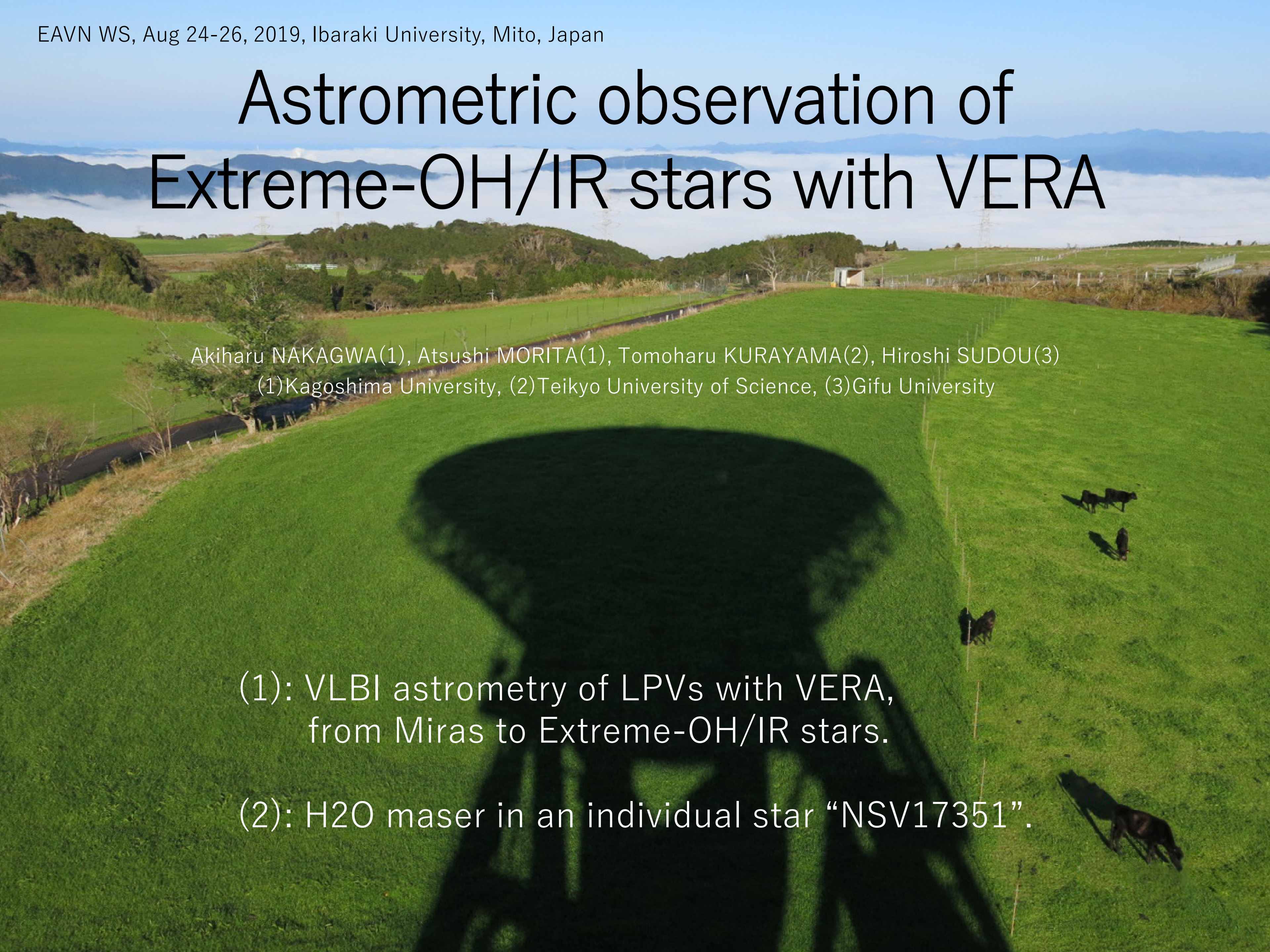

EAVN WS, Aug 24-26, 2019, Ibaraki University, Mito, Japan

Astrometric observation of Extreme-OH/IR stars with VERA

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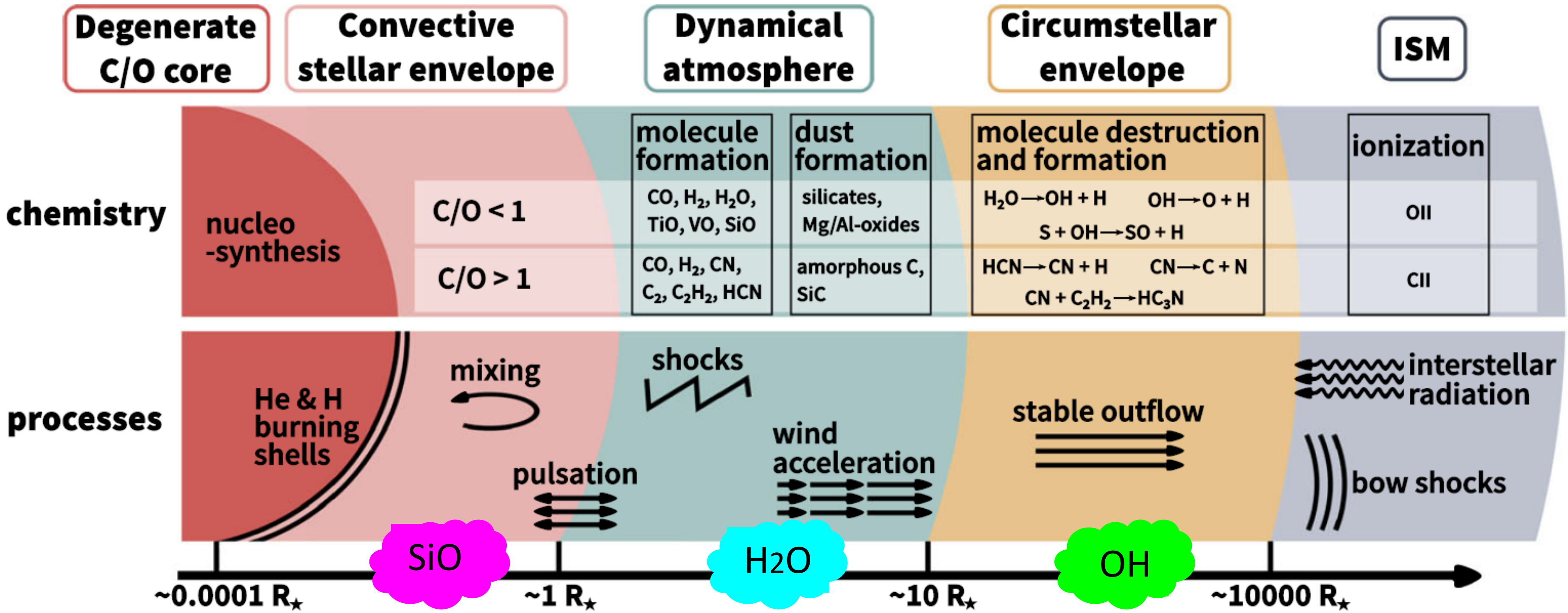
(1): VLBI astrometry of LPVs with VERA,
from Miras to Extreme-OH/IR stars.

(2): H2O maser in an individual star “NSV17351”.

AGB, OH/IR star and Extreme-OH/IR star

Understanding of stellar parameters and evolution based on precise VLBI astrometry



Hofner & Olofsson(2018)

a few au　　a few × 10 au　　a few × 1000au

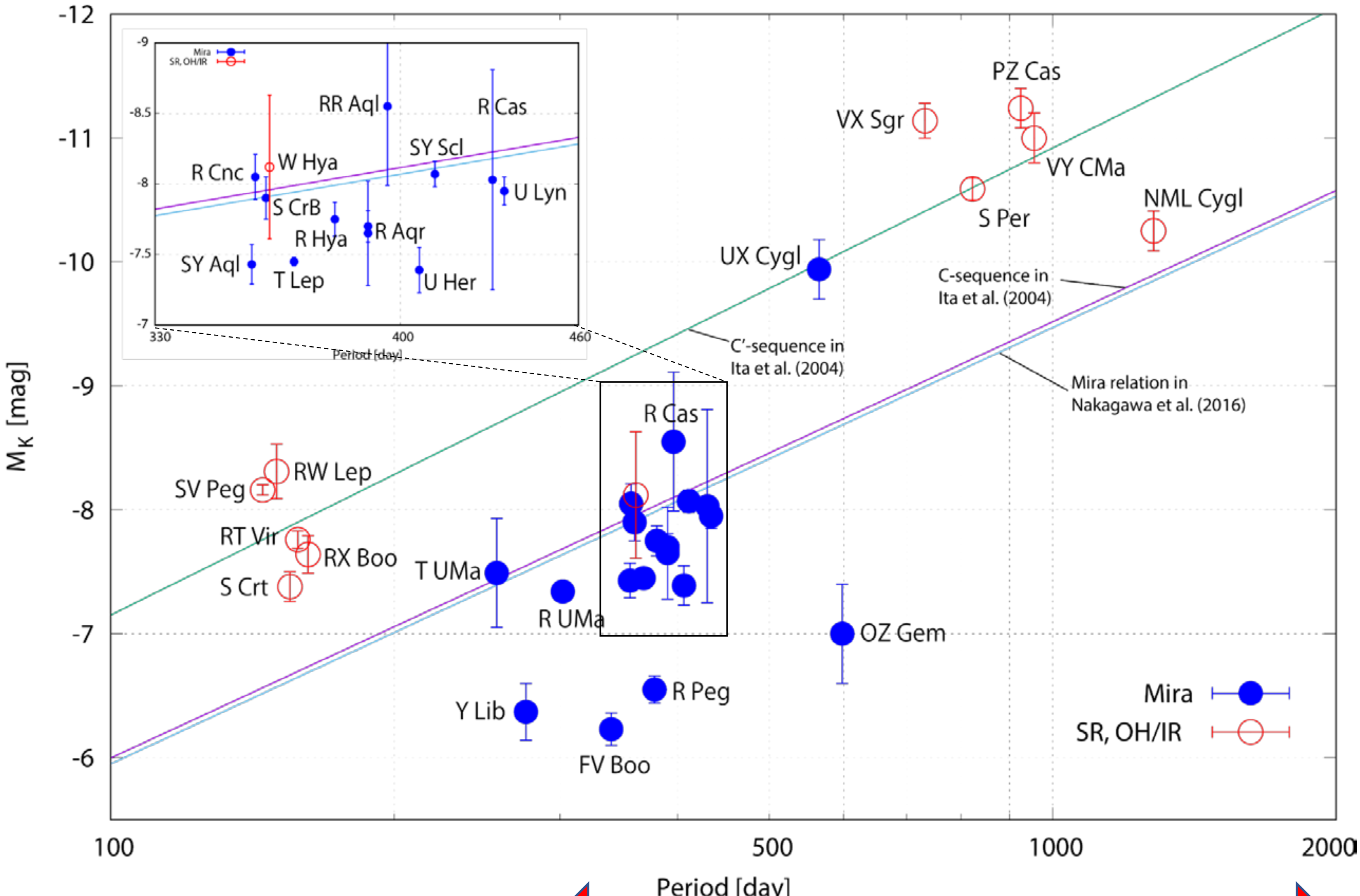
- Mass　1～8 M◎　(Typical Mira:1～2.5 M◎)
- C/O-core, He-shell, H-rich envelope →O-rich/C-rich
- Period　100～1000 d, P>1000 d
- High mass loss ratio →Chemical evolution
- P-M relation → Distance estimator

65 project sources, ~30 parallaxes were measured.

ID	Src.	Type	R.A.	Dec.
1	W Hya	SR	13h49m01.9980s	-28d22m03.488
2	T Lep	Mira	05h04m50.7999s	-21d54m16.500
3	RX_Boo	SR	14h24m11.5998s	+25d42m13.000
4	S_Crt	SR	11h52m45.1000s	-07d35m48.100
5	AP Lyn	Mira	06h34m33.8999s	+60d56m26.199
6	R UMa	Mira	10h44m38.3999s	+68d46m32.298
7	WX_Psc	Mira	01h06m25.8998s	+12d35m53.000
8	Z Pup	Mira	07h32m38.1000s	-20d39m29.199
9	SY Scl	Mira	00h07m36.2000s	-25d29m40.000
10	Y Lib	Mira	15h11m41.2999s	-06d00m41.399
11	VX UMa	Mira	10h55m39.8999s	+71d52m09.800
12	GX Mon	Mira	06h52m46.8999s	+08d25m19.000
13	U Lyn	Mira	06h40m46.5000s	+59d52m01.600
14	T UMa	Mira	12h36m23.5000s	+59d29m13.000
15	S CrB	Mira	15h21m24.0000s	+31d22m02.600
16	SW Lib	Mira	15h55m33.3999s	-12d51m05.099
17	FS Lib	Mira	16h00m23.8000s	-12d20m57.500
18	IRC-20540	Mira	19h08m56.0000s	-22d14m19.399
19	IRC+10374	Mira	18h43m36.7000s	+13d57m22.800
20	X Hya	Mira	09h35m30.3000s	-14d41m28.600
21	R Cnc	Mira	08h16m33.7999s	+11d43m34.500
22	FV_Boo	SR	15h08m25.8000s	+09d36m18.199
23	RU_Ari	SR	02h44m45.5000s	+12d19m03.000
24	RW_Lep	SR	05h38m52.7000s	-14d02m27.199
25	BW_Cam	Mira	05h19m52.5600s	+63d15m55.798
26	BX_Cam	Mira	05h46m44.2999s	+69d58m24.199
27	U_Ori	Mira	05h55m49.2000s	+20d10m30.699
28	QX_Pup	Mira	07h42m16.8298s	-14d42m52.100
29	RS_Vir	Mira	14h27m16.3998s	+04d40m41.100
30	SY_Aql	Mira	20h07m05.4000s	+12d57m06.299
31	SV_Peg	SRb	22h05m42.0850s	+35d20m54.536
32	R_Tau	Mira	04h28m18.0000s	+10d09m44.798
33	OZ_Gem	Mira	07h33m57.7500s	+30d30m37.798

ID	Src.	Type	R.A.	Dec.
34	V353_Pup	SR	07h46m34.1510s	-32d18m16.260
35	HU_Pup	SR	07h55m40.1600s	-28d38m54.840
36	HS_UMa	LPV	11h35m30.70408s	+34d52m04.1775
37	R_LMi	Mira	09h45m34.28304s	+34d30m42.7839
38	BX_Eri	SR	04h40m32.754s	-14d12m02.39
39	V637_Per	SR	03h54m02.28s	+36d32m17.6
40	U_CVn	Mira	12h47m19.61s	+38d22m30.5
41	RU_Hya	Mira	14h11m34.39861s	-28d53m07.4089
42	NSV17351	OHIR	07h07m49.38s	-10d44m05.9
43	R_Peg	Mira	23h06m39.16689s	+10d32m36.0892
44	R_Hya	Mira	13h29m42.78187s	-23d16m52.7747
45	OH127.8	OHIR	01h33 51.21s	+62d26m53.2
46	NSV25875	OHIR	22h19m27.48s	+59d51m21.7
47	UU_Peg	Mira	21h31m04.156s	+11d09m13.24 92
48	R_Cas	Mira	23h58m24.87336s	+51d23m19.7011
49	S_Ser	Mira	15h21m39.53475s	+14d18m53.1002
50	W_Leo	Mira	10h53m37.43245s	+13d42m54.3666
51	OH32.8-0.3	OHIR	18h52m24.682333s	-00d14m57.612
52	V391CYG	Mira	19h40m52.394300s	+48d47m41.52658
53	RAFGL5201	OHIR	06h34m28.052569s	-05d03m42.85697
54	OH83.4-0.9	OHIR	20h50m58.619647s	+42d48m11.44793
55	OH141.7+3.5	OHIR	03h33m30.618480s	+60d20m08.85024
56	CU_Cep	OHIR	22h11m31.882483s	+57d02'17.46857"
57	DU_Pup	Mira	07h35m03.978770s	-23d59'14.80023"
58	RAFGL2445	OHIR	19h44m07.000754s	+35d14'08.25184"
59	OH39.7+1.5	OHIR	18h58m30.094784s	+06d42'57.69806"
60	EUAND	C	23h19m58.881502s	+47d14'34.57638"
61	AWTAU	Mira	05h47m30.209209s	+27d08'12.40939"
62	I17411-3154	Mira	17h44m24.003874s	-31d55'35.42862"
63	OH26.5+0.6	OHIR	18h37m32.51s	-05d23'59.2"
64	OH42.3-0.1	OHIR	19h09m07.466221s	+08d16'22.70258"
65	TXCAM	Mira	05h00m51.156996s	+56d10'54.09311"

Period-Mk diagram of Miras in the Galaxy

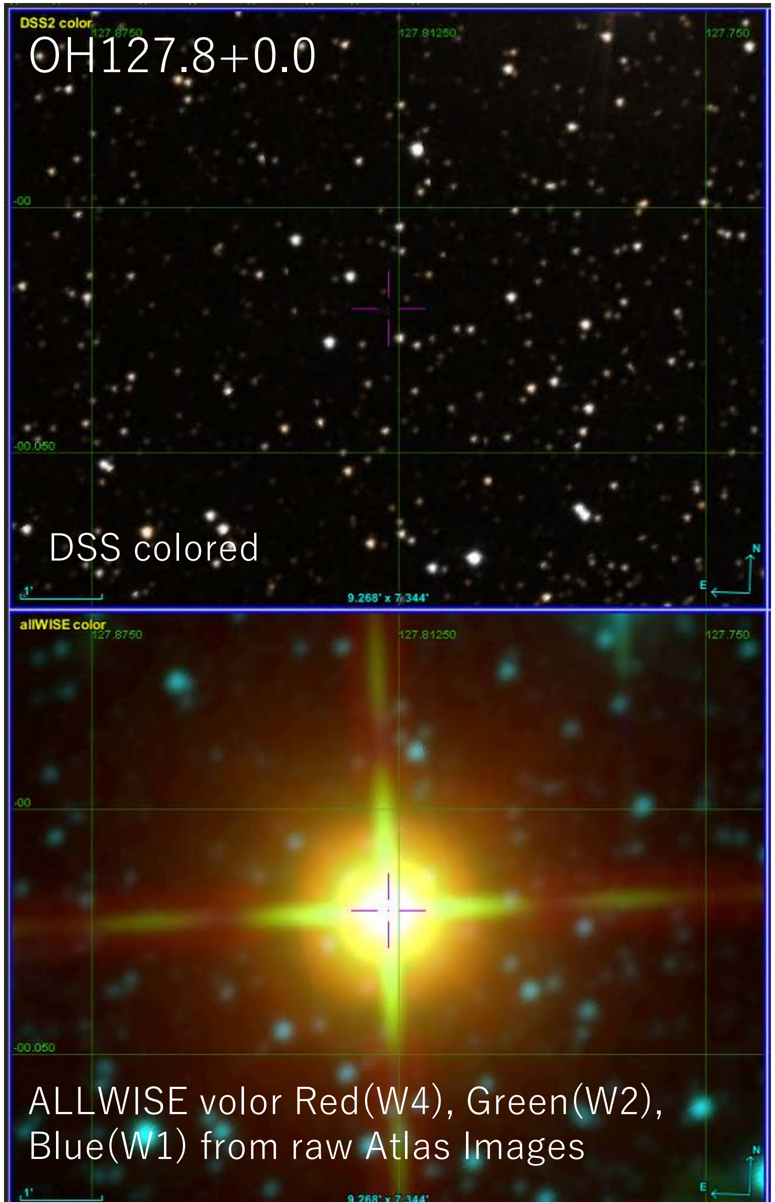


We need wide period coverage.

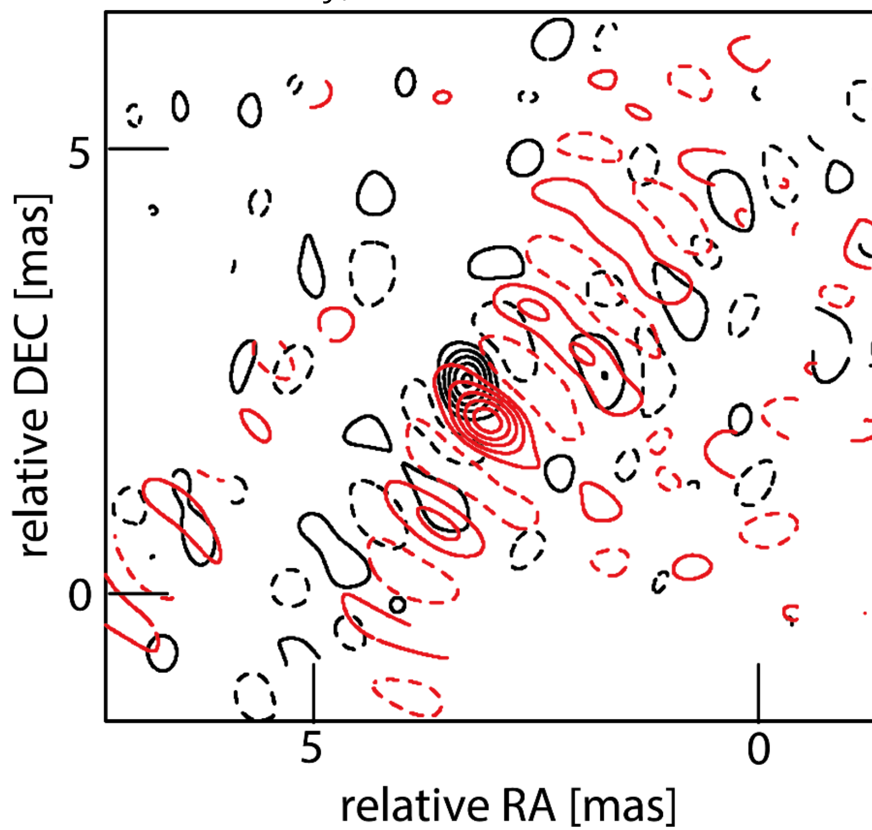
Nakagawa et al. IAUS343 Proceeding

Images of Extreme-OH/IR stars

VLBI and Gaia are complementary to each other.



NSV25875
Peak 1.97 Jy/beam

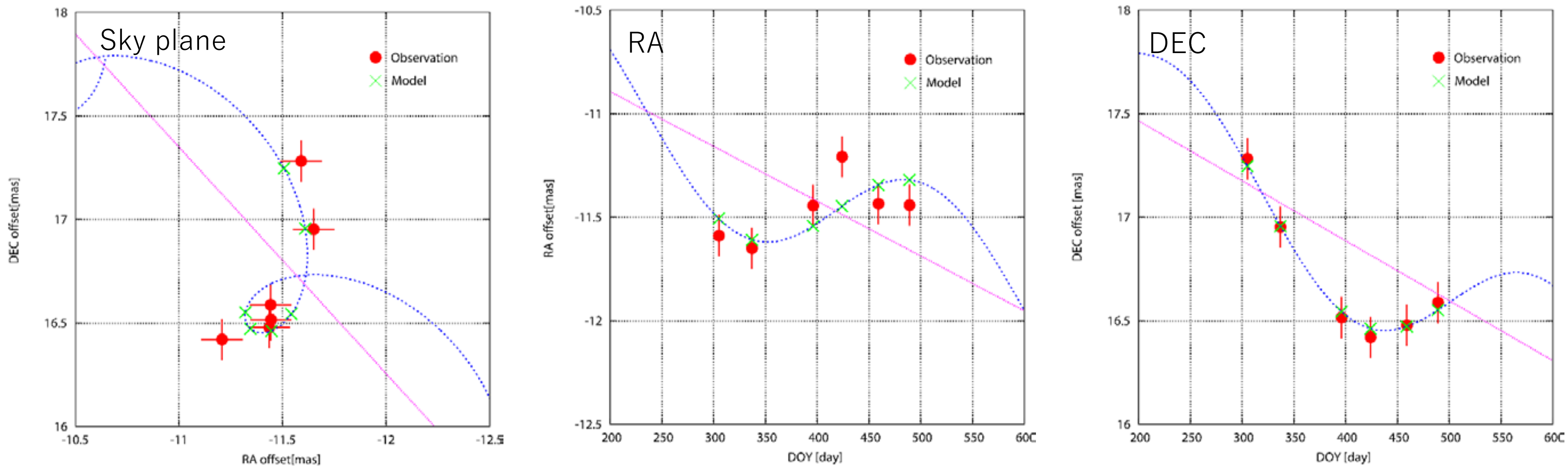


- 43GHz astrometric observation with VERA from Nov. 2017
- QSO: J2231+5922, ~240mJy@43GHz
- SiO maser (v=2), S/N=10

Phase referencing observation @43GHz, 2Gbps (512MHz BW for QSO)

NSV25875

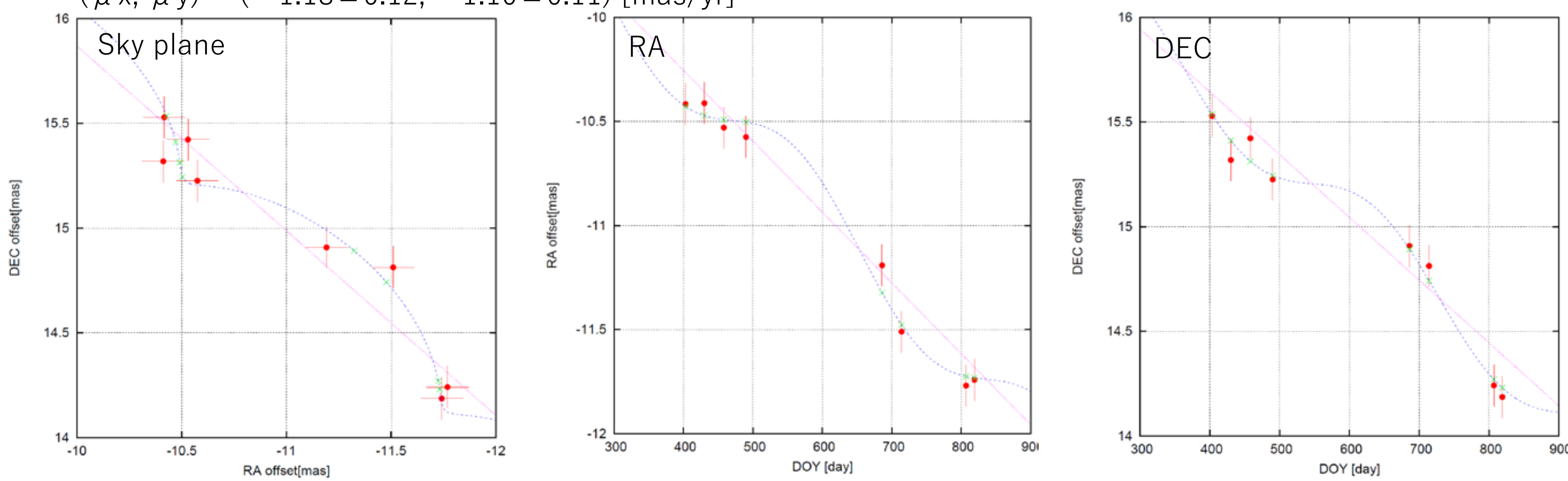
Parallax = 0.38 ± 0.13 mas, D = 2.60 ± 0.85 kpc



OH127.8+0.0

Parallax = 0.22 ± 0.08 mas, D = 4.54 ± 1.14 kpc

(μx, μy) = (−1.18 ± 0.12, −1.10 ± 0.11) [mas/yr]



Phase referencing observation of NSV17351 @22GHz, 1Gbps (240MHz BW for QSO)

【VLBI】

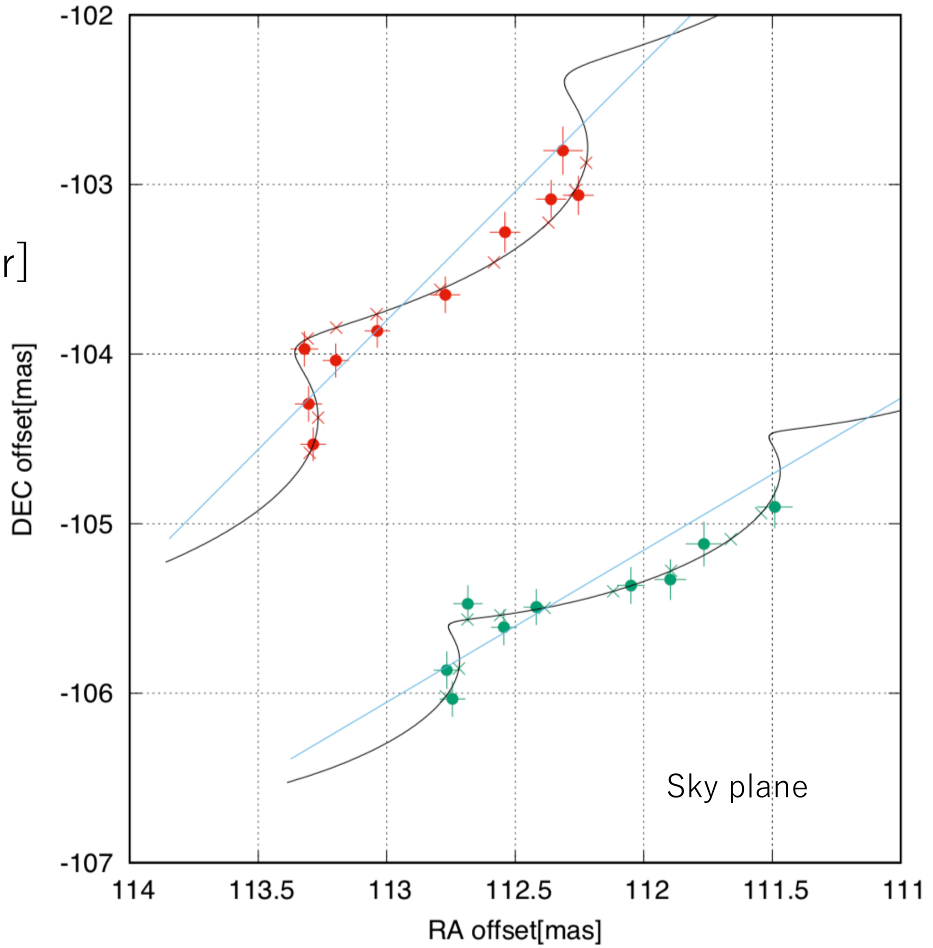
- Parallax(VERA) = 0.25±0.01 mas
  -> D = 3.95±0.2 kpc
- (μx, μy) = (−1.16±0.05, 1.35±0.09) [mas/yr]

⇕

【Gaia】

- Parallax(DR2) = 0.35±0.23 mas
- (μx, μy) = (1.34±0.4, -0.38±0.4) [mas/yr]

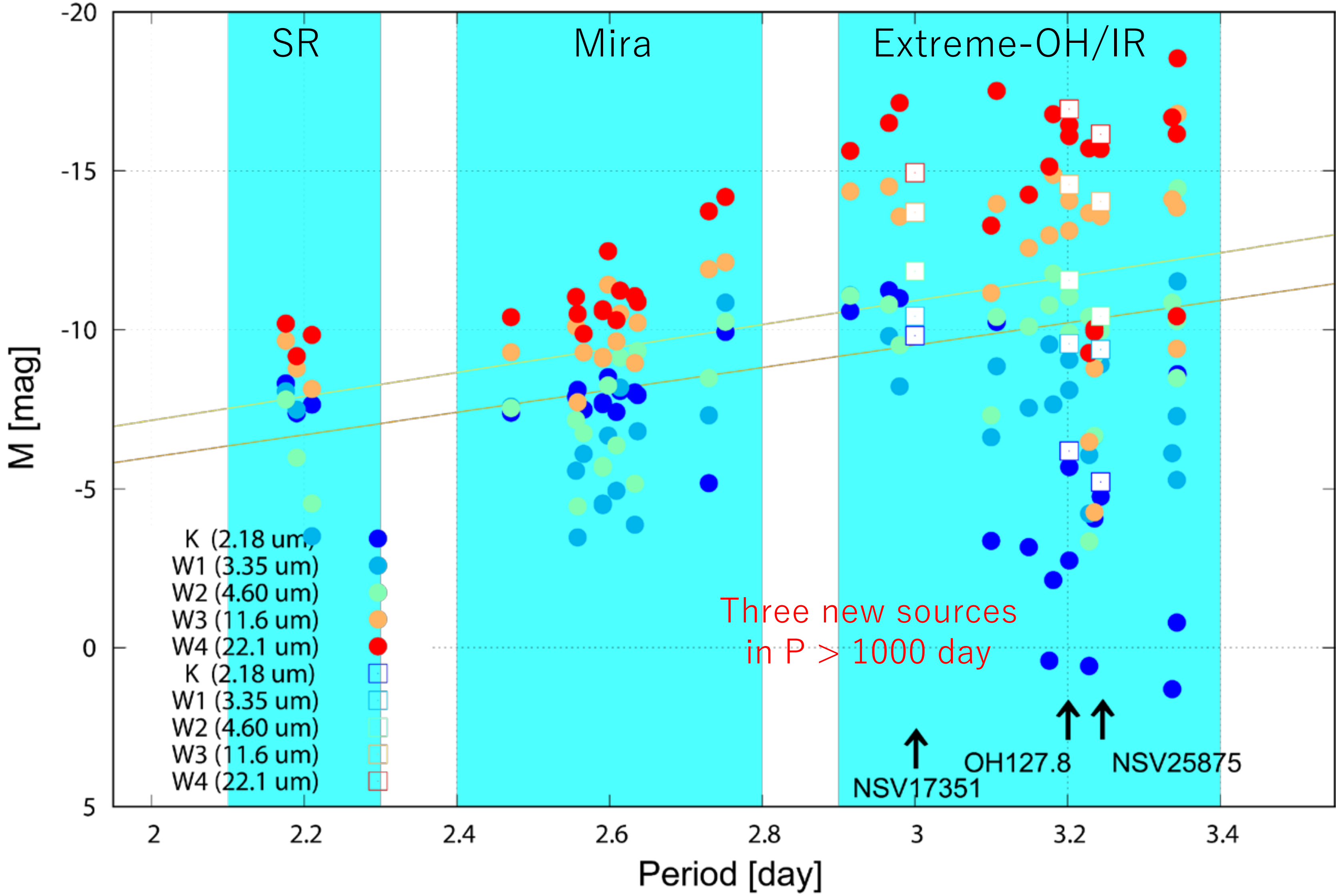
No Gaia DR2 parallax for previous two Extreme-OH/IR stars, NSV25875 and OH127.8.



● -> VLSR = 38.73 km/s
● -> VLSR = 40.41 km/s

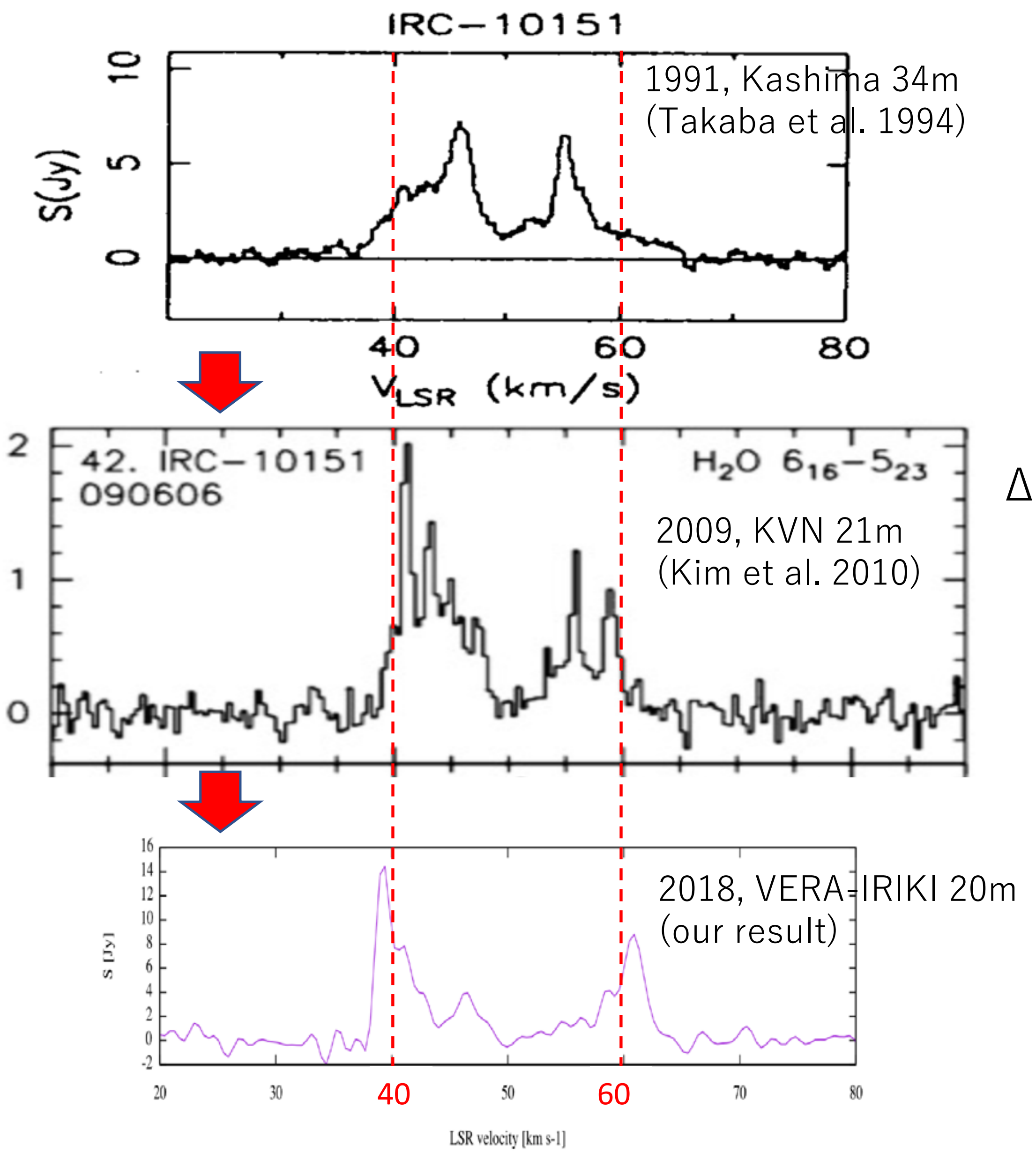
P-Mk diagram with continuous period coverage

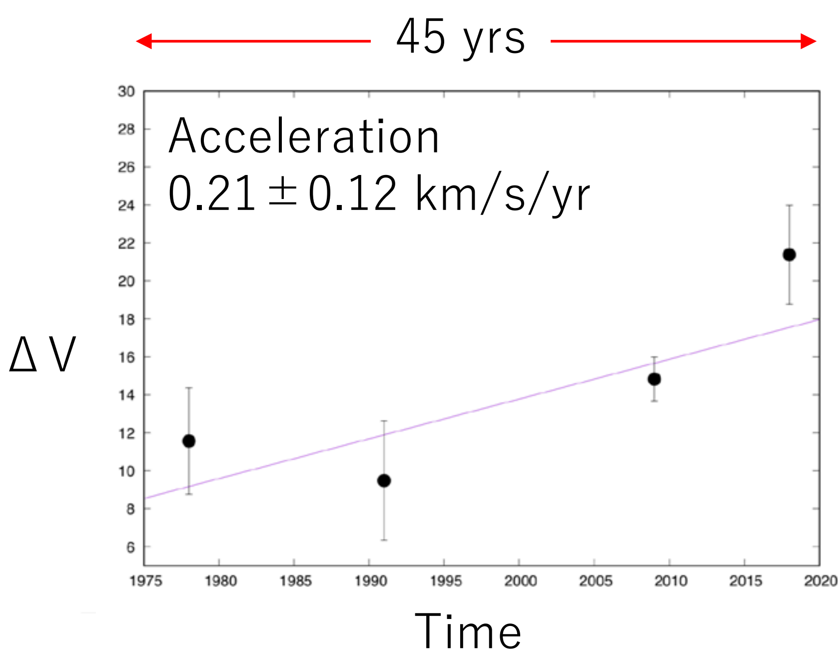
Three annual parallax of Extreme-OH/IR stars were added.



(2): H2O maser in an individual star
“NSV17351”.

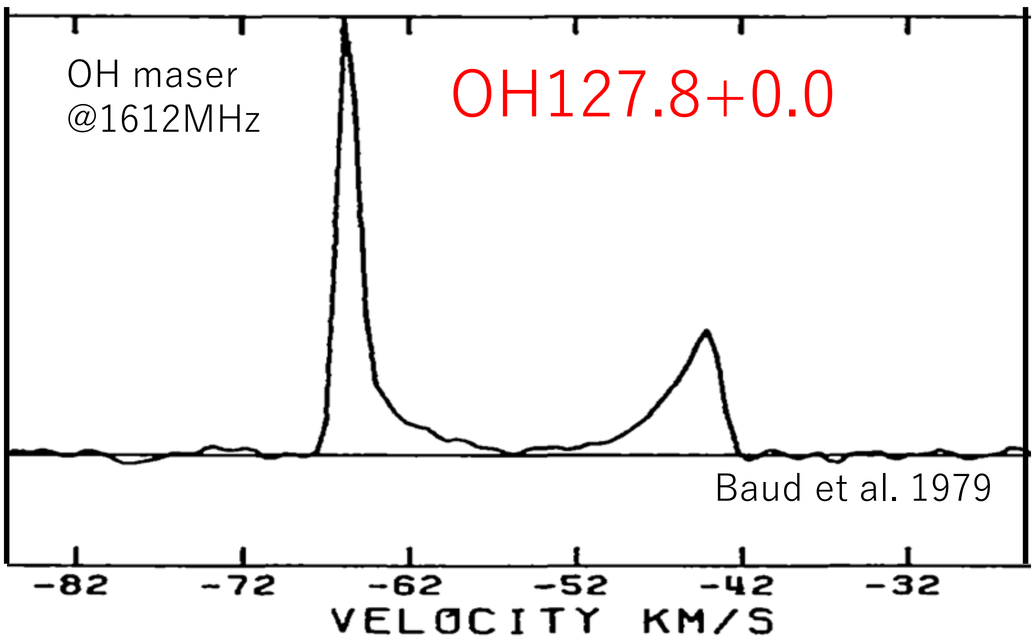
Acceleration of H2O maser in NSV17351

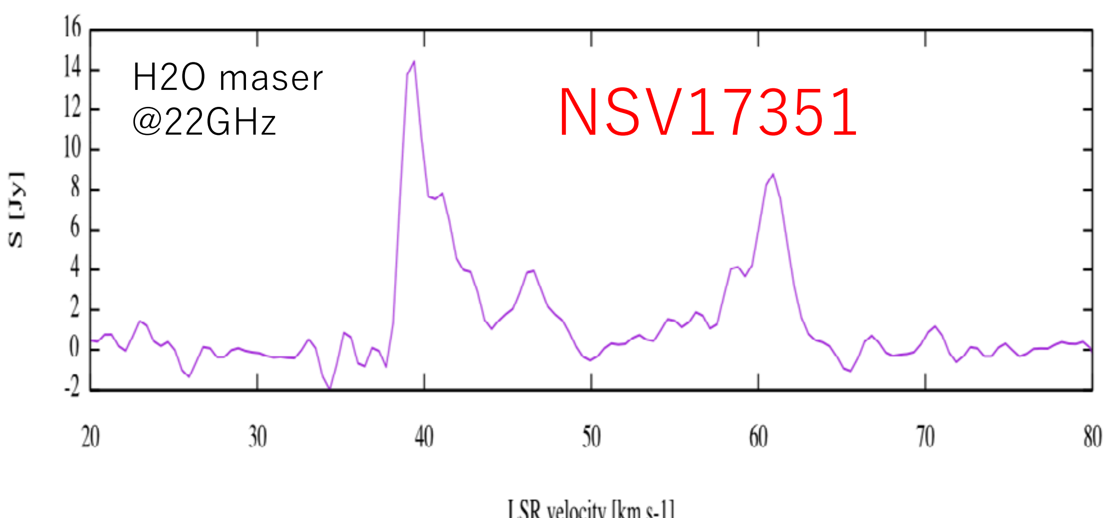




- $\Delta V = | V\_blue - V\_red |$
- Very weak 1612 MHz OH maser (~400mJy in 1987)

Similarity of spectrums, H2O and OH maser





Similar characteristics between H2O and OH

- Steep edges
- U-shaped hollow

<Hypothesis>

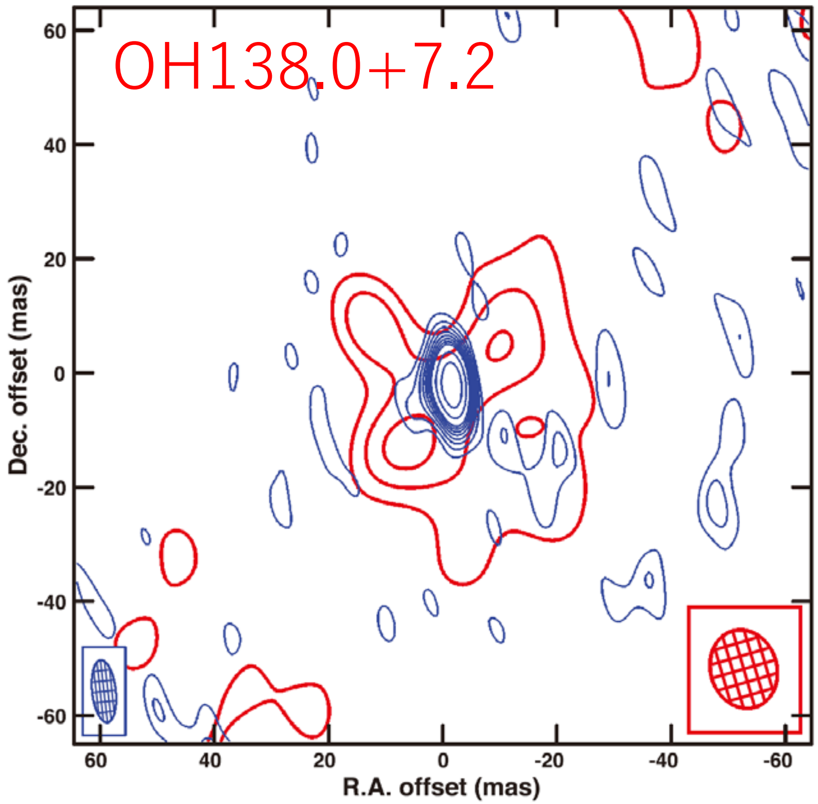
H2O gas in NSV17351 has experienced an acceleration and reached a terminal velocity in the last 45 years.

H2O shell radius at the terminal velocity is calculated to be >65 au.

Similarity of positions between H2O and OH maser also supports the hypothesis

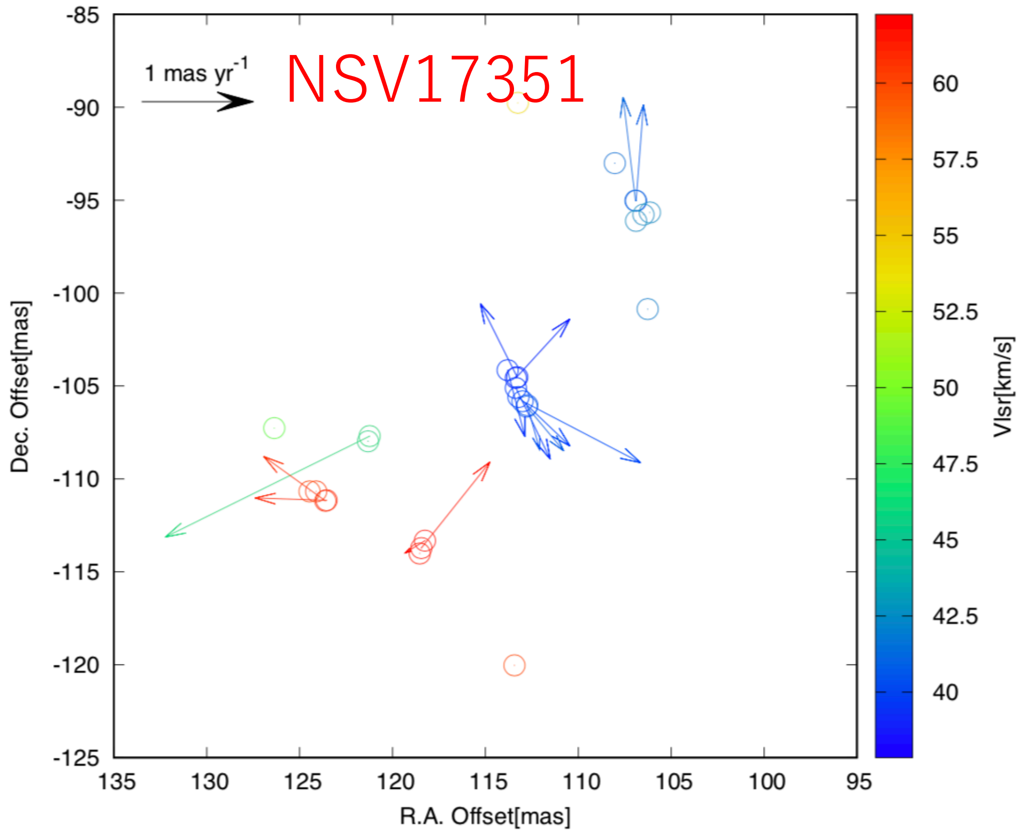
Bluest emission was found at an assumed stellar position.

OH maser @ 1612 MHz



Orosz et al. 2018

H2O maser @ 22 GHz



Our result

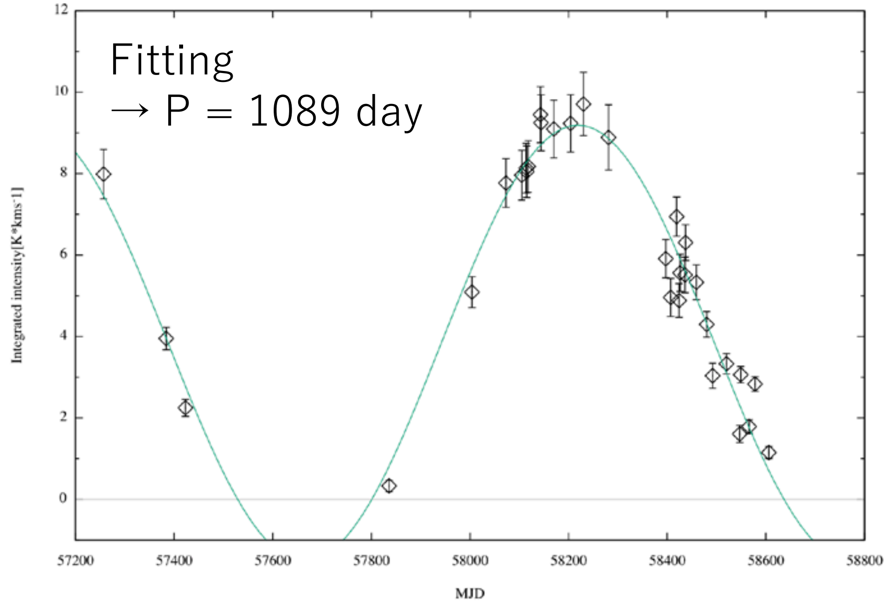
...However, sky plane motion of the bluest masers are puzzling.

Summary:

(1): VLBI astrometry of LPVs, from Miras to Extreme-OH/IR stars.

- Study of evolutional relation of LPVs
- 22 and 43GHz astrometric observation
- ~30 parallaxes were determined
- New parallaxes of 3 extreme-OH/IR stars
- Single-dish monitoring is also ongoing

H2O maser@22GHz, NSV17351



Variability in 1600 days(4.4 yr)

(2): H2O maser in an individual star "NSV17351".

- Acceleration was found in H2O maser spectrum
- We detected 45 years acceleration of circumstellar H2O gas
- Similarities of spectrum shapes and positions of H2O maser supports the hypothesis
- Single dish monitoring of H2O/SiO maser at VERA-IRIKI station for determination of periods of Extreme-OH/IRstars