

Twenty-Six-Year Monitoring of Water Masers

**G.M. Rudnitskij¹, M.I. Pashchenko¹, V.F. Esipov¹,
V.A. Samodurov², I.A. Subaev², A.M. Tolmachev² and E.E. Lekht^{1,3}**

¹Sternberg Astronomical Institute, Moscow State University,
13 Universitetskij prospekt, Moscow, 119992 Russia (gmr@sai.msu.ru)

²Pushchino Radio Astronomy Observatory, Astrospace Center of the Lebedev
Institute of Physics, Russian Academy of Sciences, Pushchino,
Moscow Region, 142290 Russia (sam@prao.ru)

³Instituto Nacional de Astrofísica, Óptica y Electrónica,
Luis Enrique Erro No. 1, Apdo Postal 51 y 216, 72840 Tonantzintla, Puebla,
México (lekht@inaoep.mx)

Contents of the work

- **A sample of H₂O 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 H₂O 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

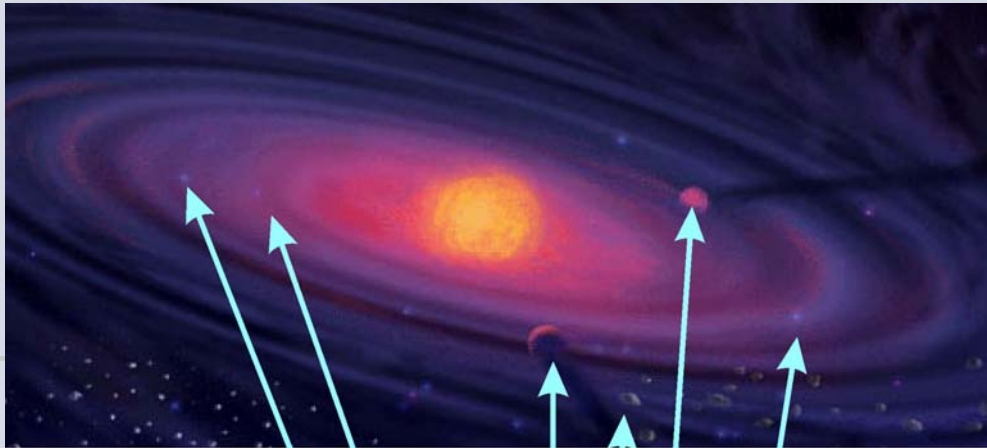
- **RT-22 radio telescope (Pushchino, Moscow Region)**
- **Helium-cooled FET amplifier of the 1.35-cm band ($T_N = 150\text{--}200\text{ K}$)**
- **2048-channel autocorrelation spectrometer (velocity resolution 0.082 km/s)**
- **Sensitivity at the 3σ level about 10 Janskys**



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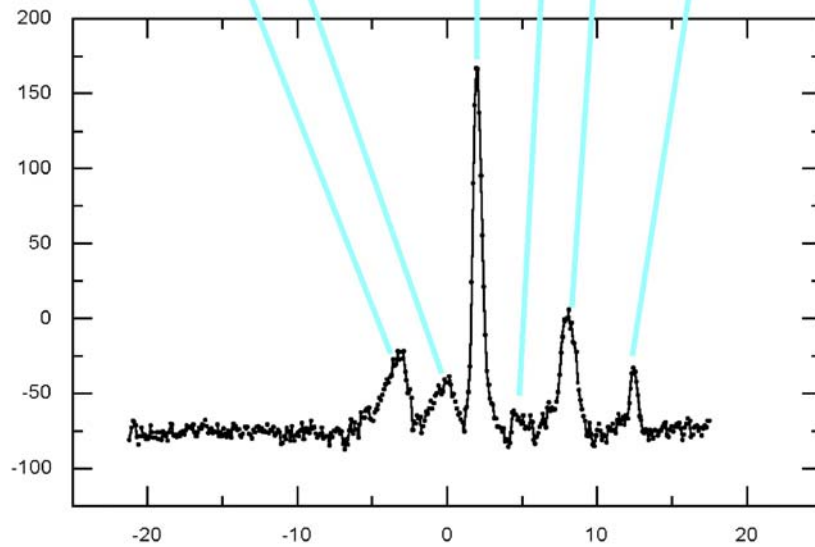
Star-forming regions

- **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)

Flux density, Jy

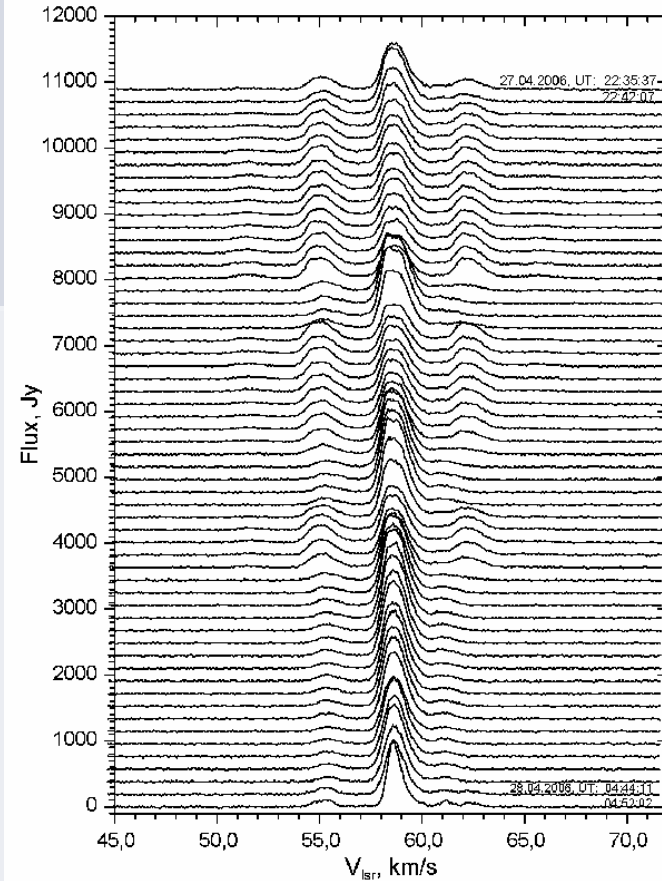
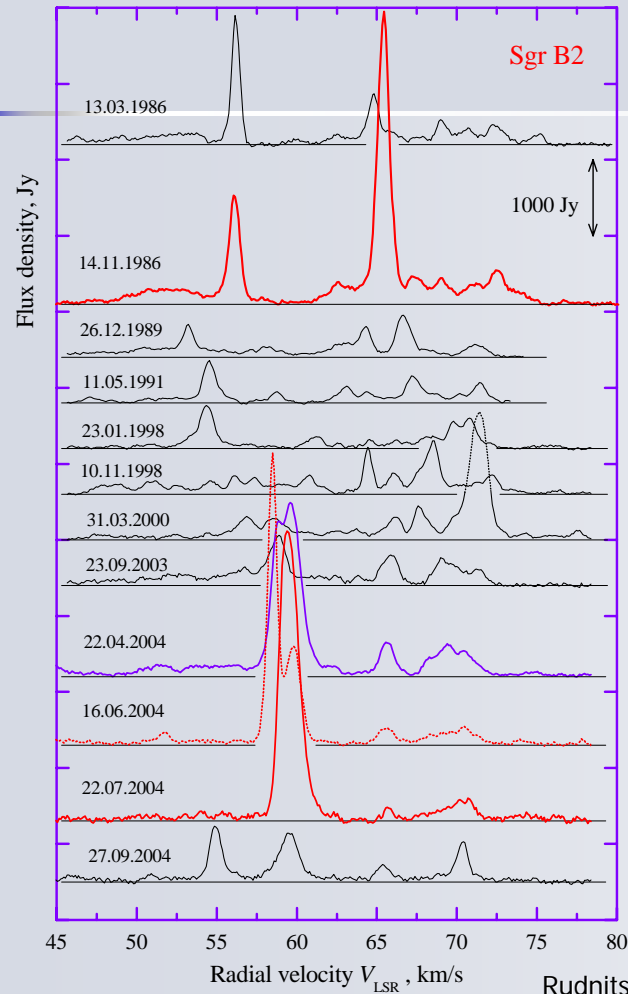


Radial velocity, LSR, km/s

**S255: H₂O line profile
5 February 2002**

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Sgr B2 H₂O flares

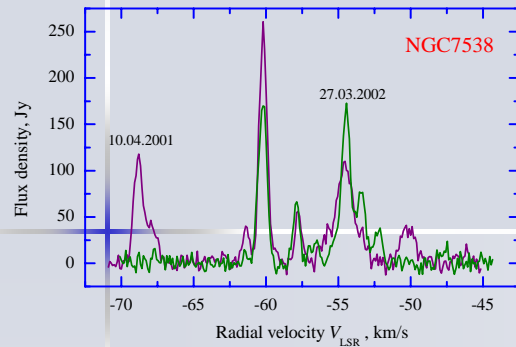


**Rapid variability in the H₂O maser W33B
27-28 April 2006, UT 22:35:07-04:52:02
58 spectra (6.5 min exposure each)**

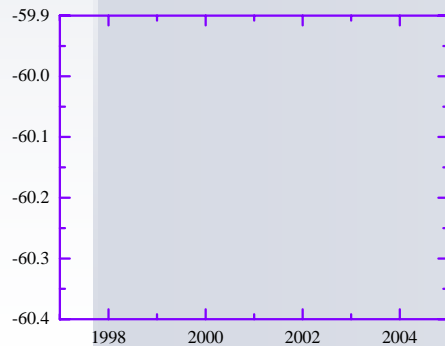
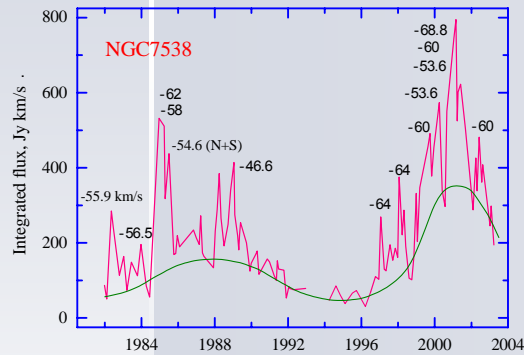
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NGC 7538

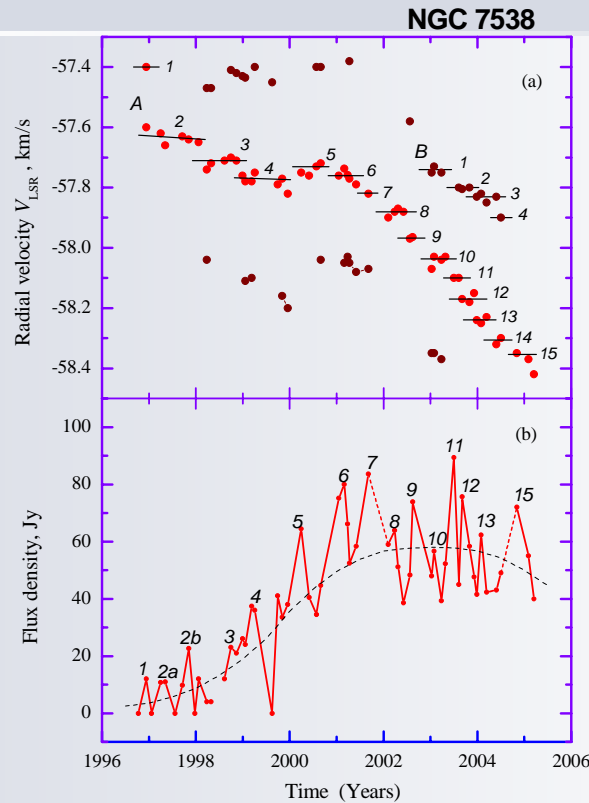
Sample H₂O spectra



Integrated H₂O line flux



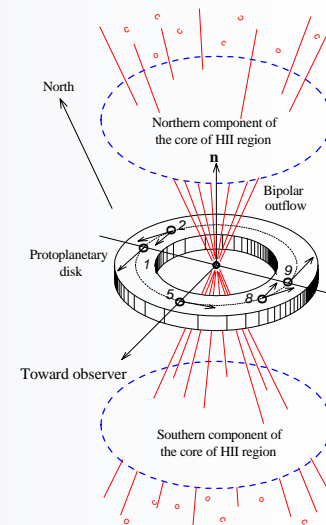
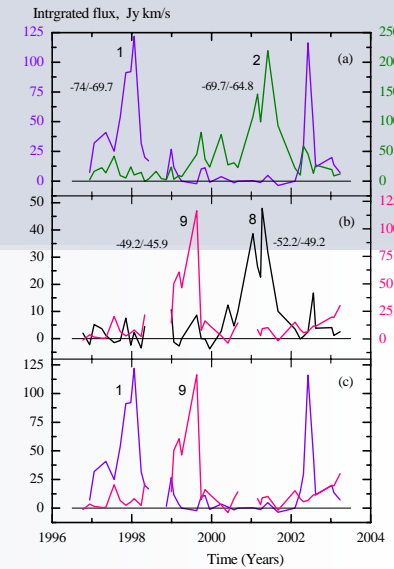
Velocity drifts of the H₂O features (chains)



Turbulent vortex

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Anticorrelation



Model: rotating disc and bipolar outflow

Stellar masers

H₂O

**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**

H₂O + H α

**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**

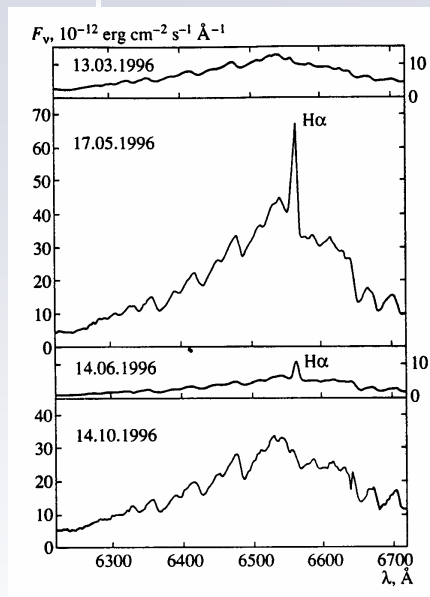
Semiregular variables underlined

Optical spectroscopy

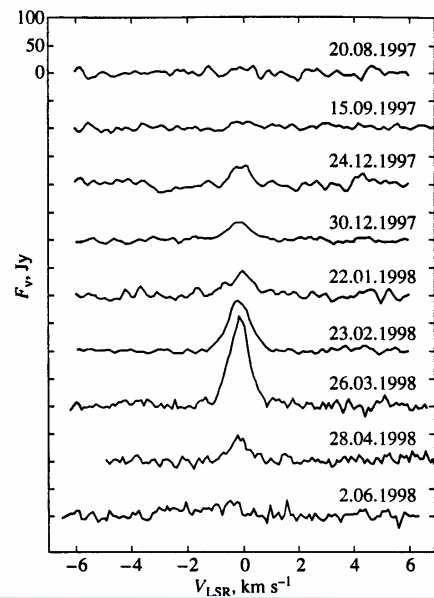
- **125-cm telescope, Crimea**
- **Grating spectrograph**
- **CCD cameras, Santa Barbara Instruments Group**
- **Sensitivity in the $H\alpha$ region: a spectrum of an 11th magnitude star can be obtained in a 10-min exposure.**

Mira-type variable R Leo, $P = 310^d$

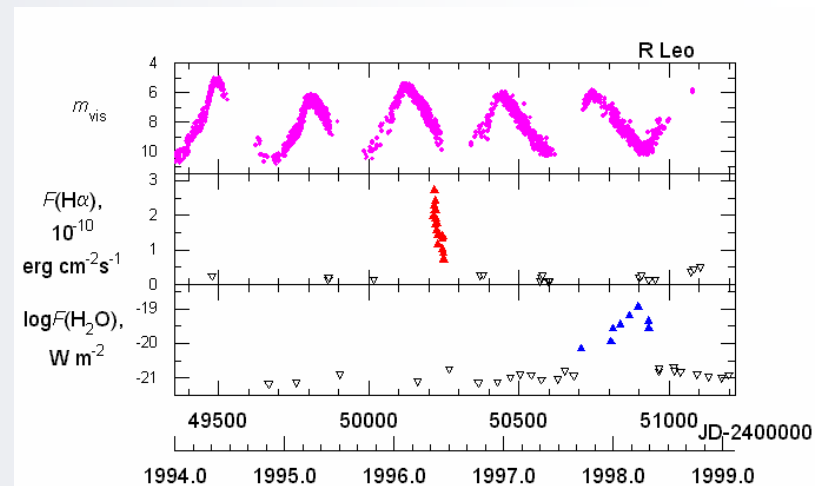
Optical spectrum



H_2O line

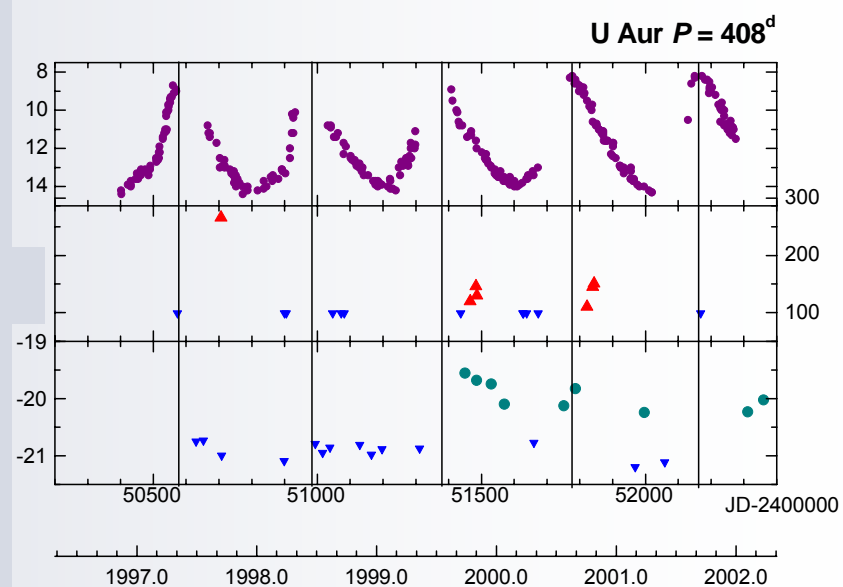
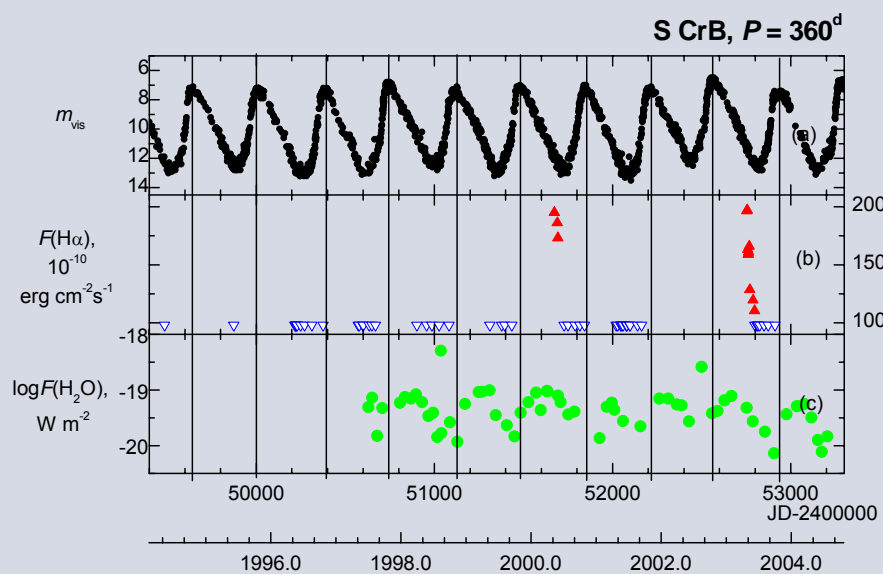


$\text{H}\alpha$ - H_2O integrated flux



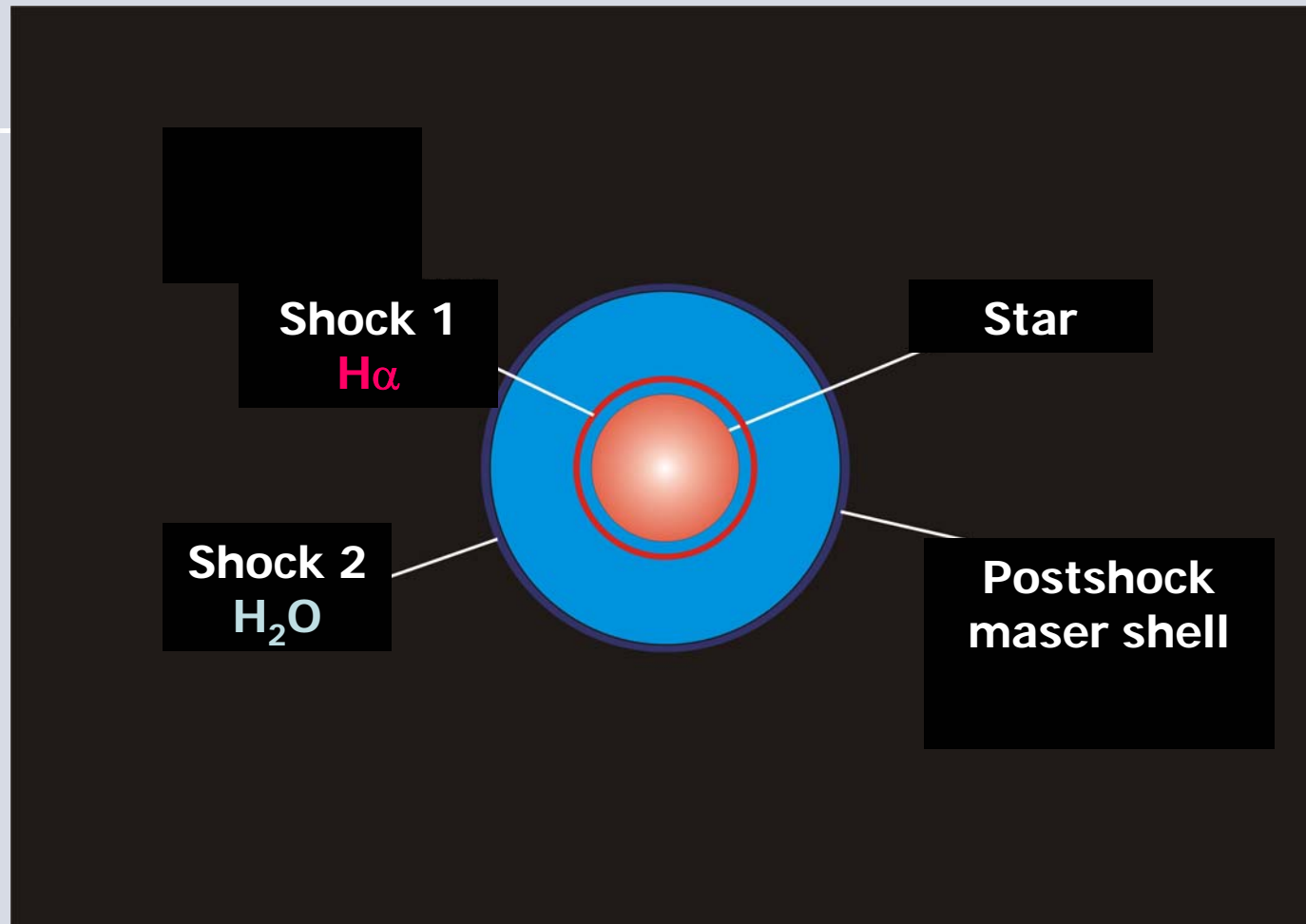
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Mira-type variables S CrB and U Aur: visual light curves, $H\alpha$ and H_2O integrated fluxes



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Model: Shock wave in a mira's atmosphere



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