# Radio Continuum and Radio Recombination Line Observations of the Galactic Center Lobe by Yamaguchi 32-m Radio Telescope

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## Abstract

We have studied physical property and formation process of the Galactic Center Lobe (GCL) using continuum and H92α radio recombination line (RRL) observations 8.3 GHz with Yamaguchi 32-m telescope. The observed intensity distributions of both continuum and RRL show two ridges at east and west side of the galactic center which are perpendicular to the galactic plane at east and west sides of the galactic center. Although the shapes of the continuum and RRL ridges are similar, the spatial positions of continuum and RRL ridges are not coincident: RRL ridges locate at the inner side of the continuum ridges. Line-of-sight velocity of RRL of GCL ranges within ±10 km s$^{-1}$ at entire observed regions. This velocity is far slow compared with the Galactic rotation velocity (~220 km s$^{-1}$). From intensity and velocity distribution of RRL, we consider a formation model of GCL which GCL was rotating at near the GC before, and then it was spread outward under a force. This model is consistent with our observation result.

## Galactic Center Lobe (GCL)

- GCL was found in 10 GHz radio continuum survey of the GC region by Nobeyama 45-m Radio Telescope [1].
- The presence of ionized gas:
  -Spectral index α ~ 0 [2]
  -RRL were detected [3]
- There is a strong magnetic structure (a part of Non-Thermal Filaments; NTF) at eastern ridge [4].
- Thermal and non-thermal emissions at GCL are mixed.

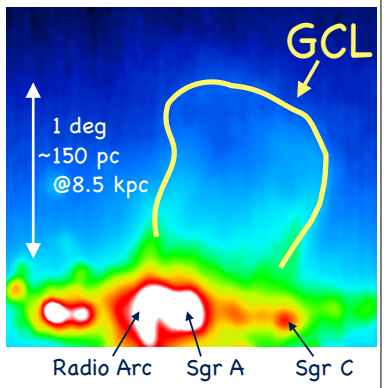



Fig. 1 The 8 GHz radio continuum map of the GCL, obtained by Yamaguchi 32-m telescope.

## Observation

- We have made radio continuum and radio recombination line observations to reveal nature of the GCL.

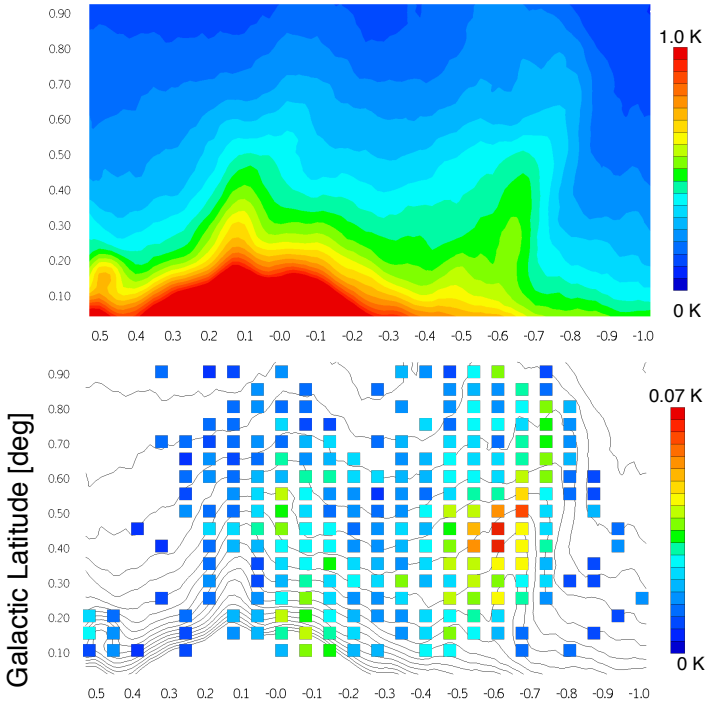
Radio Continuum observation

| | |
|---|---|
| Telescope | Yamaguchi 32-m radio telescope (HPBW = 4′.2 at 8.3 GHz) |
| Date | 16-17th April and 4th June, 2006 |
| Region | $-2°.55 < l < 2°.45$, $-2°.42 < b < 2°.58$ |
| Sampling grid | 1′ × 1′ |
| Observed frequency | 8380 MHz |
| Method | Continuous (non-switching) |
| integration time | 0.2 sec per each point |
| Circular polarizatiion | RHCP, LHCP |
| Detection limit | 7 mK |

Radio Recombination Line observation

| | |
|---|---|
| Telescope | Yamaguchi 32-m radio telescope (HPBW = 4′.2 at 8.3 GHz) |
| Date | July 2011 to August 2013 (total 780 hours) |
| Region | $-1°.00 < l < 0°.53$, $0°.10 < b < 0°.90$ (OFF point : $l = 0°.50$, $b = 2°.00$) |
| Sampling grid | 0°.067 (4′ ) for $l$, and 0°.05 (3′ ) for $b$ |
| Rest frequency | 8309.38 MHz (H92α) |
| Bandwidth | 32 MHz (8293.0 - 8325.0 MHz) |
| Method | Position switching |
| Integration time | 60 sec per each scan (same in ON and OFF point) total ON source time: 45 min |
| Circular polarization | RHCP, LHCP |
| Detection limit (2σ) | 6 mK |
| Velocity resolution | 2.26 km s$^{-1}$ |

## Result



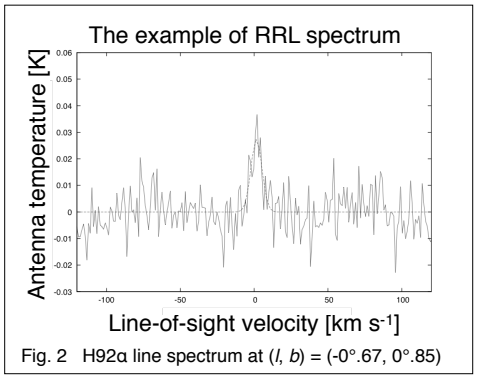




Fig. 2 H92α line spectrum at ($l$, $b$) = (-0°.67, 0°.85)

Intensity of radio continuum (top) and RRL (middle)

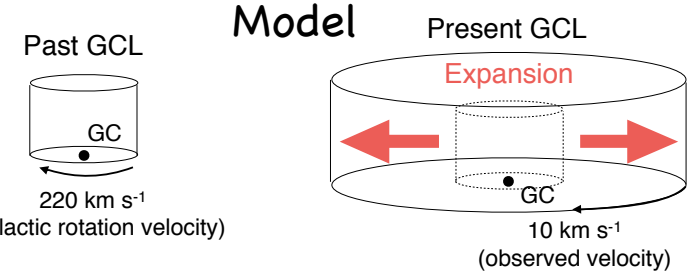
- Both continuum and RRL show two ridges, but, spatial distribution is different.
- The emission peak of RRL is $l \sim -0.60$ deg and $b \sim 0.45$ deg.
- The lobe structure is continued till $b \sim 0.90$ deg.

# Discussion

- The model of formation process of GCL
  - ✱ GCL was rotating at near the GC before, and then it was spread outward under a force (e.g. starburst, supernova, etc.).

⟶ As a result, rotation velocity becomes slower.

## Model




| | Past | | Present |
|---|---|---|---|
| Rotation velocity | 220 km $s^{-1}$ | → | 10 km $s^{-1}$ |
| Radius | 5.5 pc (~ 0.04 deg) | → | 120 pc (~ 0.8 deg) |

- ✱ The time required for one rotation of the galactic rotation is ~ $10^6$ yr.
- ✱ Assuming that expanding time is $10^5$ yr, the velocity required in order to spread 120 pc is 740 km $s^{-1}$.

- It is necessary to have a structure in the depth direction if the expansion was isotropic, since the structure of GCL is asymmetry with respect to GC.

- ✱ When each components are separated by 120 deg, the eastern component of the GCL is located at $l$ ~ 0.4 deg and line-of-sight velocity is 5 km $s^{-1}$.

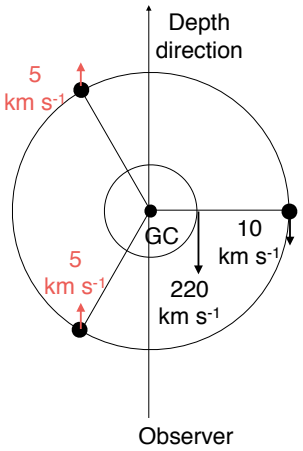



Fig 4. A schematic view of the galactic center near the GCL.

⟶ This is consistent with our observation result.

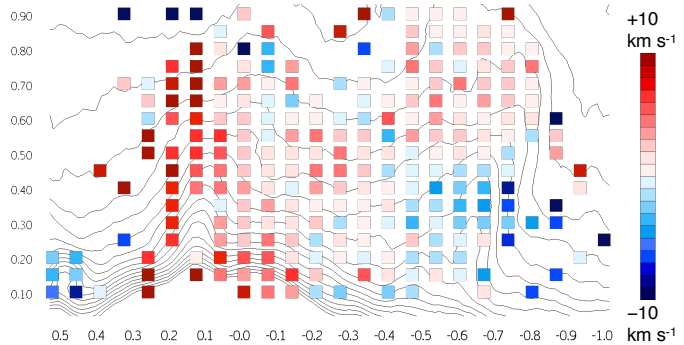



Fig. 3 The intensity distribution of radio continuum (top panel) and RRL (middle panel) for observation area. Bottom panel is distribution of line-of-sight velocity of RRL [5].

## Line-of-sight velocity of RRL

- Velocity ranges within ±10 km $s^{-1}$ at entire observed region.
- There are velocity gradient from west to east.

# Conclusions

- We have made radio observations of continuum and recombination line toward the most part of the GCL in order to understand the distribution of ionized gas of GCL.
- Both radio continuum and RRL both show two ridges, but spatial distribution is different.
- RRL velocity ranges within ±10 km $s^{-1}$ at entire observed region.
- We consider a formation process model of GCL, that GCL was rotating at 5.5 pc from GC before and then it was spread outward under the force.
- This model is consistent with our observation result.

# Future Observation

- In order to reveal the entire distribution of ionized gas in the GCL, we observe the higher latitude of GCL using RRL.

- At present, we observed till $b$ ~ 1.20 deg and obtained RRL spectra at some points.

Result in recent observations

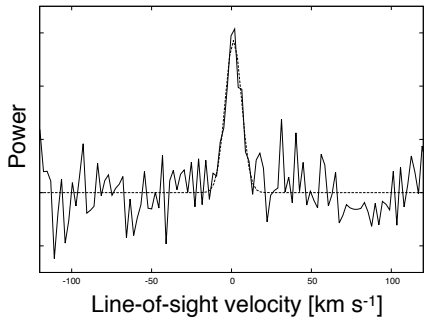



Fig. 5 H92α line spectrum at ($l$, $b$) = (-0°.60, 0°.95).

## Reference


[1] Sofue and Handa 1984 Nature, 310, 568 [2] Sofue, Y. 1985 PASJ, 37, 697 [3] Law et al. 2009 ApJ, 695, 1070
[4] Yusef-Zadeh et al. 2004 ApJS, 155, 421 [5] Yuzo Kubose vcon symposium poster 2013