

Extreme-OH/IR星の位置天文VLBI観測と Small JASMINEやTAOとの連携

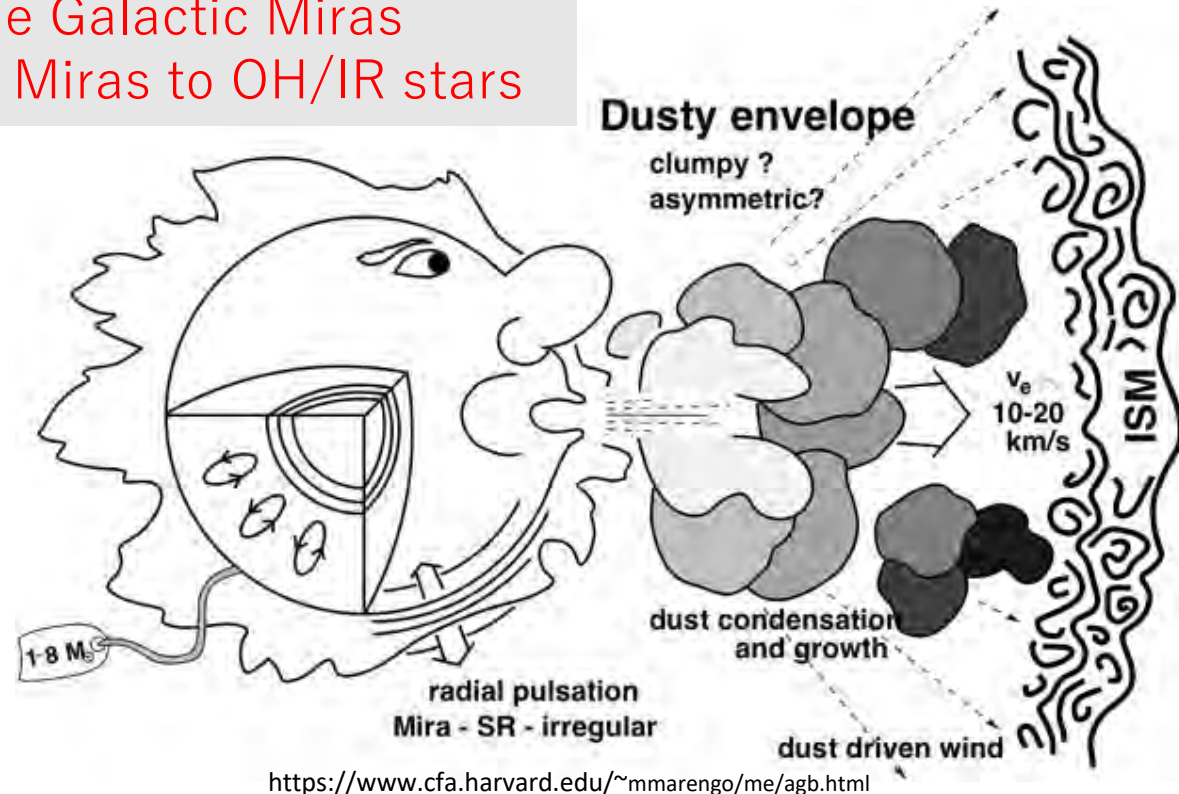
Akiharu NAKAGWA Kagoshima University

Aim of our study

- Confirming the PLR of the Galactic Miras
- Study the evolution from Miras to OH/IR stars

LPVs

- Initial Mass $0.8 - 8 M_{\odot}$
- Period $100 - 1000$ d
- Mass loss \rightarrow Chemical evolution
- P-L relation \rightarrow Distance



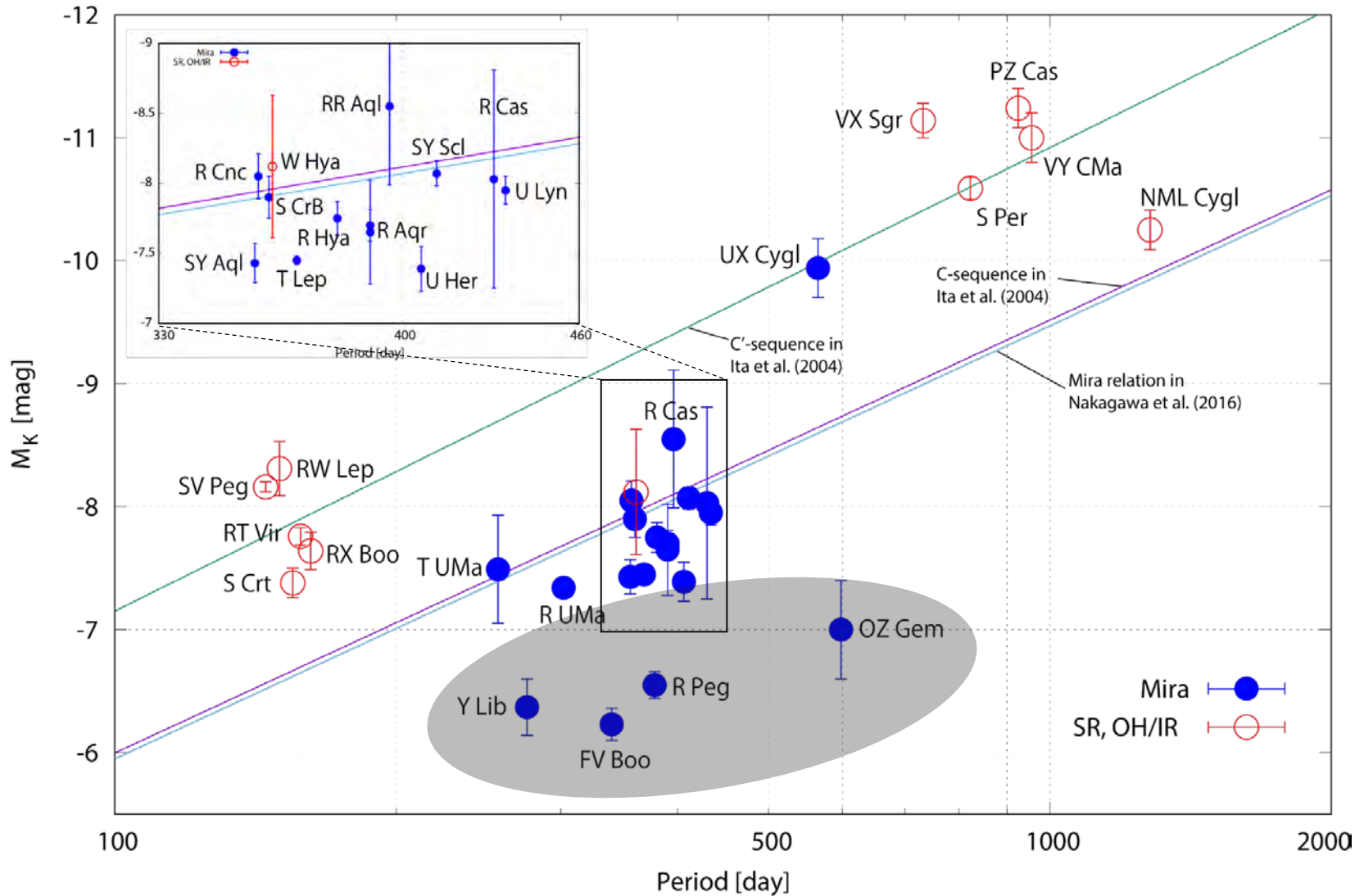
Today's topics

- (1): Astrometry of LPVs with VERA, VLBI and Gaia
- (2): Observations of LPVs to grasp its evolution from Miras to OH/IR stars
- (3): Collaboration with TAO, Small-Jasmine

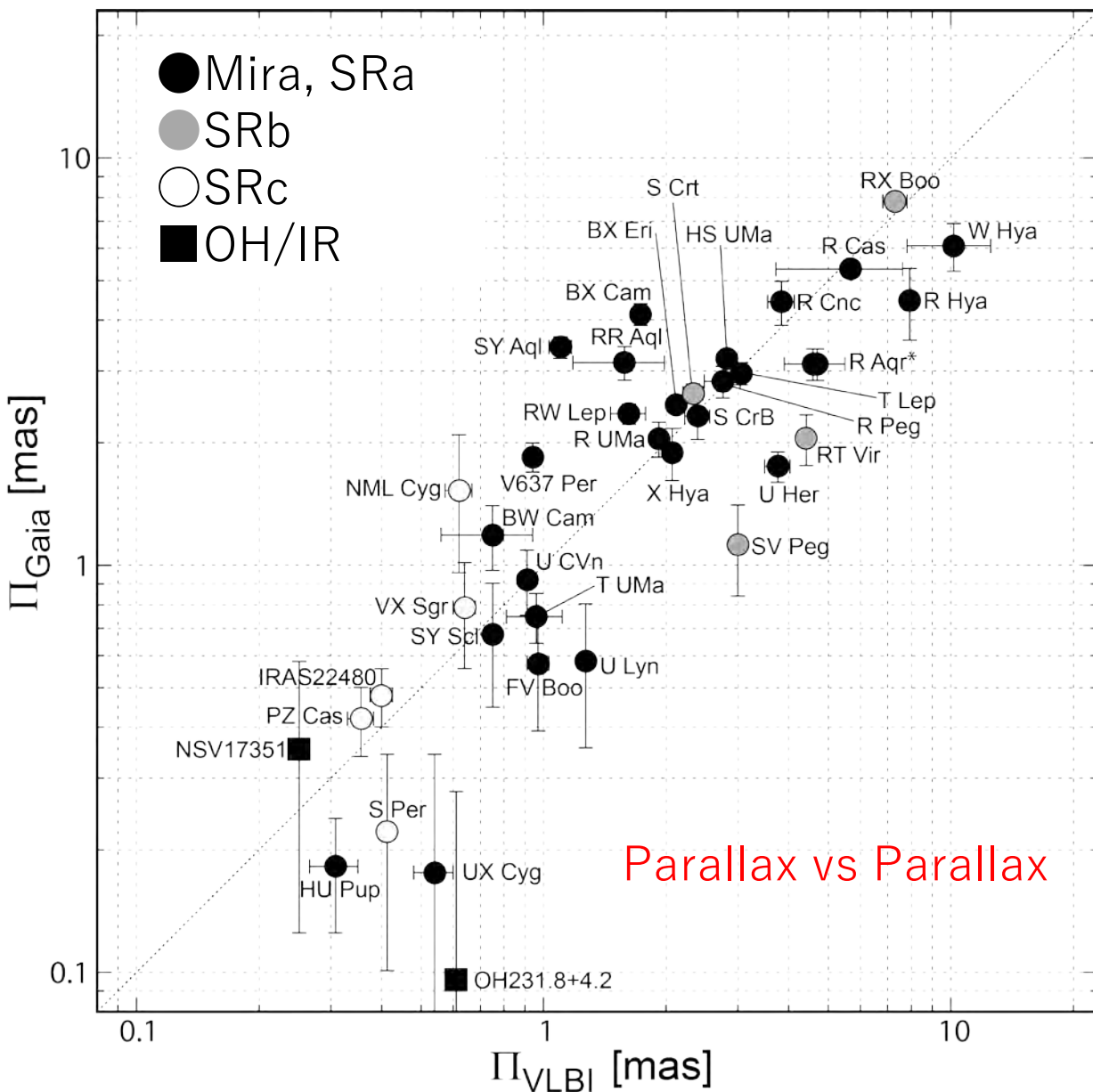
65 project sources, ~30 parallaxes were measured.

ID	Src.	Type	R.A.	Dec.	ID	Src.	Type	R.A.	Dec.
1	W Hya	SR	13h49m01.9980s	-28d22m03.488	34	V353_Pup	SR	07h46m34.1510s	-32d18m16.260
2	T Lep	Mira	05h04m50.7999s	-21d54m16.500	35	HU_Pup	SR	07h55m40.1600s	-28d38m54.840
3	RX_Boo	SR	14h24m11.5998s	+25d42m13.000	36	HS_UMa	LPV	11h35m30.70408s	+34d52m04.1775
4	S_Crt	SR	11h52m45.1000s	-07d35m48.100	37	R_LMi	Mira	09h45m34.28304s	+34d30m42.7839
5	AP Lyn	Mira	06h34m33.8999s	+60d56m26.199	38	BX_Eri	SR	04h40m32.754s	-14d12m02.39
6	R UMa	Mira	10h44m38.3999s	+68d46m32.298	39	V637_Per	SR	03h54m02.28s	+36d32m17.6
7	WX_Psc	Mira	01h06m25.8998s	+12d35m53.000	40	U_CVn	Mira	12h47m19.61s	+38d22m30.5
8	Z Pup	Mira	07h32m38.1000s	-20d39m29.199	41	RU_Hya	Mira	14h11m34.39861s	-28d53m07.4089
9	SY Scl	Mira	00h07m36.2000s	-25d29m40.000	42	NSV17351	OHIR	07h07m49.38s	-10d44m05.9
10	Y Lib	Mira	15h11m41.2999s	-06d00m41.399	43	R_Peg	Mira	23h06m39.16689s	+10d32m36.0892
11	VX UMa	Mira	10h55m39.8999s	+71d52m09.800	44	R_Hya	Mira	13h29m42.78187s	-23d16m52.7747
12	GX Mon	Mira	06h52m46.8999s	+08d25m19.000	45	OH127.8	OHIR	01h33 51.21s	+62d26m53.2
13	U Lyn	Mira	06h40m46.5000s	+59d52m01.600	46	NSV25875	OHIR	22h19m27.48s	+59d51m21.7
14	T UMa	Mira	12h36m23.5000s	+59d29m13.000	47	UU_Peg	Mira	21h31m04.156s	+11d09m13.24 92
15	S CrB	Mira	15h21m24.0000s	+31d22m02.600	48	R_Cas	Mira	23h58m24.87336s	+51d23m19.7011
16	SW Lib	Mira	15h55m33.3999s	-12d51m05.099	49	S_Ser	Mira	15h21m39.53475s	+14d18m53.1002
17	FS Lib	Mira	16h00m23.8000s	-12d20m57.500	50	W_Leo	Mira	10h53m37.43245s	+13d42m54.3666
18	IRC-20540	Mira	19h08m56.0000s	-22d14m19.399	51	OH32.8-0.3	OHIR	18h52m24.682333s	-00d14m57.612
19	IRC+10374	Mira	18h43m36.7000s	+13d57m22.800	52	V391CYG	Mira	19h40m52.394300s	+48d47m41.52658
20	X Hya	Mira	09h35m30.3000s	-14d41m28.600	53	RAFGL5201	OHIR	06h34m28.052569s	-05d03m42.85697
21	R Cnc	Mira	08h16m33.7999s	+11d43m34.500	54	OH83.4-0.9	OHIR	20h50m58.619647s	+42d48m11.44793
22	FV_Boo	SR	15h08m25.8000s	+09d36m18.199	55	OH141.7+3.5	OHIR	03h33m30.618480s	+60d20m08.85024
23	RU_Ari	SR	02h44m45.5000s	+12d19m03.000	56	CU_Cep	OHIR	22h11m31.882483s	+57d02'17.46857"
24	RW_Lep	SR	05h38m52.7000s	-14d02m27.199	57	DU_Pup	Mira	07h35m03.978770s	-23d59'14.80023"
25	BW_Cam	Mira	05h19m52.5600s	+63d15m55.798	58	RAFGL2445	OHIR	19h44m07.000754s	+35d14'08.25184"
26	BX_Cam	Mira	05h46m44.2999s	+69d58m24.199	59	OH39.7+1.5	OHIR	18h58m30.094784s	+06d42'57.69806"
27	U_Ori	Mira	05h55m49.2000s	+20d10m30.699	60	EUAND	C	23h19m58.881502s	+47d14'34.57638"
28	QX_Pup	Mira	07h42m16.8298s	-14d42m52.100	61	AWTAU	Mira	05h47m30.209209s	+27d08'12.40939"
29	RS_Vir	Mira	14h27m16.3998s	+04d40m41.100	62	I17411-3154	Mira	17h44m24.003874s	-31d55'35.42862"
30	SY_Aql	Mira	20h07m05.4000s	+12d57m06.299	63	OH26.5+0.6	OHIR	18h37m32.51s	-05d23'59.2"
31	SV_Peg	SRb	22h05m42.0850s	+35d20m54.536	64	OH42.3-0.1	OHIR	19h09m07.466221s	+08d16'22.70258"
32	R_Tau	Mira	04h28m18.0000s	+10d09m44.798	65	TXCAM	Mira	05h00m51.156996s	+56d10'54.09311"
33	OZ_Gem	Mira	07h33m57.7500s	+30d30m37.798					

Recent result of the period-M_K diagram of Miras in the Galaxy

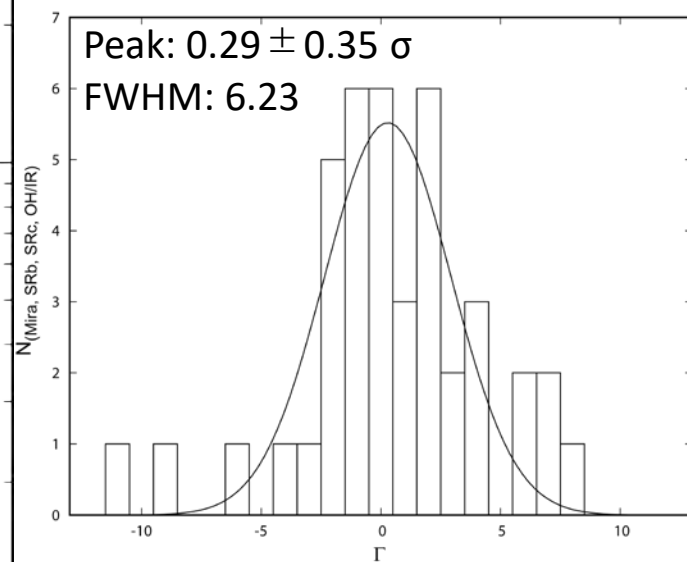


VLBI and Gaia



差分の評価指標

$$\Gamma = \frac{\Pi_{\text{VLBI}} - \Pi_{\text{Gaia}}}{\sqrt{\sigma_{\Pi_{\text{VLBI}}}^2 + \sigma_{\Pi_{\text{Gaia}}}^2}}$$



VLBI and Gaia

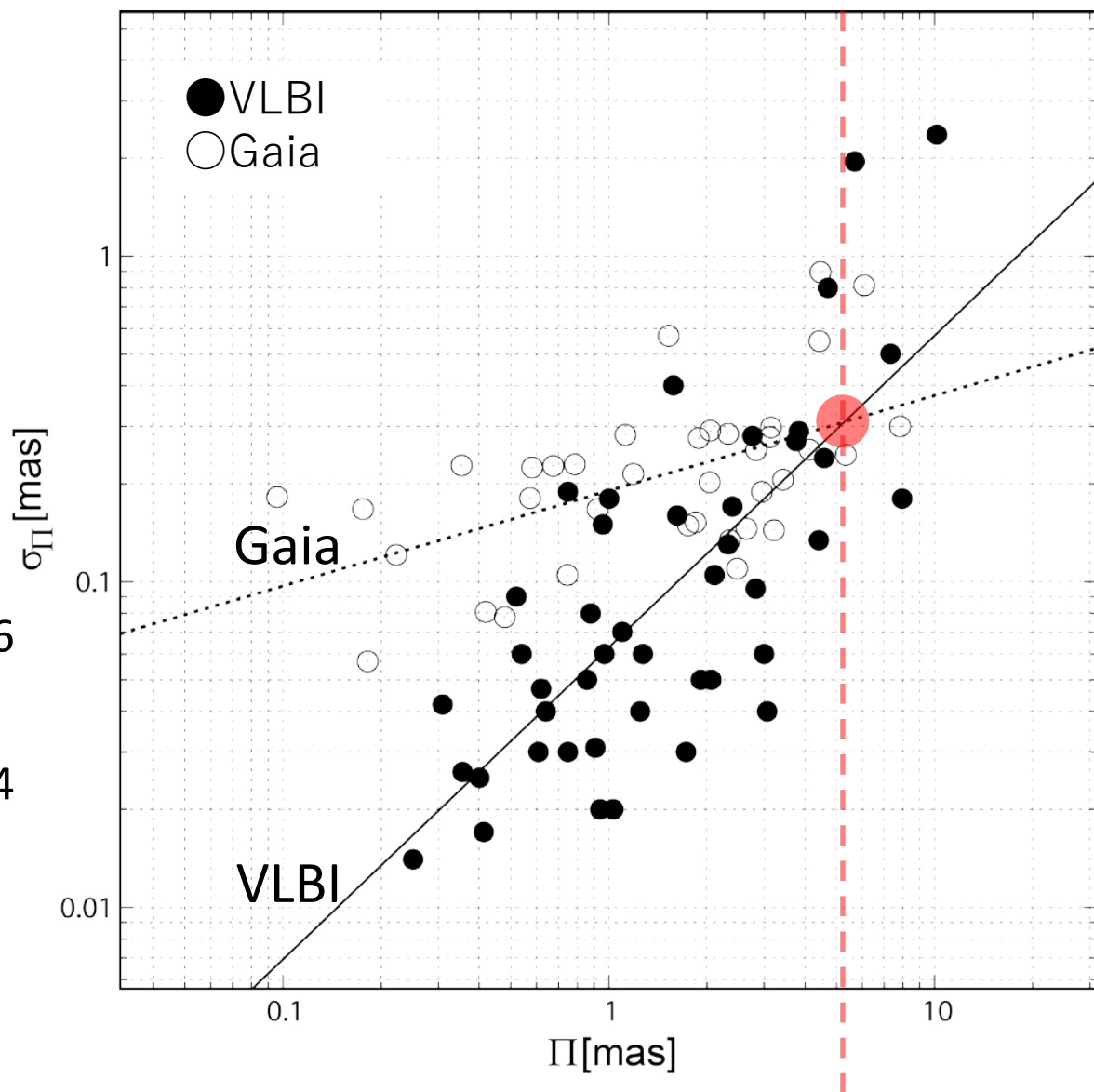
Parallax vs error

VLBI ———

$$y = (0.96 \pm 0.13) \text{Log}\Pi - 1.20 \pm 0.06$$

Gaia ·····

$$y = (0.29 \pm 0.07) \text{Log}\Pi - 0.72 \pm 0.04$$

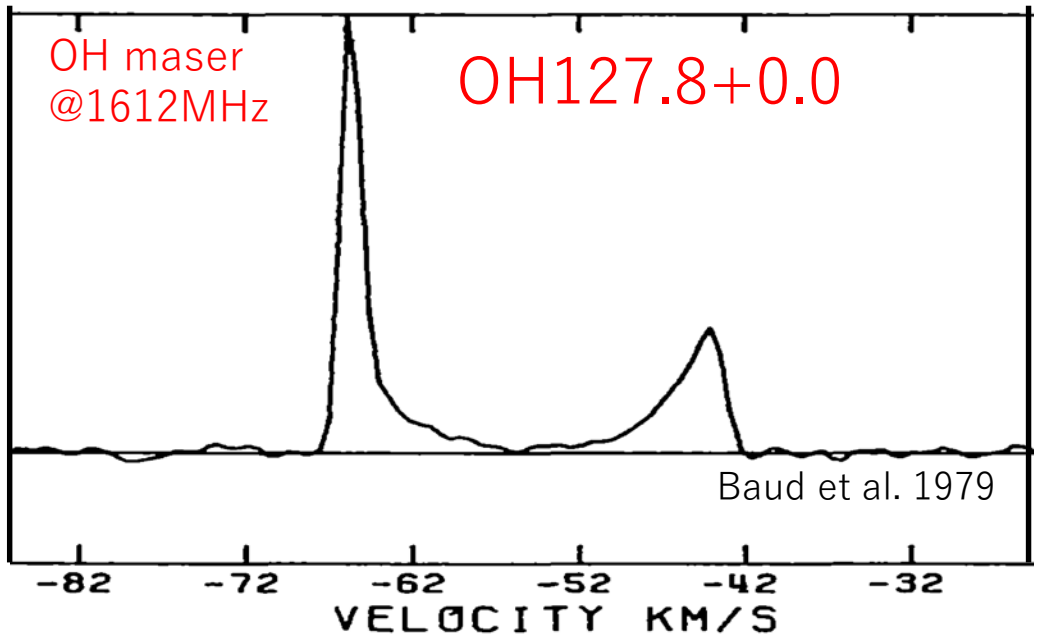


およそ190 pcを境に
遠方はVLBIが有利, 近傍はGaiaが有利

$\Pi = 5.20$
($D = 192$ pc)

Observations of LPVs to grasp its evolution from Miras to OH/IR stars

H2OとOH maserのスペクトル類似性



Similar characteristics between H2O and OH

- Steep edges
- U-shaped hollow

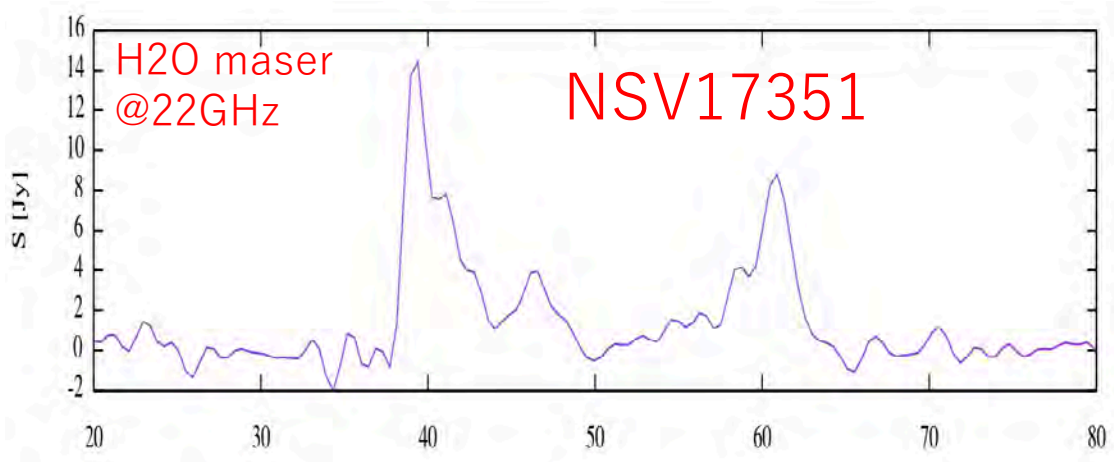


<Hypothesis>

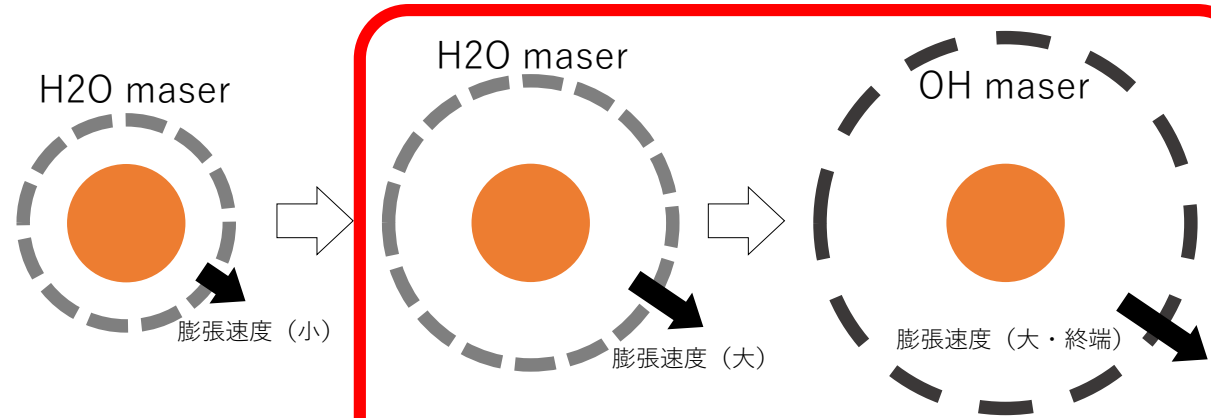
H2O gas in NSV17351 has experienced an acceleration and reached a terminal velocity in the last 45 years.

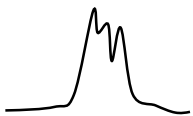



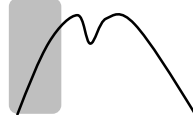
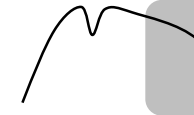


H2O shell radius at the terminal velocity is calculated to be >65 au.



Observations of LPVs to grasp its evolution from Miras to OH/IR stars

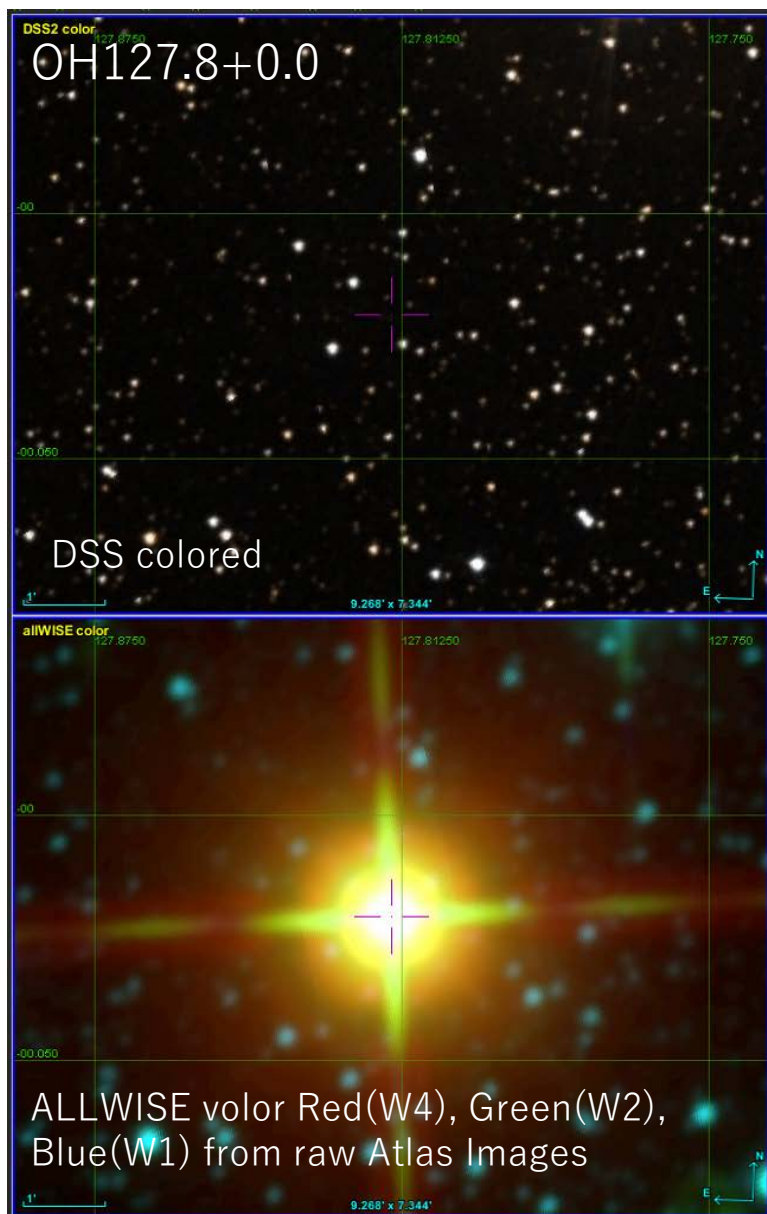


進化	① Mira型変光星 ⇨	② Mira型変光星 ⇒ OH/IR星 ⇨	③ OH/IR星
メーザーの種類	星周でH2Oメーザーが励起される ⇨	H2Oメーザーが加速を受けて外層へと広がる ⇨	H2Oメーザーが外縁部で光乖離されてOHメーザーが励起され始める
メーザーの速度	ある速度で膨張 ⇨	次第に加速されて速度は速くなる ⇨	加速が終わり、速度は終端速度に達する
メーザーのスペクトル	<p>H2Oメーザー</p>  <p>膨張速度を反映したスペクトルの広がり。 ⇨</p>	<p>H2Oメーザー</p>  <p>加速により幅が徐々に広がる様子が見える。 ⇨</p>	<p>OHメーザー</p>  <p>加速が終わり終端速度に到達したOHメーザーが観測される。切り立つエッジが特徴的。</p>
SEDの様子	 <p>可視から赤外まで広く輻射あり</p>	 <p>ダストにより可視が抑えられ再放射による赤外の過多</p>	 <p>厚いダストによる中間赤外から遠赤外の過多が目立つ</p>

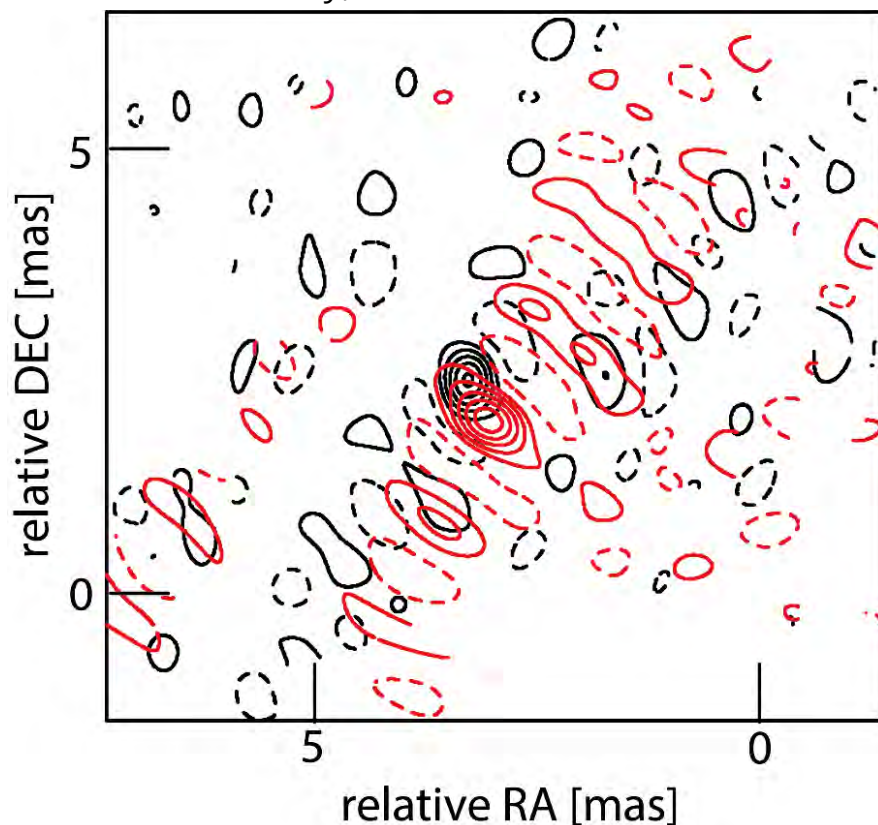
VLBI observation

VLBI observation of extreme-OH/IR stars

VLBI and Gaia are complementary to each other.



NSV25875
Peak 1.97 Jy/beam

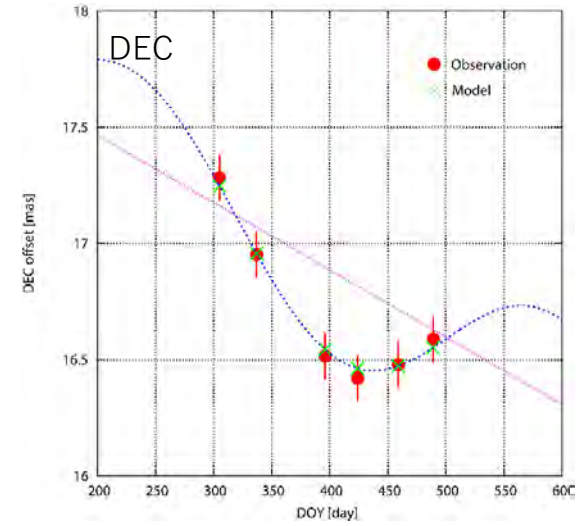
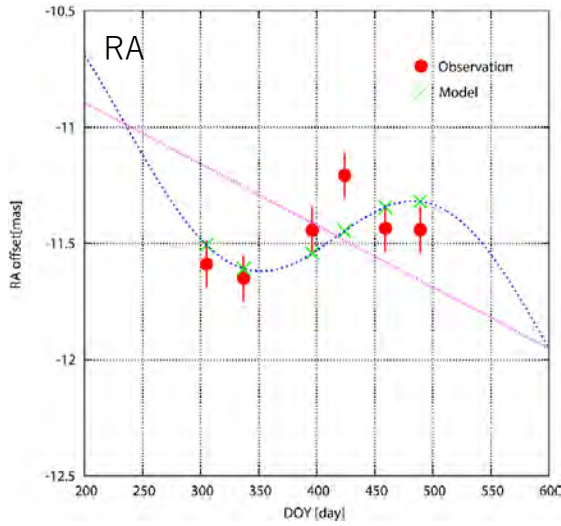
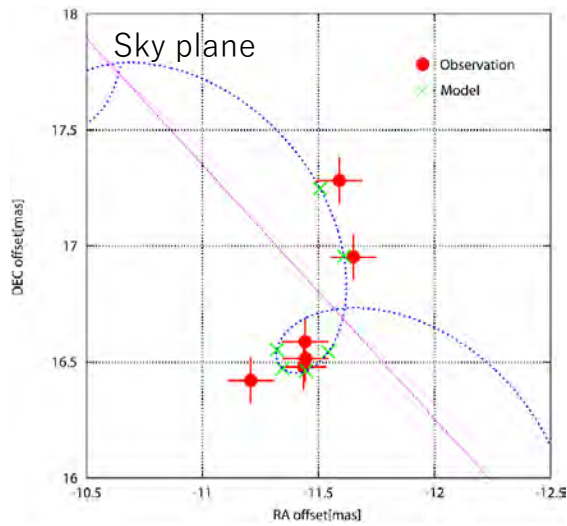


- 43GHz astrometric observation with VERA from Nov. 2017
- QSO: J2231+5922, $\sim 240\text{mJy}@43\text{GHz}$
- SiO maser ($\nu=2$), S/N=10

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

NSV25875

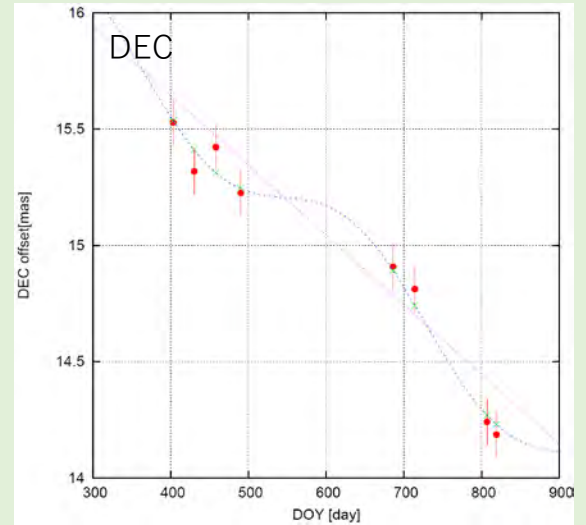
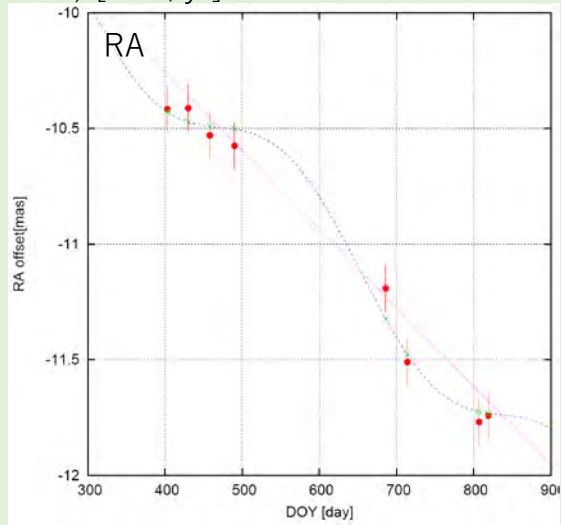
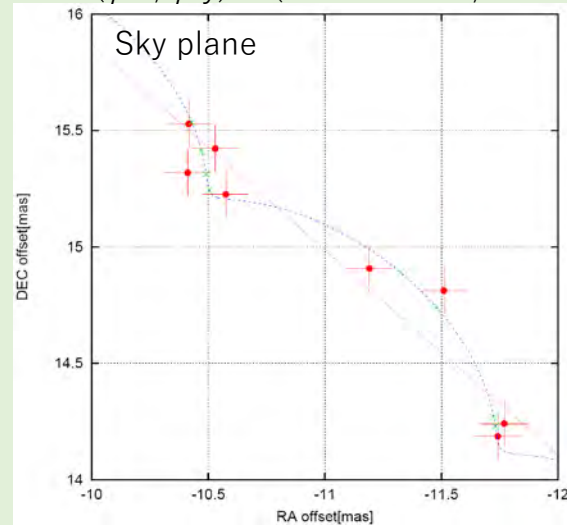
Parallax = 0.38 ± 0.13 mas, $D = 2.60 \pm 0.85$ kpc



新しい観測結果

Parallax = 0.22 ± 0.08 mas, $D = 4.54 \pm 1.14$ kpc
(μ_x, μ_y) = $(-1.18 \pm 0.12, -1.10 \pm 0.11)$ [mas/yr]

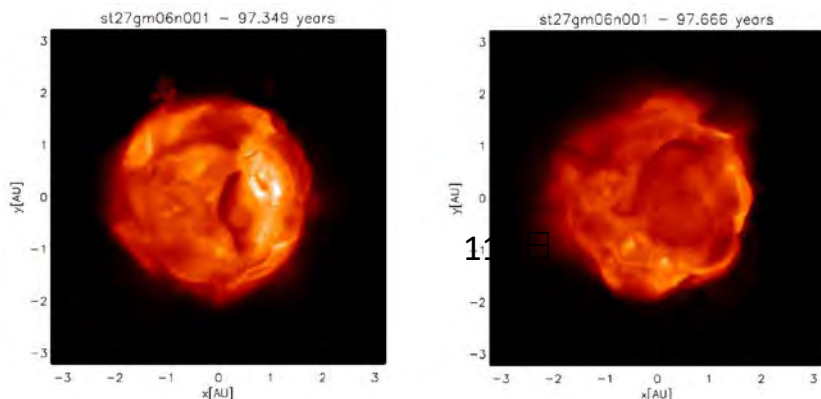
OH127.8+0.0



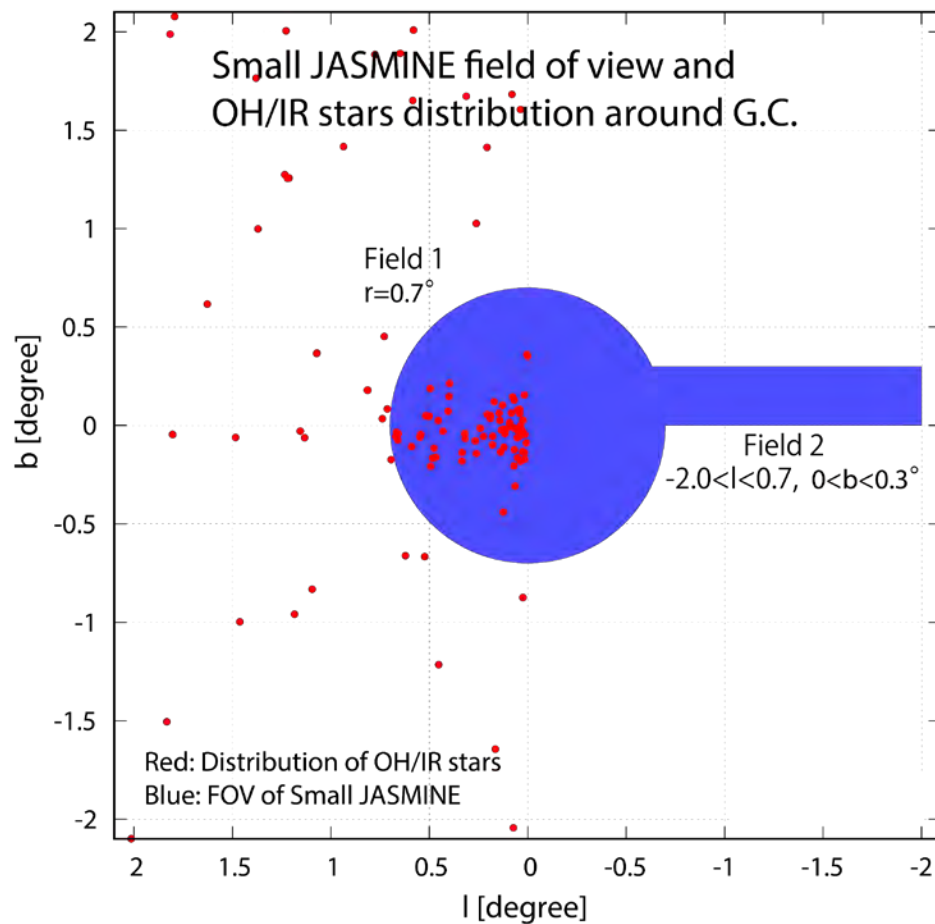
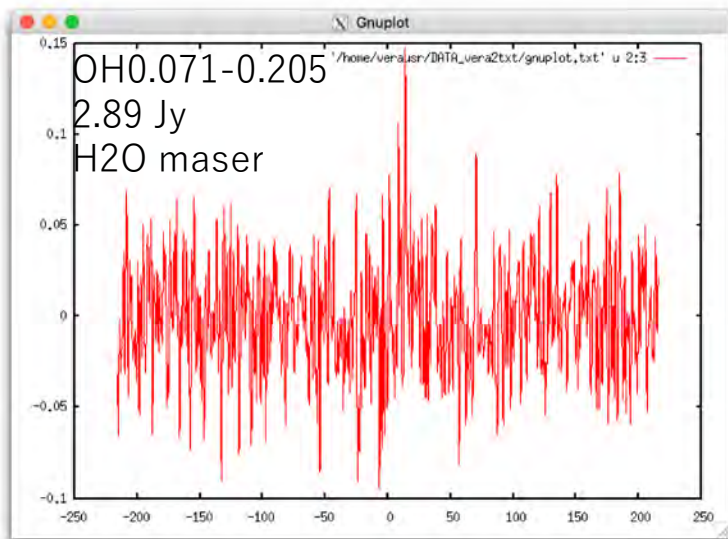
Small-Jasmine

- Verification of AGB star astrometry
- Single dish survey at Iriki (22, 43 GHz)

表面輝度構造変化の影響



Chiavassa et al. 2018 (arXiv:1808.02548v1)
3D radiative-hydrodynamics simulations of convection

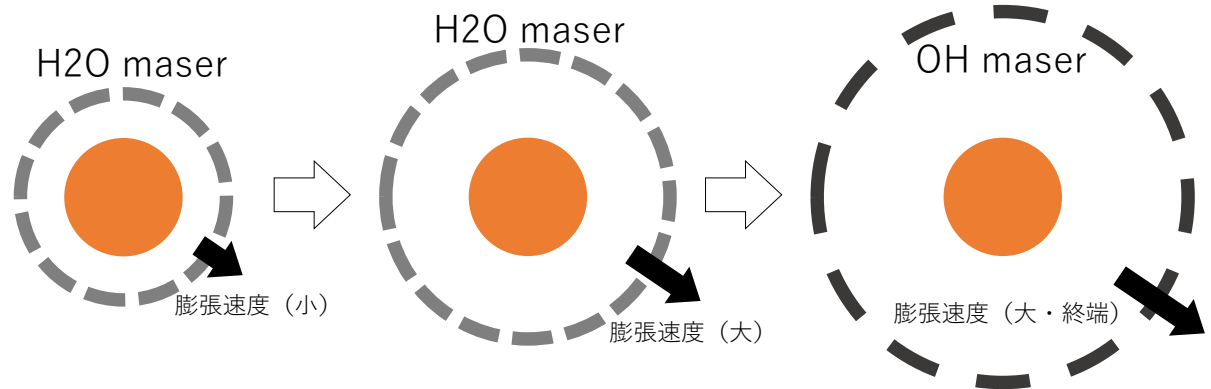


TAO

Short term and long term SED acquisition



MIMIZUKU
2 - 38 μ m



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TAO

Summary:

(1): Astrometry of LPVs with VERA, VLBI and Gaia

- PLR of the Galactic LPVs
- ~30 parallaxes were determined from VERA
- Parallaxes from VLBI and Gaia

(2): Observations of LPVs to grasp its evolution from Miras to OH/IR stars

- Acceleration found in H₂O maser spectrum
- VLBI observation can determine parallax of OH/IR stars to determine

(3): Collaboration with TAO, Small-Jasmine

- TAO: Short term and long term SED monitoring
- Small-Jasmine: Verification of parallaxes from infrared astrometry

