Twenty-Six-Year Monitoring of Water Masers

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Contents of the work

- A sample of $\text{H}_2\text{O}$ maser emission sources has been observed since 1980. The sample includes 125 sources (65 star-forming regions and 60 late-type variable stars).
- The purpose of this work is to study the variability of the $\text{H}_2\text{O}$ maser emission on a long time interval. The observations are carried out on the average once per month.
- Since 1994 late-type stars are observed also spectroscopically to find out correlation between maser variations and optical emission lines.
Radio spectroscopy

- RT-22 radio telescope (Pushchino, Moscow Region)
- Helium-cooled FET amplifier of the 1.35-cm band ($T_N = 150-200$ K)
- 2048-channel autocorrelation spectrometer (velocity resolution 0.082 km/s)
- Sensitivity at the $3\sigma$ level about 10 Janskys
Star-forming regions

- HII regions
- Young stellar clusters (W31)
- Bipolar outflows
- IRAS sources in cool interstellar clouds
- Protoplanetary discs (S255, NGC 7538 and others)
Maser in a protoplanetary disc (S255)

S255: H$_2$O line profile
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Sgr B2
H$_2$O flares

Rapid variability in the H$_2$O maser W33B
58 spectra (6.5 min exposure each)
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NGC 7538

Velocity drifts of the H2O features (chains)

Integrated H2O line flux

Turbulent vortex

Sample H2O spectra

Anticorrelation

Intrgrated flux, Jy km/s

Radial velocity, V LSR, km/s

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# Stellar masers

<table>
<thead>
<tr>
<th>H$_2$O</th>
<th>H$_2$O + H$\alpha$</th>
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</thead>
<tbody>
<tr>
<td>Y Cas, IK Tau, W Eri, RS Eri, R Tau, NV Aur, IRC+60154, AW Tau, IRC+60169, U Lyn, GX Mon, VY CMa, Z Pup, QX Pup, X Hya, U CVn, RU Hya, Y Lib, WX Ser, VX Sgr, IRC- 10414, V1111 Oph, RW Lyr, IRC- 20540, RT Aql, V391 Cyg, SY Aql, DR Cyg, NML Cyg, UU Peg, AM Cep, PZ Cas</td>
<td>R Aql, RR Aql, U Aur, RX Boo, R Cas, S CrB, R Crt, S Crt, U Her, W Hya, R Leo, R LMi, U Ori, R Peg, S Per, R Tri, RS Vir, RT Vir</td>
</tr>
</tbody>
</table>

*Semiregular variables underlined*
Optical spectroscopy

- 125-cm telescope, Crimea
- Grating spectrograph
- CCD cameras, Santa Barbara Instruments Group
- Sensitivity in the Hα region: a spectrum of an 11th magnitude star can be obtained in a 10-min exposure.
Mira-type variable R Leo,  \( P = 310^d \)

Optical spectrum

H\(_2\)O line

H\(_\alpha\)-H\(_2\)O integrated flux

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R Leo

\( F_{\nu} \), \( 10^{-12} \) erg cm\(^{-2}\) s\(^{-1}\) \( \AA^{-1} \)

\( \lambda \) \( \AA \)

\( V_{\text{r,sys}} \), km s\(^{-1} \)

\( \log(F(H_2O)) \), W m\(^{-2} \)

\( \nu(H_\alpha) \), erg cm\(^{-2}\) s\(^{-1} \)
Mira-type variables S CrB and U Aur: visual light curves, $H\alpha$ and $H_2O$ integrated fluxes

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Model: Shock wave in a mira’s atmosphere

- Shock 1
  - $H_\alpha$

- Shock 2
  - $H_2O$

- Star

- Postshock maser shell