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Database of molecular masers and variable stars

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Abstract We present the database of maser sources in H_2O, OH and SiO lines that can be used to identify and study variable stars at evolved stages. Detecting the maser emission in H_2O, OH and SiO molecules toward infrared-excess objects is one of the methods for identifing long-period variables (LPVs, including miras and semiregulars), because these stars exhibit maser activity in their circumstellar shells. Our sample contains 1803 known LPV objects. Forty-six percent of these stars (832 objects) manifest maser emission in the line of at least one molecule: H_2O, OH or SiO. We use the database of circumstellar masers in order to search for LPVs which are not included in the General Catalogue of Variable Stars (GCVS). Our database contains 4806 objects (3866 objects without associations in GCVS) with maser detection in at least one molecule. Therefore it is possible to use the database in order to locate and study the large sample of LPV stars. The database can be accessed at *http://maserdb.net*.

Key words: catalogs — astronomical databases: stars: variables: general — stars: masers — physical data and processes

1 INTRODUCTION

At the end of their evolution, stars of a few solar masses become red giants and increase the radius of their stellar atmosphere from $1\,R_\odot$ to $10^2\,R_\odot$. After that, the atmosphere is expelled into outer space and the star becomes a white dwarf surrounded by a planetary nebula. The red giant phase is usually short in time and lasts only a few hundred thousand years.

Many red giant stars exhibit variability on the scales of a few hundred days. The variability of these stars is therefore called long-period, and thus they are known as long-period variables (LPVs). According to Kholopov et al. (1985), LPVs are divided into two subgroups — miras with periods usually between 150 and 600 d and magnitude variation $\Delta m > 2.5$, and semiregular variables with a shorter period (50 to 150 d) and smaller magnitude variation ($\Delta m < 2.5$). After leaving the star, the ejected matter forms a gas-dust circumstellar envelope. Large infrared (IR) excess is characteristic of these stars because the circumstellar envelope is re-emitting stellar light.

The envelopes of red giant stars manifest maser and thermal emission in a number of molecular lines. Maser emission arises in the lines of the following molecules: OH ($\lambda = 18$ cm), H_2O ($\lambda = 1.35$ cm), SiO ($\lambda = 7$ mm, 3.5 mm and others) and HCN ($\lambda = 3.3$ mm). Thermal emission is found in the lines of CO ($\lambda = 2.6$ mm), SiO, HCN and other molecules. Most H_2O, OH and SiO masers are identified in oxygen-rich miras, but SiO masers are sometimes associated with semiregular stars. HCN maser emission is found in carbon stars. IR emission of the star is responsible for pumping the OH masers (He et al. 2005) and the impact of the shock waves on the interior layers of a circumstellar envelope is responsible for pumping the SiO, H_2O and HCN masers (Gray 2012).

OH masers are most important for studies of mira variables. Most LPVs that exhibit maser emission in OH lines have strong 1612 MHz emission. This is distinct from the OH masers in star-forming regions which have 1665 and 1667 MHz maser emission stronger than the 1612 MHz one.

Until now, the compilations comprehensively including three major maser species in evolved stars (i.e., SiO, H_2O, OH) have been practically limited only to the catalog Benson et al. (1990) which was published more than a quarter of century ago. For OH masers solely, there is the University of Hamburg (UH) database, but there is no updated compilation work for H_2O and SiO masers. In order to utilize information on masers in astrophysical research, it is highly desirable to have a database containing information on all three maser species. We are currently compiling a database including SiO, H_2O and OH masers (Nakashima et al. 2018). This database consists of a web-service which allows users to access compiled maser observations from published papers and combines them with the newly collected data. An example of the source list from the web-service showing detected masers in H_2O, OH and SiO molecular lines is given in Figure 1. IR and other data on each source are attached from the published surveys and catalogs. The archives currently used are the OH maser archive from Engels & Bunzel (2015), and H_2O and SiO archives, which are currently under construction. So far, information on about 27 000 observations (∼11 000 objects) has been implemented. We also have a plan to extend the database by including methanol maser emission and other types of objects, such as young stellar objects (YSOs), in the future.

2 SUMMARY OF THE COLLECTED DATA

The initial release of the database is dedicated to the circumstellar maser sources of variable stars mainly in the following maser lines: SiO $J = 1{-}0$, $v = 1$ & 2 (43 GHz), H_2O 22 GHz, and OH 1612, 1665, 1667 MHz. The data are taken mainly from five published/unpublished compilation catalogs. The OH data are based on the OH maser archive from Engels & Bunzel (2015). The H_2O data are based on an ongoing compilation work (PI: Engels, D.). A significant amount of additional data on other maser transitions (for example, SiO $J = 1 - 0$, v =0 & 3, SiO $J = 2 - 1$, v =1 & 2, ^{29}SiO $J = 1 - 0$, $v = 0$, etc.) is also included in the database, but the surveys acquiring data for these lines are still not completed (the data will keep being updated). We note that a non-negligible number of unpublished data from the Nobeyama SiO maser survey project are released to the public for the first time (the number of unpublished Nobeyama observations is about 400). In addition to the basic line parameters (such as intensity, velocity, line-profile, etc.), for a part of the observations, spectral data in ascii format are available, so that users can process the spectral data for their own purposes. In total, at this moment, $\sim 11\,000$ objects, which have been observed in at least one of the OH, H_2O or SiO maser lines, or in multiple maser lines, are included in the database (the distribution of the objects in Galactic coordinates is given in Fig. 2). Among the ∼11 000 sources, the number of objects observed in the SiO, H_2O and OH maser lines are ∼4100, ∼4000 and ∼6700 respectively (overlaps exist between different maser species).

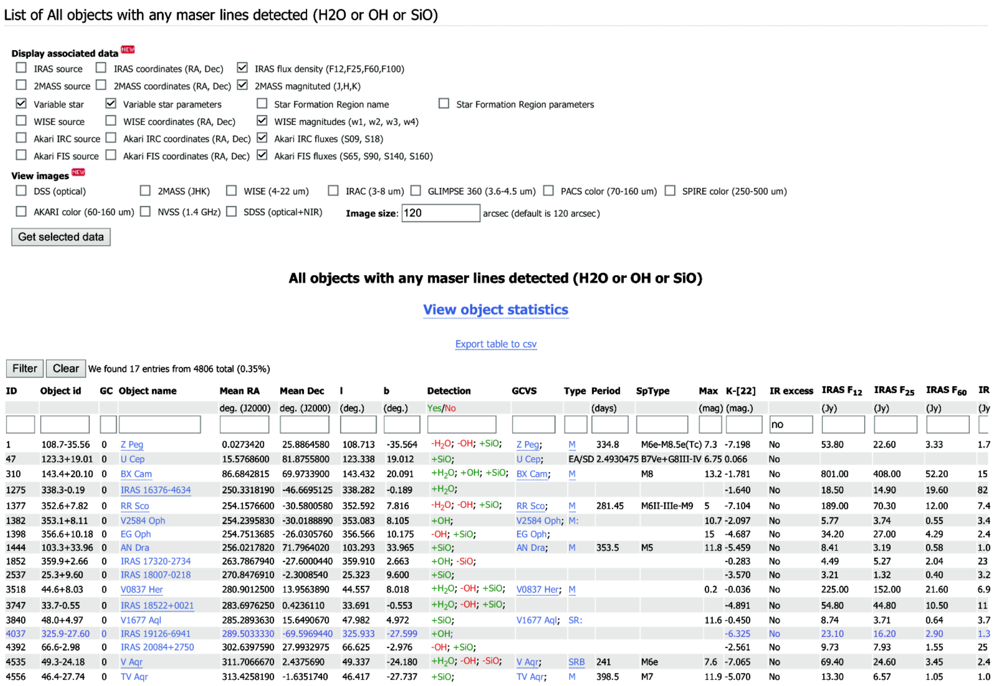
3 WEB-BASED SYSTEM FOR THE MASER DATABASE

The web-based system[1] for the database of maser sources was developed in order to collect and display the large dataset of maser sources. The system is written in the PERL/CGI language and uses external modules for full functionality, including ALADIN LITE API, VIZIER TAP service, SIMBAD identification service and ADS service for publication search. The system allows the user to collect, display and analyze a large maser dataset from the available literature. Entering data into the database is done by using the CSV format that comes from optical character recognition of article text in PDF format or importing from the VIZIER archive if available. Entering the spectral profiles is done by using digitizing software – IM2GRAPH.

A list of the features incorporated in the web-system include the following:

- Search for maser data by coordinates, source name or list of sources.
- Parallel data search in popular astronomical catalogs from VizieR.
- Association of maser observations with popular IR and stellar catalogs - *IRAS*, 2MASS, UKIDSS, *WISE*, *Akari*, GCVS, etc., with instantaneous output of photometric and other data from these catalogs.
- Cross-identification of masers in different molecules. It is possible to identify objects in which emission is present in several maser molecules.
- Ability to download the observational data in CSV format.
- Detailed research can be done for each object in the database using images in different spectral ranges (from optical to radio).
- For some observations (∼3.2 thousand) there are spectra themselves, which can be viewed and analyzed directly in the system.
- Statistical analysis of data - the construction of color-color and longitude-velocity diagrams, histograms of

[1] *http://maserdb.net*



List of All objects with any maser lines detected (H2O or OH or SiO)

Display associated data NEW
☐ IRAS source ☐ IRAS coordinates (RA, Dec) ☑ IRAS flux density (F12,F25,F60,F100)
☐ 2MASS source ☐ 2MASS coordinates (RA, Dec) ☑ 2MASS magnituted (J,H,K)
☑ Variable star ☑ Variable star parameters ☐ Star Formation Region name ☐ Star Formation Region parameters
☐ WISE source ☐ WISE coordinates (RA, Dec) ☑ WISE magnitudes (w1, w2, w3, w4)
☐ Akari IRC source ☐ Akari IRC coordinates (RA, Dec) ☑ Akari IRC fluxes (S09, S18)
☐ Akari FIS source ☐ Akari FIS coordinates (RA, Dec) ☑ Akari FIS fluxes (S65, S90, S140, S160)

View images NEW
☐ DSS (optical) ☐ 2MASS (JHK) ☐ WISE (4-22 um) ☐ IRAC (3-8 um) ☐ GLIMPSE 360 (3.6-4.5 um) ☐ PACS color (70-160 um) ☐ SPIRE color (250-500 um)
☐ AKARI color (60-160 um) ☐ NVSS (1.4 GHz) ☐ SDSS (optical+NIR) **Image size:** 120 arcsec (default is 120 arcsec)

Get selected data

All objects with any maser lines detected (H2O or OH or SiO)

View object statistics

Export table to csv

Filter Clear We found 17 entries from 4806 total (0.35%)

ID	Object id	GC	Object name	Mean RA	Mean Dec	l	b	Detection	GCVS	Type	Period	SpType	Max	K-[22]	IR excess	IRAS F_{12}	IRAS F_{25}	IRAS F_{60}	IR
				deg. (J2000)	deg. (J2000)	(deg.)	(deg.)	Yes/No			(days)		(mag)	(mag.)		(Jy)	(Jy)	(Jy)	(Jy
															no				
1	108.7-35.56	0	Z Peg	0.0273420	25.8864580	108.713	-35.564	$-H_2O$; -OH; +SiO;	Z Peg;	M	334.8	M6e-M8.5e(Tc)	7.3	-7.198	No	53.80	22.60	3.33	1.7
47	123.3+19.01	0	U Cep	15.5768600	81.8755800	123.338	19.012	+SiO;	U Cep;	EA/SD	2.4930475	B7Ve+G8III-IV	6.75	0.066	No				
310	143.4+20.10	0	BX Cam	86.6842815	69.9733900	143.432	20.091	$+H_2O$; +OH; +SiO;	BX Cam;	M		M8	13.2	-1.781	No	801.00	408.00	52.20	15
1275	338.3-0.19	0	IRAS 16376-4634	250.3318190	-46.6695125	338.282	-0.189	$+H_2O$;						-1.640	No	18.50	14.90	19.60	82
1377	352.6+7.82	0	RR Sco	254.1576600	-30.5800580	352.592	7.816	$-H_2O$; -OH; +SiO;	RR Sco;	M	281.45	M6II-IIIe-M9	5	-7.104	No	189.00	70.30	12.00	7.4
1382	353.1+8.11	0	V2584 Oph	254.2395830	-30.0188890	353.083	8.105	+OH;	V2584 Oph;	M:			10.7	-2.097	No	5.77	3.74	0.55	3.4
1398	356.6+10.18	0	EG Oph	254.7513685	-26.0305760	356.566	10.175	-OH; +SiO;	EG Oph;				15	-4.687	No	34.20	27.00	4.29	2.4
1444	103.3+33.96	0	AN Dra	256.0217820	71.7964020	103.293	33.965	+SiO;	AN Dra;	M	353.5	M5	11.8	-5.459	No	8.41	3.19	0.58	1.0
1852	359.9+2.66	0	IRAS 17320-2734	263.7867940	-27.6000440	359.910	2.663	+OH; -SiO;						-0.283	No	4.49	5.27	2.04	23
2537	25.3+9.60	0	IRAS 18007-0218	270.8476910	-2.3008540	25.323	9.600	+SiO;						-3.570	No	3.21	1.32	0.40	3.2
3518	44.6+8.03	0	V0837 Her	280.9012500	13.9563890	44.557	8.018	$+H_2O$; -OH; +SiO;	V0837 Her;	M			0.2	-0.036	No	225.00	152.00	21.60	6.9
3747	33.7-0.55	0	IRAS 18522+0021	283.6976250	0.4236110	33.691	-0.553	$+H_2O$; -OH; +SiO;						-4.891	No	54.80	44.80	10.50	11
3840	48.0+4.97	0	V1677 Aql	285.2893630	15.6490670	47.982	4.972	+SiO;	V1677 Aql;	SR:			11.6	-0.450	No	8.74	3.71	0.64	3.7
4037	325.9-27.60	0	IRAS 19126-6941	289.5033330	-69.5969440	325.933	-27.599	+OH;						-6.325	No	23.10	16.20	2.90	1.3
4392	66.6-2.98	0	IRAS 20084+2750	302.6397590	27.9932975	66.625	-2.976	-OH; +SiO;						-2.561	No	9.73	7.93	1.55	25
4535	49.3-24.18	0	V Aqr	311.7066670	2.4375690	49.337	-24.180	$+H_2O$; -OH; -SiO;	V Aqr;	SRB	241	M6e	7.6	-7.065	No	69.40	24.60	3.45	2.4
4556	46.4-27.74	0	TV Aqr	313.4258190	-1.6351740	46.417	-27.737	+SiO;	TV Aqr;	M	398.5	M7	11.9	-5.070	No	13.30	6.57	1.05	1.0

Fig. 1 List of objects from the web-based system displaying the maser detection in different molecules together with IR characteristics.

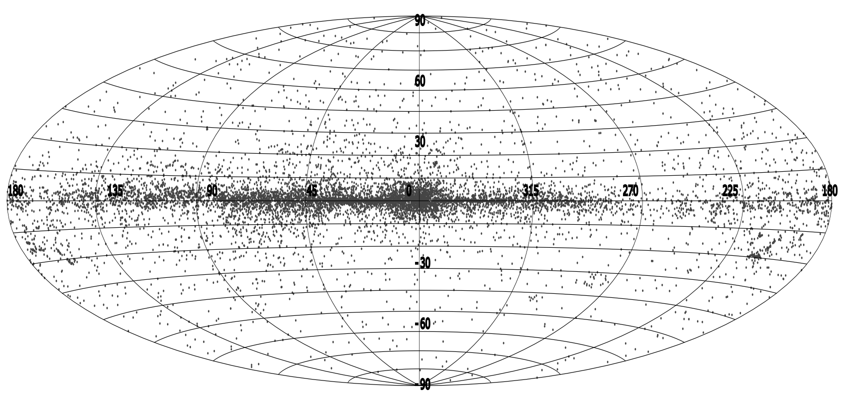


Fig. 2 Distribution of ∼11 000 objects included in the database at the Galactic plane. These objects are observed, in at least one of the OH, H_2O or SiO maser lines, and both detections and non-detections are included.

the spatial distribution of masers, etc. It has the ability to plot 1D histograms, and 2D and 3D distribution plots of any parameter sets.

Development of the web-based system is not limited only to H_2O, OH and SiO molecules. The ability to input CH_3OH (methanol) data is also included in the presented maser database system, allowing users to study not only late-type stars (i.e., LPVs and asymptotic giant branch (AGB) stars) but also early-type objects (YSOs, star formation regions, etc.).

4 IDENTIFICATION OF VARIABLE STARS WITH MASER EMISSION

Currently, the General Catalogue of Variable Stars (GCVS; Samus' et al. 2017) contains variable stars which are identified mostly by observations in the optical range. Among them, LPV stars (including miras) are most common. The high detection rate of LPV stars is explained by the high luminosity of these stars (up to $10^3 - 10^4\ L_{\odot}$) in the LPV stage and high amplitude of variability in visible light ($> 2.5^{\rm m}$ for miras). LPV is a relatively short stage of stellar evolution (only several hundred thousand years), thus these stars compose a relatively small portion of the total stellar population of the Galaxy. However, this stage is very important. At this stage, all stars of low and intermediate mass are actively losing their matter, forming a gas-dust circumstellar shell and at the end forming a planetary nebula with a white dwarf in the center.

Miras emit most of their light in the IR because the circumstellar envelope heated by the starlight is rather extended. Detection of miras in the optical range is sometimes missing. The optical light curve of some variable stars can have its minimum phase during the period of observations, thus these stars will not be detected in the optical range. Because variations in the magnitudes may be in the range from $2.5^{\rm m}$ to $11^{\rm m}$ and the period varies in the range 80–1000 d, only long-term monitoring observations (up to several years) may reveal variability in these stars. IR emission of these stars is more stable - variations of intensity in K band for miras usually do not exceed $0.9^{\rm m}$ (see GCVS for explanations).

We are suggesting another way to identify candidates for LPV stars, including most common miras. Maser emission in the circumstellar shell of a late-type star has good prospects to identify and locate such stars. The envelopes of red giant stars emit maser emission in the lines of H_2O, OH and SiO molecules, and sometimes HCN (in carbon-rich stars). We analyzed our database and considered all objects where maser emission of H_2O, OH and SiO molecules is detected. Because our database is cross-matched with GCVS, we can explore maser detection rate for stars of known type.

At first, we select all objects from the database where at least one maser line is observed (H_2O, OH or SiO) in available literature, including negative detections. We exclude 579 objects from the Galactic Center region ($359 < l < 1, -2 < b < 2$) because the high surface density of stars does not allow reliable association of maser observations with known variable stars from GCVS. There are a total of 10 701 objects in the database, excluding the Galactic Center region. Among them, 2344 objects are included in GCVS. Then we select objects which are confirmed LPVs (miras and semiregular variable stars) from GCVS. We find 1803 such stars. Then we investigate maser detection in this LPV sample.

Among 1803 LPV stars, 836 objects (46%) have maser detection in at least one maser molecule (H_2O, OH or SiO); 331 objects (18%) have maser detection in at least two maser molecules and 154 (8%) have positive detection in all three maser molecules. Among 744 LPV stars with masers observations available in all three molecules (H_2O, OH and SiO), including negative detections, only 30 stars have negative detection in all three maser molecules. We can see that almost half of LPV stars exhibits maser emission in at least one maser line. Thirty stars with negative detection in all three maser molecules may be associated with a minimum of maser variability. Therefore, high maser detection rate (46%) for LPV stars shows that the maser emission has high potential for identifying LPV star candidates, including miras and semiregular stars.

Table 1 displays a list of objects which were selected using maser emission but are not included in GCVS, along with their IR excess characteristics (see Sect. 6). These objects are potential candidates for mira variable stars. In order to confirm the variability of these objects, optical observations are needed. Alternatively, variability data can be taken from the new data release (DR2) of the *Gaia* mission (Holl et al. 2018).

5 COLOR-COLOR DIAGRAMS

Analyzing the objects which are not included in GCVS, we found that 3866 objects from our database have detection in at least one molecule (H_2O, OH and SiO) but have no association with GCVS objects. However, star-forming regions may be also included in our sample, because star-forming regions sometimes have color characteristics similar to those of late-type stars (see discussion in Nakashima et al. 2015, 2016). Many authors from the database use color criteria in order to select objects for observations and star-forming regions that can be present in the observed source sample.

In Figures 3–6 we plot the 2MASS, *Akari*, *WISE* and *IRAS* color-color diagrams of selected objects respectively. The known LPVs are selected in these diagrams using different colors. The *WISE* color-color diagram is presented using (W1-W3) and (W2-W4) colors. The 2MASS color-color diagram is presented using $(J-H)$ and $(H-K)$ colors. The *IRAS* color-color diagram is presented using the following color indices:

$$[12]-[25] = 2.5\log_{10}\left(\frac{F_{25}}{F_{12}}\right)\ ,$$

$$[25]-[60] = 2.5\log_{10}\left(\frac{F_{60}}{F_{25}}\right)\ .$$

The *Akari* color-color diagram appears similar to that of *IRAS* but using $[09]-[18]$ and $[18]-[65]$. The *Akari* diagram is similar to the one in Yung et al. (2013) and reveals many objects that exhibit color characteristics of AGB stars with long-period variability, as defined in Yung

Table 1 Examples of objects with maser emission that are not included in GCVS – possible candidates for LPVs. The full version of this table is available online at *http://maserdb.net*.

id	Galactic id	Object name	Mean RA Deg. (J2000)	Mean Dec Deg. (J2000)	Maser detection H_2O/OH/SiO	2MASS K (mag)	*WISE* [22] (mag)	K–[22] (mag)
1	117.7–7.60	IRAS 00127+5437	3.850714	54.9041685	–H_2O –OH +SiO	4.159	–1.22	5.379
2	119.7+3.32	IRAS 00170+6542	4.96446	65.991863	+H_2O +OH +SiO	6.047	–1.466	7.513
3	301.4–29.42	IRAS 03074–8732	43.096667	–87.338889	+H_2O +OH +SiO	2.897	–2.391	5.288
4	138.0+7.26	IRAS 03206+6521	51.285417	65.535279	–H_2O +OH +SiO	8.548	–2.54	11.088
5	141.7+3.53	IRAS 03293+6010	53.3775075	60.33597	–H_2O +OH +SiO	7.559	–2.347	9.906
6	161.1–17.17	IRAS 03453+3207	57.134583	32.278611	+H_2O –OH +SiO	4.165	0.289	3.876
7	187.7–17.57	IRAS 04575+1251	75.099583	12.934903	+H_2O +OH –SiO	4.861	–2.306	7.167
8	163.0+4.33	IRAS 05131+4530	79.19629	45.5677295	–H_2O +OH +SiO	6.331	–2.307	8.638
9	186.1–7.59	IRAS 05284+1945	82.852917	19.788611	–H_2O +OH +SiO	11.643	–0.254	11.897
10	176.5+0.18	IRAS 05345+3157	84.449259	31.99	+H_2O +OH –SiO	10.243	–0.345	10.588
11	174.1+14.12	IRAS 06297+4045	98.3155835	40.714139	+H_2O +OH +SiO	2.325	–3.132	5.457
12	215.5–6.08	IRAS 06319–0501	98.6091685	–5.060556	+H_2O +OH –SiO	5.704	–2.059	7.763
13	212.1–4.07	IRAS 06329–0106	98.8829185	–1.156944	–H_2O –OH +SiO	3.685	–0.338	4.023
14	193.6+16.22	IRAS 07045+2418	106.893032	24.221952	+H_2O +OH +SiO	4.087	–0.477	4.564
15	224.3–1.30	IRAS 07054–1039	106.95575	–10.73497	+H_2O +OH +SiO	3.651	–1.472	5.123
16	149.9+26.48	IRAS 07051+6601	107.5244695	65.940188	+H_2O –OH +SiO	3.29	–0.86	4.15
17	237.5–5.49	IRAS 07153–2411	109.365833	–24.286667	+H_2O –OH +SiO	5.309	–0.8	6.109
18	228.1+0.21	IRAS 07180–1314	110.081458	–13.3369545	+H_2O +OH +SiO	3.534	–2.185	5.719
19	252.8–1.00	IRAS 08089–3511	122.6992825	–35.346389	–H_2O +OH +SiO	4.242	–1.038	5.28
20	235.3+18.10	IRAS 08357–1013	129.536602	–10.404549	+H_2O +OH +SiO	4.395	–2.504	6.899

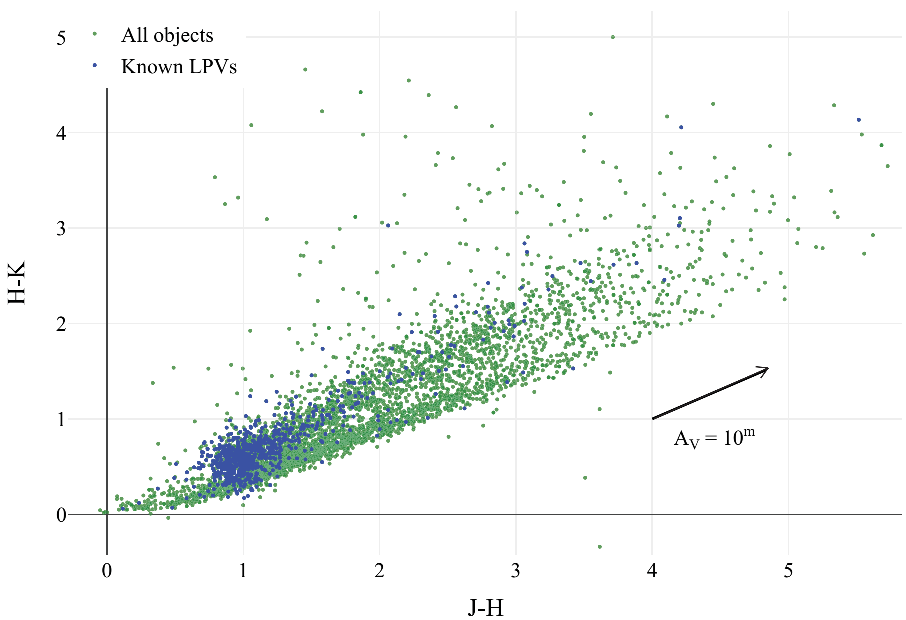


Fig. 3 2MASS color-color diagram for objects with detected maser emission of H_2O, OH or SiO molecules. *Blue dots* represent known LPV stars (miras and semiregular variable stars) from GCVS. *Black line* represents the reddening vector with $A_V = 10^{\mathrm{m}}$.

et al. (2013). *IRAS* color-color diagrams indicate that most of the known LPVs fall into groups II, IIIa and VII, according to the definition of van der Veen et al. (1987). These groups are the following: variable stars with "young" O-rich circumstellar shells, variable stars with more evolved O-rich circumstellar shells and variable stars with more evolved C-rich circumstellar shells, respectively. All objects with maser detections (green dots) fill other groups of objects in the *IRAS* color-color diagram. The 2MASS color-color diagram demonstrates that known LPVs fill a quite limited range of the values: $0.5 \lesssim (J-H) \lesssim 1.5$, $0.2 \lesssim (H-K) \lesssim 1.3$. Selecting the objects using color criteria is a possible way to identify the LPVs, but a more

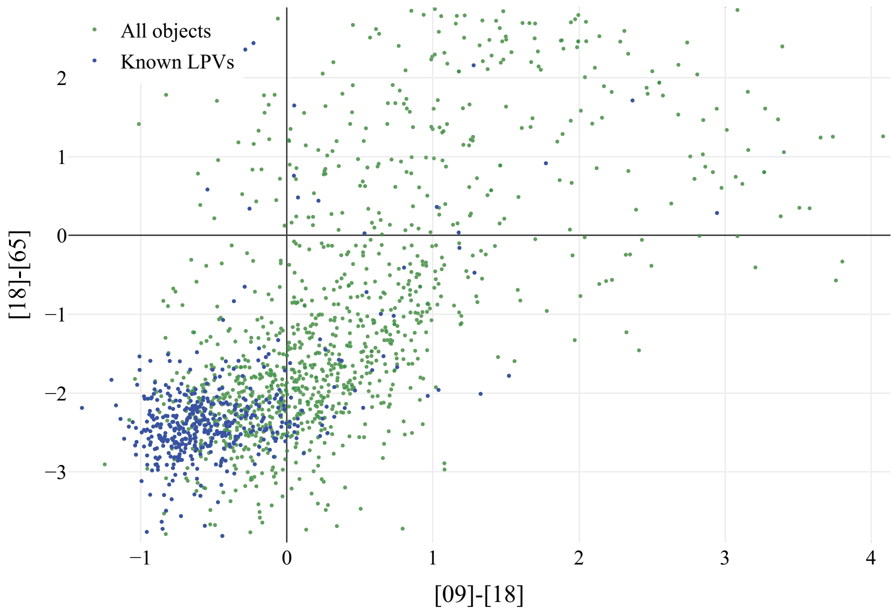


Fig. 4 *Akari* color-color diagram for objects with detected maser emission of H_2O, OH or SiO molecules. *Blue dots* represent known LPVs (miras and semiregular variable stars) from GCVS.

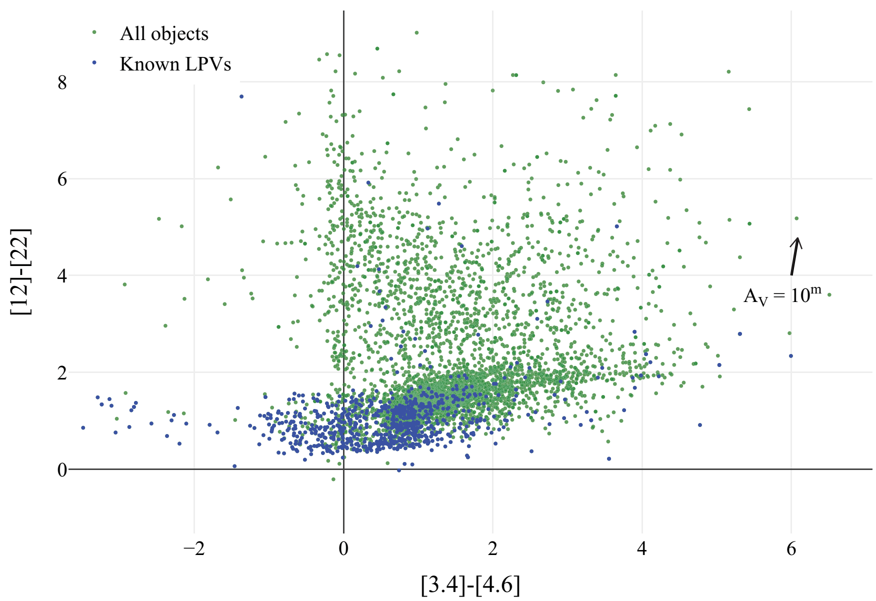


Fig. 5 *WISE* color-color diagram for objects with detected maser emission of H_2O, OH or SiO molecules. *Blue dots* represent known LPVs (miras and semiregular variable stars) from GCVS. *Black line* represents the reddening vector with $A_V = 10^{\mathrm{m}}$.

detailed study is necessary in order to find the color-based criteria for selecting LPV stars.

6 IR EXCESS OF SELECTED STARS

Because LPV stars (including miras) have a circumstellar shell, these stars should have IR excess. We follow the scheme described in Wu et al. (2013) in order to identify IR excess stars. The authors used *WISE* and 2MASS photometry in order to select IR-excess stars. The basic criterion is the following: $(K_s - [22])$ should be greater than some certain value ($\simeq$0.2). This constant is a subject for improvement over the years. Gorlova et al. (2004, 2006) found that this constant is equal to 0.33. In Hovhannisyan et al. (2009) this value was changed to 0.2. In the paper Wu et al. (2013), the authors improved the constant value according to the

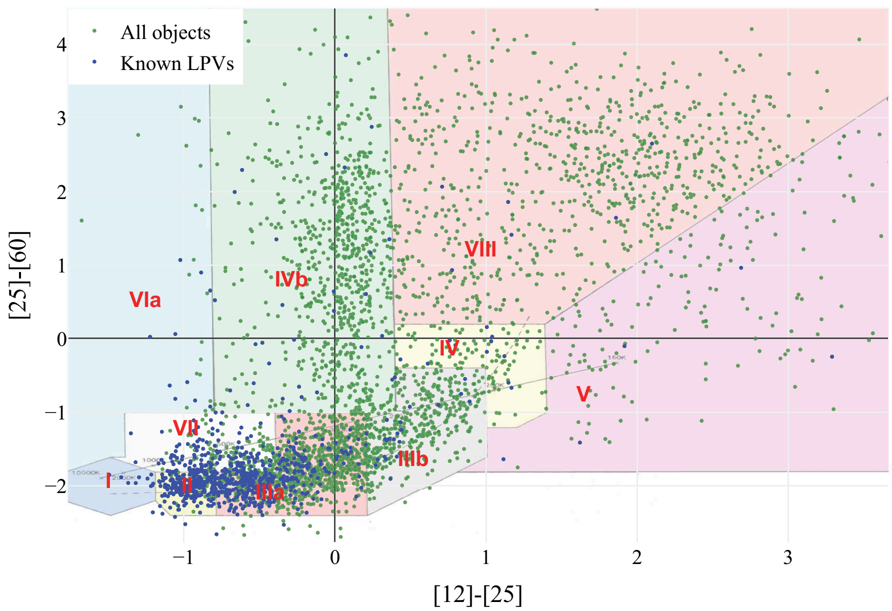


Fig. 6 *IRAS* color-color diagram for objects with detected maser emission of H_2O, OH or SiO molecules. *Blue dots* represent known LPVs (miras and semiregular variable stars) from GCVS. Background image is the regions from van der Veen et al. (1987).

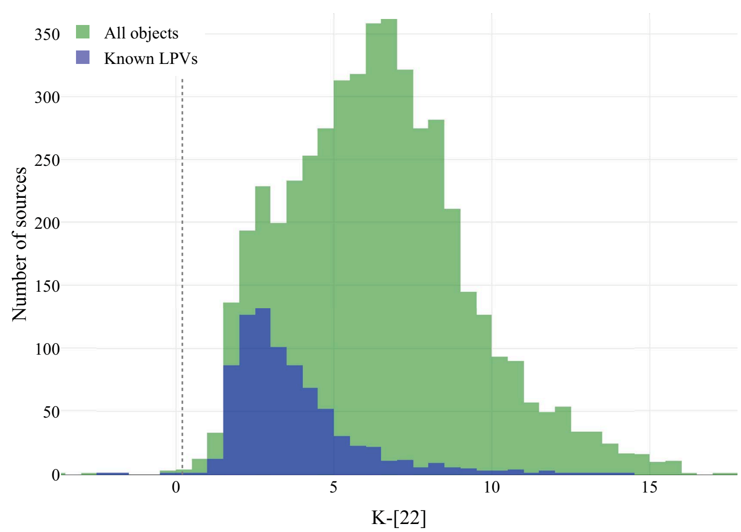


Fig. 7 Histogram distribution of IR excess as defined in Wu et al. (2013). The *green histogram* shows objects where a maser is detected and *blue histogram* shows known LPVs (miras and semiregular variable stars). *Vertical dotted line* represents the border between the presence and absence of IR excess in objects according to the definition in Wu et al. (2013).

shift between 2MASS and *WISE* zero-points. The constant value lies in the range 0.26–0.22, depending on the value of $(J - H)$ color. We used this criterion to check for the presence of IR excess in our candidates and known miras. Our database includes cross-matched *WISE* and 2MASS photometry for each object, thus it is possible to study the IR characteristics of the objects.

In Figure 7, we plot the histogram of IR excess for all objects with maser detection. The histogram reveals that most of the objects have IR excess.

Among 832 known LPVs with detected maser emission in at least one molecule, only nine stars (Z Peg, BX Cam, RR Sco, V2584 Oph, AN Dra, V0837 Her, V1677 Aql, V Aqr and TV Aqr) do not have IR excess, according to the definition in Wu et al. (2013). All other 823 LPVs have IR excess.

We considered objects which are not included in GCVS but have positive maser detection in at least one maser line. We found that only six objects (IRAS 16376–4634, IRAS 17320–2734, IRAS 18007–0218, IRAS 18522+0021, IRAS 19126–6941 and IRAS 20084+2750) have no IR excess. The existence of IR excess in the mira candidates confirms the potential association of these objects with mira variability.

7 POSSIBLE APPLICATIONS FOR VARIABLE STAR STUDIES

The maser database presented in this paper has the potential to significantly contribute to research in the field of variable star studies. Firstly, there is a large overlap between the stellar maser sources and variable stars, because a non-negligible amount of stellar maser sources is evolved stars exhibiting pulsation. Secondly, maser properties could be an evolutionary probe of stars in their late stages of evolution. Thirdly, the database system has been equipped with functionality allowing cross-identification between different catalogs. With these capabilities, for example, if we cross-check with stellar catalogs at other wavelengths, such as far, mid and near-IR, ultraviolet and X-rays, we may be able to identify stars belonging to key evolutionary stages, such as post-AGB and proto-planetary nebula stages.

8 CONCLUSIONS

In this paper, we describe the potential of implementing an astrophysical maser database for variable star identification and research. The main findings of the paper are the following:

– The maser database contains about 11 000 objects with data on maser emission obtained (including non-detections) for at least one molecule of H_2O, OH and SiO; ~ 4806 objects have maser detection in at least one molecule.
– Among the known LPVs in our sample (1803 objects), 46% of stars (832 objects) have maser emission of at least one molecule (H_2O, OH or SiO), thus maser emission may be used as the criterion to identify variable stars.
– Almost all objects with maser emission have positive IR excess according to the definition in Wu et al. (2013).

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