Absolute proper motion measurement of Sgr D HII region with VERA

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Outline

- Introduction
  - the Galactic Center and my long-term goal
  - Sgr D region
- Observations
- Results
  - Maser distributions and proper motions of Sgr D HII region
- Discussion
  - Distance to Sgr D HII region
- Summary
Introduction

The Galactic Center

- Center of the Galaxy
- SMBH $4 \times 10^6 M_\odot$
- Peculiar sources
  - Sgr B2
  - Sgr C
  - Sgr D

- Central Molecular Zone (CMZ)
  - Molecular ring at 300 pc radius
  - Mass reservoir toward the center
  - Outstanding non-circular motion

Larosa 2000
Introduction

Motion of CMZ region

- **Resonance orbit model**
  - ILR due to bar potential
  - $x1$ and $x2$ orbit family
  
  (Binney et al. 1991)

- **Expanding ring model**
  - Due to past Sgr A* activity

  (Kaifu et al. 1972)

Measuring proper motion with VLBI is important to distinguish two models.
How can we distinguish 2 models?

(1) Expanding ring model
(2) Resonance orbit model

In longitude-velocity diagram, 2 models fall in same shape.

In longitude-proper motion diagram, significant difference emerge at outer parts.

These can be distinguished by measuring proper motion.
Introduction

**Sgr D region**

- Galactic longitude $l = 1.1^\circ$
- **HII region** and SNR region
- CS line has been detected
  - Velocity $= -16 \text{ km s}^{-1}$
  - Width $= 4 \text{ km s}^{-1}$
- H$_2$O maser detected
- Distance
  1. CMZ (in GC)
     - Star count
  2. Disk
    - Narrow line width

**The Distance has not been determined yet!**

Mehringer et al. 1998

**HII region**

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14年10月28日火曜日
Observations

Telescopes: VERA
Line: Water maser (22 GHz)
Date: 2008-2011 (13 epochs)
Mode: 2-beam
  • Sgr D (A-beam)
    - Target source
  • J1745-2820 (B-beam)
    - Position ref. source (QSO)
Results

Maser distribution

- Bi-polar like
  - 60mas (500 AU@8 kpc)
- Expanding
- Red shift on the east
- Blue shift on the west
- Typical internal motion 1 mas/yr
  - 38 km/s@8 kpc
Results

**Absolute proper motion**

: Motion relative to position reference source

**Fitting Results**

Parallax:

0.181±0.076 mas

Distance:

5.53 +4.00/-1.63 kpc

Proper mot.(RA dir.):

-1.74±0.045 mas/yr

Proper mot.(Dec dir.):

-2.83±0.39 mas/yr
Discussion
Motion of Sgr D region

We calculated its motion on cases that Sgr D HII region is located on

1. the Galactic Center (D~8 kpc) or
2. near 3 kpc arm (D~5 kpc)

Proper motion of maser source for 1. and 2. (Units are km s^{-1})

<table>
<thead>
<tr>
<th></th>
<th>(U^{GC})</th>
<th>(V^{GC})</th>
<th>(W^{GC})</th>
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</thead>
<tbody>
<tr>
<td>D=8 kpc</td>
<td>-24(\pm)2.0</td>
<td>140(\pm)13</td>
<td>12(\pm)10</td>
</tr>
<tr>
<td>D=5 kpc</td>
<td>-50(\pm)2.0</td>
<td>75(\pm)8.3</td>
<td>7.3(\pm)6.4</td>
</tr>
</tbody>
</table>

\(U^{GC}\): Toward GC  
\(V^{GC}\): Toward Galactic rotation  
\(W^{GC}\): Toward Galactic north pole
Discussion  Distance to Sgr D region (**Disk** case)

- Compare with other sources within 4 kpc from GC (Sanna+2014)

- Sanna et al. 2014 suggests that sources in range 2 kpc < R < 4 kpc have 120 km s⁻¹ < V_GC < 240 km s⁻¹

- If Sgr D is located in this range of radius V_GC for Sgr D is 75 km s⁻¹

**This seems not to be plausible** unless Sgr D have large (more than 50 km s⁻¹) peculiar motion
Discussion  Distance to Sgr D region (GC case)

- Superpose observational data on two models
- Even if either model adopted, Sgr D should locate on near side against GC
- Unfortunately, Both results (This result and Reid+09) could not act crucial roles to distinguish two models.

We have to increase the number of sources!!
Summary

- It is essential to **measure absolute proper motions with VLBI** for revealing the dynamics in the center of the Galaxy.
- The distance to **Sgr D HII** region has not determined yet, even though This source is one of the brightest radio source in the Galactic Center.
- We measured absolute proper motion of Sgr D HII region relative to QSO with **VERA**
- We estimate the distance by considering the proper motion in the cases of
  ① **CMZ(R~300 pc)** and
  ② **3 kpc arm(R~3 kpc)**
- ② does not match other measured results
- ① is similar to results for Sgr B2, but only two measurement → We need to increase the number of source