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

Ross Burns - Kagoshima-U. D2

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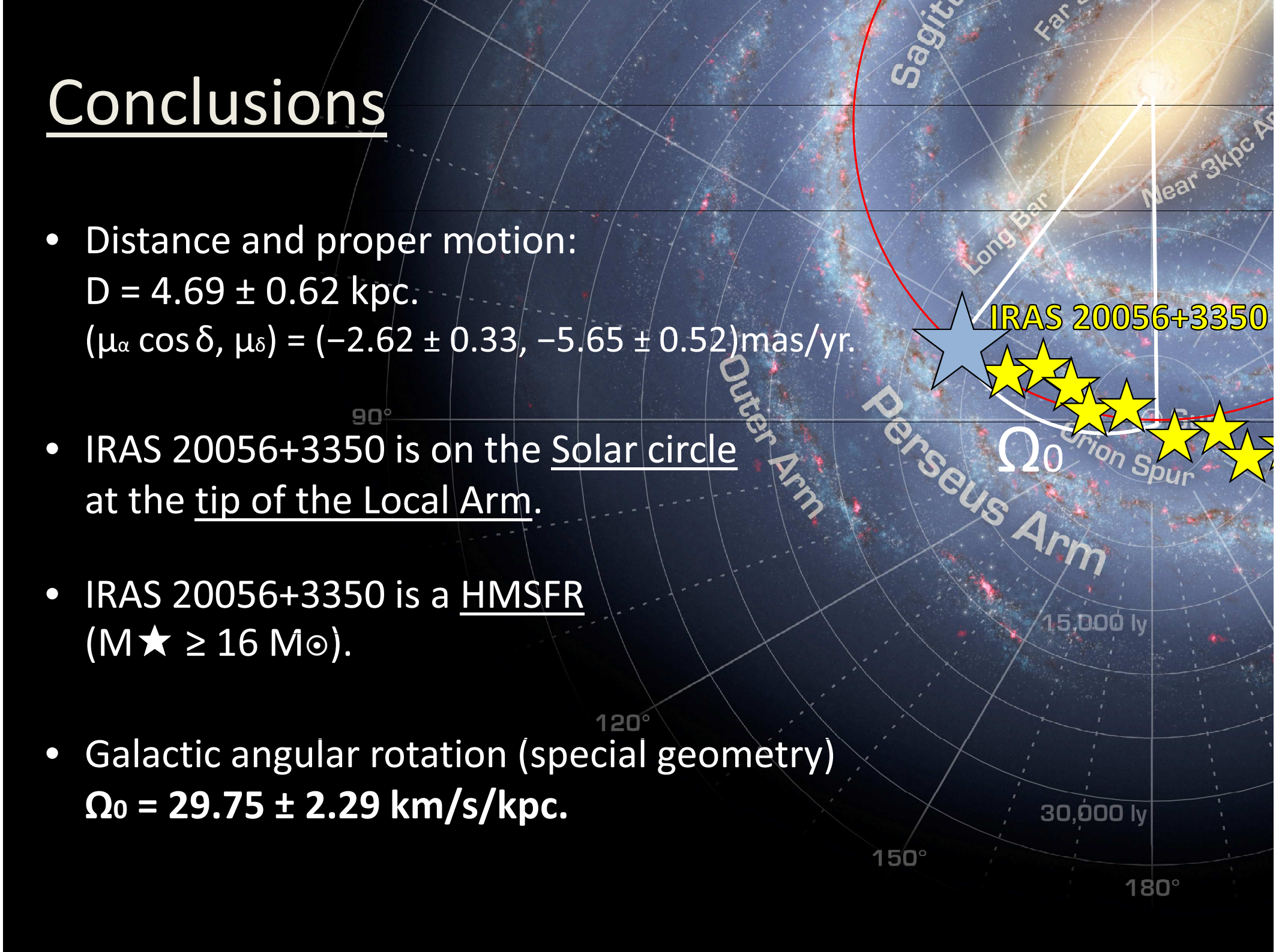
Conclusions

- Distance and proper motion:
  D = 4.69 ± 0.62 kpc.
  $(\mu_\alpha \cos\delta, \mu_\delta)$ = (−2.62 ± 0.33, −5.65 ± 0.52)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)
  Ω_0 = 29.75 ± 2.29 km/s/kpc.



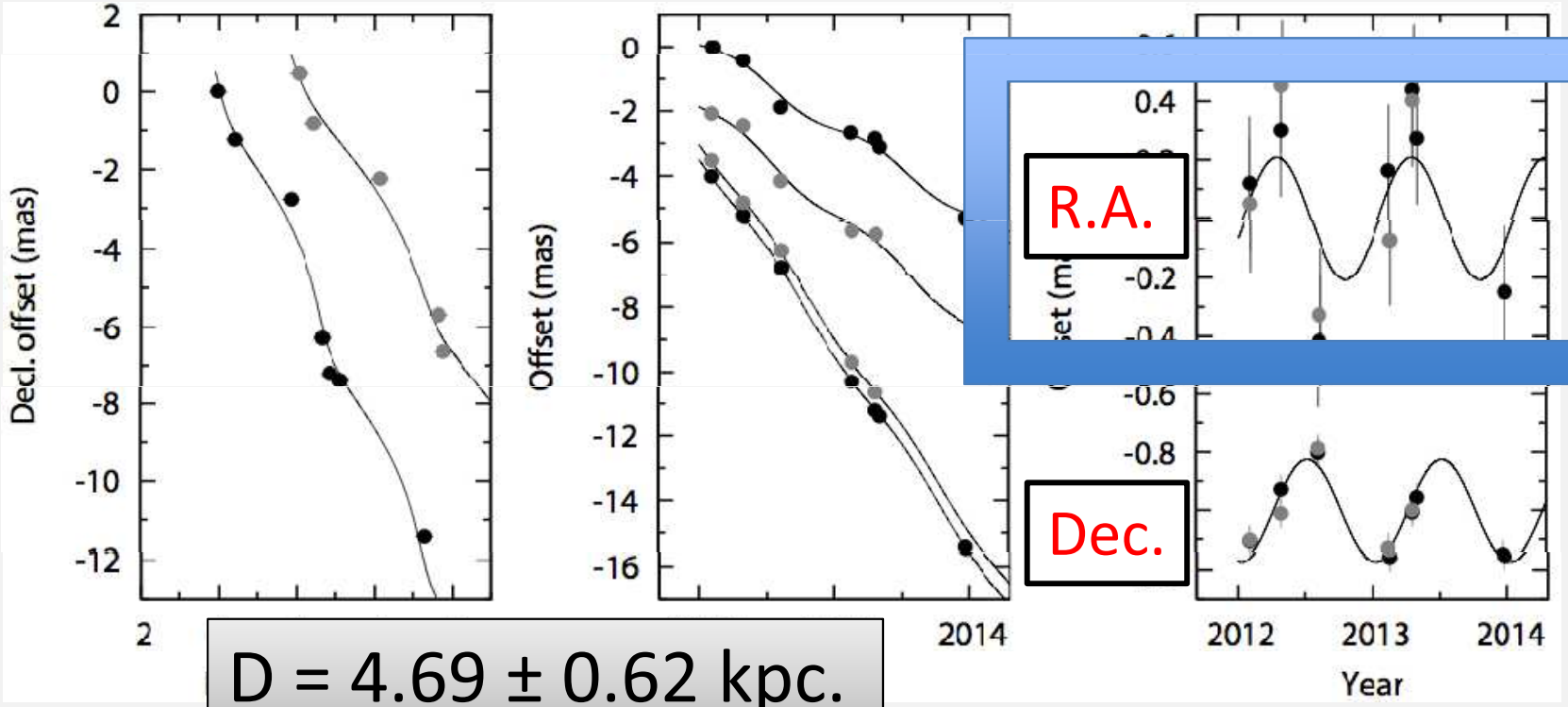
Conclusions Problems

- Distance and proper motion:
  D = 4.69 ± 0.62 kpc. Maser elongation
  $(\mu_\alpha \cos\delta, \mu_\delta)$ = (−2.62 ± 0.33, −5.65 ± 0.52)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
  ($M\bigstar \geq 16\ M\odot$). How can we prove it is a HMSFR?
- Galactic angular rotation (special geometry)
  Ω_0 = 29.75 ± 2.29 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

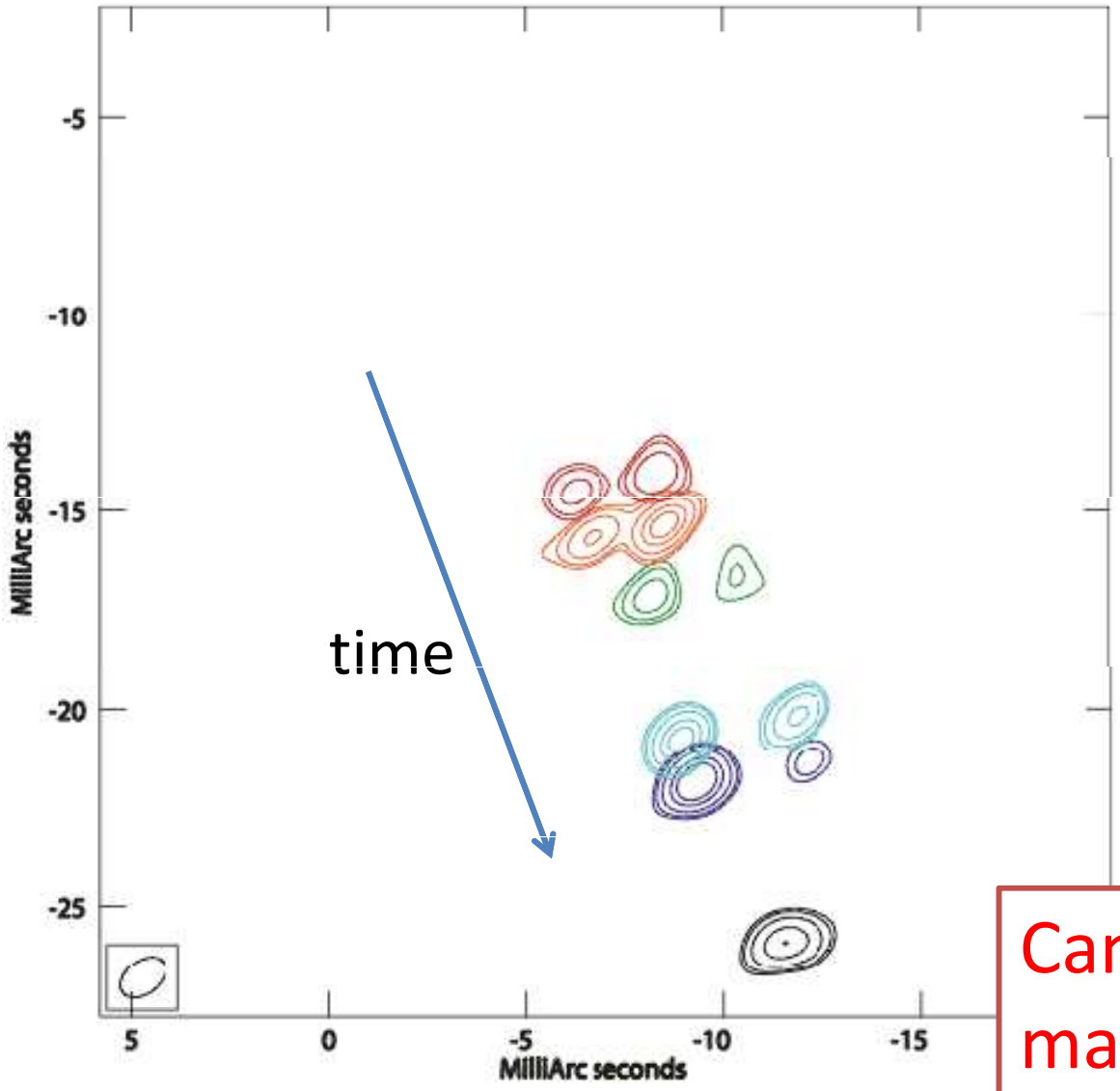
Error floor:
0.050mas

D = 4.69 ± 0.62 kpc.

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

Why?

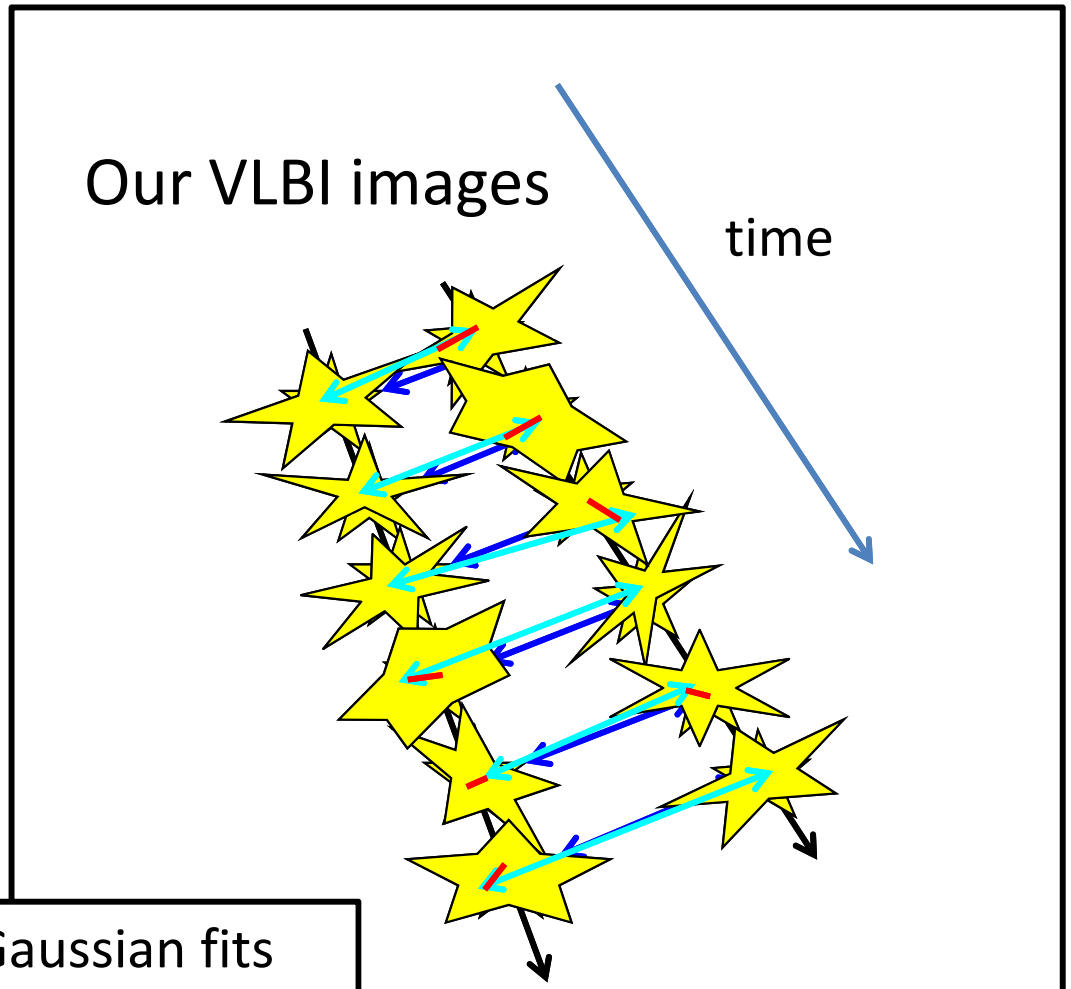
#1 Trigonometric distance: Maser structure



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

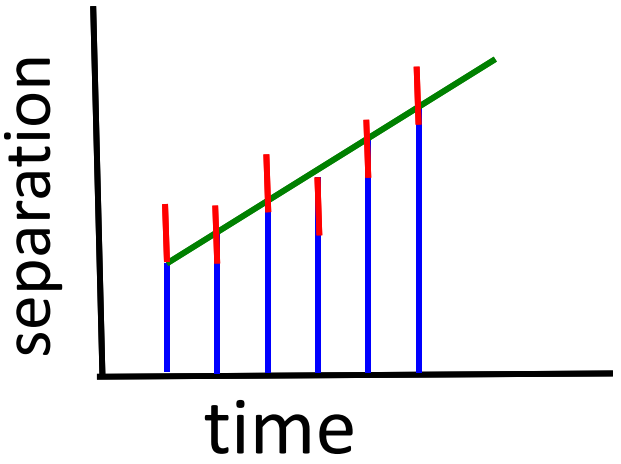
Can we <u>evaluate</u> the maser structure effect?

#1 Trigonometric distance: Maser structure effect



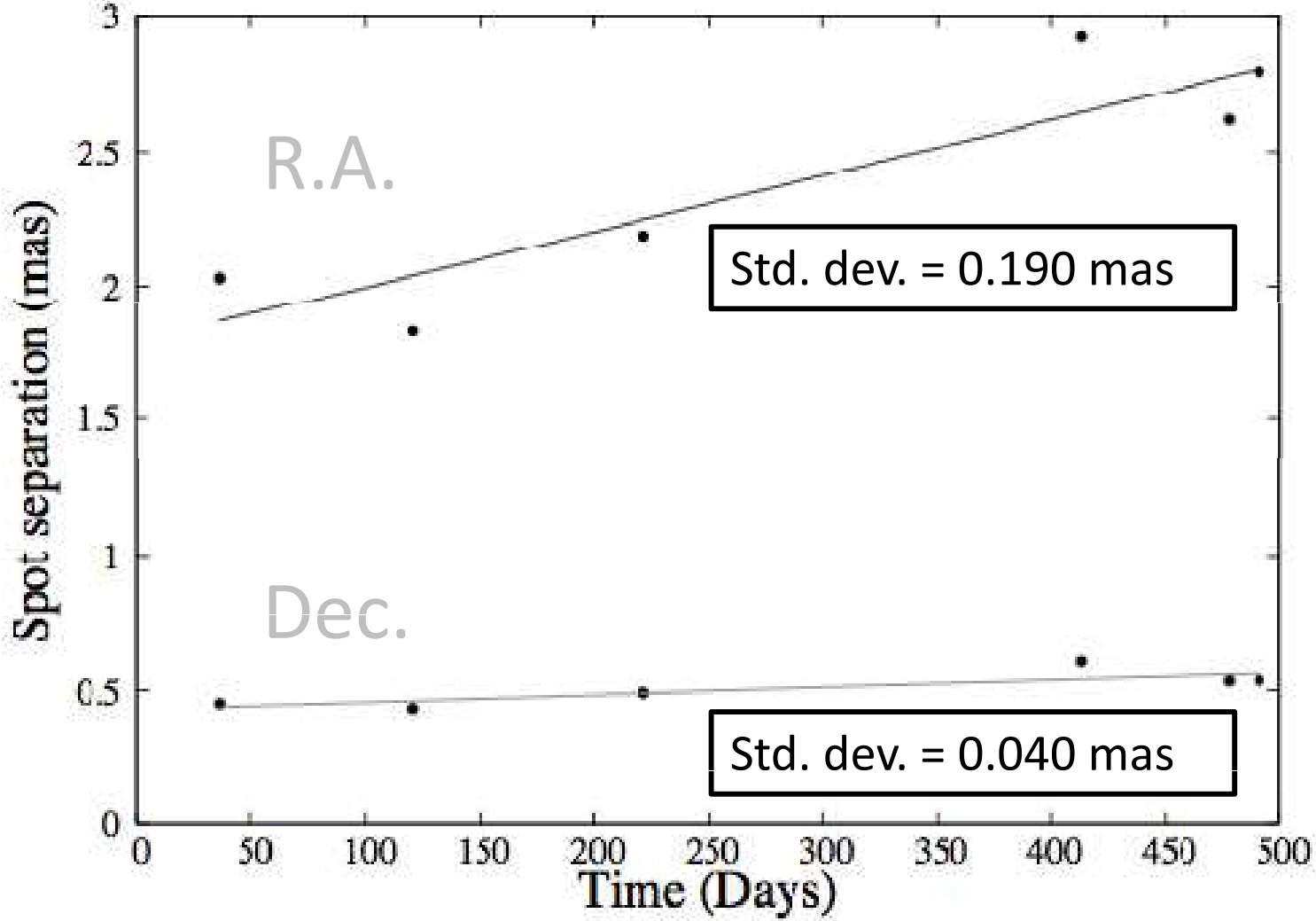
2D Gaussian fits affected by maser structure

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



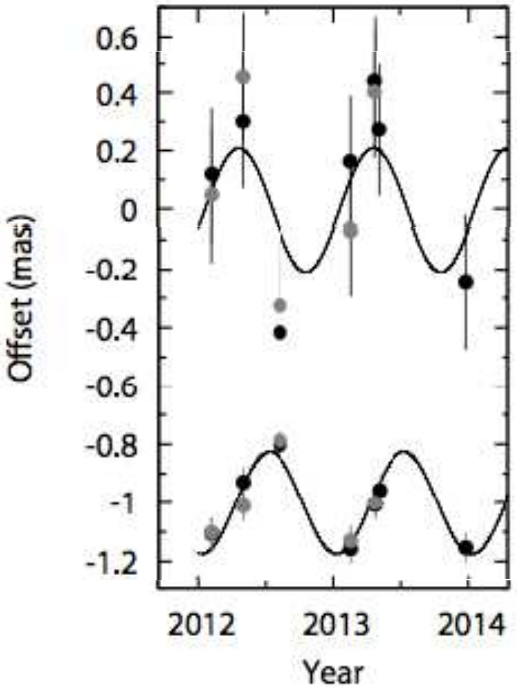
Deviation from a linear fit indicates bad astrometric accuracy

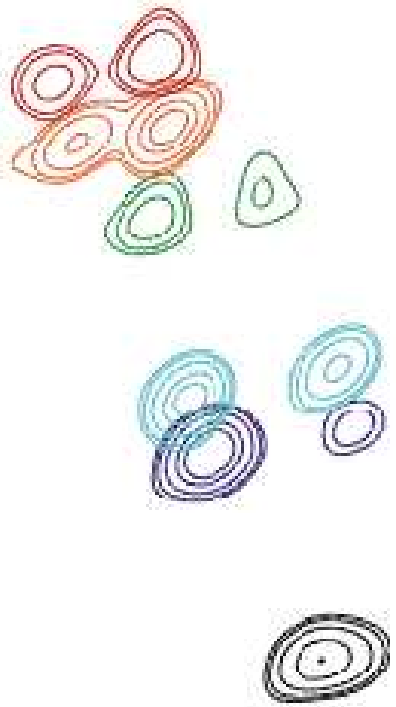
#1 Trigonometric distance: Maser structure effect



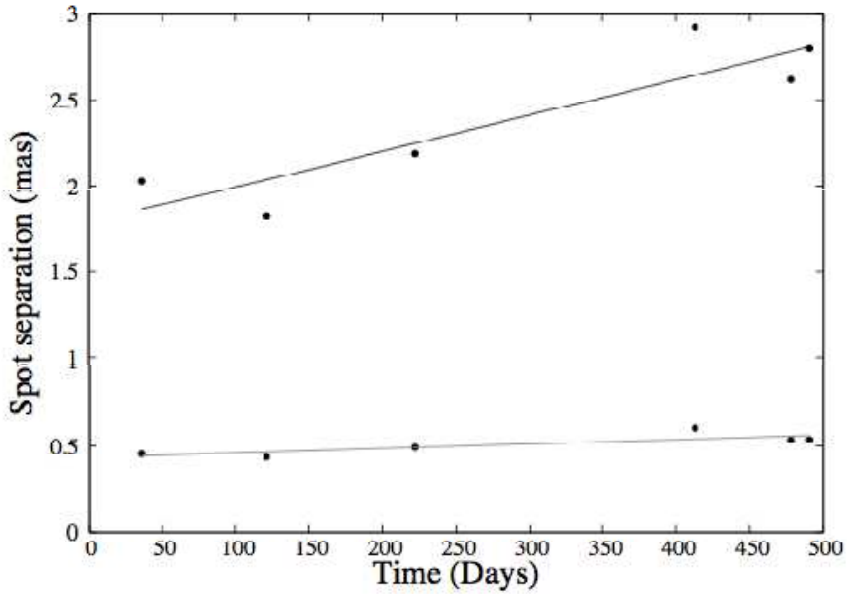
#1 Trigonometric distance: Maser structure effect

Parallax fitting





Maser structure error



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

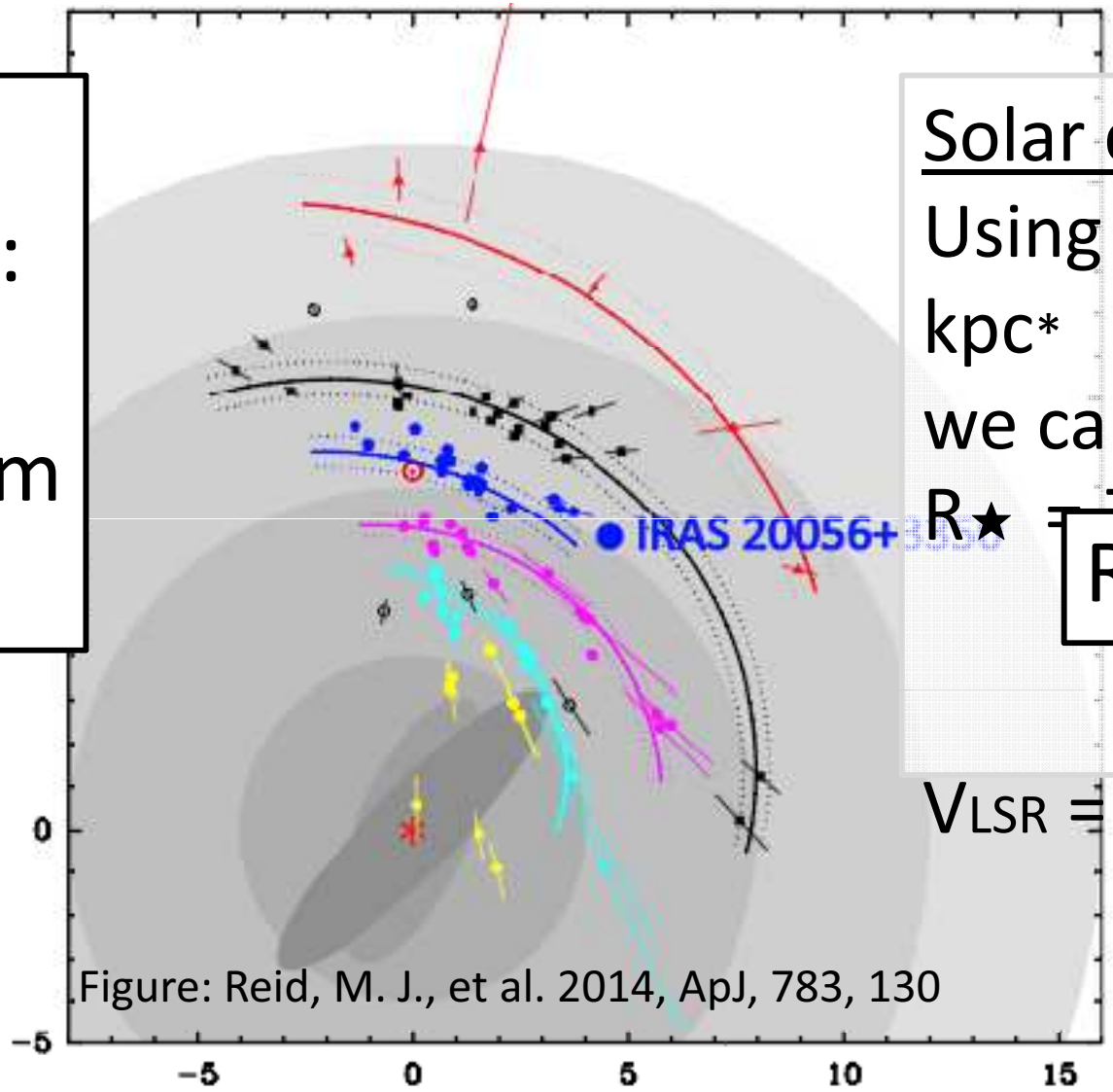


Figure: Reid, M. J., et al. 2014, ApJ, 783, 130

Solar circle

Using R_0 = 8.05 kpc*

we calculate

$R_\star$ = 7.91 kpc

$R_\star \approx R_0$

V_{LSR} = 9 km/s**

❖Xu, Y., et al. 2013, ApJ, 769, 15

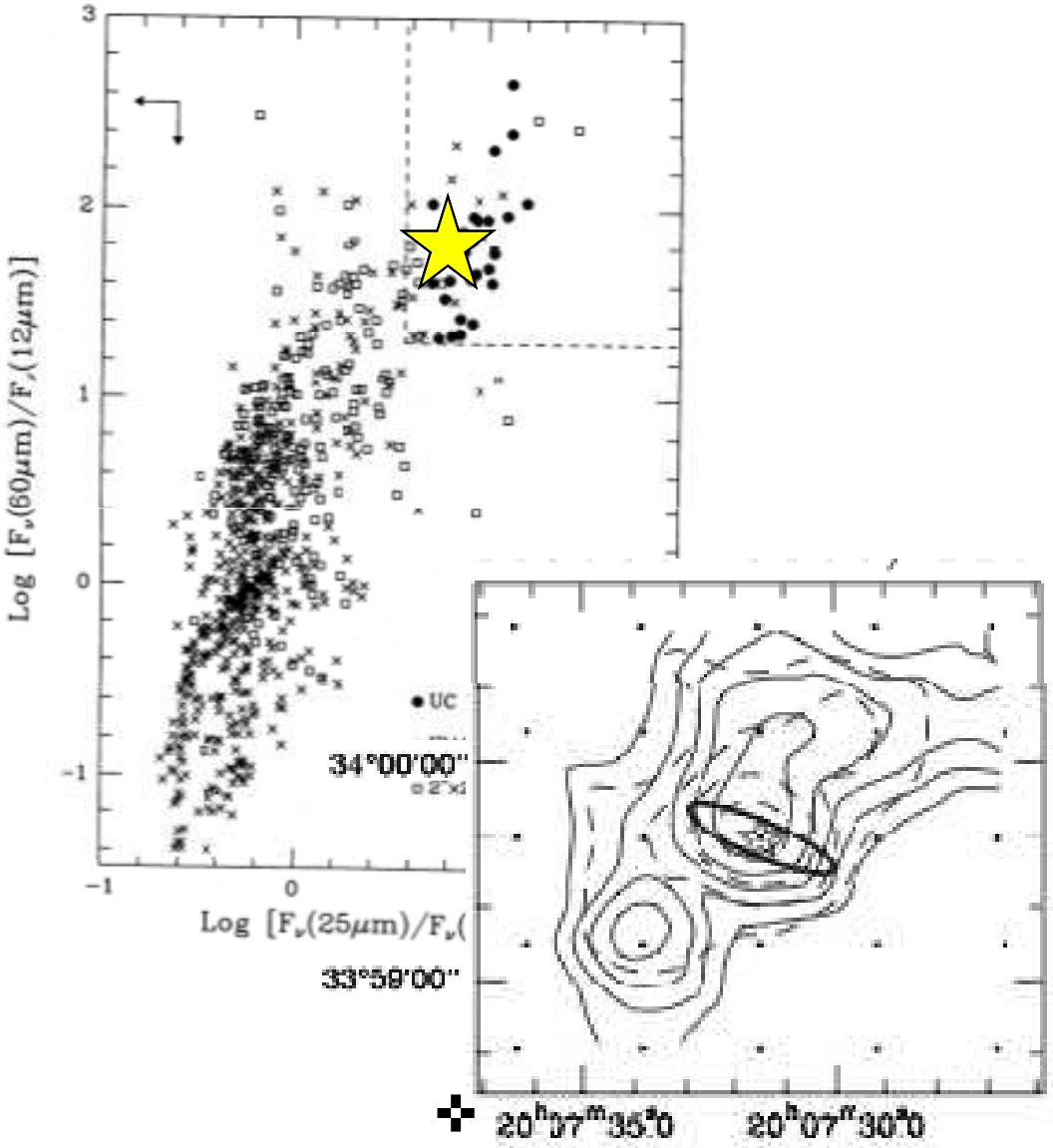
*Honma, M., et al. 2012, PASJ, 64, 136

**Jenness, T., et al. 1995, MNRAS, 276, 1024

#3 Physical nature of the IRAS 20056+3350 SFR

#3 IRAS 20056+3350 is a HMSFR: Archive data

Wood. & Churchwell., 1989, ApJ, 340, 265



Re-evaluated archive data:

L = 24247L⊙ ❖

M★ = 16 M⊙ ❖

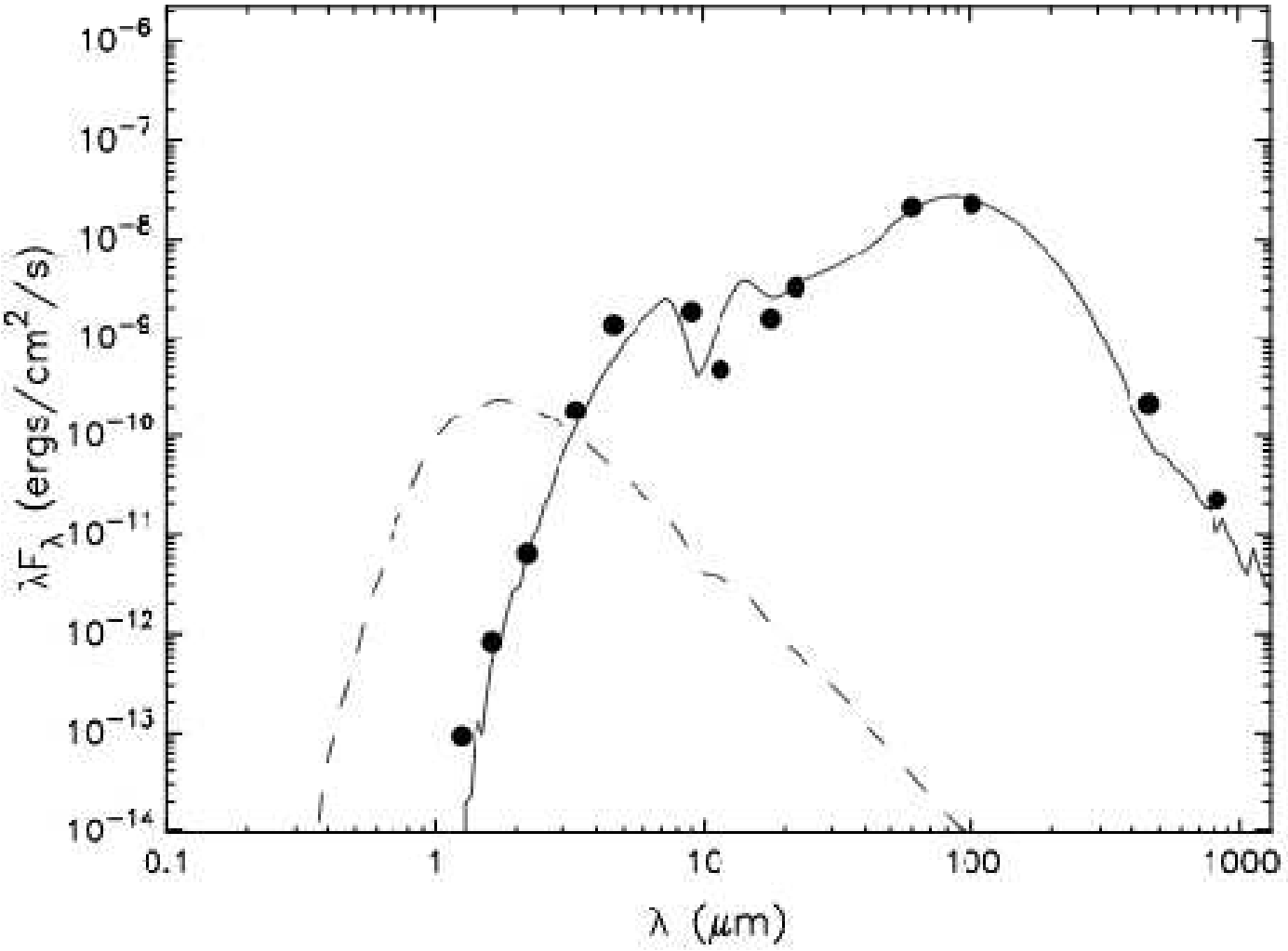
M_{H_2} = 1200 M⊙ ❖

Line of sight outflow ✣

❖ Original data: Casoli, F., et al. 1986, A&A, 169, 281

✣ Original data: Zhang, Q., et al. 2005, ApJ, 625, 864

#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$_{env}$ = 3300 M$\odot$

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

SED fitting software: Robitaille, T. P., et al., 2007, ApJS, 169, 328

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

Archive data:

$L = 24247\ L_\odot$

$M_\star = 16\ M_\odot$

$M_{H_2} = 1200\ M_\odot$

Line-of-sight outflow

$\approx$

SED model

$L = 24500\ L_\odot$

$M_\star = 18.4\ M_\odot$

$M_{env} = 3300\ M_\odot$

Inclination = 18°

Consistency is reassuring

#4 Galactic angular rotation of the LSR, Ω_0

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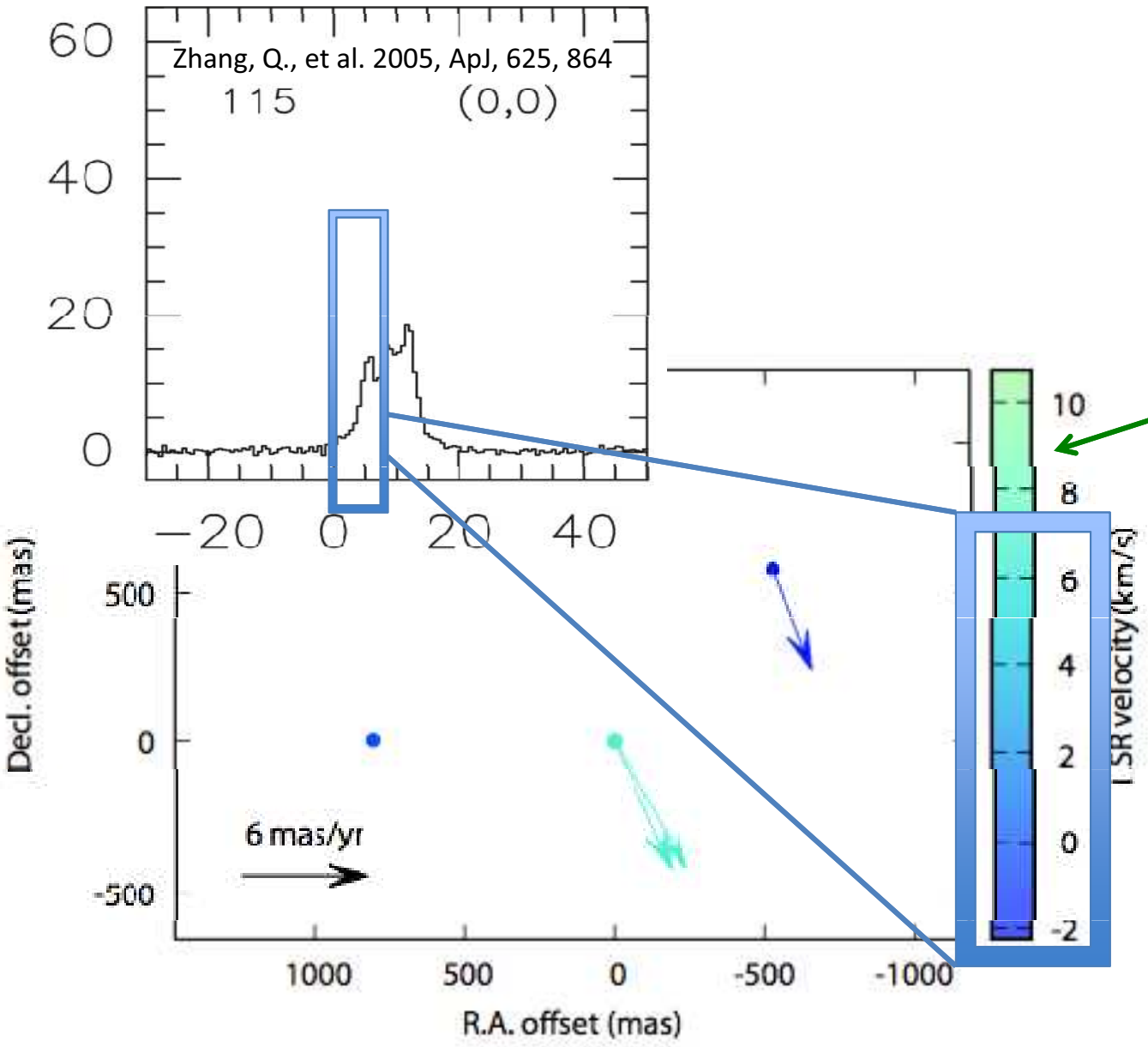


Observed masers:

V_{LSR} > 9 km/s

(velocity of cloud)

Only measured motions of 3 maser spots

However, masers trace blue lobe of the outflow.

#4 Galactic angular rotation of the LSR, Ω_0

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, Ω_0

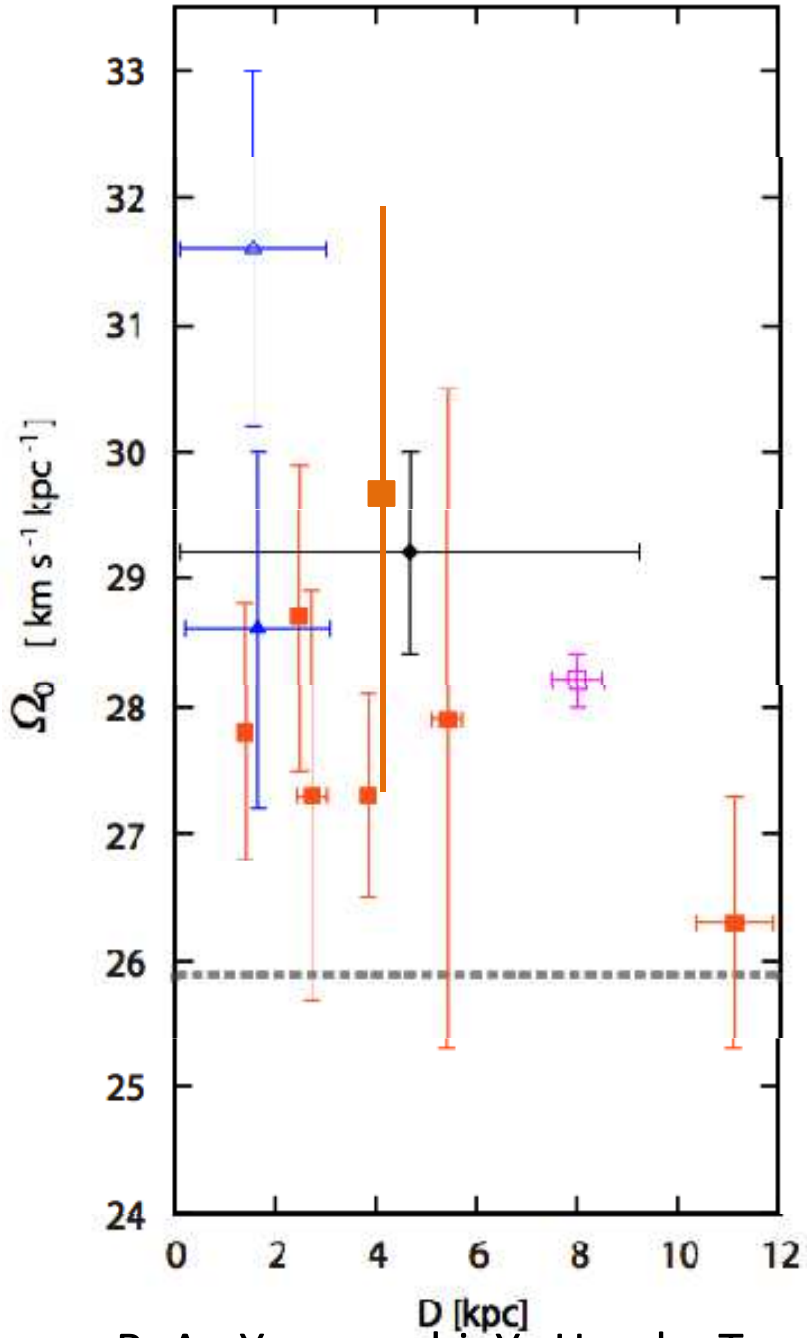
- D = 4.69 ± 0.62 kpc.
- IRAS 20056+3350 is on the Solar circle
- Proper motion:
  $(\mu_\alpha \cos\delta, \mu_\delta) = (-2.62 \pm 0.33, -5.65 \pm 0.52)$ mas/yr.
- V_{LSR} = 9 ± 1 km/s

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:
Ω_0 = 29.75 ± 2.29 km/s/kpc.

#4 Galactic angular rotation of the LSR, Ω_0



Values of Ω_0: tangent point and Solar circle SFRs (special geometry)

IRAS 20056+3350:
Ω_0 = 29.75 ± 2.29 km/s/kpc.

Consistent with other SFRs
At tangent points
and Solar circle

Burns, R. A., Yamaguchi, Y., Handa, T., et al. 2014, accepted for PASJ, arXiv:1404.5506

Conclusions Problems Solutions

- Distance and proper motion:
  D = 4.69 ± 0.62 kpc.
  $(\mu_\alpha \cos\delta, \mu_\delta)$ = (−2.62 ± 0.33, −5.65 ± 0.52)mas/yr.

Maser elongation ✓ Use Dec offsets

Only one lobe traced by masers ✓ Line-of-sight inclination

- 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?

$R_\star \approx R_0$, V_{LSR} = 9 km/s ✓

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

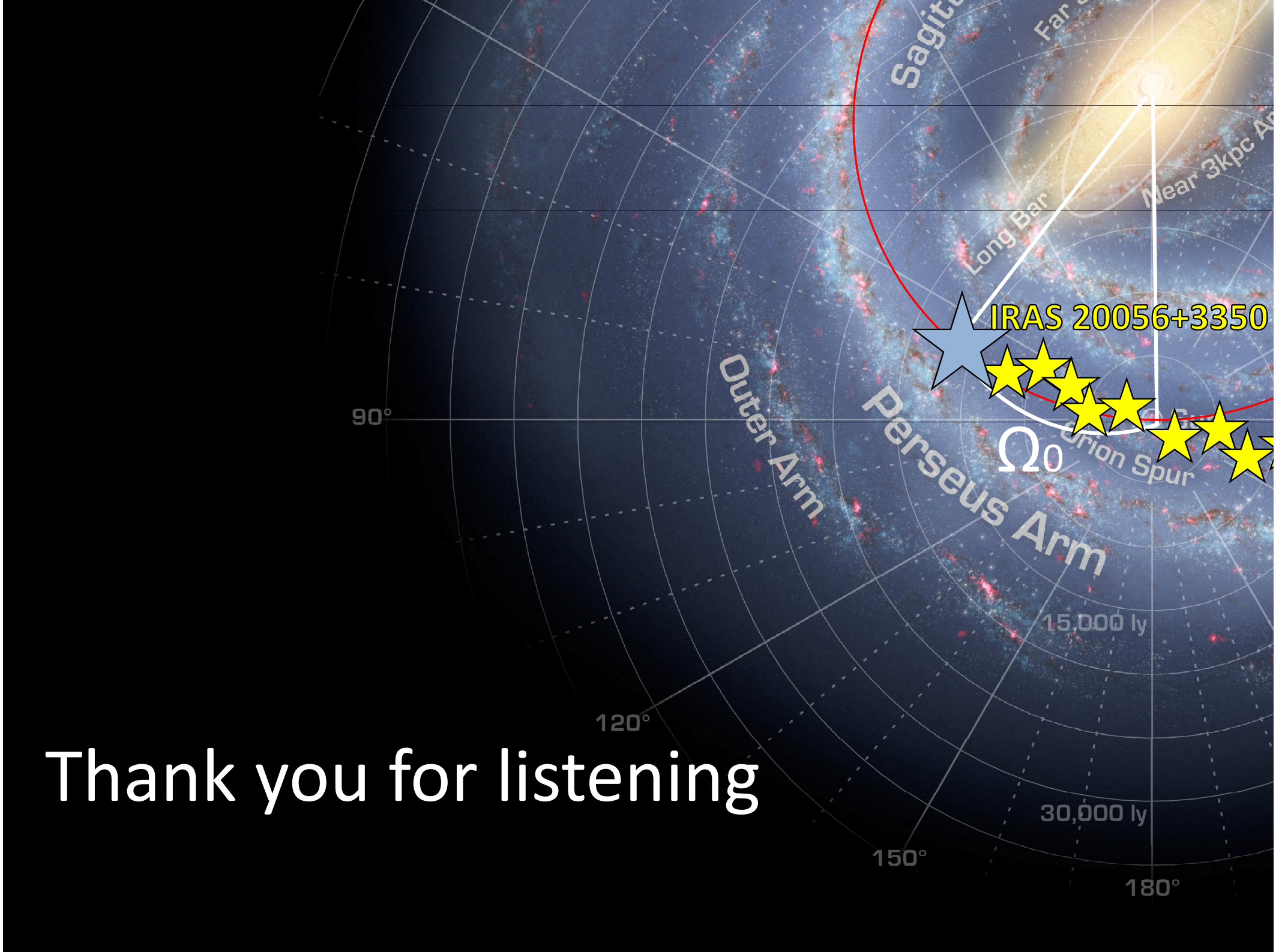
How can we prove it is a HMSFR?

Archive data <-> SED model ✓

- Galactic angular rotation (special geometry)
  Ω_0 = 29.75 ± 2.29 km/s/kpc.

Is this value reasonable? ✓

Consistent with tangent point and Solar circle SFRs



Thank you for listening