Trigonometric Distance to IRAS 20056+3350: Massive Star Forming Region on the Solar Circle

Ross Burns - Kagoshima-U. D2

T. Handa, T. Nagayama, T. Omodaka, A. Nakagawa, H. Nakanishi, M. Hayashi, M. Shizugami
Conclusions

• Distance and proper motion: 
  \( D = 4.69 \pm 0.62 \text{ kpc} \).
  \( (\mu_\alpha \cos \delta, \mu_\delta) = (-2.62 \pm 0.33, -5.65 \pm 0.52) \text{ mas/yr} \).

• IRAS 20056+3350 is on the Solar circle
  at the tip of the Local Arm.

• IRAS 20056+3350 is a HMSFR
  \((M \star \geq 16 M_\odot)\).

• Galactic angular rotation (special geometry)
  \( \Omega_0 = 29.75 \pm 2.29 \text{ km/s/kpc} \).
Conclusions

- Distance and proper motion:
  \[ D = 4.69 \pm 0.62 \text{ kpc}. \]
  \[ (\mu_x \cos \delta, \mu_y) = (-2.62 \pm 0.33, -5.65 \pm 0.52) \text{ mas/yr}. \]
  Maser elongation
  \[ (\mu_x \alpha \cos \delta, \mu_y \delta) = (-2.62 \pm 0.33, -5.65 \pm 0.52) \text{ mas/yr}. \]
  Only one lobe traced by masers

- IRAS 20056+3350 is on the Solar circle at the tip of the Local Arm. How can we show that IRAS 20056+3350 is on the Solar circle?

- IRAS 20056+3350 is a HMSFR (M★★ \( \geq 16 \text{ M}_\odot \)). How can we prove it is a HMSFR?

- Galactic angular rotation (special geometry)
  \[ \Omega_0 = 29.75 \pm 2.29 \text{ km/s/kpc}. \]
  Is this value reasonable?
#1 Trigonometric distance of the IRAS 20056+3350 SFR
#1 Trigonometric distance

\[ X^2 = 1 \]

Error floor: 0.227mas

Error floor: 0.050mas

\[ D = 4.69 \pm 0.62 \text{ kpc} \]

- Observations: 7 epochs with VERA (Dual-beam mode)
- Total: 4 spots    Parallax: 2 spots
- Data reduction: AIPS
- R.A. bad fitting

Why?
#1 Trigonometric distance: Maser structure

- Maser elongated in R.A. direction.
- Emission smearing.

Can we evaluate the maser structure effect?
#1 Trigonometric distance: Maser structure effect

In the absence of acceleration spot separation should be **linear** vs time.

2D Gaussian fits affected by maser structure

Deviation from a linear fit indicates bad astrometric accuracy
#1 Trigonometric distance: Maser structure effect

![Graph showing spot separation over time with annotations for R.A. and Dec. and standard deviations.](image-url)
#1 Trigonometric distance: Maser structure effect

Error floors:
- R.A. direction: 0.227
- Dec. direction: 0.050

Parallax fitting of Dec offsets more reliable

Std.dev to linear fits:
- R.A. direction: 0.190
- Dec. direction: 0.040

Maser structure is a significant error in our VERA observations
#2 IRAS 20056+3350 on the Solar circle, at the tip of the Local Arm.
#2 IRAS 20056+3350: Solar circle, tip of the Local Arm

**Local Arm**  
3 models*:  
- Branch  
- Major arm  
- Spur

**Solar circle**  
Using $R_0 = 8.05$ kpc, we calculate $R_{\odot} \approx R_0$

$R_{\odot} = 7.91$ kpc

$V_{\text{LSR}} = 9$ km/s**


#3 Physical nature of the IRAS 20056+3350 SFR
#3 IRAS 20056+3350 is a HMSFR:

Archive data

Re-evaluated archive data:

- $L = 24247L_\odot$
- $M_* = 16 M_\odot$
- $M_{H_2} = 1200 M_\odot$

Line of sight outflow

#3 IRAS 20056+3350 is a HMSFR: Spectral energy distribution

Photometry data:
- UKIDSS (J, H, K)
- AKARI IRC (9, 18 μm)
- WISE (3.4, 4.6, 12, 22 μm)
- IRAS (12, 24, 60, 100 μm)
- JCMT (450, 850 μm)

SED model
- \( L = 24500 \, L_\odot \)
- \( M_\star = 18.4 \, M_\odot \)
- \( M_{\text{env}} = 3300 \, M_\odot \)

Inclination = 18°
(near line-of-sight)

IRAS 20056+3350 is a HMSFR:
Spectral energy distribution

Archive data:
L = 24247 L⊙
M★ = 16 M⊙
M_H2 = 1200 M⊙

SED model
L = 24500 L⊙
M★ = 18.4 M⊙
M_env = 3300 M⊙

Line-of-sight outflow
Inclination = 18°

Consistency is reassuring
#4 Galactic angular rotation of the LSR, $\Omega_0$
Observe masers: $V_{\text{LSR}} > 9$ km/s (velocity of cloud)

Only measured motions of 3 maser spots

However, masers trace blue lobe of the outflow.
Assumption:
Maser proper motions w.r.t driving source --> small
i.e. the largest velocity components is along the line-of-sight

Approximation:
Group motion of masers --> reasonable approximation of source proper motion
#4 Galactic angular rotation of the LSR, $\Omega_0$

- $D = 4.69 \pm 0.62$ kpc.
- IRAS 20056+3350 is on the Solar circle
- Proper motion: 
  \[(\mu_\alpha \cos \delta, \mu_\delta) = (-2.62 \pm 0.33, -5.65 \pm 0.52)\ \text{mas/yr.}\]
- $V_{\text{LSR}} = 9 \pm 1$ km/s

Using Equation 1. from Nagayama et al. 2011, PASJ, 63, 23

$$\Omega_0 = -a_0 \mu_l + v_r \left(\frac{1}{D\tan l} - \frac{1}{R_0 \sin l}\right)$$

VERA observations of IRAS 20056+3350 give: 
$\Omega_0 = 29.75 \pm 2.29$ km/s/kpc.
#4 Galactic angular rotation of the LSR, $\Omega_0$

Values of $\Omega_0$: tangent point and Solar circle SFRs (special geometry)

IRAS 20056+3350:
$\Omega_0 = 29.75 \pm 2.29$ km/s/kpc.

Consistent with other SFRs At tangent points and Solar circle

Conclusions

• Distance and proper motion:
  \[ D = 4.69 \pm 0.62 \text{ kpc.} \]
  \[ (\mu_\alpha \cos \delta, \mu_\delta) = (-2.62 \pm 0.33, -5.65 \pm 0.52) \text{mas/yr.} \]

  Maser elongation
  \[ \text{Use Dec offsets} \]
  \[ \text{Only one lobe traced by masers} \]

• IRAS 20056+3350 is on the Solar circle at the tip of the Local Arm.

  How can we show that IRAS 20056+3350 is on the Solar circle?

• IRAS 20056+3350 is a HMSFR (M★ ≥ 16 M☉).

  How can we prove it is a HMSFR?

  \[ R★ \approx R_0, \ V_{\text{LSR}} = 9 \text{ km/s} \]

  Archive data <-> SED model

• Galactic angular rotation (special geometry)
  \[ \Omega_0 = 29.75 \pm 2.29 \text{ km/s/kpc.} \]

  Is this value reasonable?

  Consistent with tangent point and Solar circle SFRs
Thank you for listening