Absolute proper motion measurement of Sgr D HII region with VERA

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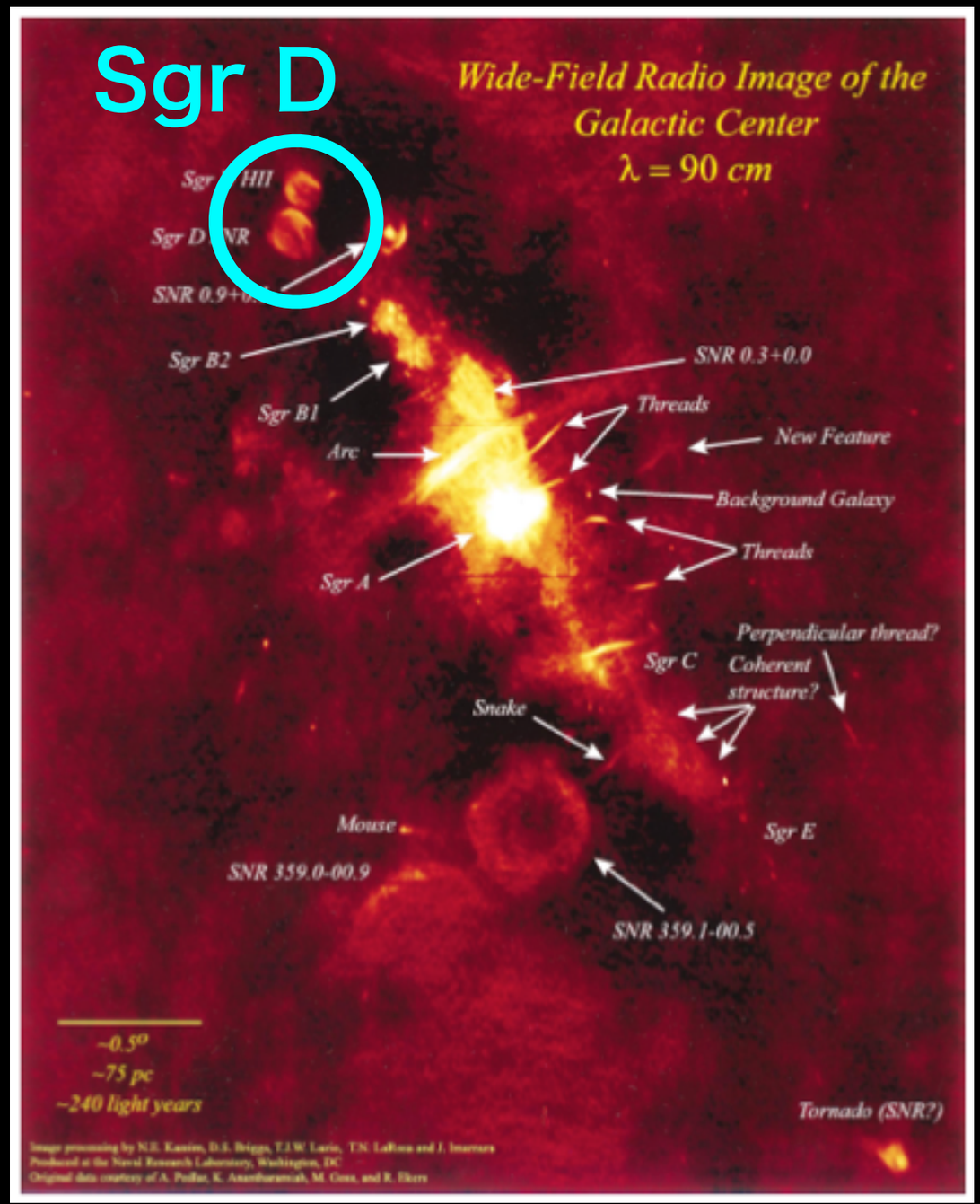
Introduction

The Galactic Center

- Center of the Galaxy
- SMBH $4\times10^6 M_\odot$
- 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



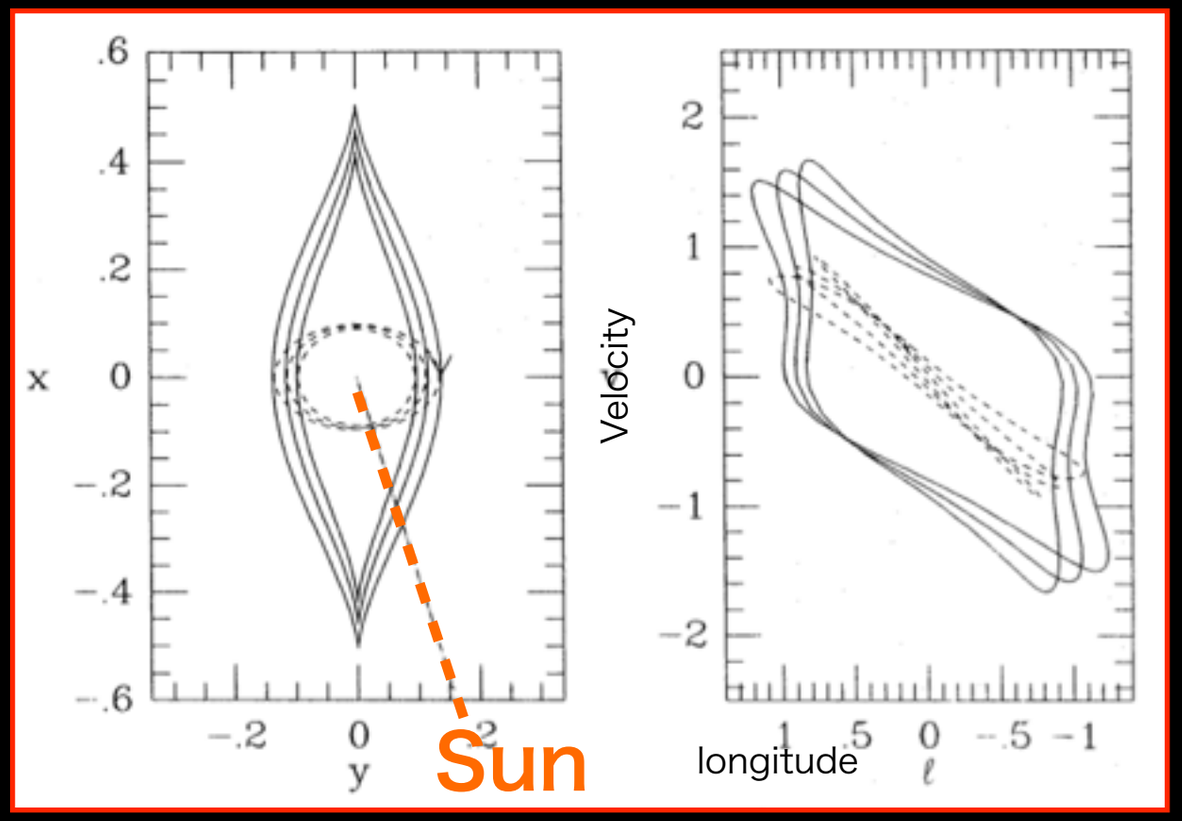
Larosa 2000

Introduction

Motion of CMZ region

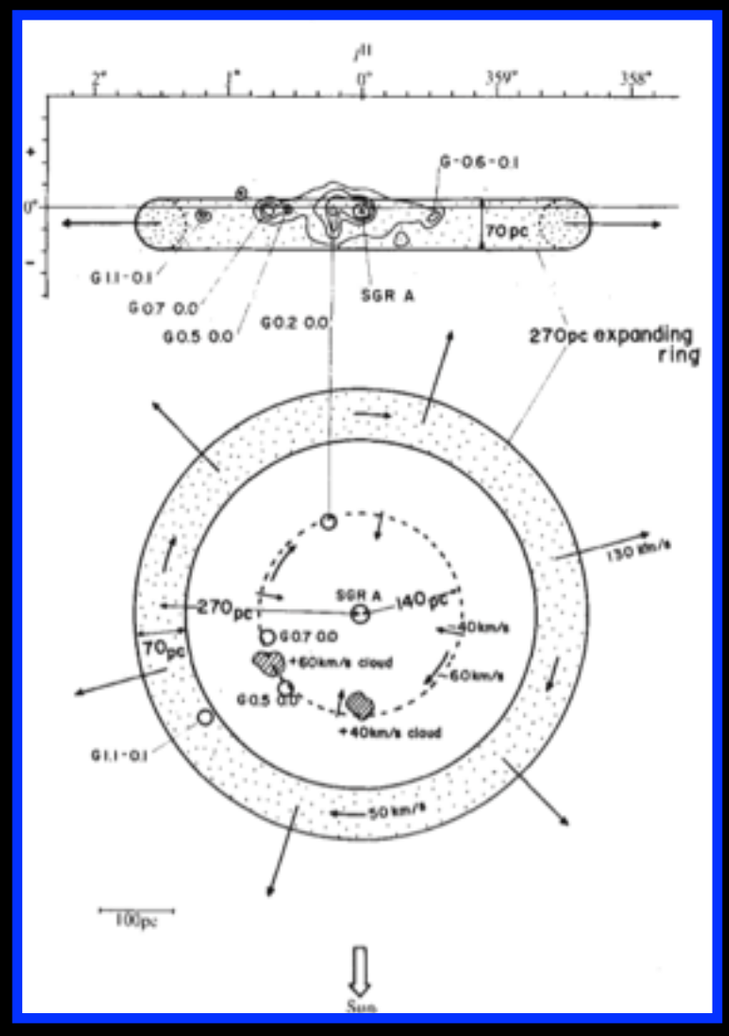
- **Resonance orbit model**
  - -ILR due to bar potential
  - -x1 and x2 orbit family

(Binney et al. 1991)



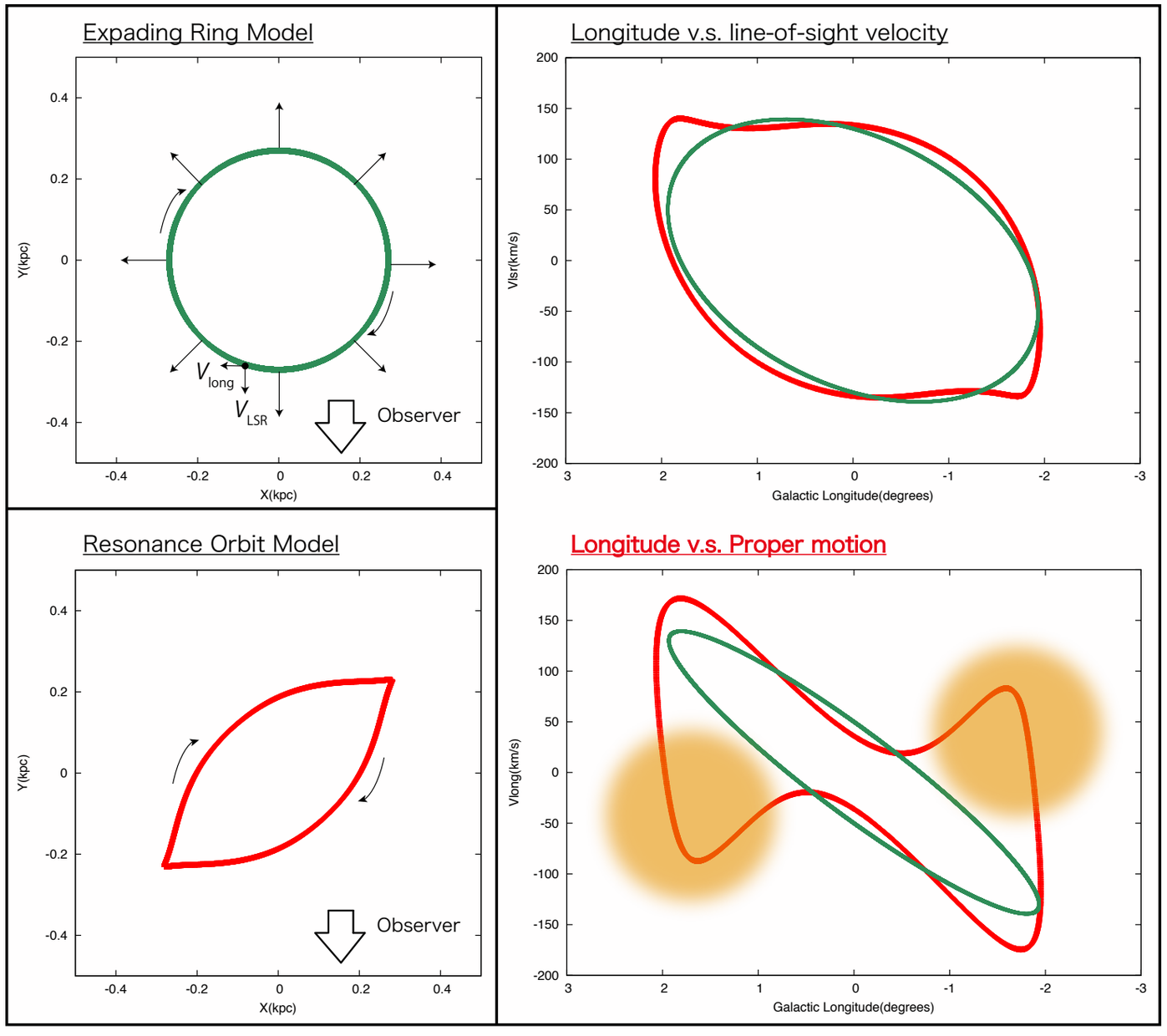
- **Expanding ring model**
  - -Due to past Sgr A* activity

(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.

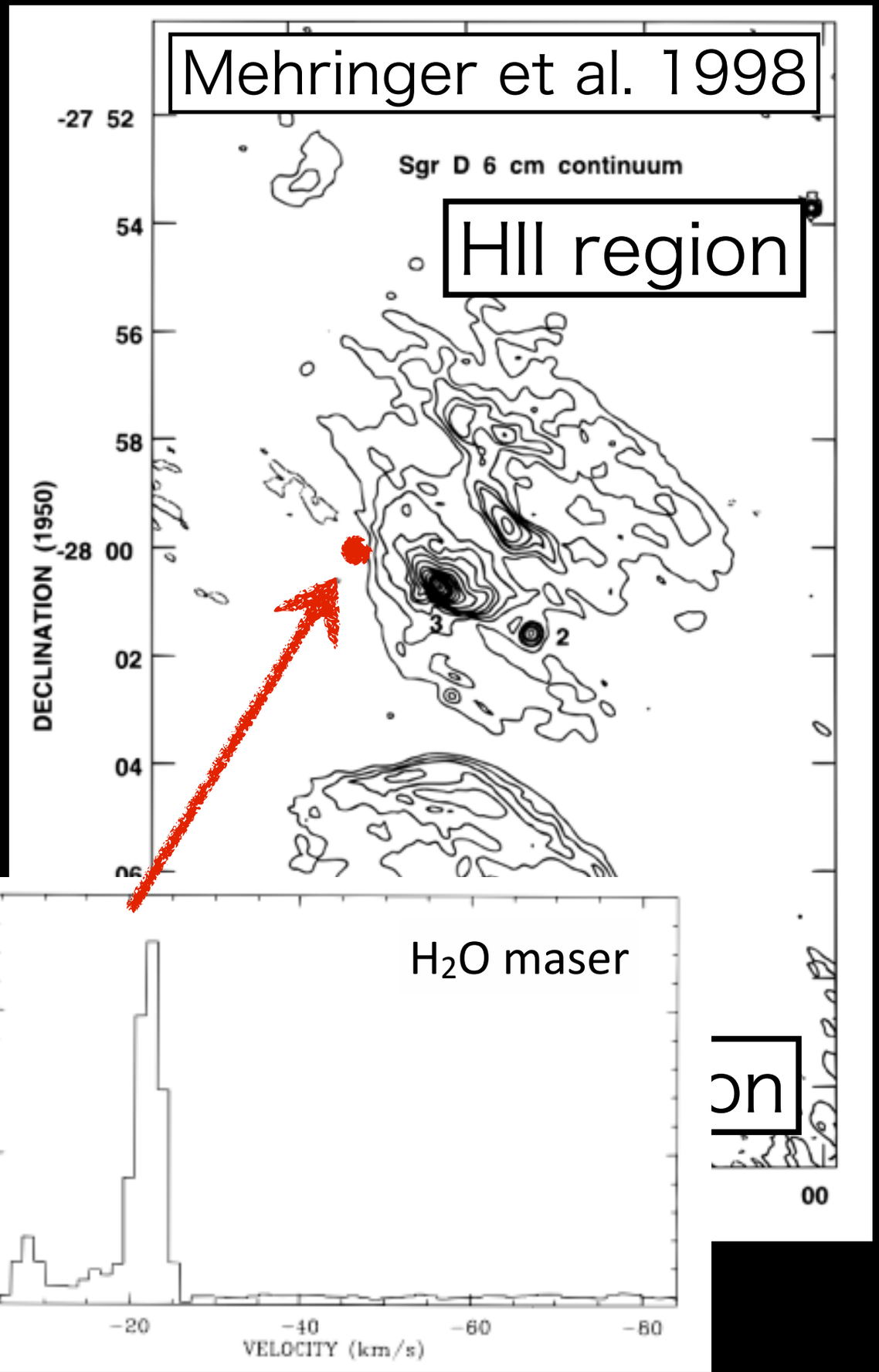
These can be distinguished by measuring proper motion

Introduction

Sgr D region

- Galactic longitude l=1.1°
- **HII region** and SNR region
- CS line has been detected
  - Velocity=-16 km s^{-1}
  - Width=4 km s^{-1}
- H_2O maser detected
- Distance
  1. CMZ(in GC)
     -Star count
  2. Disk
     -Narrow line width

The Distance has not been determined yet!



Observations

Telescopes:VERA

Line: Water maser(22 GHz)

Date: 2008-2011(13 epochs)

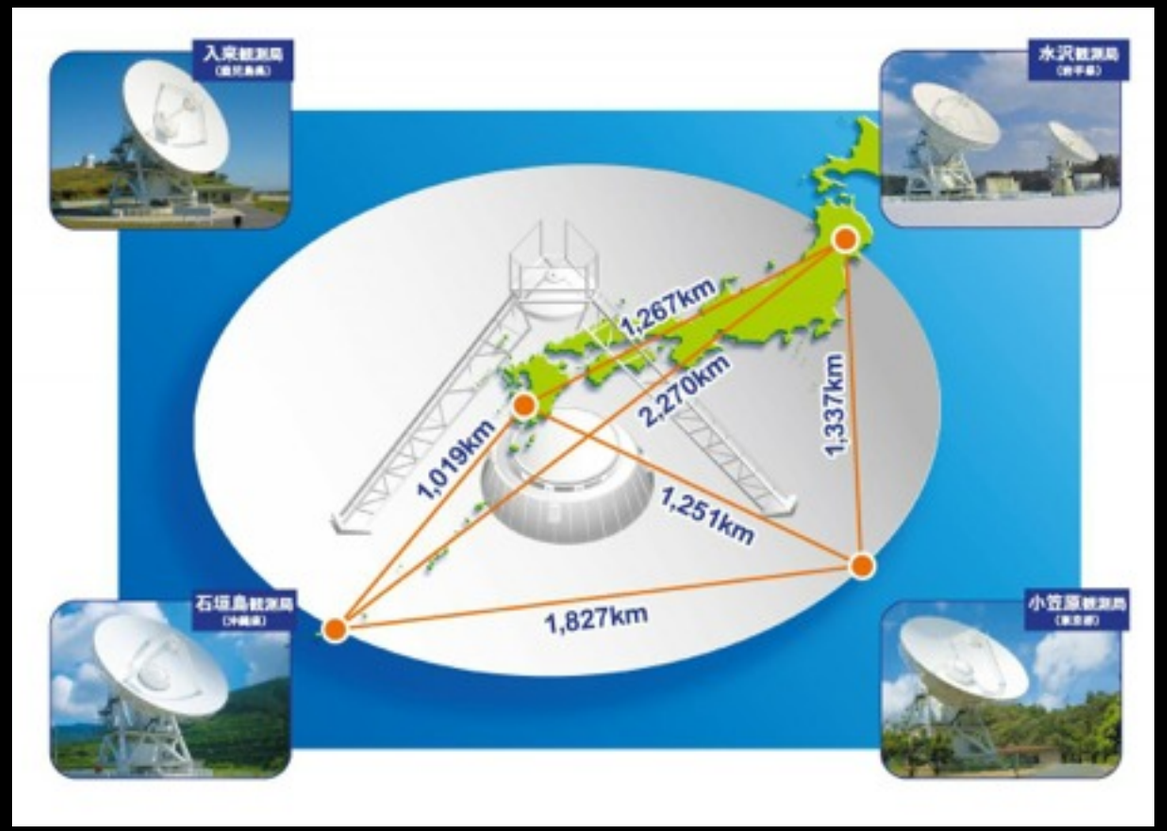
Mode: 2-beam

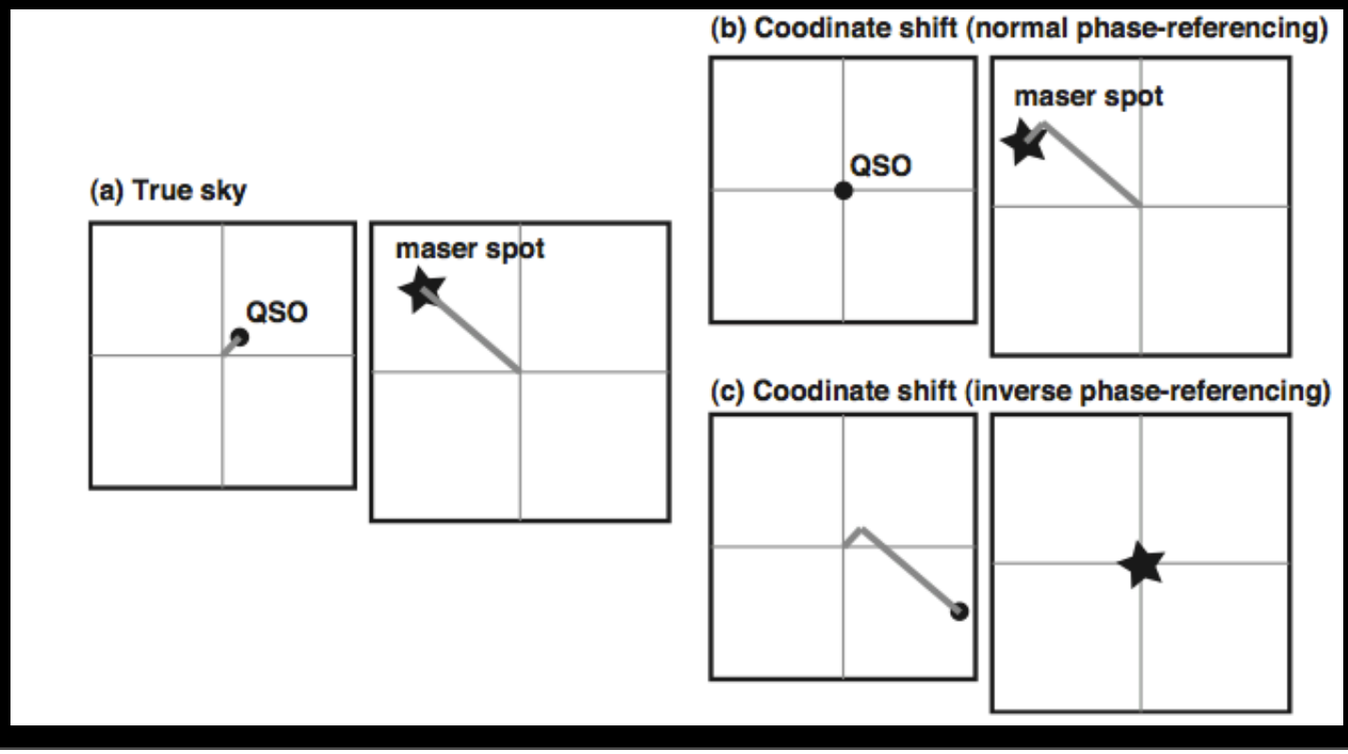
- Sgr D (A-beam)

  -Target source

- J1745-2820 (B-beam)

  -Position ref. source(QSO)

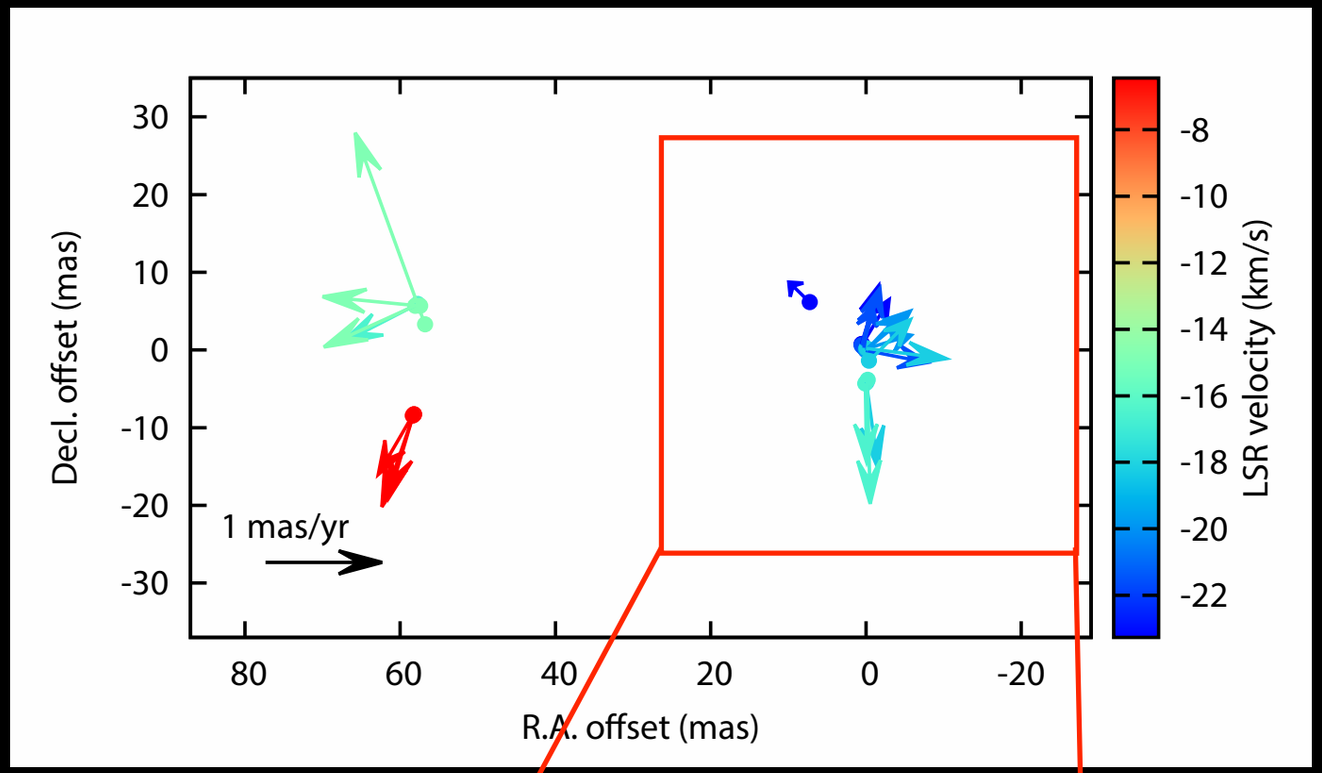


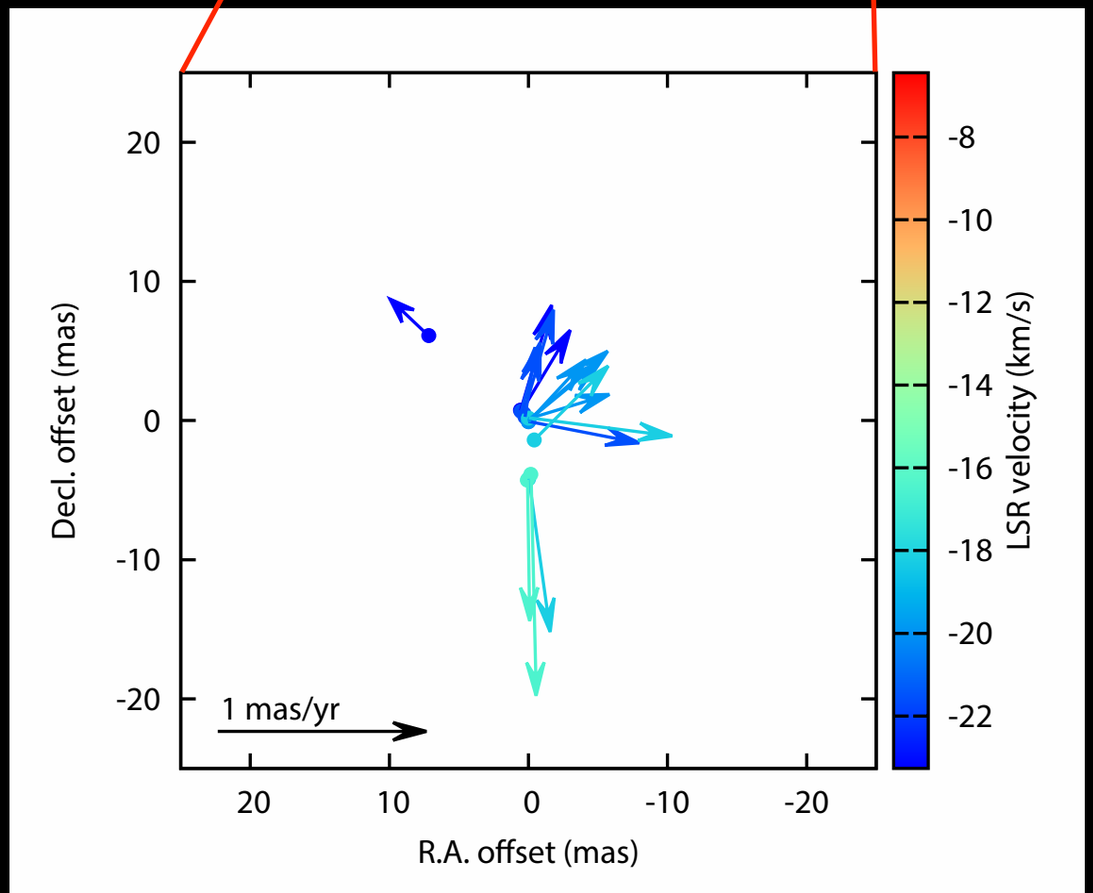


Results

Maser distribution

- Bi-polar like
  - 60mas(500 AU@8 kpc)
- Expanding
- Red shift on the east
- Blue shift on the west
- Typical internal motion1 mas/yr
  - 38 km/s@8 kpc

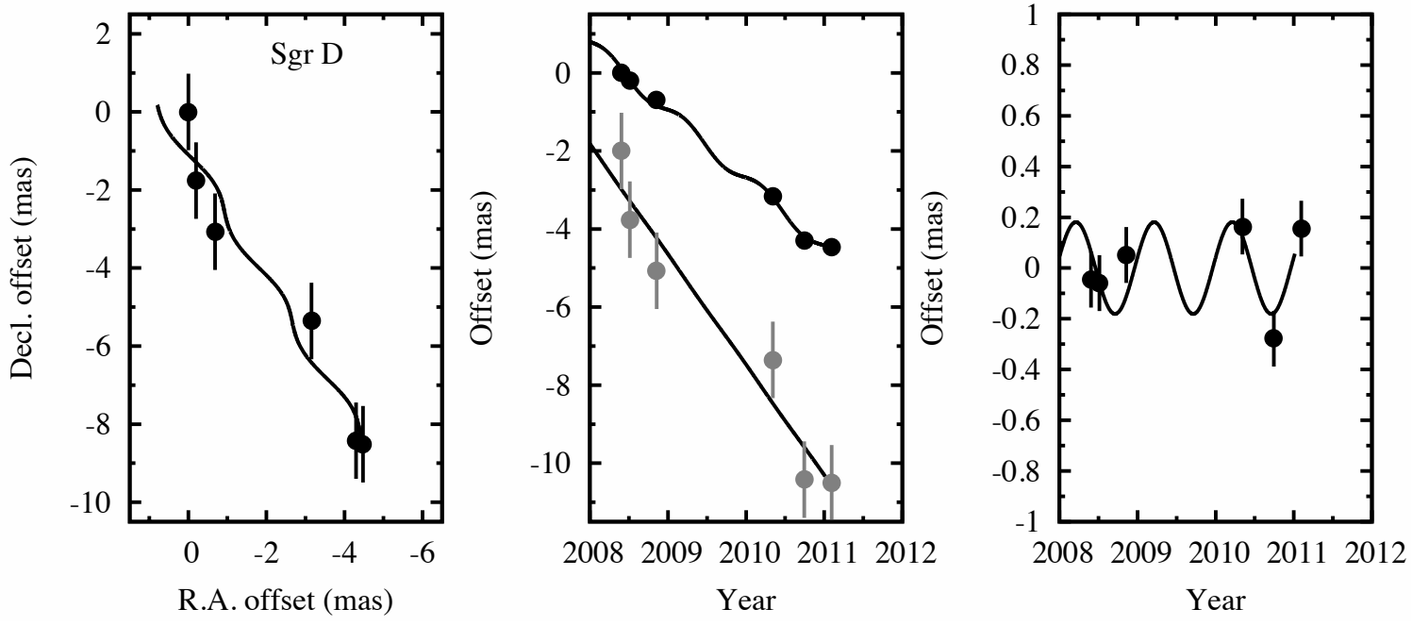




Results

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±0.045mas/yr

Proper mot.(Dec dir.):

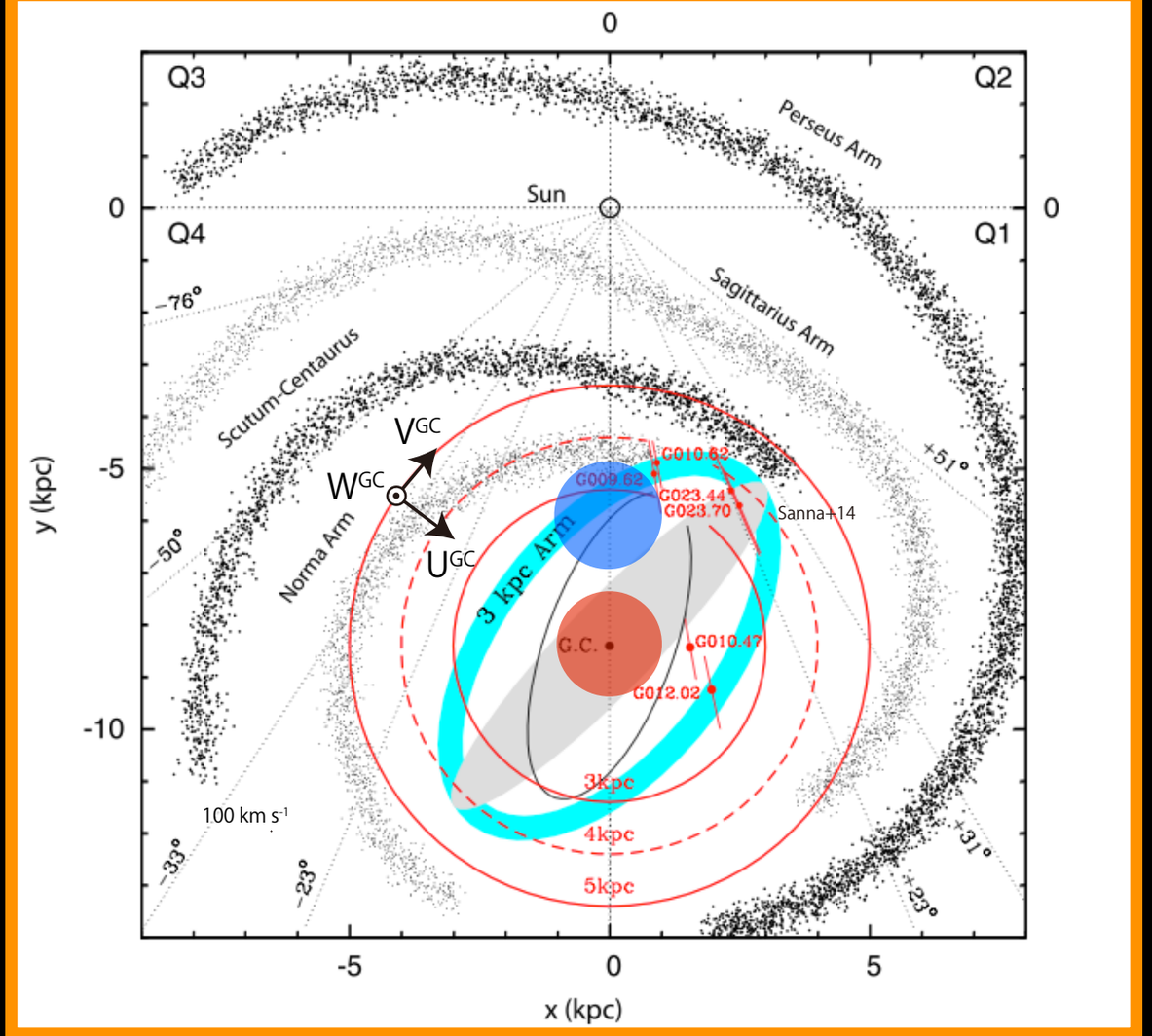
-2.83±0.39 mas/yr

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)

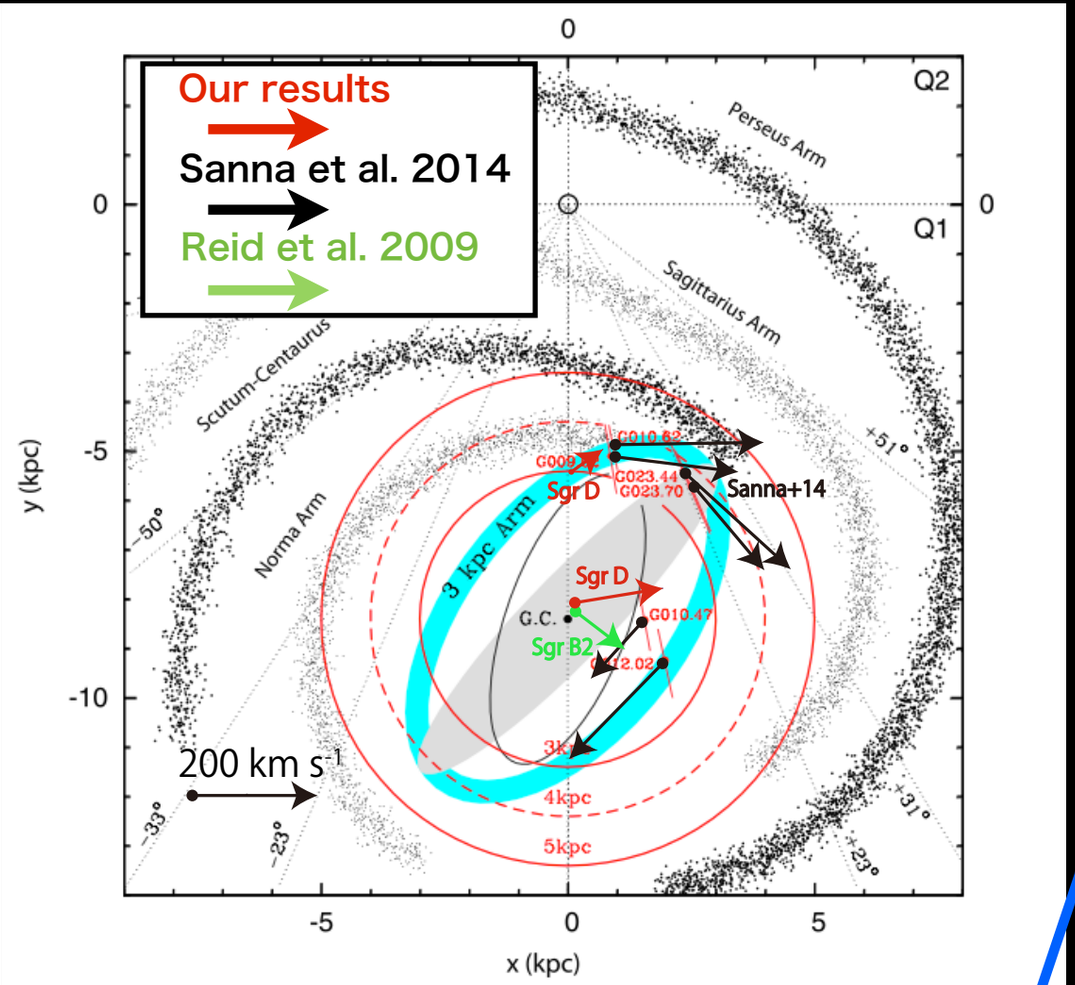


Proper motion of maser source for 1. and 2. (Units are km s^{-1})

	U^{GC}	V^{GC}	W^{GC}
①D=8 kpc	-24±2.0	140±13	12±10
②D=5 kpc	-50±2.0	75±8.3	7.3±6.4

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)

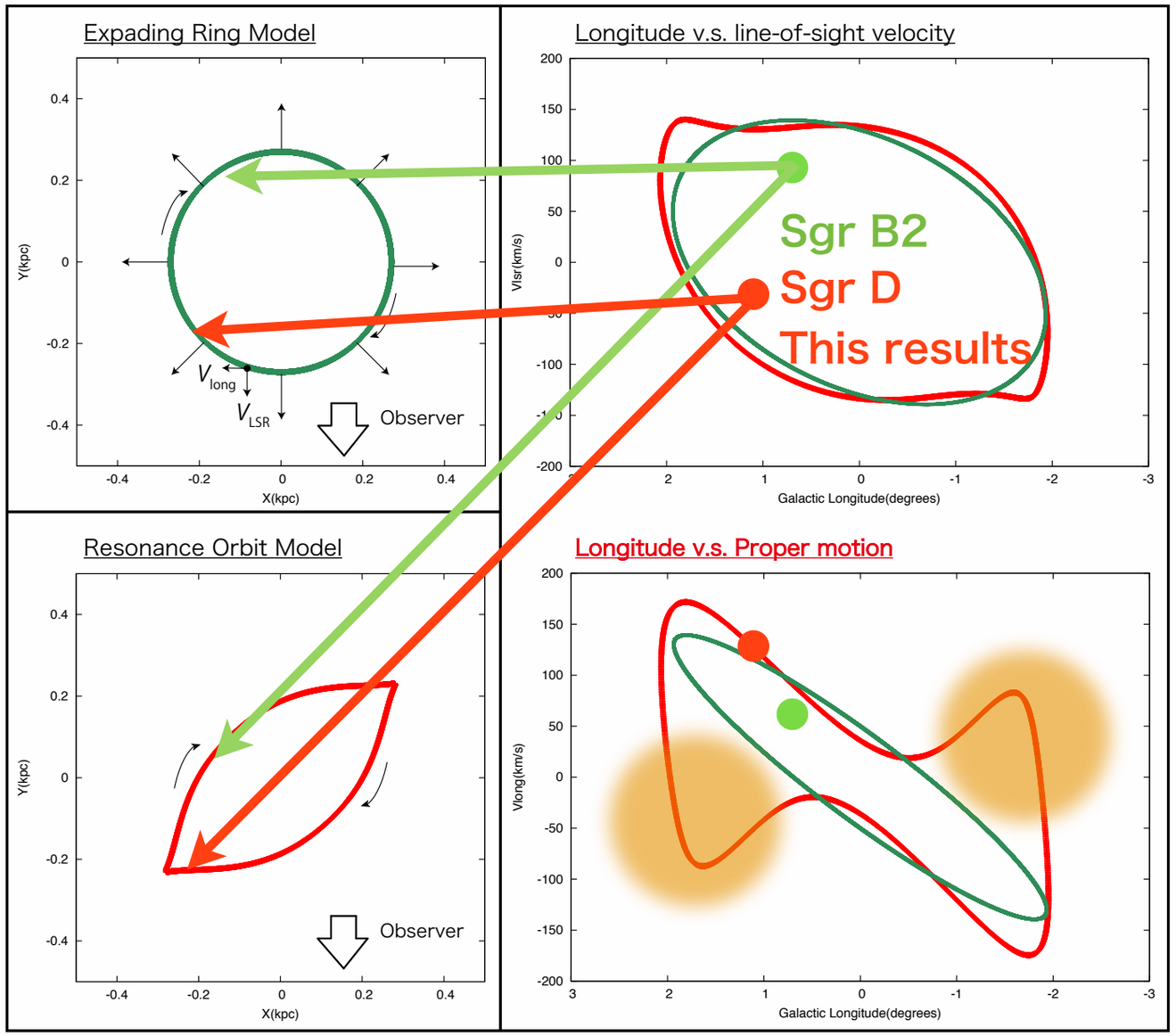
・Sanna et al. 2014 suggests that sources in range 2 kpc < R < 4 kpc have 120 km s^{-1} < V_{GC} < 240 km s^{-1}

・If Sgr D is located in this range of radius V_{GC} for Sgr D is 75 km s^{-1}

Disk case	R (kpc)	U_{GC} (km s^{-1})	V_{GC} (km s^{-1})	W_{GC} (km s^{-1})
Sgr D	3.0(assumed)	-49±2.0	**75**±8.3	7.3±6.4
G0.09.62+00.19	3.4	-36±17	190±15	-10±4.1
G010.47+00.02	1.6	30±22	120±16	18 ±1.8
G10.62-00.38	3.6	-60±14	230 ±6.7	8.1±1.8
G012.02-00.03	2.1	26±33	220±27	1.5±5.8
G023.44-00.18	3.8	4.7±43	230±18	2.0±3.1
G023.70-00.19	3.7	51 ±16	170±12	4.6±2.6
GC case				
Sgr D	0.3(assumed)	-24±2.0	**140**±13	12±10
Sgr B2	0.1	-18±1.7	110±5.0	-38±5.6

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

①CMZ(R~300 pc) and

②3 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