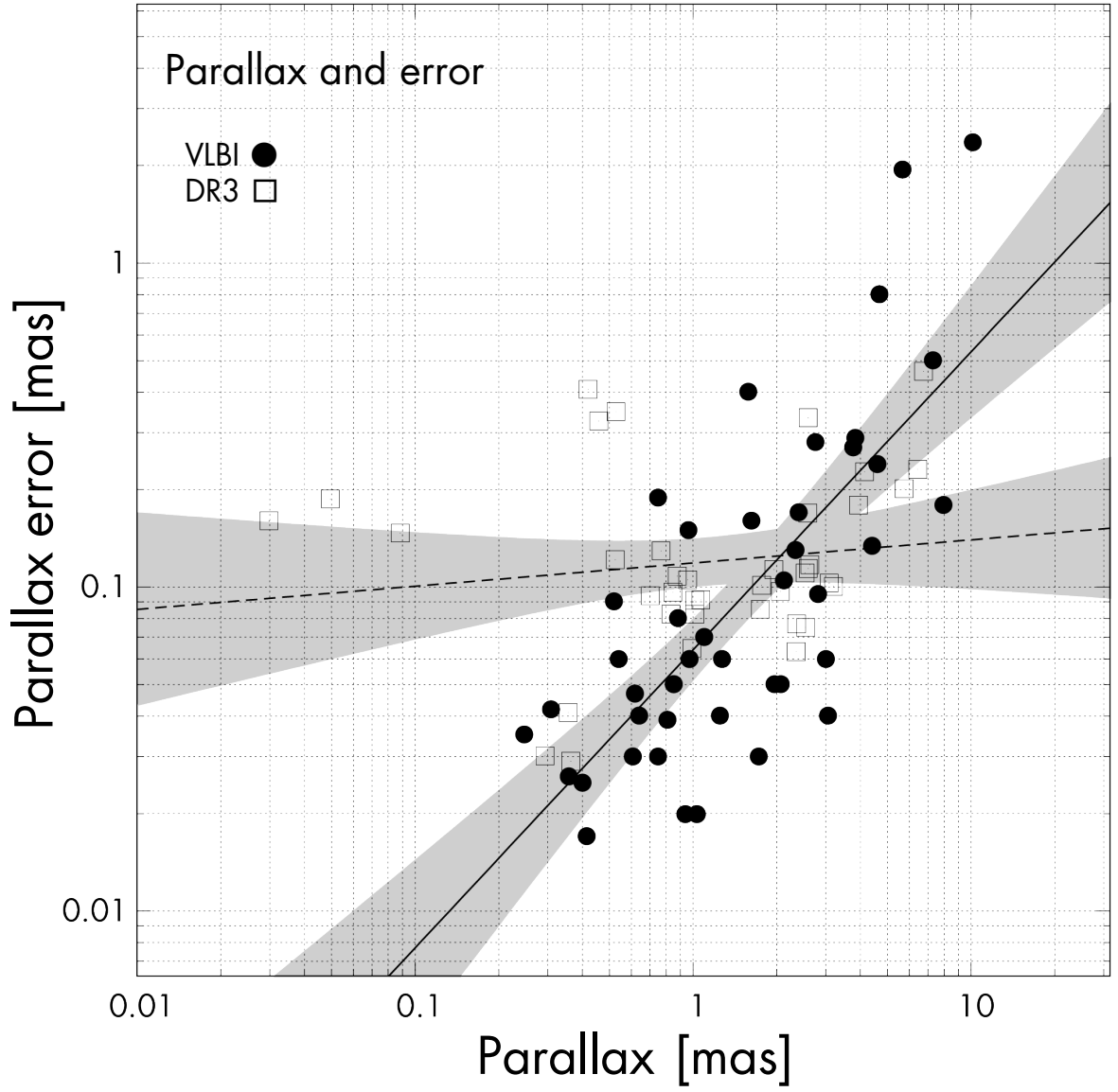
Why are VLBI observations important ?

Relative error
0～600%





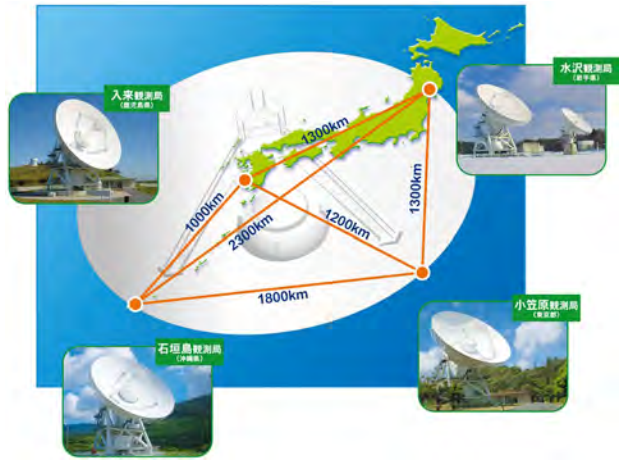
Relative error
0～100%



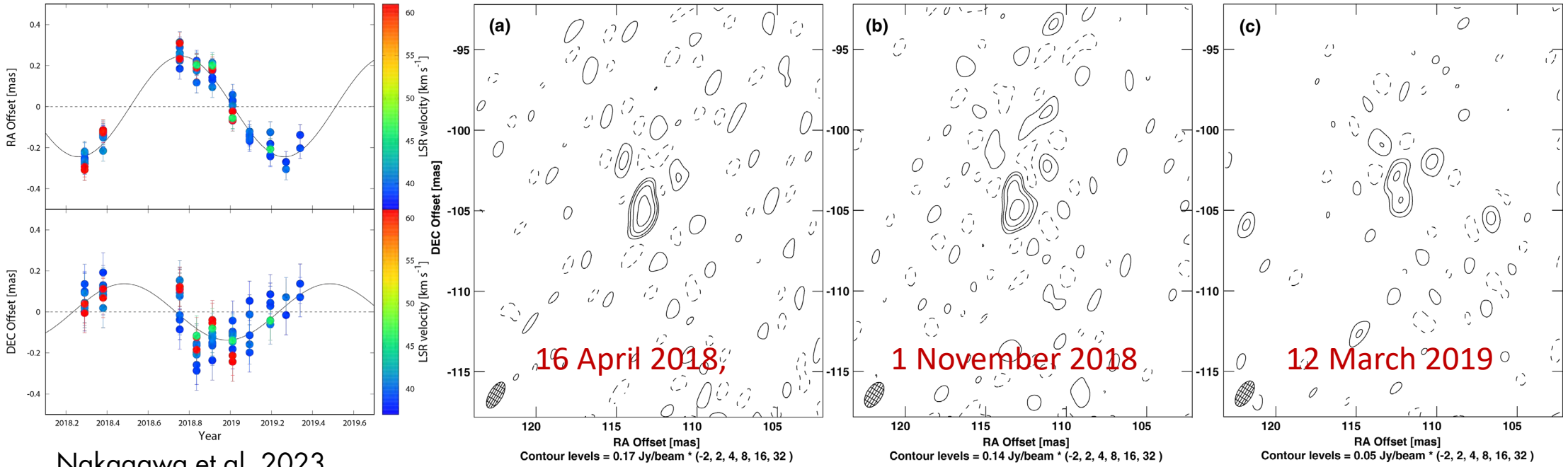
Nakagawa et al. (in prep.)

Parallax of NSV17351 using H2O maser

- NSV17351 is a candidate of an extreme OH/IR star, very long pulsation period.
- VERA observation from 2018 to 2019, H_2O maser at 22GHz
- Parallax 0.247±0.035 mas → Distance 4.05±0.59 kpc
- Stellar system proper motion (−1.19 ± 0.11, 1.30 ± 0.19) mas/yr.



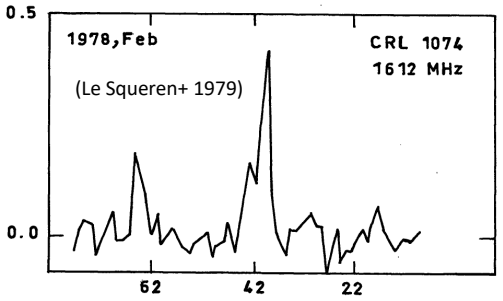
Time variation of maser spot of H2O maser



Nakagawa et al. 2023

40 yrs non-detection of OH maser and acceleration of H2O maser during the period

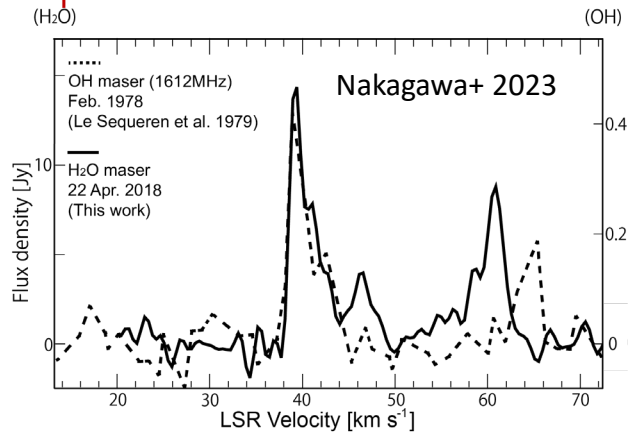
OH maser in 1978



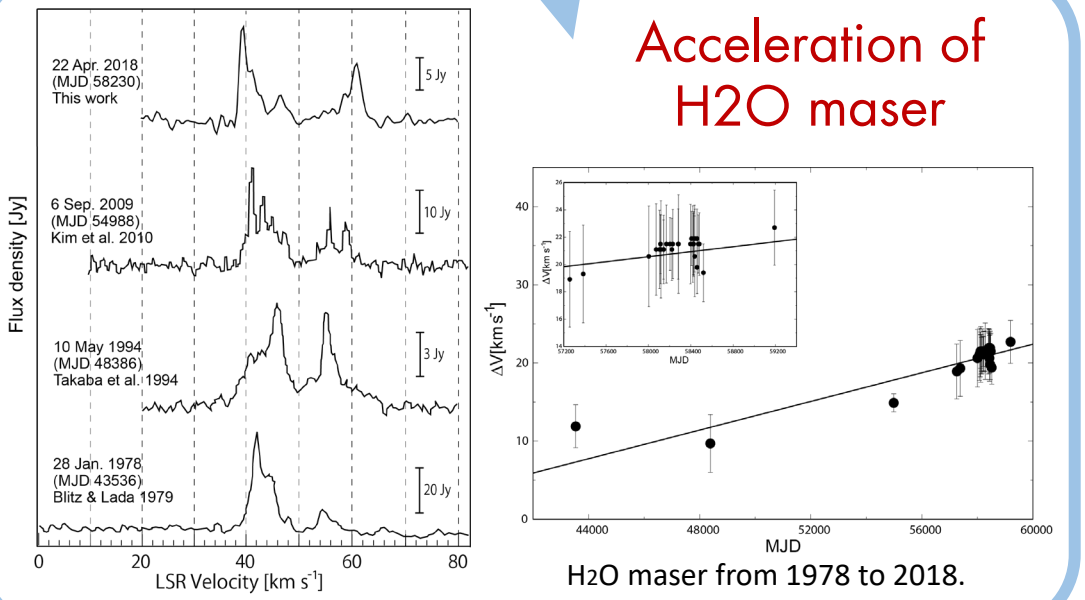
Although an OH maser emission was detected 47 years ago, only one observation was performed during this interval, which resulted in non-detection until 2024.

46 yrs non-detection of OH maser

Overlap of LSR velocities in OH and H2O maser



Acceleration of H2O maser



H2O maser from 1978 to 2018.

Hypothesis:

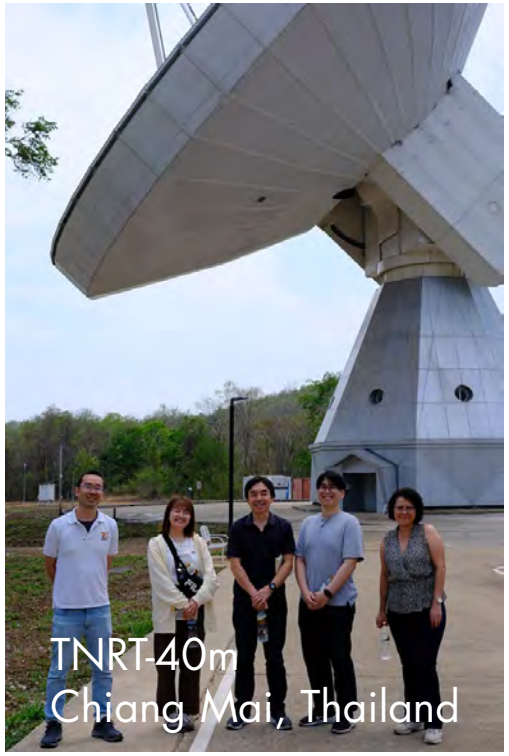
NSV17351 has long-term instability of mass loss.
We need to test this hypothesis.

Prediction:

H2O will soon be photo-dissociated to form OH maser

(1) Single-dish observations using TNRT(Thailand) and NRT(France) May 2024～Aug. 2025
(2) VLBI observation of OH maser using EVN, Sep. 2024

Single-dish observation of OH maser in NSV17351

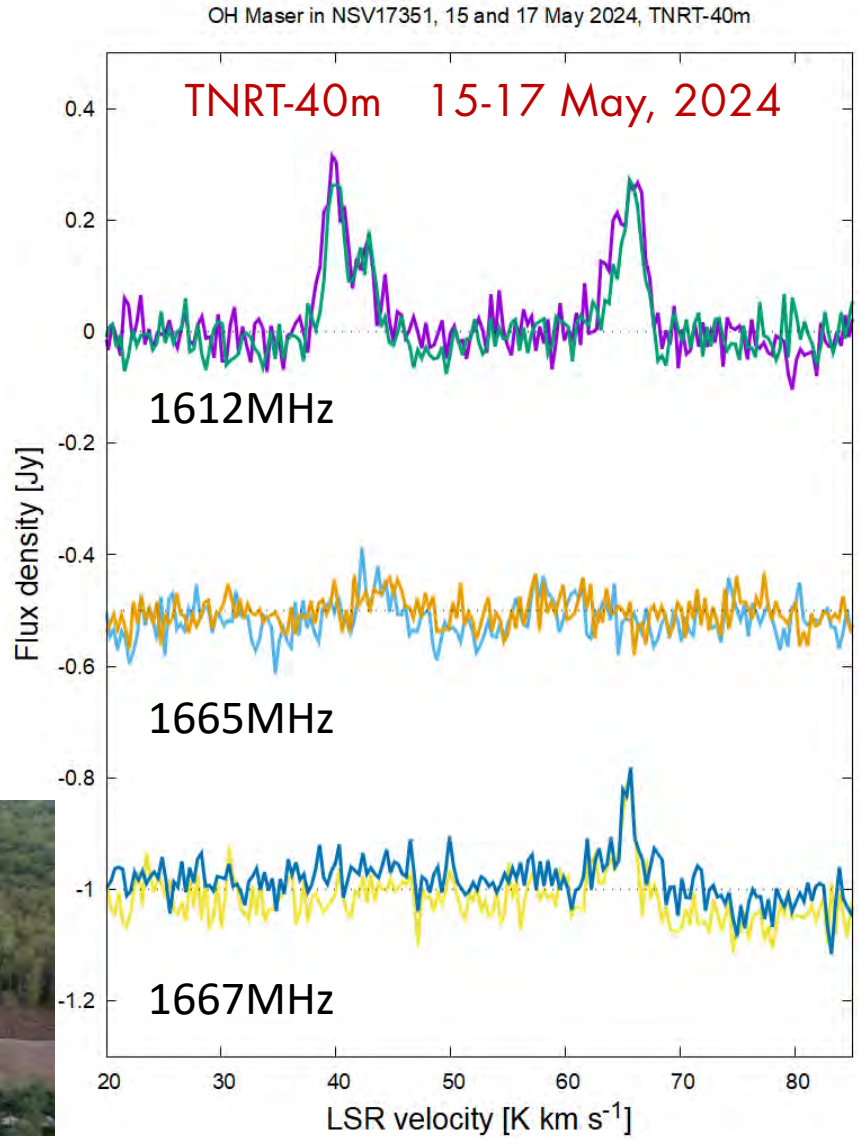


Detection OH maser in NSV17351

2024/05/15 @ NARIT
TNRT 40m telescope

We detected 1612 MHz OH maser for the first time in 46 years.

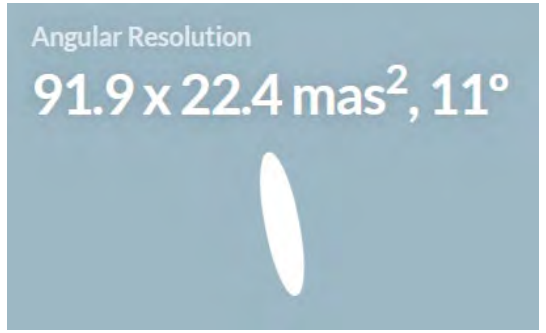




VLBI observation of OH maser : EVN@1.6GHz

Locations of OH maser and H2O maser can also contribute to confirm our hypothesis.

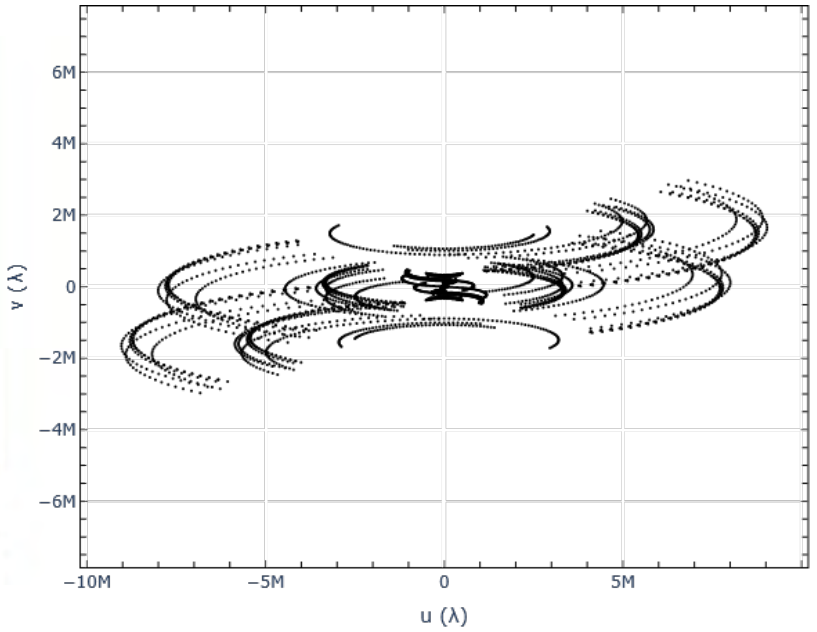
Method: Phase-referencing VLBI
Frequency: 1665, 1667 MHz (Main line), 1612 MHz (Satellite line)
Date : 18/10/2024, 00:30 – 09:00 UT (Code: EN015)
Antenna : 10 stations EVN (Jb, Wb, O8, Tr, Ir) + eMERLIN (Cm, Da, Kn, Pi, De)



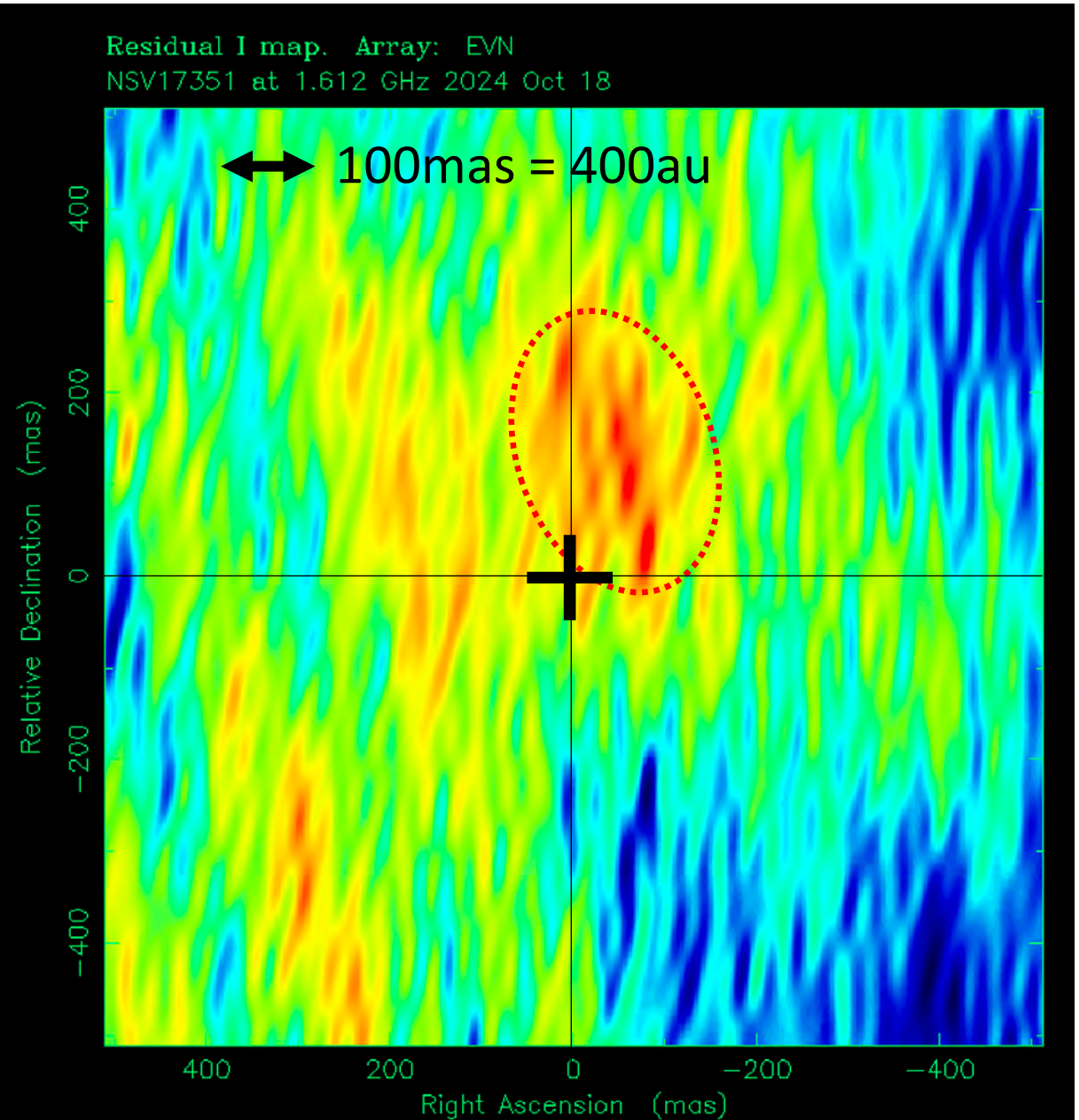




Location of the 10 stations



Phase-referenced OH maser map : EVN 1.6GHz VLBI

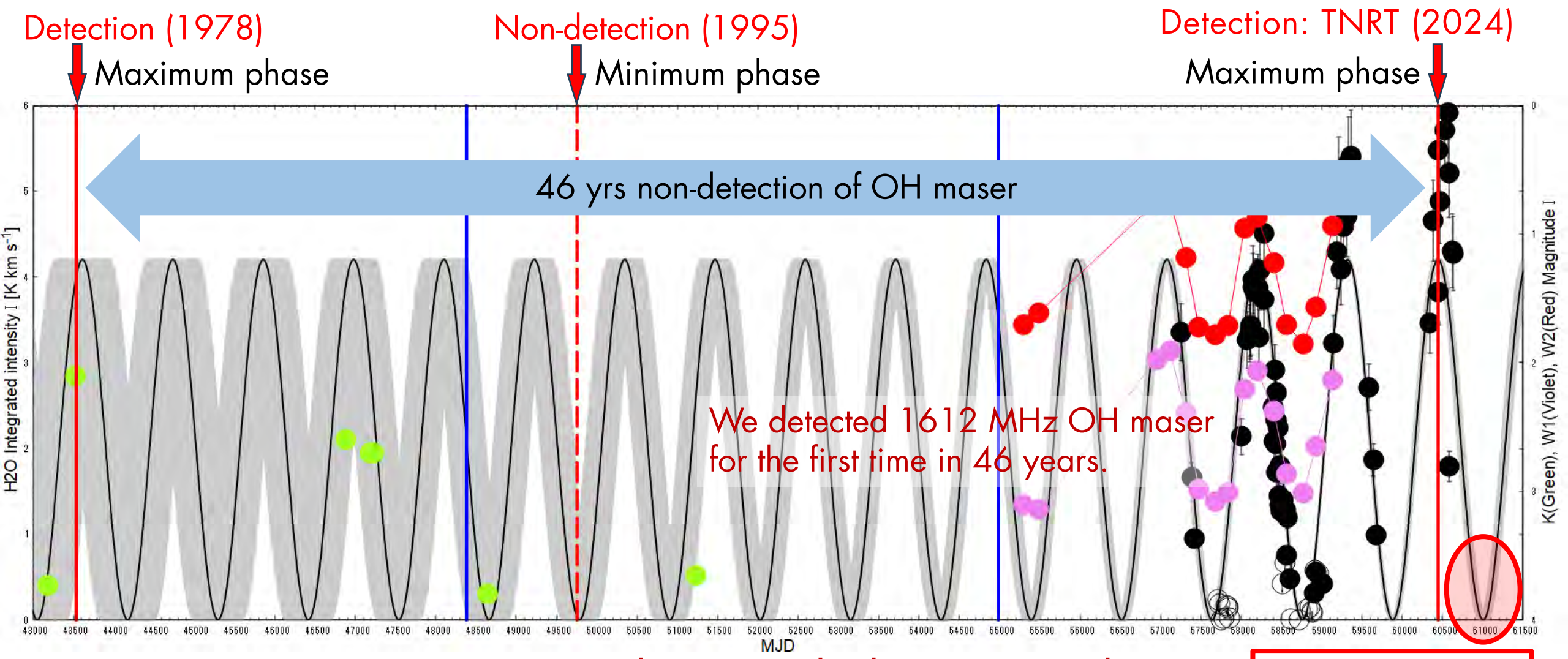


- OH maser: 1612 MHz (Satellite line)
- Vlsr = 38.5−40.5 km/s
- Natural weighting
- 1σ = ~7 mJy/beam
- Diffuse OH maser in North-west of the expected position of the star, 20 mJy/beam (S/N~4-5)
- ~400au distant from the star position

- Considering a typical shell size (~1000 au), origin of the OH maser must be NSV17351. However, there is a 400au offset from H2O maser position.

- Effect of strong RFI, Position accuracy of EVN astrometry at 1.6GHz should be considered.

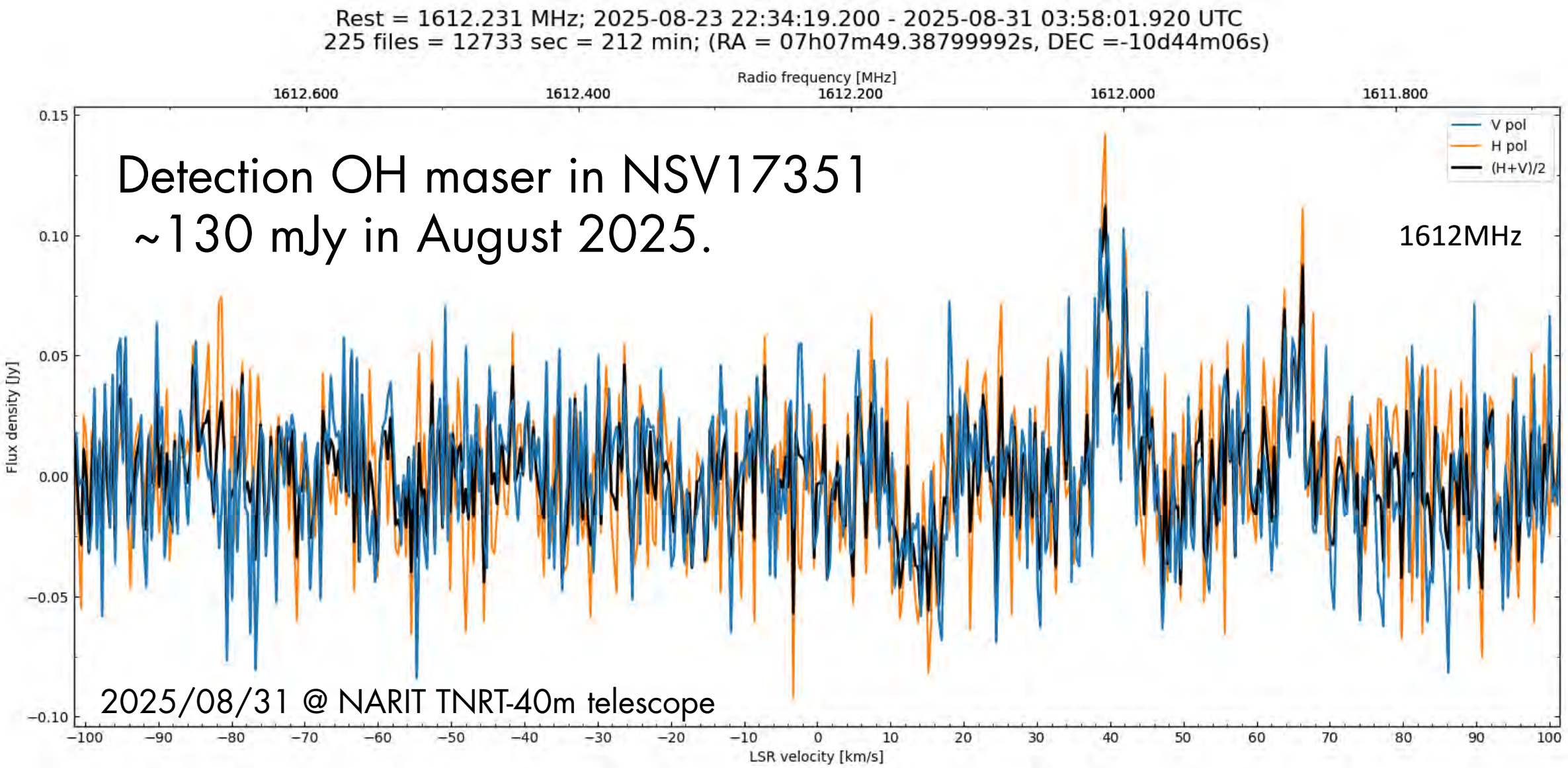
Detection and non-detection of OH maser



However, it is important to distinguish the assumed long-term instability from its periodic pulsation.

August 2025, TNRT-40m

TNRT single-dish observation in August 2025



TNRT single-dish observation in August 2025

The hypothesis "long-term instability in mass ejection" was not confirmed.
Effect of periodic pulsation can not be ruled out.

However, we confirmed a stable pulsation that persists for more than 47 years.

Summary

- OH/IR stars are important source to study evolution from AGB to post AGB stars.
- VLBI is still an important method to derive distances of dust-obscured AGB stars, and complementary to Gaia.
- 22GHz astrometric VLBI observation with VERA
- 1.6GHz Single-dish observations with TNRT-40m and NRT
- From a long absence of OH maser in NSV17352, we proposed a hypothesis of “long-term instability in mass ejection”.
- The hypothesis was rejected from the latest single-dish observation with TNRT-40m.
- However, we confirmed a stable pulsation that persists for more than 47 years.