Multi-epoch VERA observations of SiO masers toward R Aquarii
Cheulhong Min(1), Mareki Honma(1)(2), Tomoyoi Hirota(1)(2), Katsunori M. Shibata(1)(2)
and VERA project team(2)
(1) The Graduate University for Advanced Studies (SOKENDAI)
(2) National Astronomical Observatory of Japan (NAOJ)

Abstract
We carried out multi-epoch phase-referencing VERA (VLBI Exploration of Radio Astrometry) observations of v=1,2 J=1-0 SiO masers toward R Aquarii (R Aqr) covering about three stellar pulsation periods from Oct. 2011 to Jun. 2014. Overall distributions of the SiO masers show clumpy and partial ring-like structures dominant in NE (2012) and SE (2013, 14) regions. The v=2 J=1-0 SiO ring is located closer than v=1 J=1-0 SiO maser consistent with previous VLBI observations. The SiO maser rings appear to be contracting for the v=1 transition but expanding after contraction for v=2 transition due to shock propagations.

Introduction

• AGB (Asymptotic Giant Branch) stars
- Late-stage of a few solar mass stellar evolution
- Pulsation with large mass-loss rate (~10^{-6} M_{SUN} yr^{-1})
  - Main source for chemical enrichment of universe
  - Driving mechanism not well understood

• R Aquarii (R Aqr)
- The closest symbiotic star (Mira + WD binary system)
- Pulsation period: 987 days
- Hour-glass like inner & outer nebulae
- Bipolar jet feature - powered by accretion disk on the WD
- Circumstellar SiO maser source associated with Mira variable

Observations

• Multi-epoch phase-referencing VERA observations (4 stations)
• Frequency: 28SiO masers of v=1,2 J=1-0 (43.112, 42.820 GHz)
  • Simultaneous observations for the target (R Aqr) and reference source (J2348-16) – separation ~1.6 degree

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<tr>
<td>R.Aquarii</td>
<td>23h43m49.4616s</td>
<td>-15°17’04.202&quot;</td>
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<tr>
<td>J2348-1631</td>
<td>23h48m2.0685s</td>
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• SiO masers in AGB stars
- Formed mostly in Oxygen-rich ([O]/[C] >1) AGB stars
- Perfect target for VLBI observations with a high spatial resolution
- Useful for astrometry: distance (parallax) and proper motions
- Tracer of inner most region of circumstellar envelope (CSE)
  - Formed between photosphere and dust formation region
  - Important probe for studying structures and dynamics of the CSE
  - Many vibrational/rotational transitions
  - Appears as a ring-like structure
  - Tangential amplification

Results

✓ SiO masers distributions (Fig 3)
- Clumpy and Partial ring-like distributions
  • Asymmetric distributions – dominant in NE(2012) and SE(2013,2014) regions
    - Mean maser radii: R_{v=2} = 14.68 mas < R_{v=1} = 15.39 mas
    - v=2 SiO maser is closed to the star than v=1 SiO maser
  - SiO masing region R_{SiO} = 2.79 ~ 2.93 R_{MIRA} (R_{MIRA} = 1.14 AU[3])
  - Spike-like features
    - East region in 2012 / South-West region in 2014

✓ Maser ring variations (Fig 4)
- Contraction and Expansion
  • Ballistic contraction of the v=1 SiO maser region (gravitational effect)
    - Mean acceleration: 1.9 \times 10^{-7} km s^{-2}
    - Expansion: After shock encountering – following shock propagation

✓ SiO masers flux variations (Fig 45)
- Following the pulsation period of the Mira variable
  - correlation with optical light curve (phase lag ~0.1)
  - Slightly coincidence maximum radio flux with optical maximum between 2012 and 2013
  - Correlation SiO maser radii and flux variations
    - smaller radius (closed to the star) being more intense

Future Works
- Compare with SiO maser models and dynamic atmospheric models of the oxygen-rich Mira variables
- SiO maser pumping mechanism
- confine SiO maser emitting region
- correlation masing radius with its intensity
- non-uniform shock propagation
- Linked to other observational results for CES in AGB stars

References