VERAによるOH/IR星の SiOメーザー位置天文観測

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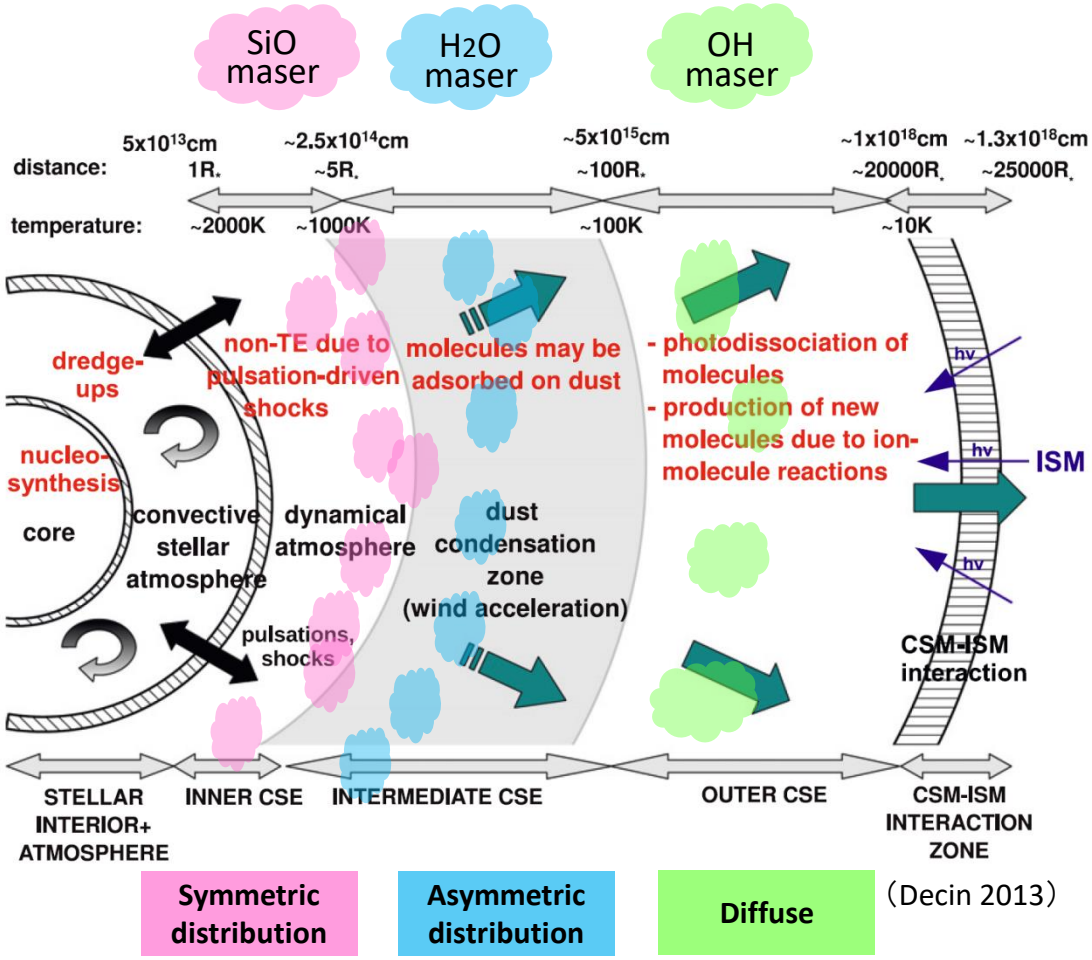
倉山智春、長谷川詩歩(帝京科学大学)、国立天文台VERA

1. VERAによるMira型変光星の観測
・約80のプロジェクト天体
・変動フェーズや周期を考慮して選定
・星周物質の運動
・Kバンド周期光度関係

2. OH/IR星の位置天文観測
・星の特徴と観測のねらい
・観測の開始と初観測の結果
・鹿島34m鏡を用いた単一鏡観測



(Decin 2013)

最近のMira型変光星観測結果（22GHz 水メーザー）

湯田晶斗、加世田大地、森川佑斗

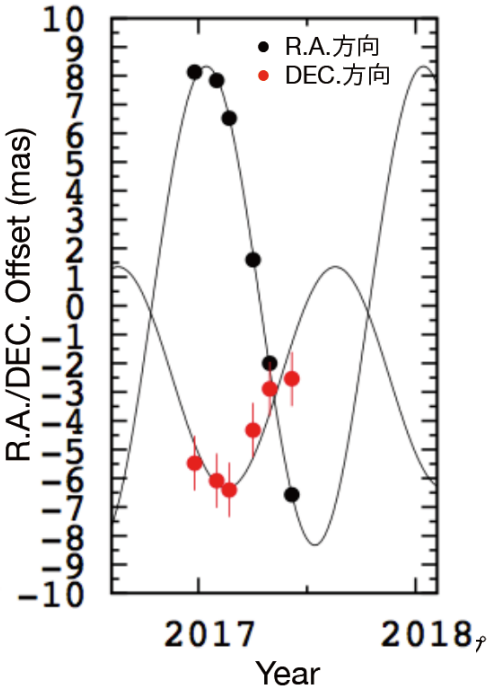


図 8. R-HyaのR.A./DEC.方向の運動

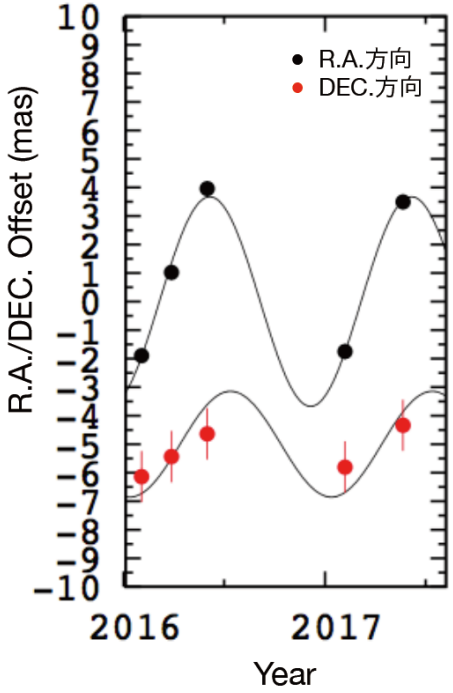
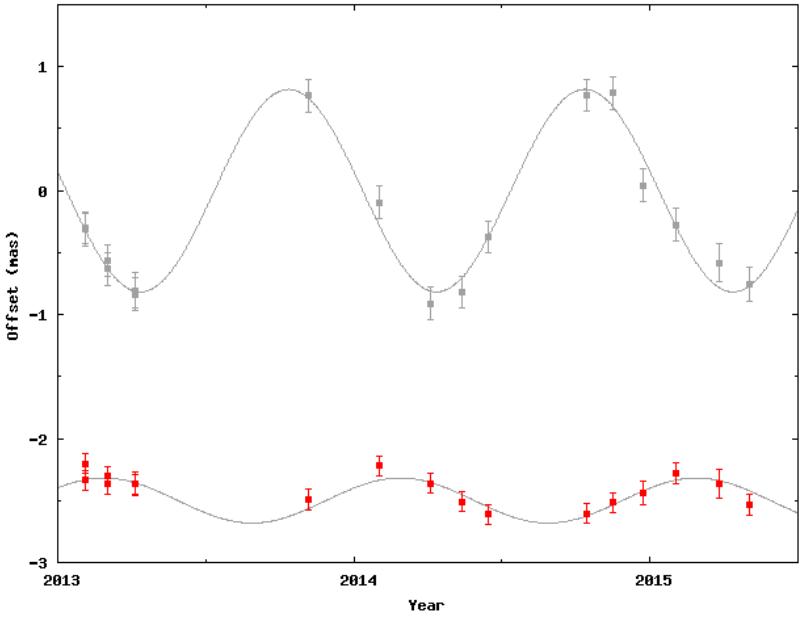


図 10. R-PegのR.A./DEC.方向の運動



R Hya

Parallax = 8.96±0.51[mas]
Distance = 0.11±0.01[kpc] –
μx=52.87±2.08[mas/yr],
μy=18.33±2.78[mas/yr]

R Peg

Parallax = 3.98±0.21[mas]
Distance = 0.25±0.01[kpc]
μx=1.55±0.26[mas/yr]
μy=-12.37±0.86[mas/yr]

OZ Gem

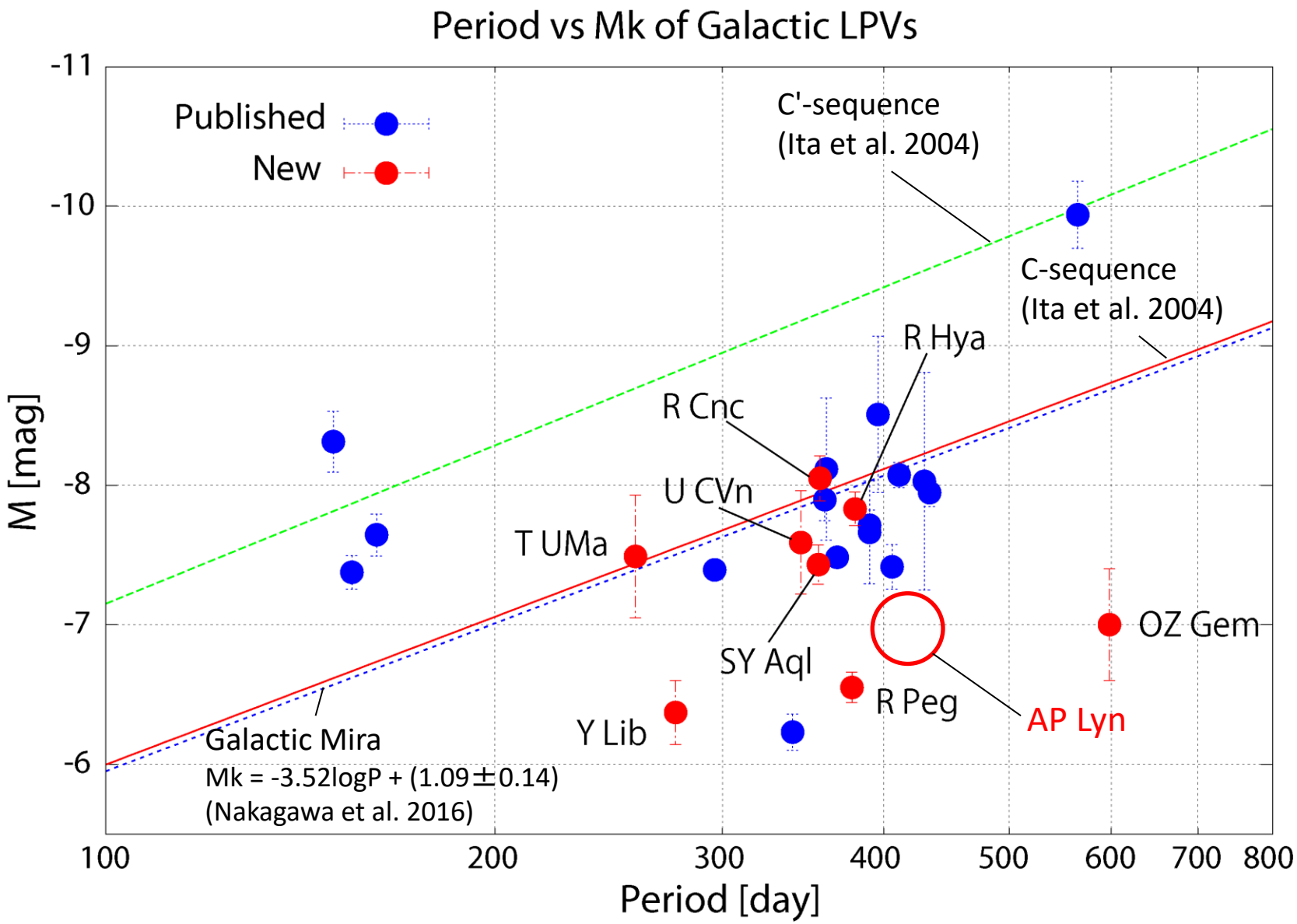
Parallax = 0.83±0.06[mas]
Distance = 1.21±0.09[kpc]
μx=-2.78±0.05[mas/yr]
μy=-9.43±0.03[mas/yr]

AGB star distances from VLBI astrometry

Source	Type	Parallax [mas]	P [day]	Log$P$	m_K [mag]	M_K [mag]	Maser	Reference† (Parallax, m_K)
RW Lep	SRa	1.62±0.16	150	2.176	0.639	-8.31 ± 0.22	H_2O	kam14, a
S Crt	SRb	2.33±0.13	155	2.190	0.786	-7.38 ± 0.12	H_2O	nak08, a
RX Boo	SRb	7.31±0.5	162	2.210	−1.96	-7.64 ± 0.15	H_2O	kam12, b
T UMa	Mira	0.96±0.15	257	2.410	2.60	-7.49 ± 0.44	H_2O	···, a
Y Lib	Mira	1.24±0.13	276	2.441	3.16	-6.37 ± 0.23	H_2O	···, a
R UMa	Mira	1.92±0.05	302	2.480	1.19	-7.39 ± 0.06	H_2O	nak16, d
U CVn	Mira	0.82±0.14	345	2.538	2.84	-7.59 ± 0.37	H_2O	···, a
SY Aql	Mira	1.10±0.07	356	2.551	2.36	-7.43 ± 0.14	H_2O	···, a
R Cnc	Mira	3.84±0.29	357	2.553	−0.97	-8.05 ± 0.16	H_2O	···, a
W Hya	SRa	10.18±2.36	361	2.558	−3.16	-8.12 ± 0.51	OH	vle03, c
S CrB	Mira	2.39±0.17	360	2.556	0.21	-7.90 ± 0.15	OH	vle07, c
T Lep	Mira	3.06±0.04	368	2.566	0.12	-7.45 ± 0.03	H_2O	nak14, c
R Peg	Mira	3.98±0.21	378	2.577	0.45	-6.55 ± 0.11	H_2O	···, a
R Hya	Mira	8.96±0.51	380	2.580	-2.51	-7.75 ± 0.12	H_2O	···, a
R Aqr	Mira	4.7±0.8	390	2.591	−1.01	-7.65 ± 0.37	SiO	kam10, c
R Aqr	Mira	4.59±0.24	390	2.591	−1.01	-7.70 ± 0.11	SiO	min14, c
RR Aql	Mira	1.58±0.40	396	2.598	0.46	-8.55 ± 0.56	OH	vle07, c
U Her	Mira	3.76±0.27	406	2.609	−0.27	-7.39 ± 0.16	OH	vle07, c
SY Scl	Mira	0.75±0.03	411	2.614	2.55	-8.07 ± 0.09	H_2O	nyu11, b
R Cas	Mira	5.67±1.95	430	2.633	−1.80	-8.03 ± 0.78	OH	vle03, c
U Lyn	Mira	1.27±0.06	434	2.637	1.533	-7.95 ± 0.10	H_2O	kam15, a
OH231.8+4.2	OH/IR	0.55±0.05	551	2.741	···	···	H_2O	···
UX Cyg	Mira	0.54±0.06	565	2.752	1.40	-9.94 ± 0.24	H_2O	kur05, a
OZ Gem	Mira	1.00±0.18	598	2.777	3.00	-7.00 ± 0.40	H_2O	···, a
V353 Pup	···	0.56±0.03	802	2.904	2.02	-9.24 ± 0.12	H_2O	···, a
S Per	SRc	0.413±0.017	822	2.915	1.33	-10.59 ± 0.09	H_2O	asa10, b
PZ Cas	SRc	0.356±0.026	925	2.966	1.00	-11.24 ± 0.16	H_2O	kus13, b
VY CMa	SRc	0.88±0.08	956	2.980	−0.72	-11.00 ± 0.20	H_2O	cho08, b
NML Cyg	···	0.62±0.047	1280	3.107	0.791	-10.25 ± 0.16	H_2O	zha12, a

(Published + preliminary data)

AGB star distances from VLBI astrometry

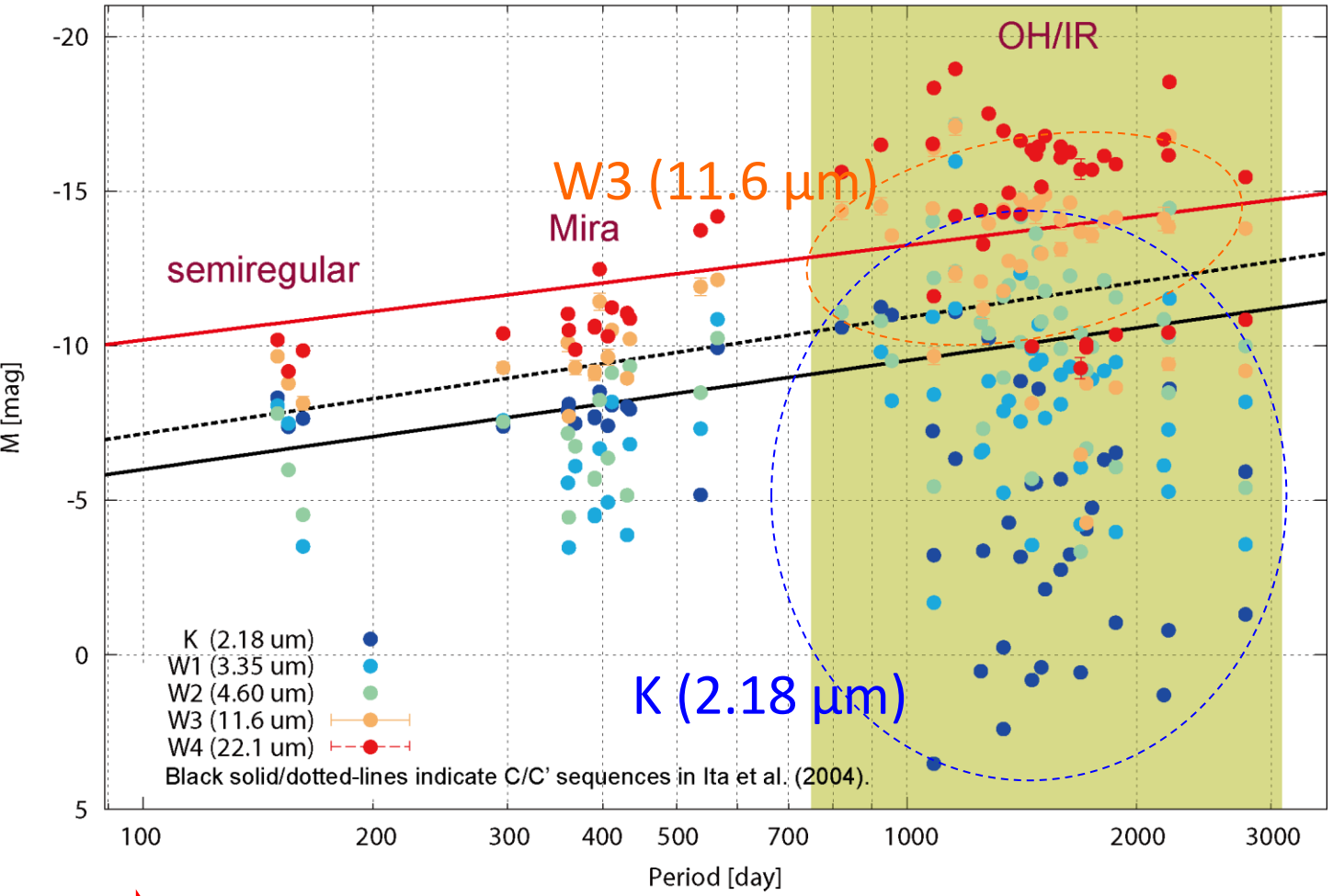


次の話題へ・・・

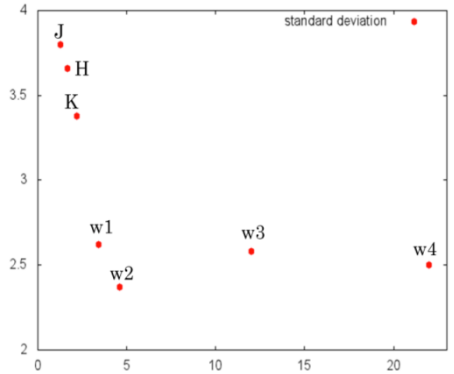
Period luminosity relation of OH/IR stars（P > 1000d）

Mid-IR absolute magnitudes of ~20 OH/IR stars with known distances.

Distances from { (1) Phase-lag method（Engels et al. 2015）
(2) Kinematic distance



波長とばらつき



➡ What can we do with the OH/IR stars (P>1000 d) ?

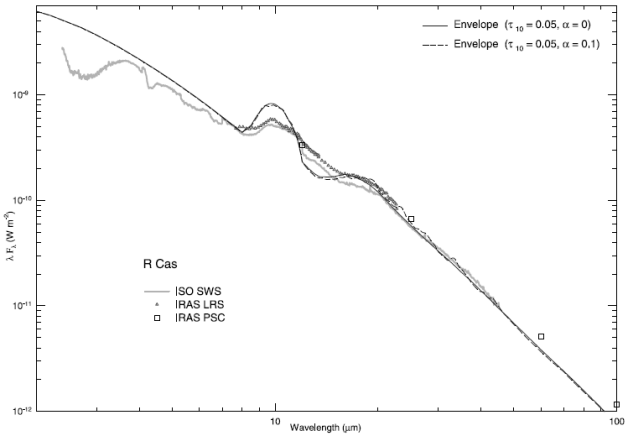
SED of OH/IR stars and Mira variable

- SED λ = 2 - 100μm ：OH/IR星 と Mira型星　ISO（Infrared Space Observatory）
- 10μm付近のシリケイトの特性
- OH/IR星は可視光で非常に暗い、見えない

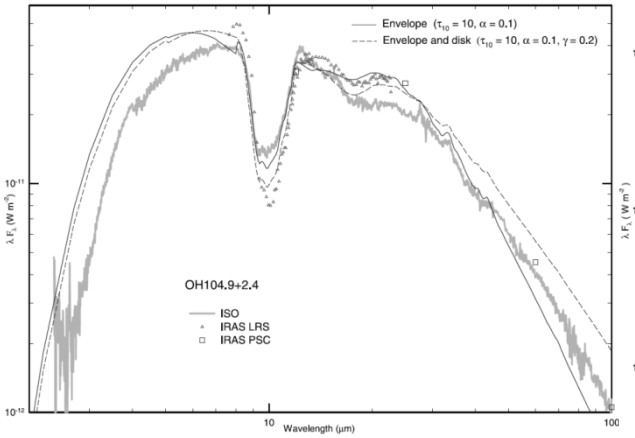
K.-W. Suh 2002

Mira variable

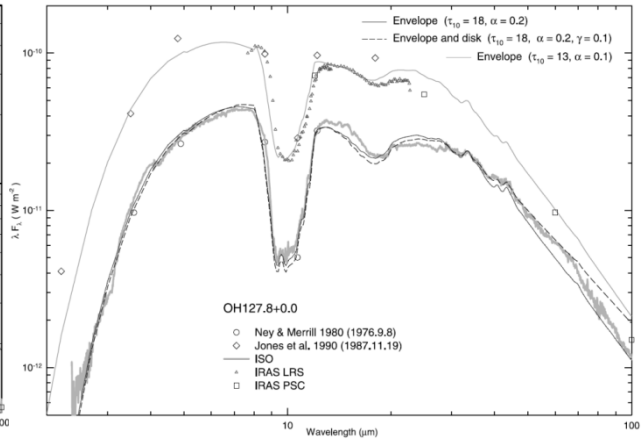
OH/IR star



R Cas



NSV25875 (OH104.9+2.4)



OH127.8+0.0

OH/IR star　（VERAでSiOメーザー位相補償観測中の2天体 ）

name	Period	U	B	V	R	I	J	H	K	F12	F25	F60	F100
	[day]	[mag]	[mag]	[mag]	[mag]	[mag]	[mag]	[mag]	[mag]	[Jy]	[Jy]	[Jy]	[Jy]
OH127.8+0.0	1380/ 1994	-	-	-	-	-	16.7	11.2	7.1	289	456	194	50.2
NSV25875	1535	-	-	-	-	-	16.4	10.7	6.9	123	229	90.7	35.0

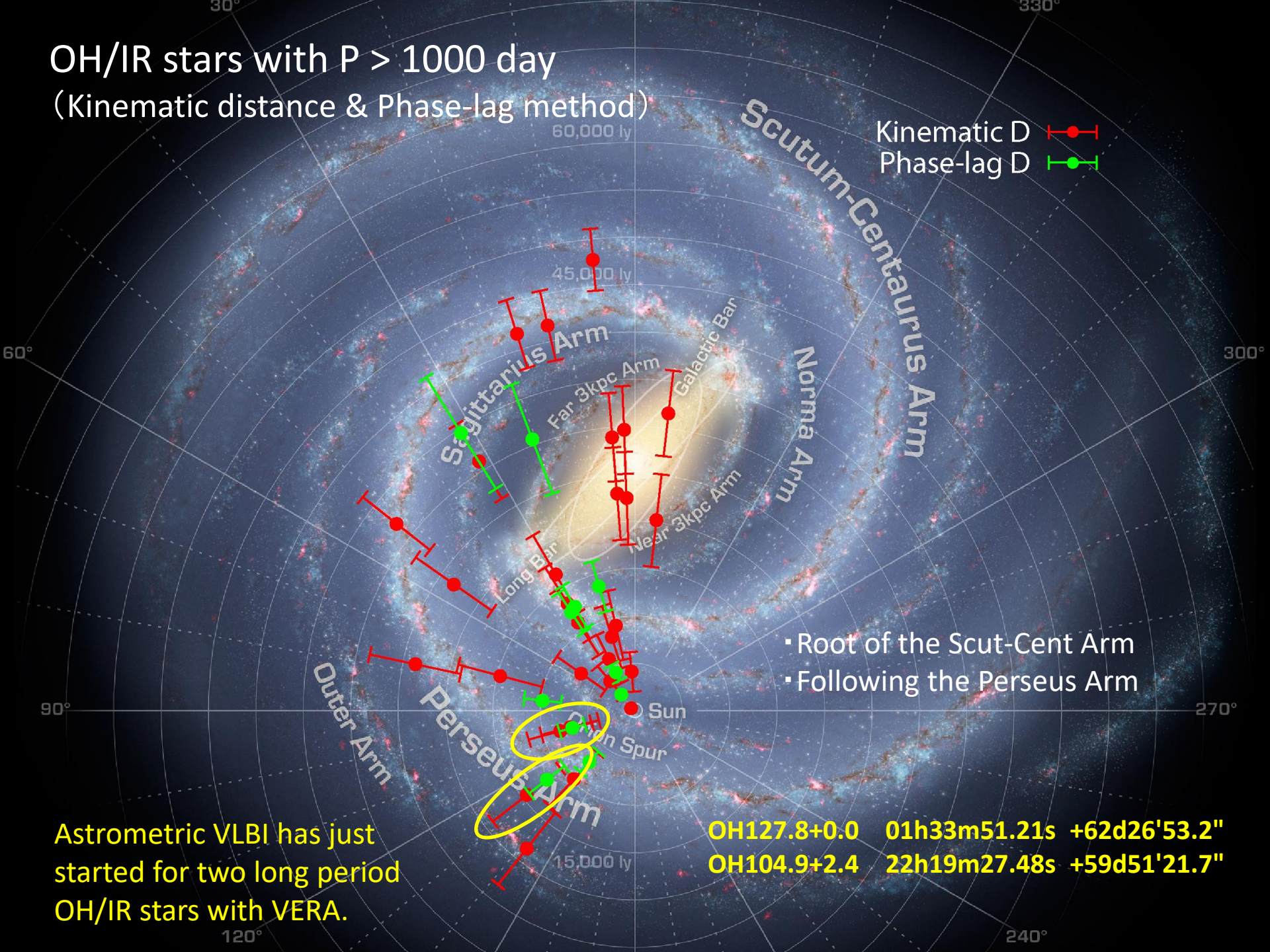
Single-dish at VERA-IRIKI station; OH/IR stars (P>1000d)

ID	name	l [deg]	b [deg]	RA [hms]	DEC [d ' "]	Period [day]	SiO V=1 [Jy]	SiO V=2 [Jy]	H2O [Jy]
1	OH 127.8+0.0	127.485	−0.0115	01 33 51.21	+62 26 53.2	1380/1994	3–11	10	
2	OH 138.0 +7.2	137.581	7.1521	03 25 08.406	+65 32 07.06	1410	3–11	9	
3	OH 141.7 +3.5	141.433	3.3108	03 33 30.59	+60 20 09.4	3500/1750	3	7	
4	OH 349.96 −0.02	349.575	−0.0131	17 19 29.3	−37 21 35	1392	6	8	
5	OH 353.61 −0.23	353.363	−0.1408	17 30 27.583	−34 27 44.79	1417			
6	IRAS 18035−2529	5.194	−2.1809	18 06 37.750	−25 29 27.73	610/1000			
7	IRAS 18042−2905	2.1559	−4.1129	18 07 24.1	−29 04 48	1500			
8	OH 12.8 +0.9	12.4532	0.5344	18 10 06.08	−17 26 34.5	1488			
9	OH16.1−0.3	16.0651	−0.1723	18 21 06.44	−15 03 29.8	2200.95			
10	IRAS 18195−2804	4.4538	−6.4001	18 22 40.1	−28 03 06	1200			
11	OH 17.4 −0.3	17.2335	−0.1718	18 23 35.0	−13 55 43	1219			
12	OH20.7+0.1	20.4054	0.0559	18 28 27.686	−10 50 19.38	1719			
13	OH 26.5 +0.6	26.3237	0.3704	18 37 32.51	−05 23 59.2	1589	20		
14	OH 30.1 −0.7	30.0528	−0.4111	18 48 41.91	−02 50 28.3	2170/853			
15	OH 32.0 +0.54	31.5905	−0.2906	18 51 26.2	−01 03 51	1520			
16	OH 32.8 −0.3	32.494	−0.1856	18 52 22.19	−00 14 13.9	1690			
17	OH 39.7 +1.5	39.4247	1.2942	18 58 30.09	+06 42 57.8	1260/1424	48	86	
18	OH 51.8 −0.1	51.4814	−0.1329	19 27 42.04	+16 37 24.0	1162			
19	OH 55.0 +0.7	54.5658	0.4407	19 30 29.48	+19 50 41.0	1270			
20	OH 77.9 +0.2	77.5458	0.132	20 28 30.677	+39 07 00.93	1339			
21	OH 75.3 −1.8	75.1605	−1.5031	20 29 08.4	+35 45 44	1652			
22	OH83.4−0.9	83.2508	−0.5318	20 50 57.7	+42 48 04	1500	6	9	17
23	IRAS21554+6204	104.075	5.5932	21 56 58.18	+62 18 43.6	1280		17	
24	IRAS 22177+5936	104.543	2.2448	22 19 27.48	+59 51 21.7	1620	8	8	

1σ = 0.05 K → ~1 Jy

OH/IR stars with P > 1000 day

（Kinematic distance & Phase-lag method）



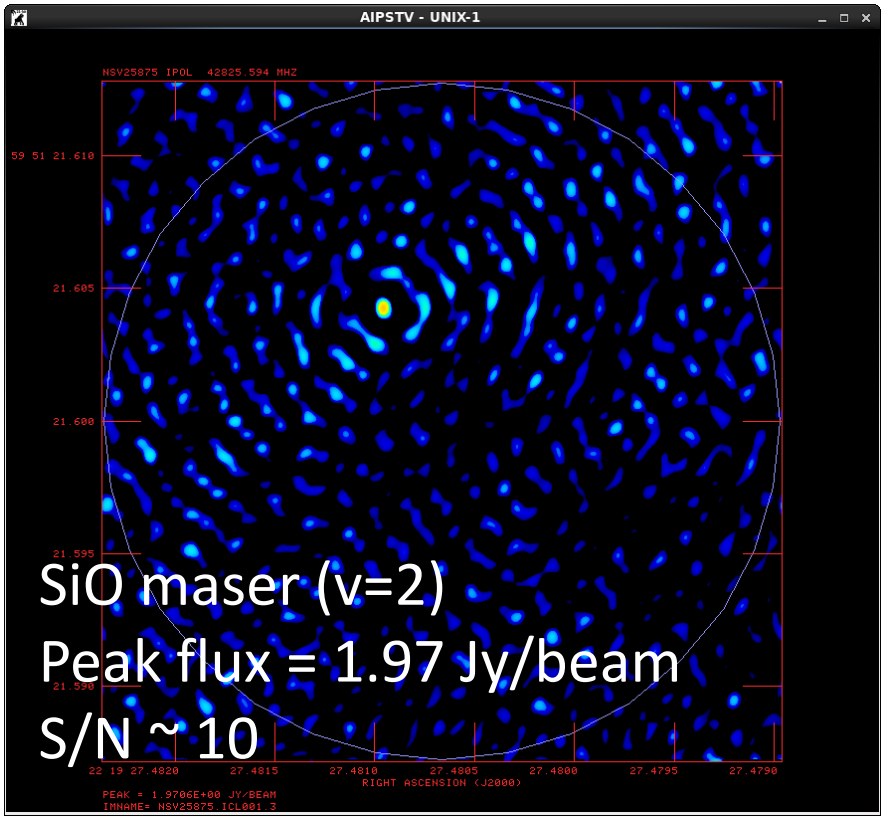
- Root of the Scut-Cent Arm
- Following the Perseus Arm

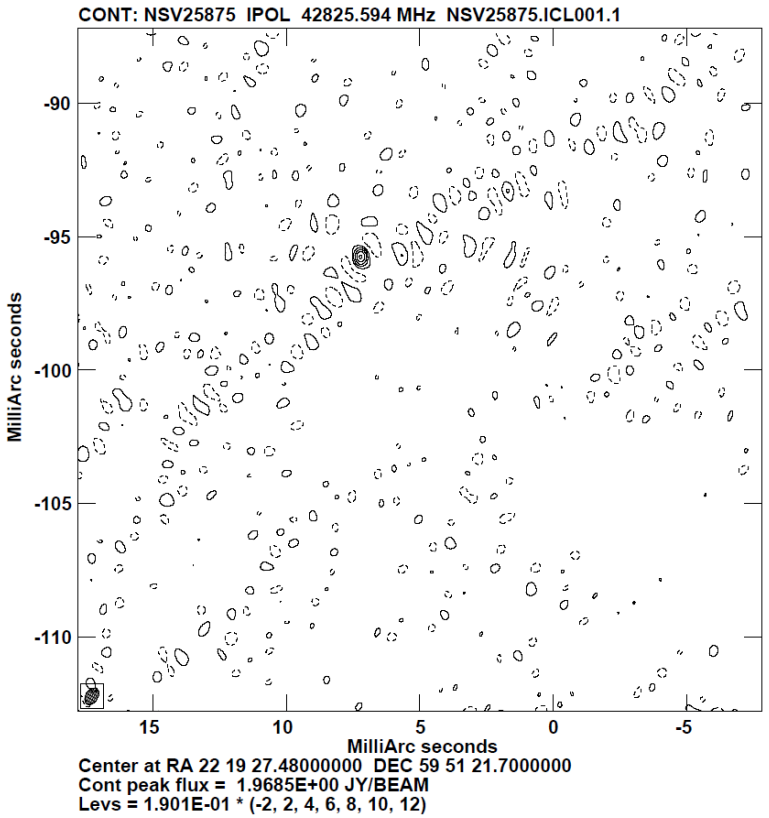
Astrometric VLBI has just started for two long period OH/IR stars with VERA.

OH127.8+0.0	**01h33m51.21s**	**+62d26'53.2"**
OH104.9+2.4	**22h19m27.48s**	**+59d51'21.7"**

VERAによる位相補償VBLI観測の開始 @ 43GHz

- NSV25875 (OH104.9+2.4)　22h19m27.48s　+59d51'21.7"
- Period = 1535 day
- 2017年11月1日　初回観測
- 広帯域記録　(2Gpbs+2Gbpsモード, #A:16MHz×2IF,　#B: 512MHz)
- 43GHz (SiOメーザー v=1, v=2)
- 参照電波源　J2231+5922　(Peak flux = 260mJy, S/N = 182 at 43GHz)





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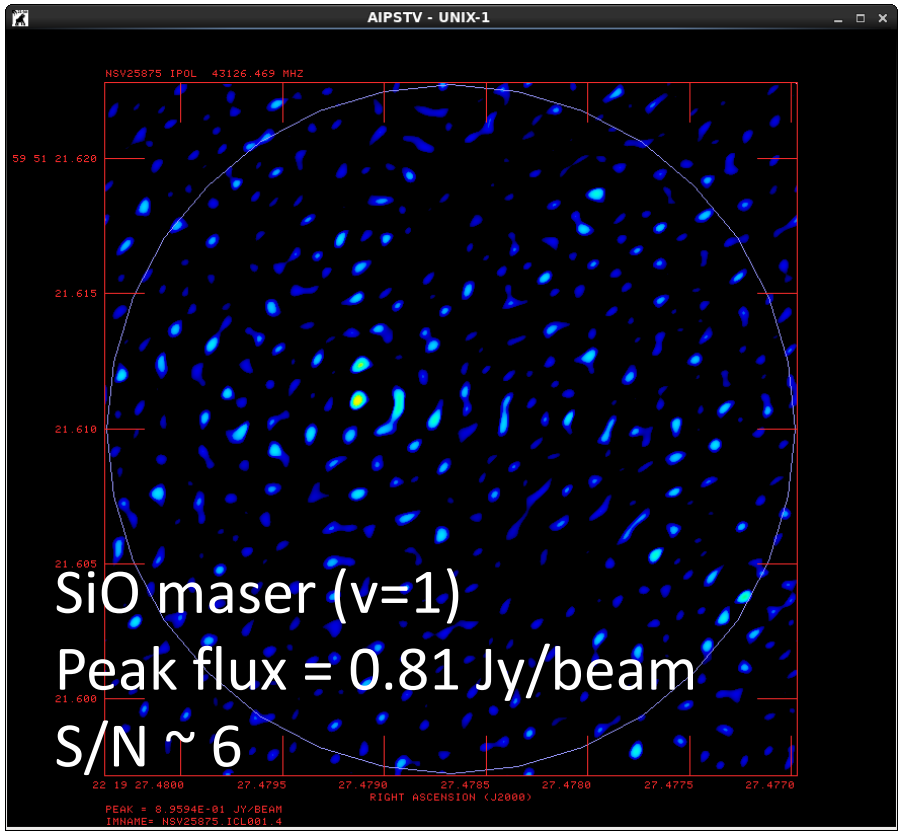
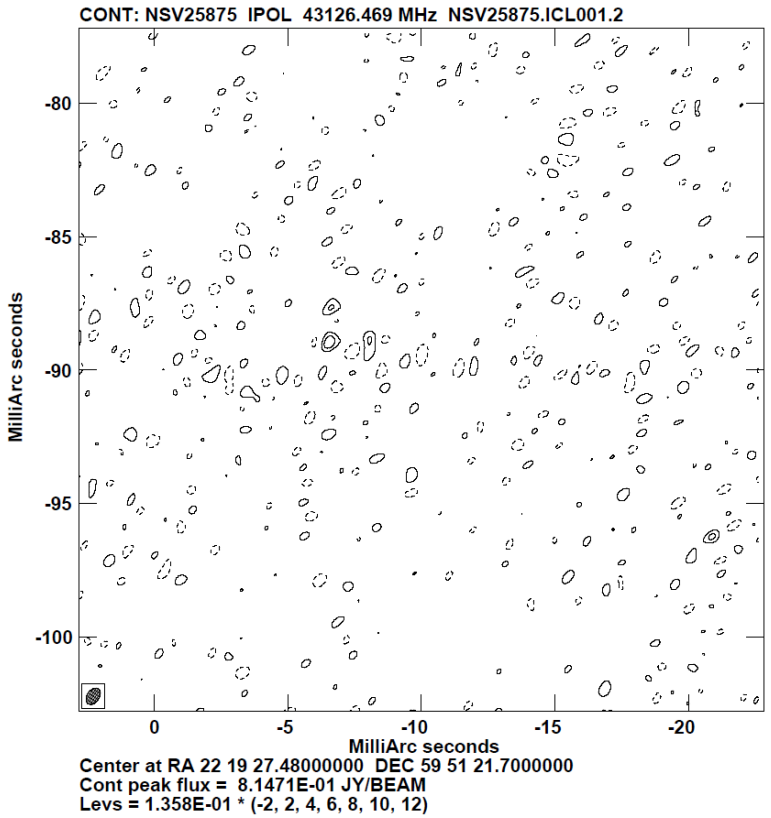
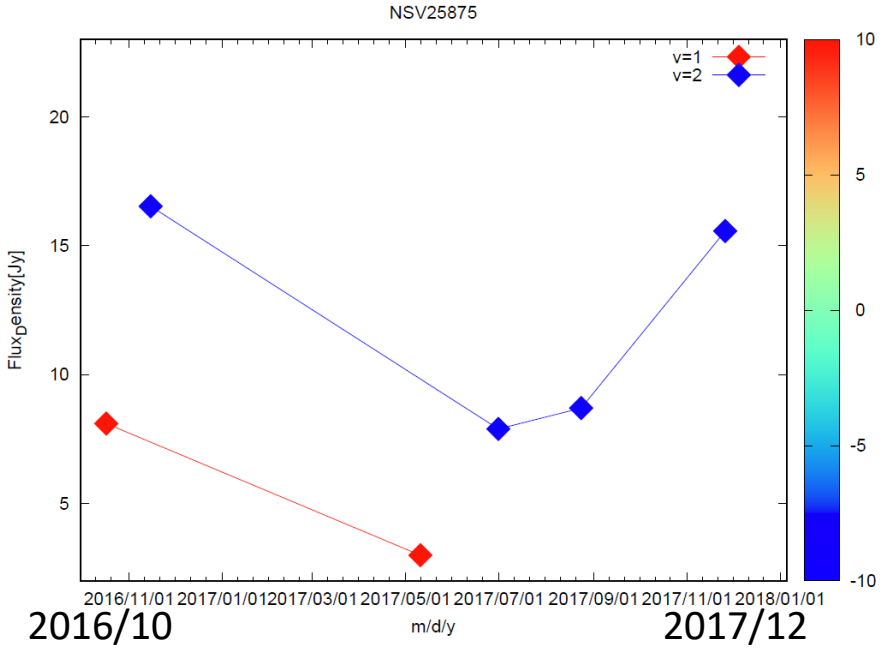
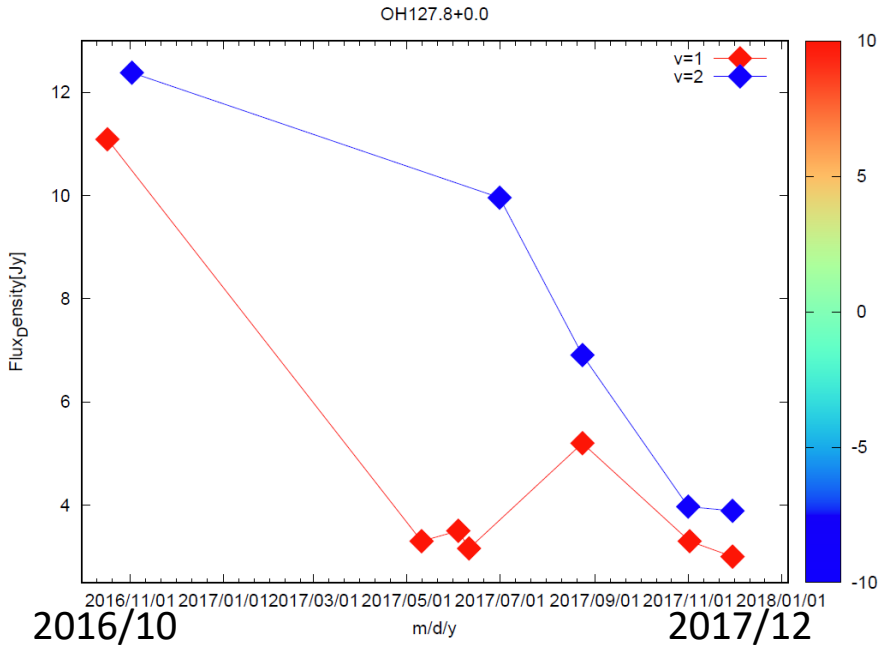




入来局単一鏡モニター（K-, Q-band）

- 観測候補の探査と周期の決定を狙う
- VERAでSiOメーザー位相補償観測中の2天体
  - NSV25875　　Period = 1535 day
  - OH127.8+0.0　　Period = 1380/1994 day





- 約60天体のOH/IR星を入来にてモニター中（22GHz, 43GHz）

→ ポスター「VERA入来局単一鏡を用いたOH/IR星のH2O, SiOメーザー単一鏡観測　」
山本由希

We need more samples; OH/IR stars (P>1000d)

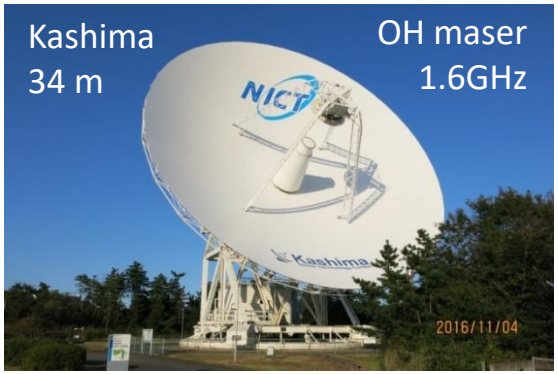
- OH maser ・Kashima 34m (NICT) Survey/Monitor
  ・**JAXA new telescope ?** Survey/Monitor
- H2O maser VERA-IRIKI 20m (NAOJ) Survey/Monitor
- SiO maser VERA-IRIKI 20m (NAOJ) Survey/Monitor

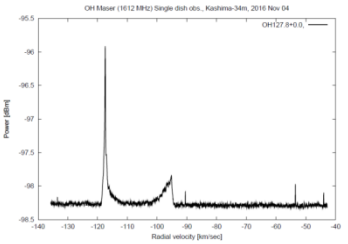
1.6 GHz OH maser :
NICT Kashima 34m telescope

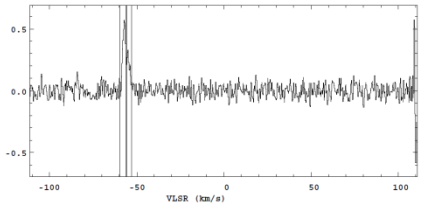
・2016 Nov. 4 (FRI)
・NICT Kashima 34m, L-band (1.6GHz) system
・OH maser (1612 MHz)

43GHz SiO maser :
VERA Iriki 20m telescope

・2016 Dec.
・VERA Iriki station 20m , Q-band (43GHz) system
・SiO maser (43GHz)

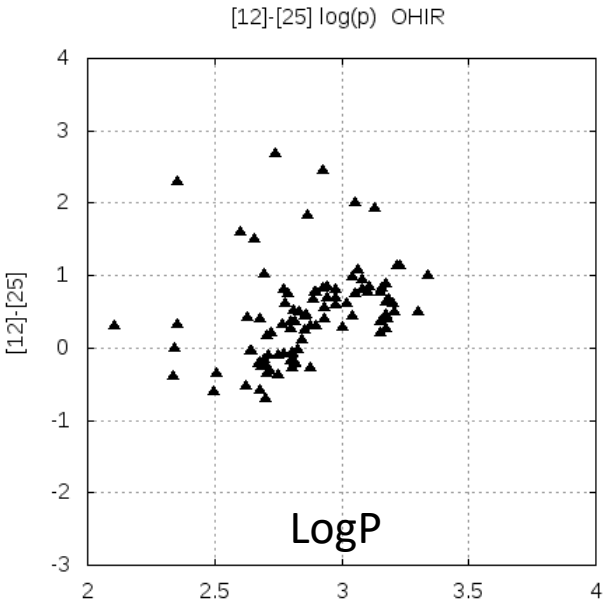




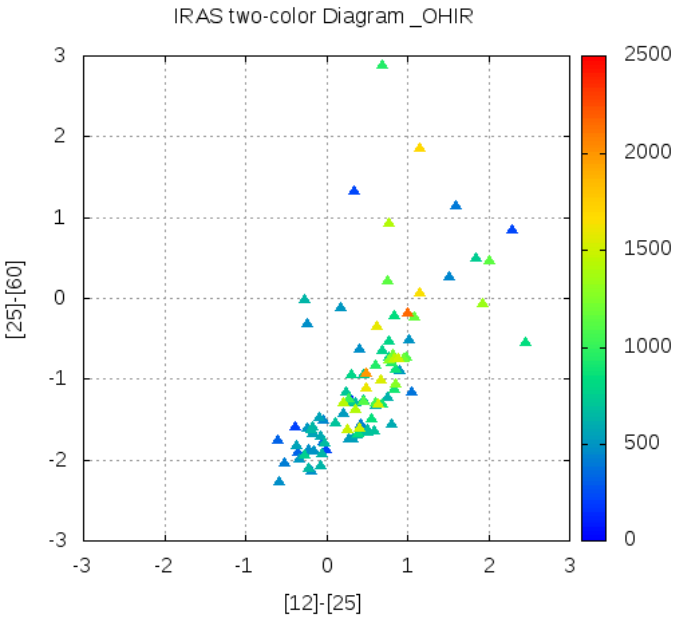


新たな観測対象を探す手がかり

- IRASカラー [12]-[25] と周期との相関が良い



- [12]-[25]がより赤い星から優先して各種メーザーを探査
  - 右図：[12]-[25]、[25]-[60]、周期の関連



IIIb, IV領域に注目

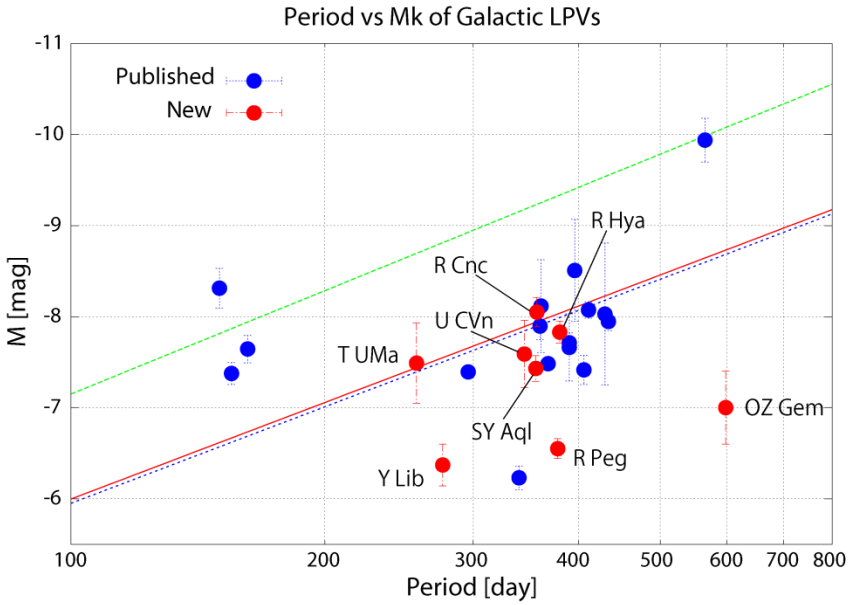
Summary

(1) Mira型変光星の位置天文観測

- VERA Phase-ref. VLBI at 22 GHz (H2O maser)
- Parallaxes of ~25 Galactic LPVs determined (Mira, Semiregular, OH/IR star)
- P-Mk relation ;

  Mk = -3.52logP + (1.09±0.14)

  (Nakagawa et al. 2016)
- Circumstellar extinction ？



(2) 長周期OH/IR星の位置天文への展開

- They offer unique samples for study dynamics of stars with age of ~10^8 years
- VLBI astrometry with SiO masers has just started
- Existence of MIR P-M relation ？
- 位相補償によるSiOメーザー検出に成功
- 鹿島、new臼田などの利用を検討させて頂きたい