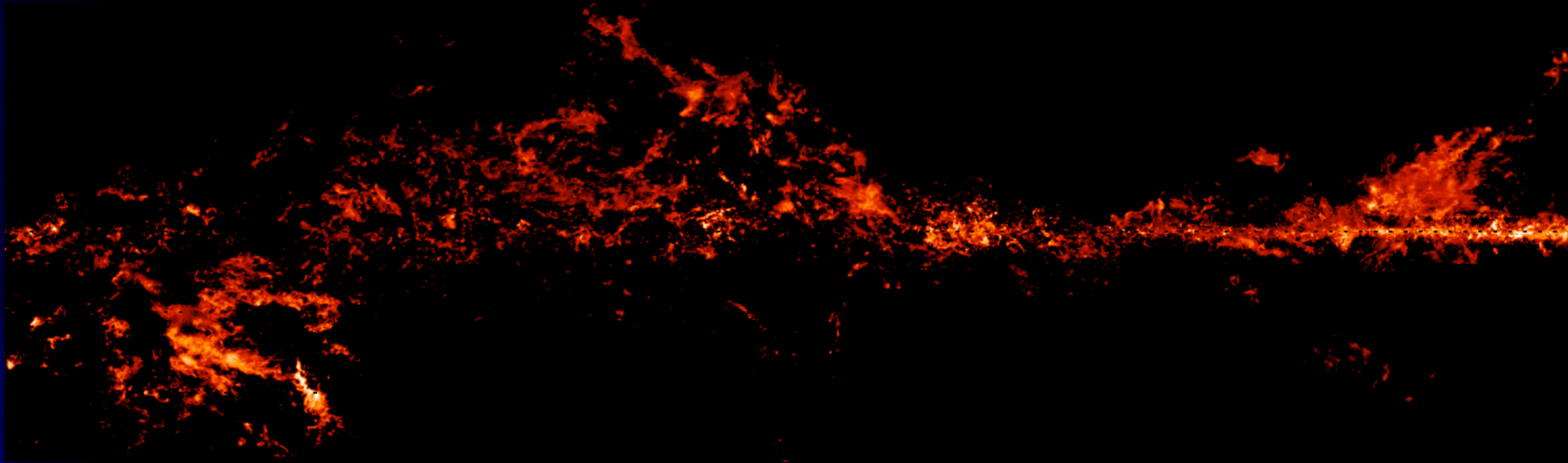


# Mapping & Modelling the Outer Milky Way

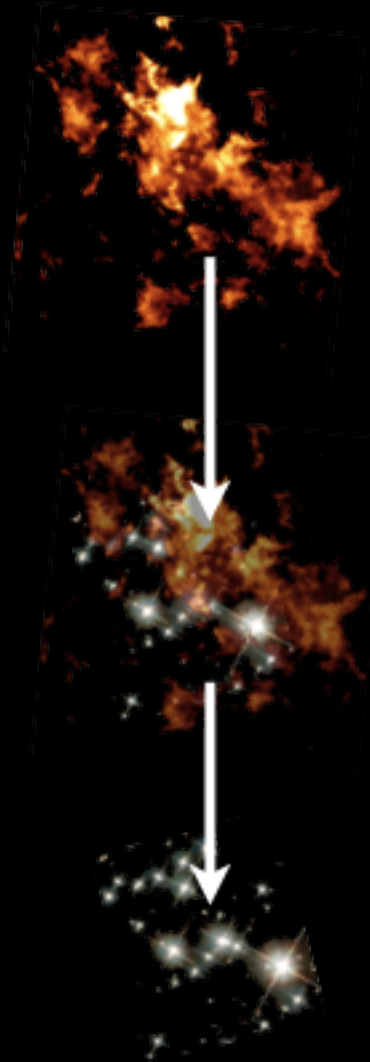


Lee J. Summers  
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University of Exeter

Chris Brunt (Exeter) & Joseph Mottram (Exeter)

# Key Questions

- Where/How do stars form?
- Where are the Spiral Arms?
  - How many?
  - Structure?
  - Velocity-Distance relation
- MW Velocity Field?



# Goals

- Model the spatial-velocity field of spiral features in the *Milky Way*.
- Extract material within the spiral features as coherent structures.
- Create an extra-Galactic style view of the *Milky Way*.

# The Milky Way

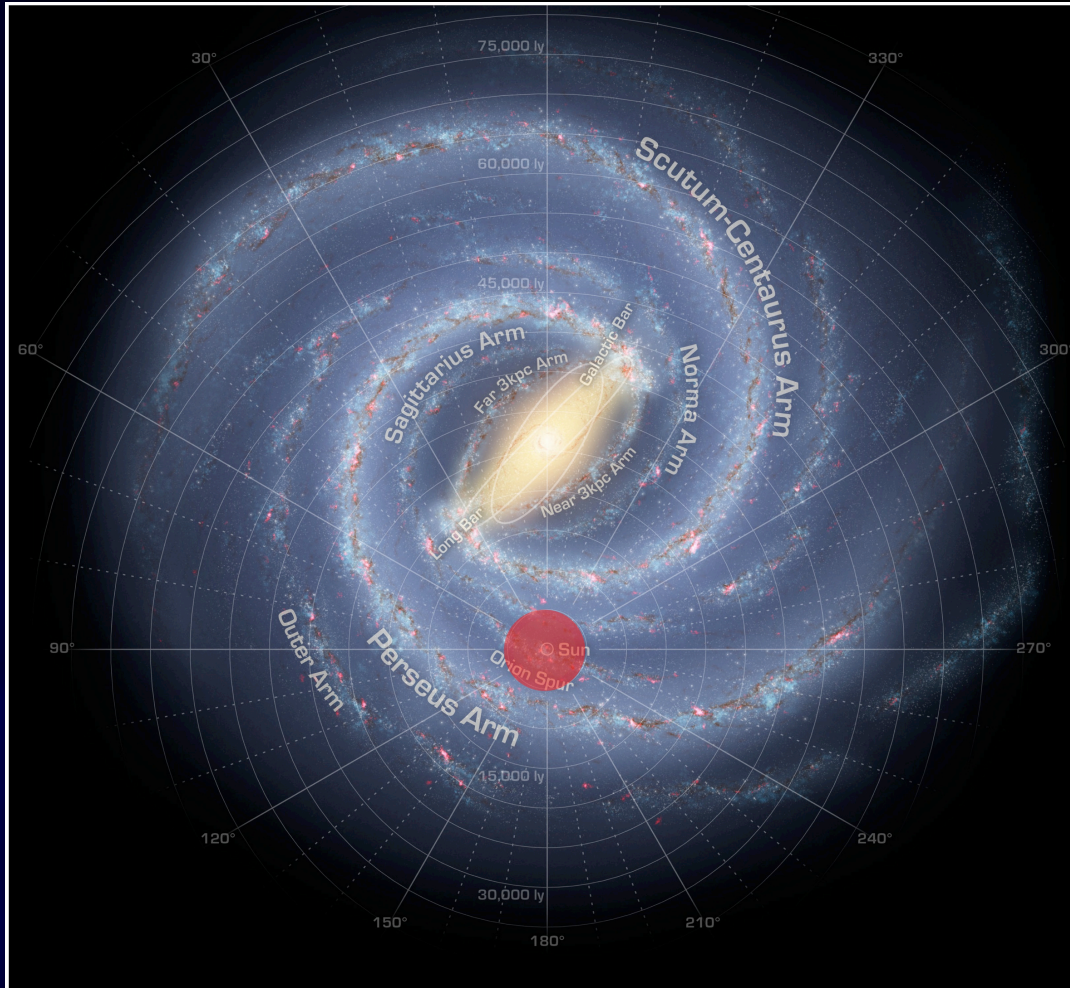
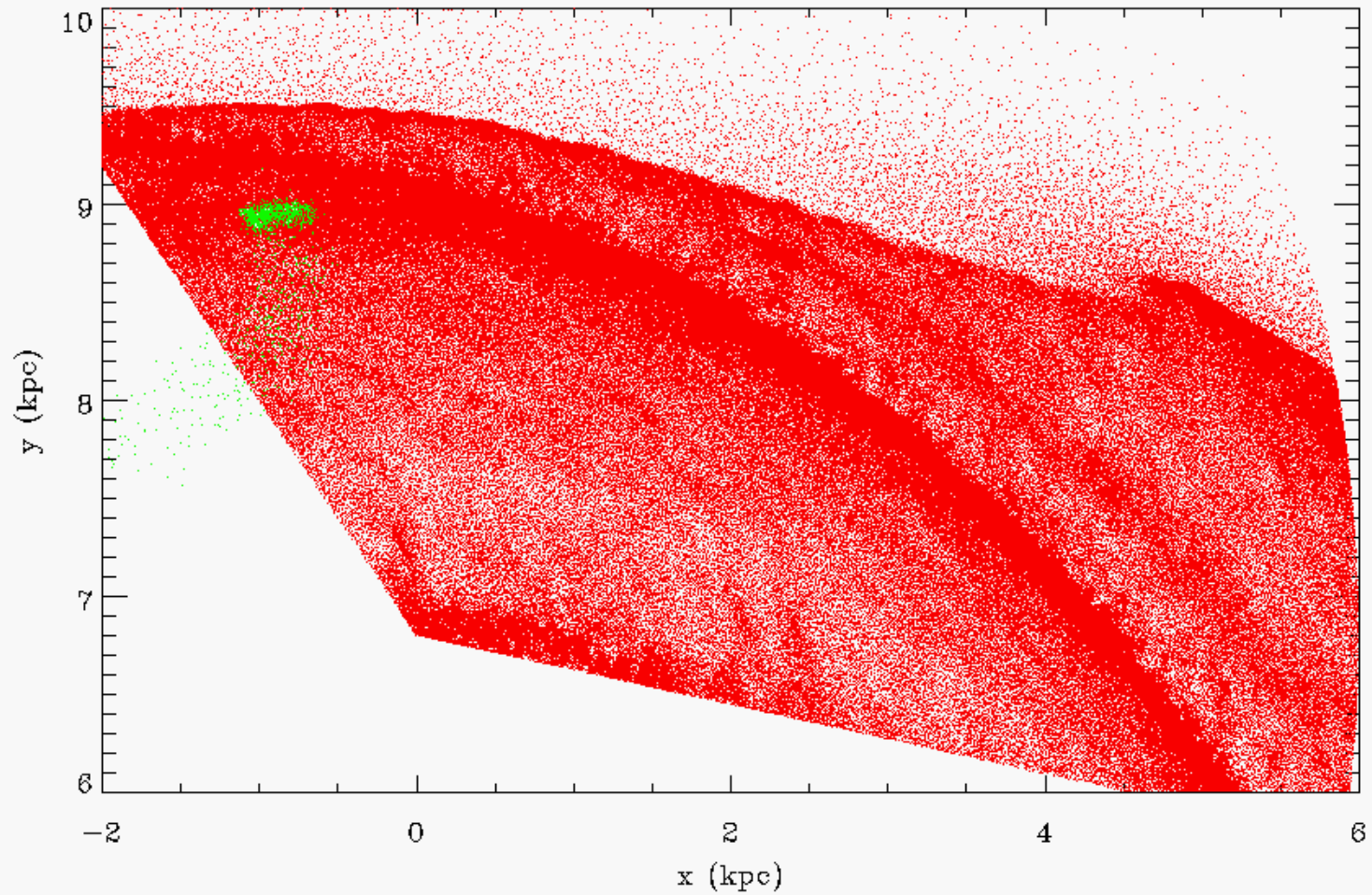


Image credit : R Hurt (SSC), JPL-Caltech, NASA.

- Geometric ambiguities
- Kinematic ambiguities

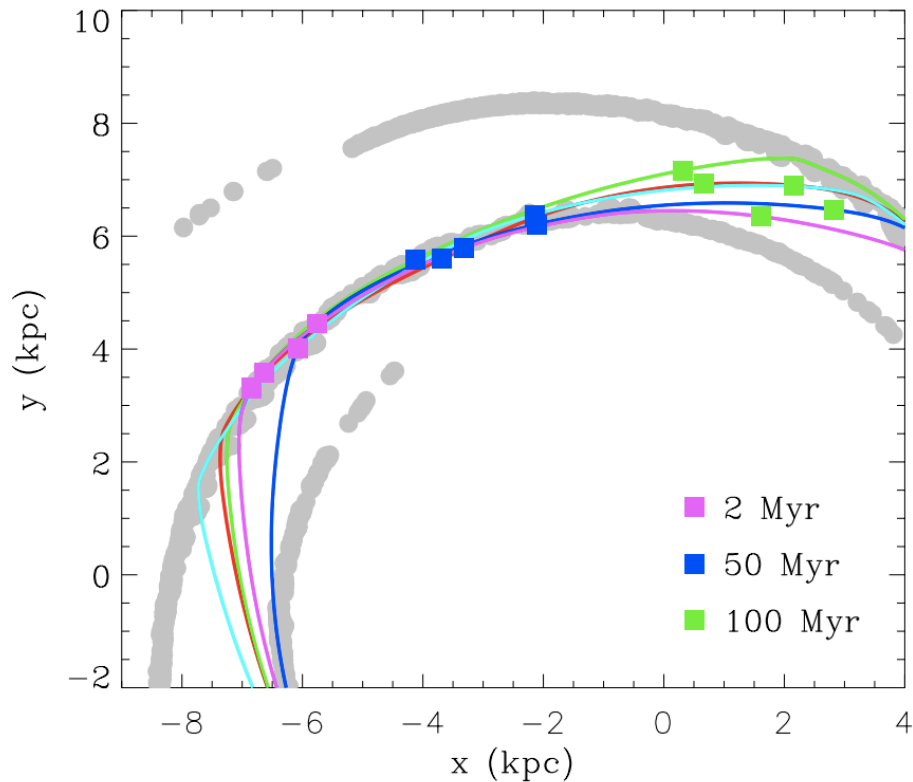
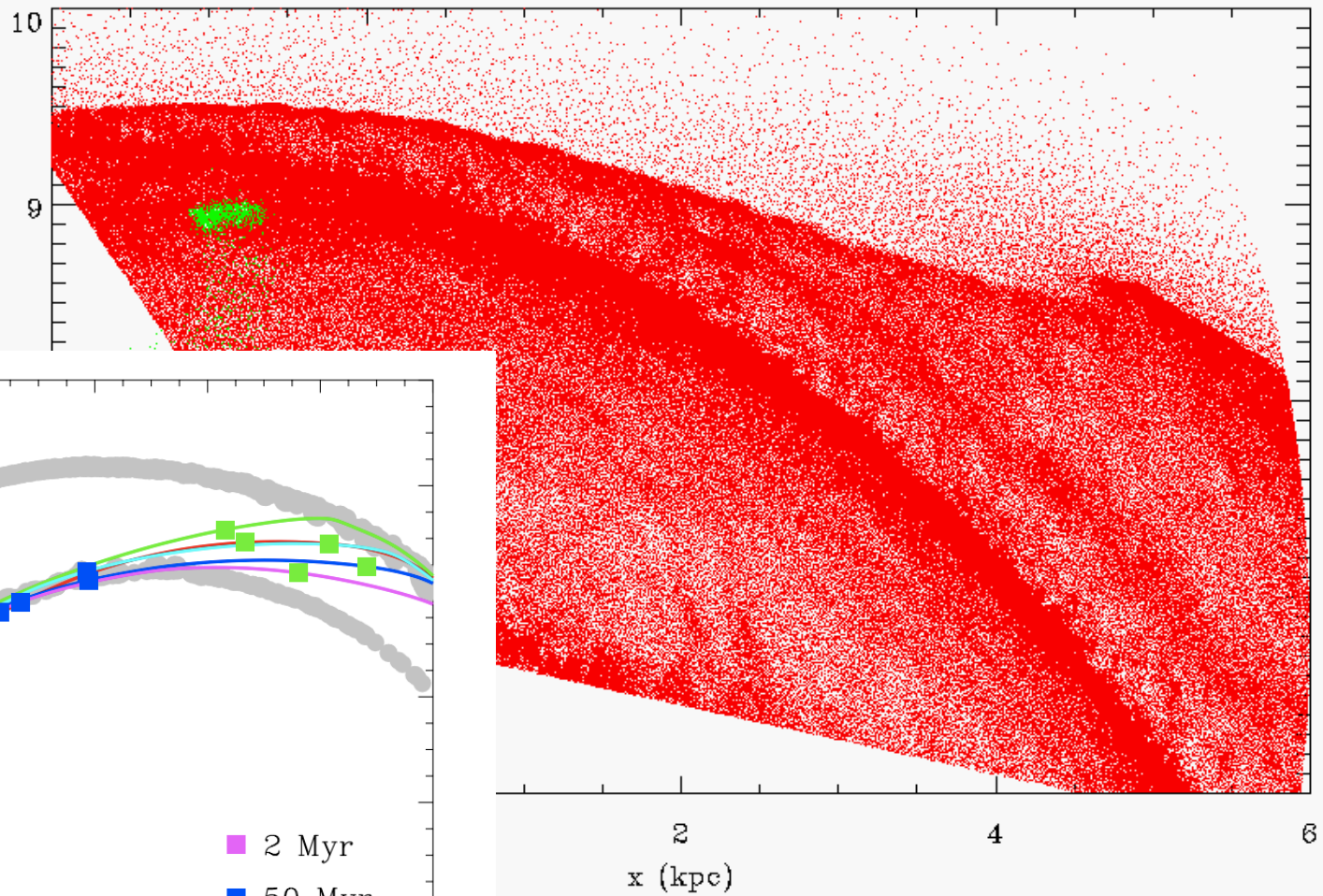
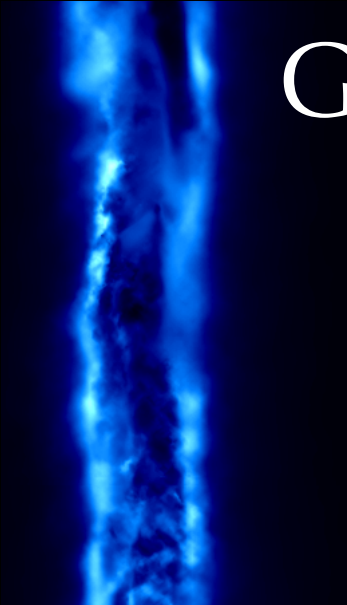
# Gas > Clouds > Stars



Movie credit : Claire Dobbs  
Image credit : Dobbs et al. (2010)

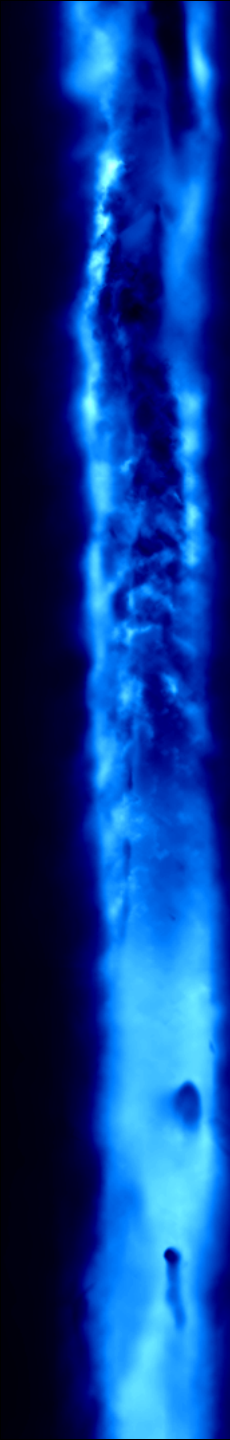
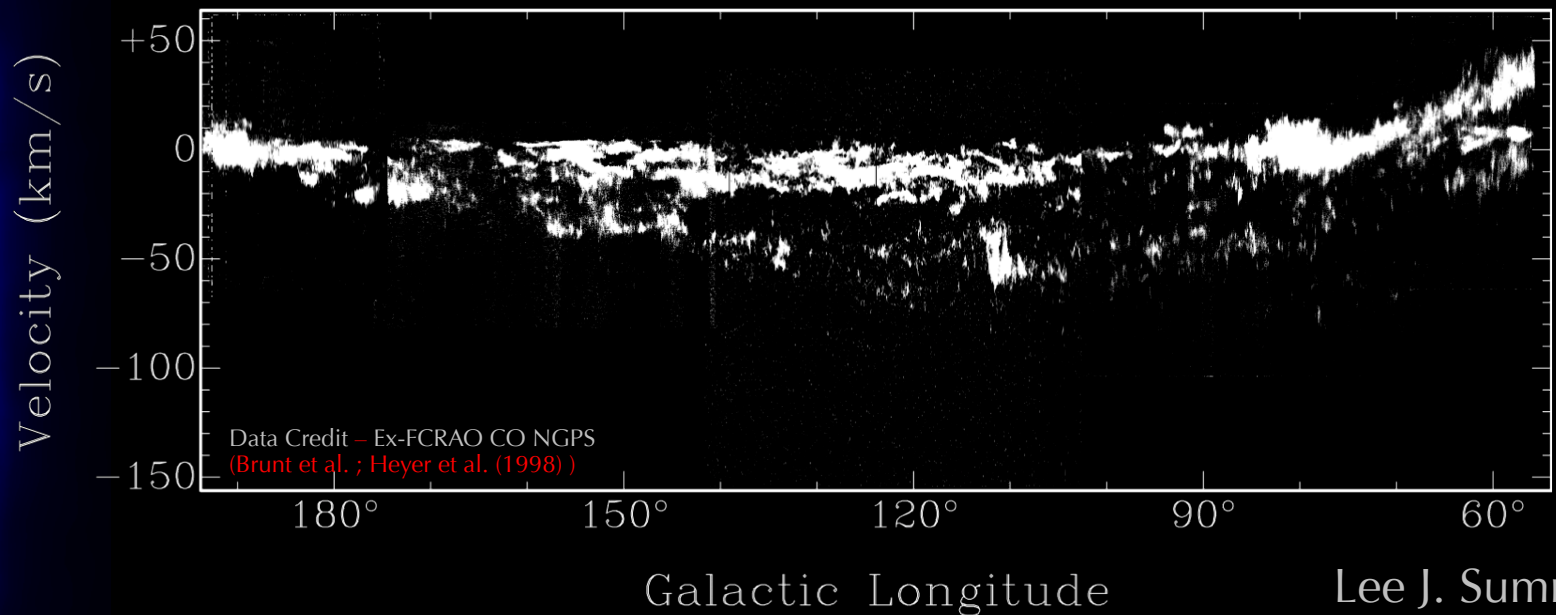
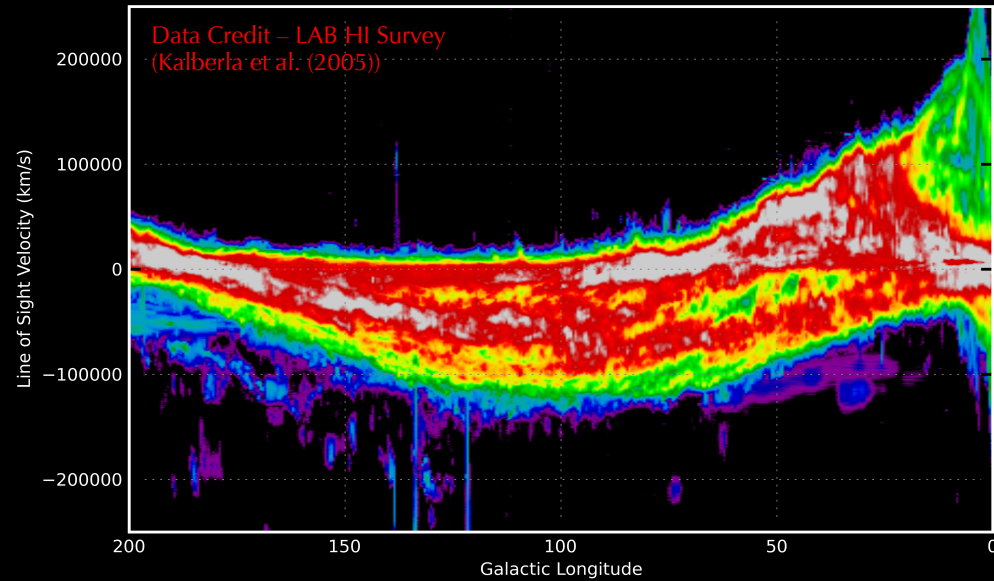
Lee J. Summers

# Gas > Clouds > Stars

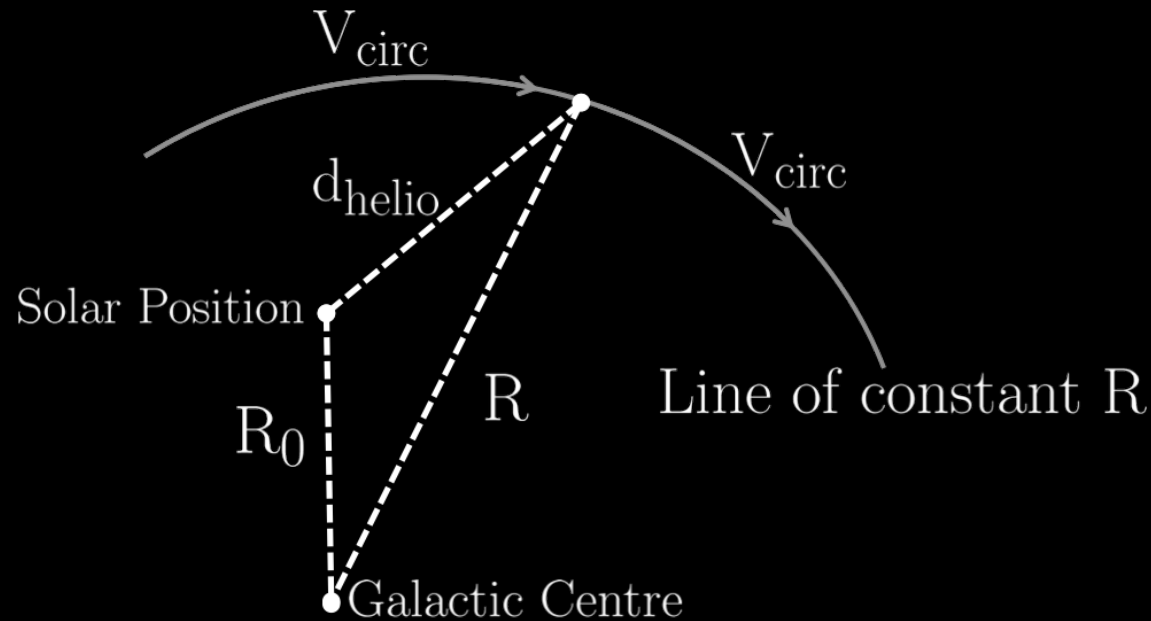


Movie credit : Claire Dobbs  
Image credit : Dobbs et al. (2010)

# Tracing Spiral Structure



# Shocked Motion Model (i)



- Distance Fit
- Arm velocity field
- Correction for kinematic distances

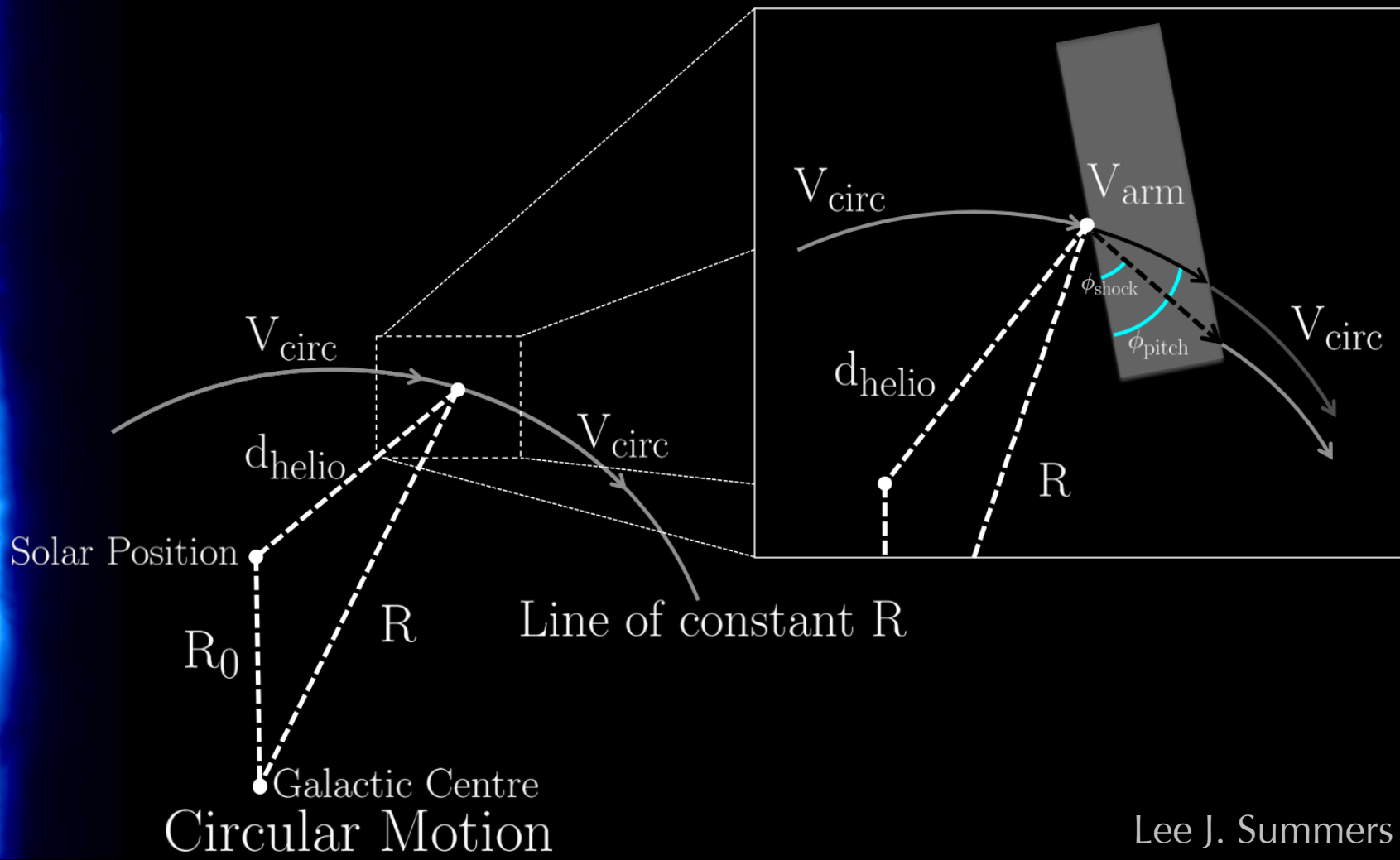


# Shocked Motion Model (ii)

$$V_{\text{los}} = (V_{\text{arm}} \cdot \sin(\epsilon)) - (V_{\text{circ}} \cdot \sin(l))$$

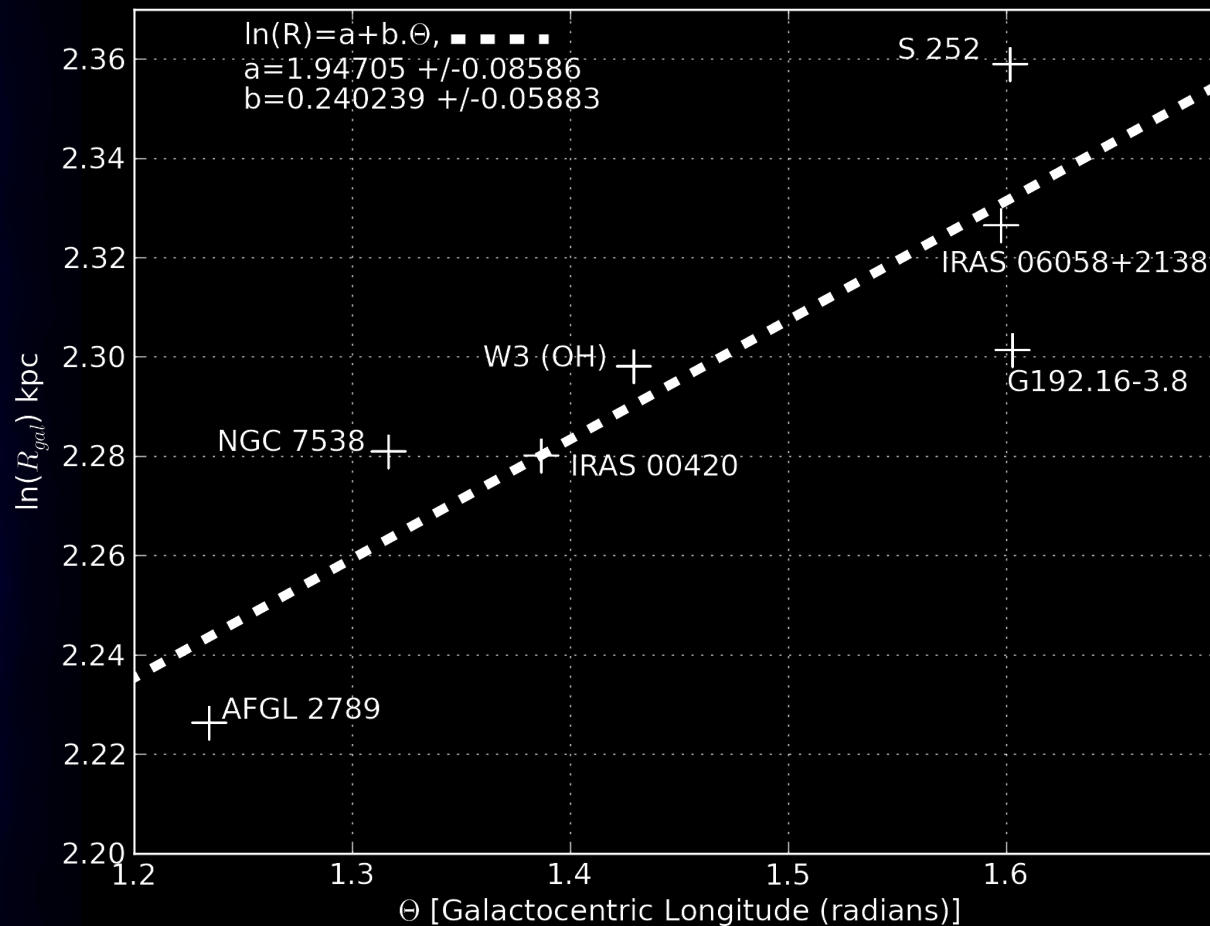
$$\epsilon = \left( \arcsin \left( \frac{R_0}{R} \cdot \sin(l) \right) - \Delta\phi_{\text{sp}} \right)$$

## Shocked Motion



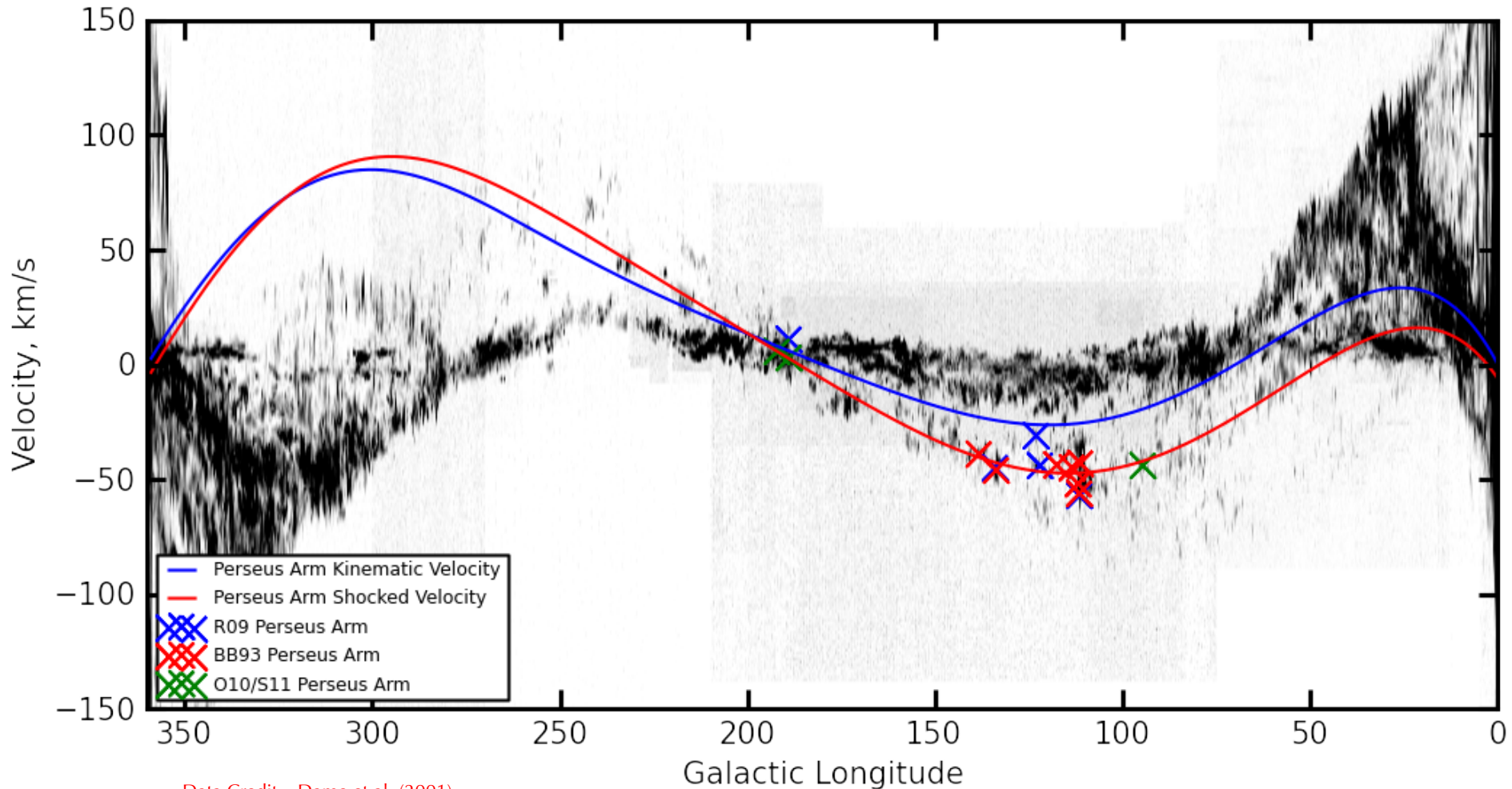
# Logarithmic Arm Fitting

- Fit a logarithmic spiral to HMSF regions
- Acquire a longitude-Galactic Radius relation.



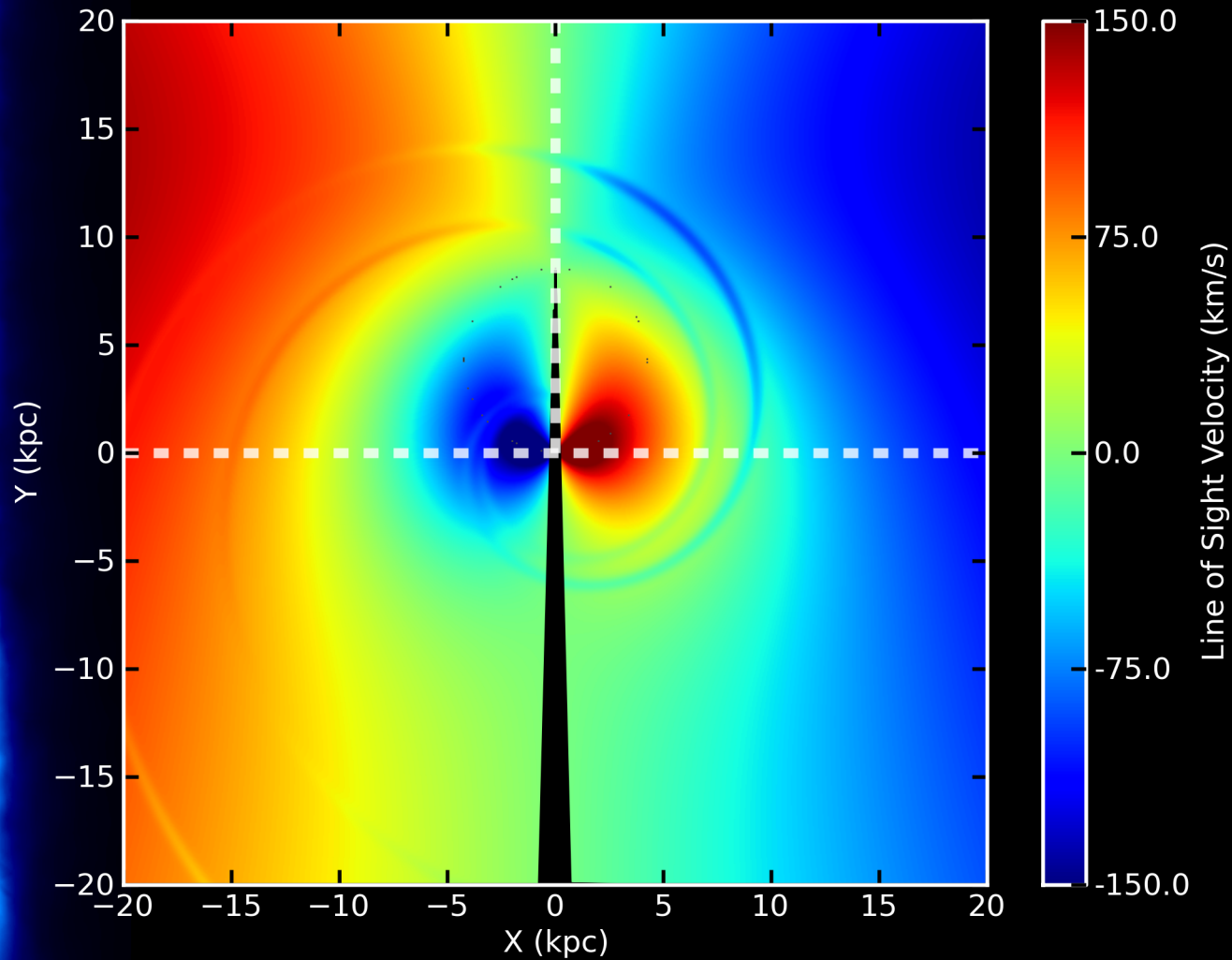
# Velocity Fitting

$$V_{\text{los}} = (V_{\text{arm}} \cdot \sin(\epsilon)) - (V_{\text{circ}} \cdot \sin(l))$$

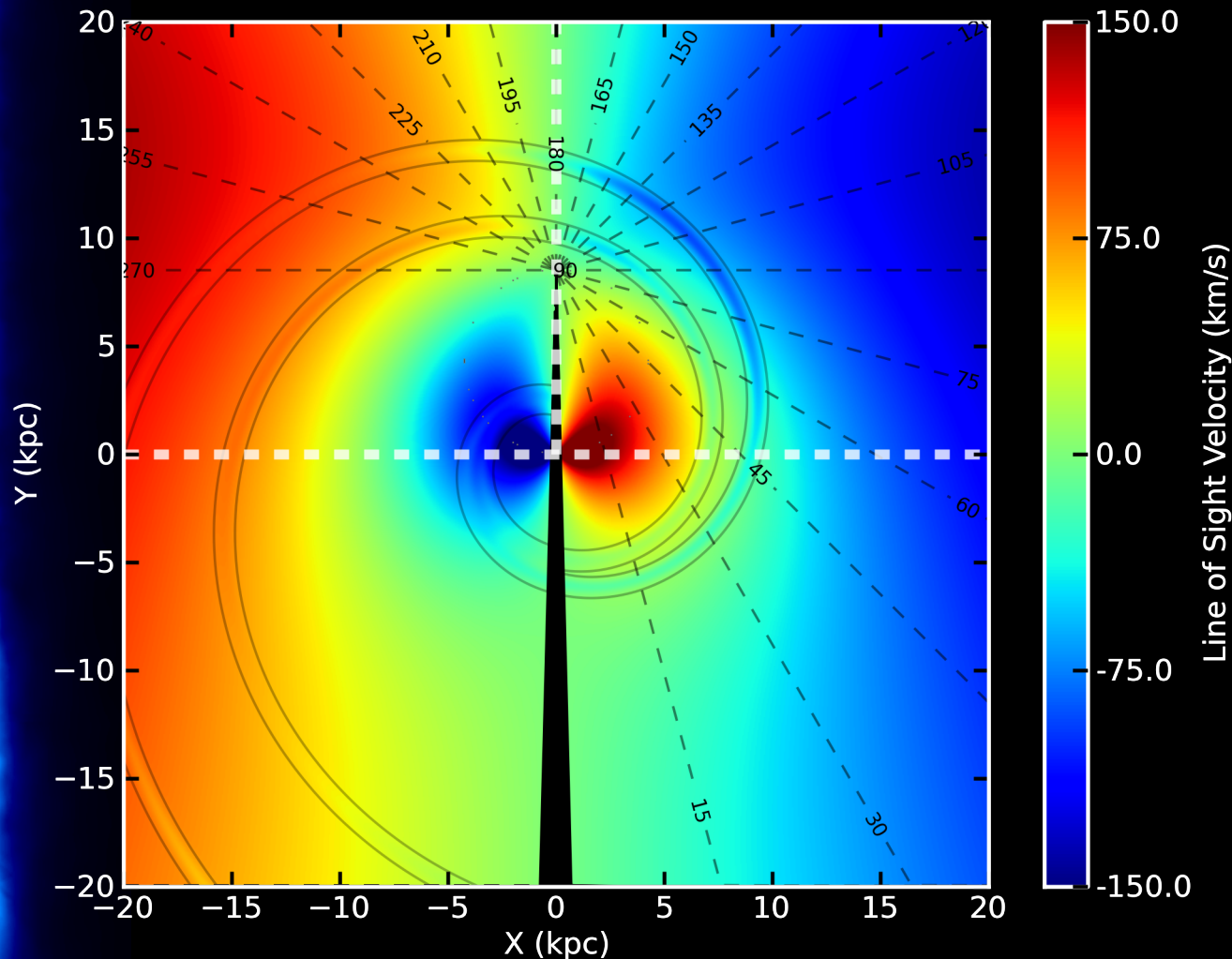


Data Credit – Dame et al. (2001)

# Shocked Motion Fit



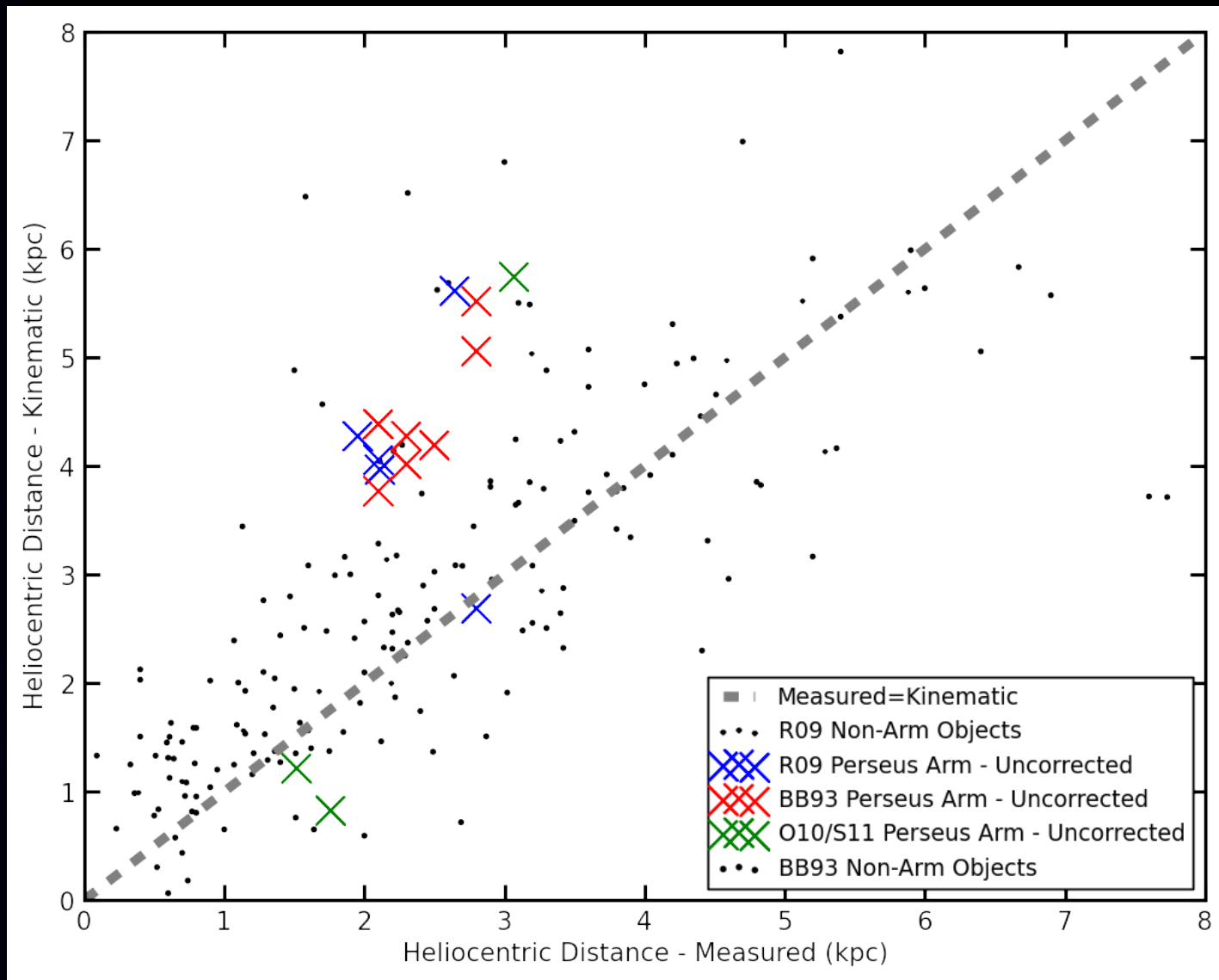
# Shocked Motion Fit



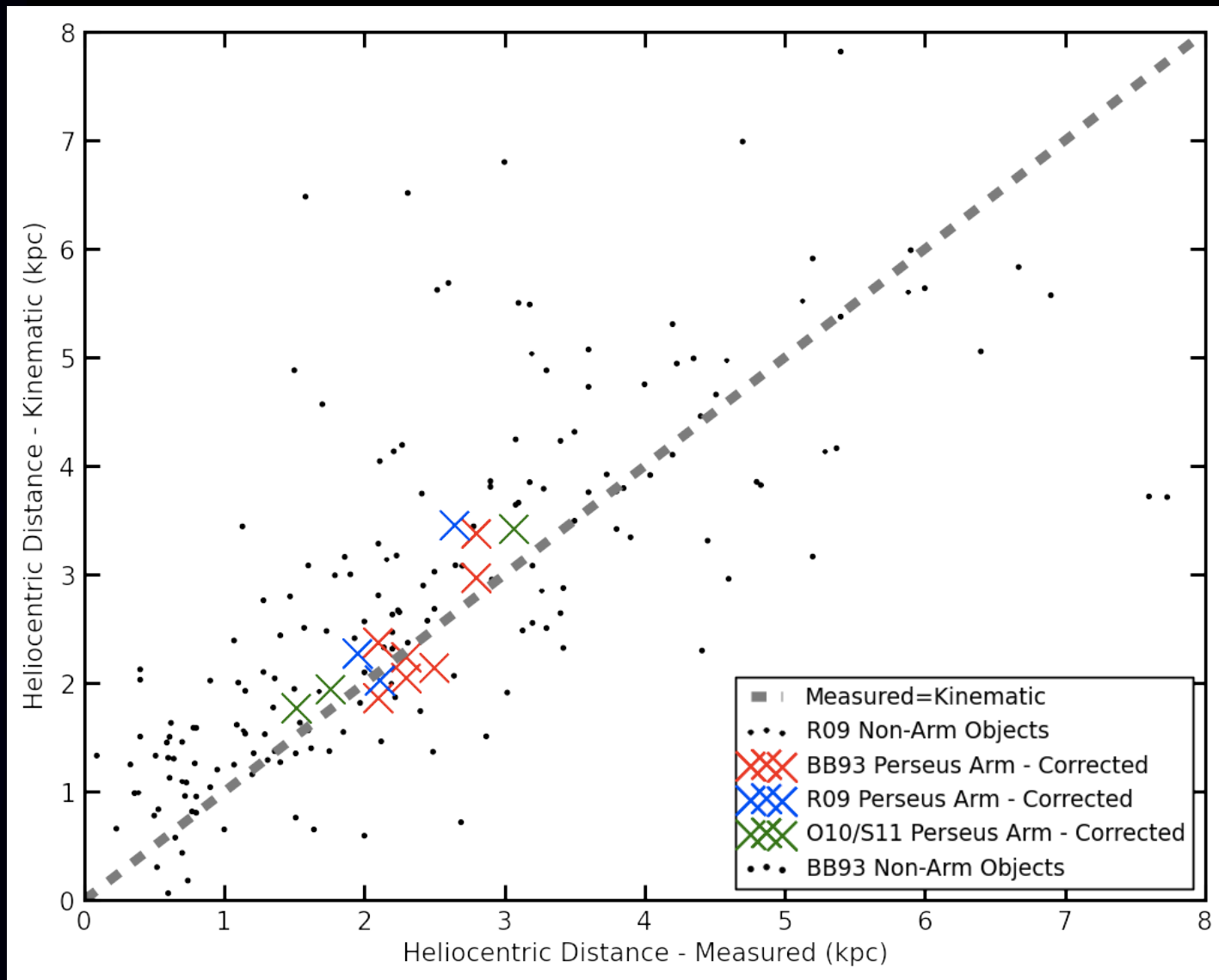
Circular Residual (backwards) = 22 km/s

Radial Residual (inwards) = 6 km/s

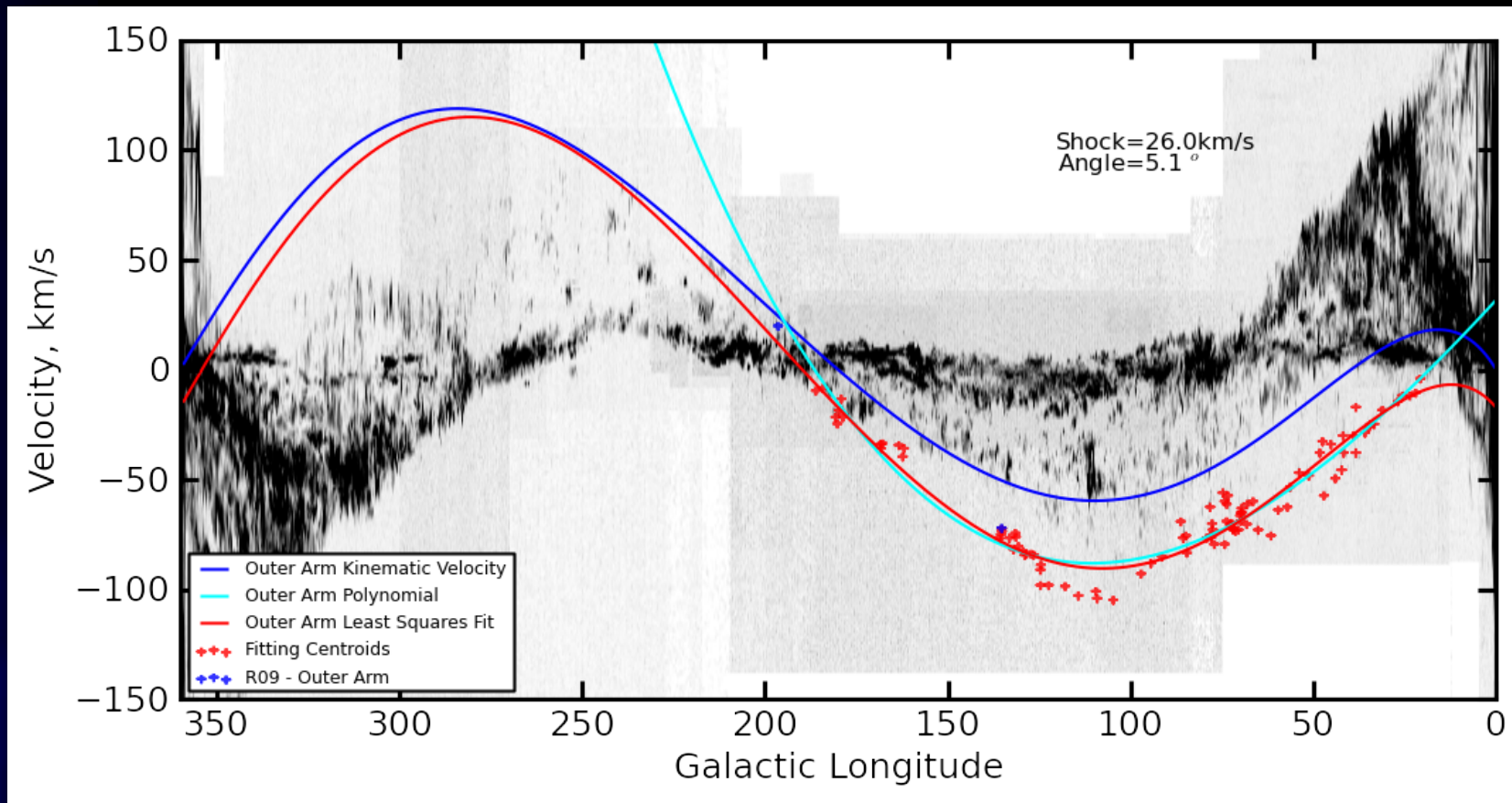
# Correcting Distance



# Correcting Distance

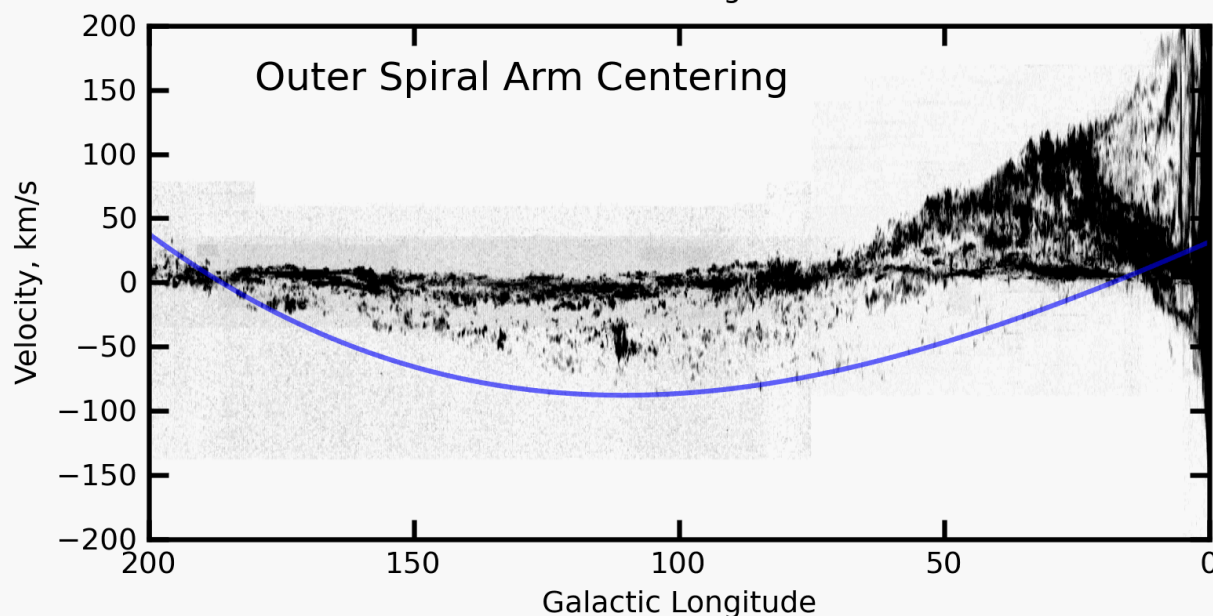
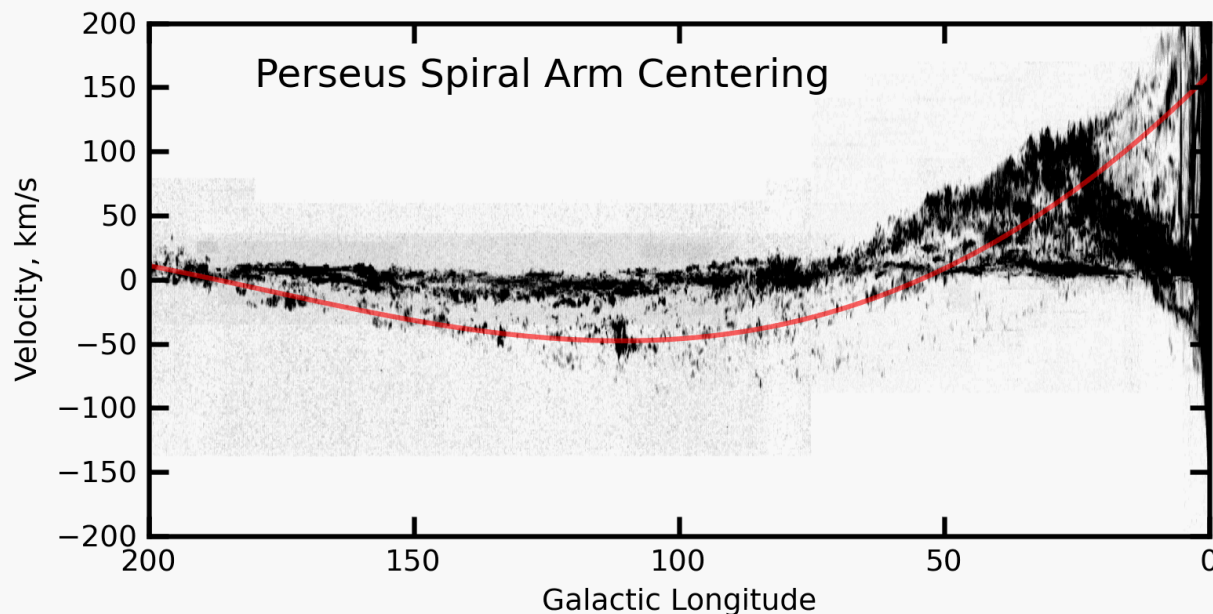


# Finding Other Arms



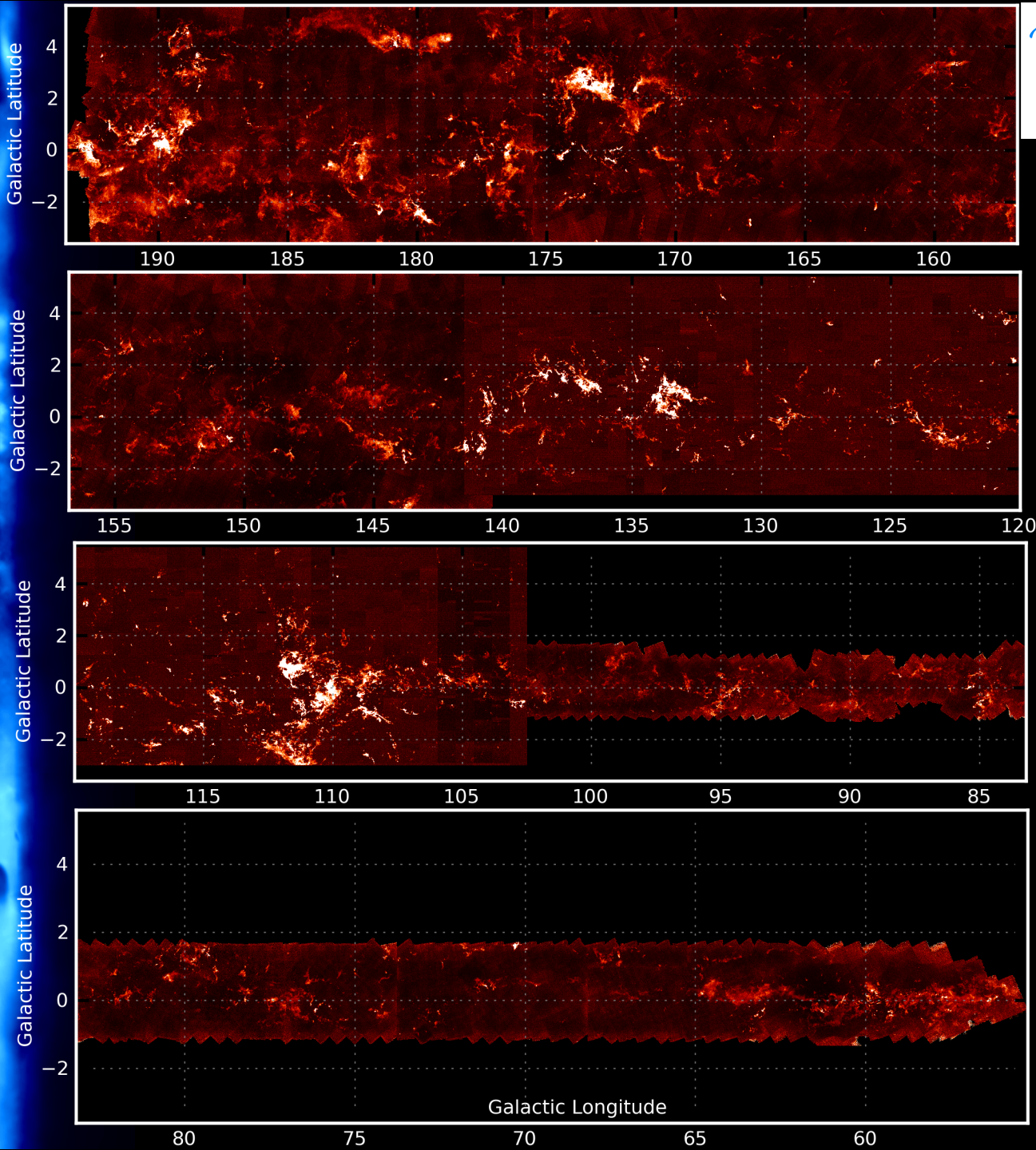


# Arm Centric Mapping (i)

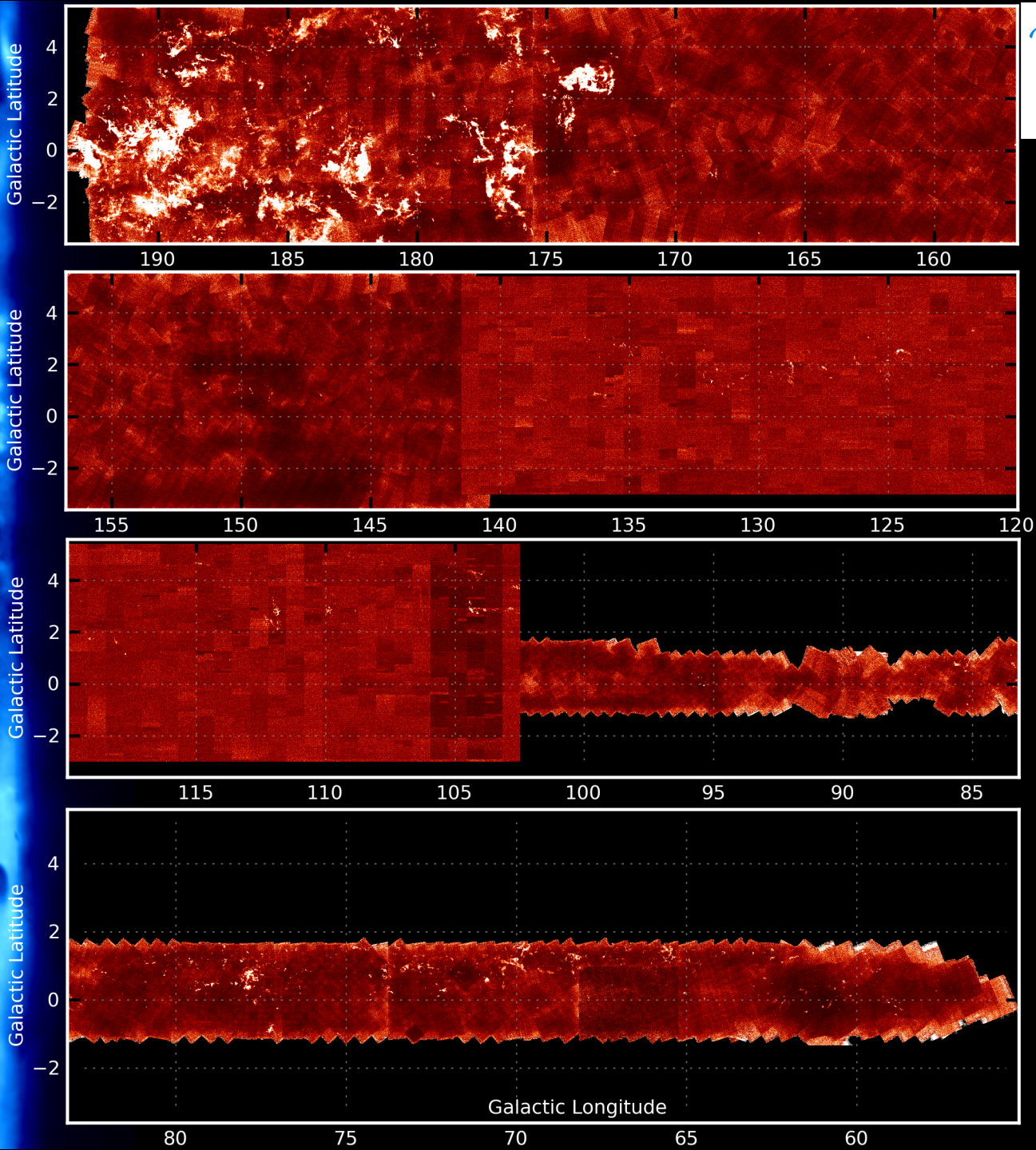


- 0 km/s = Arm Centre
- Reduces velocity span of arm-based material.
- Removes velocity gradient across arm based clouds

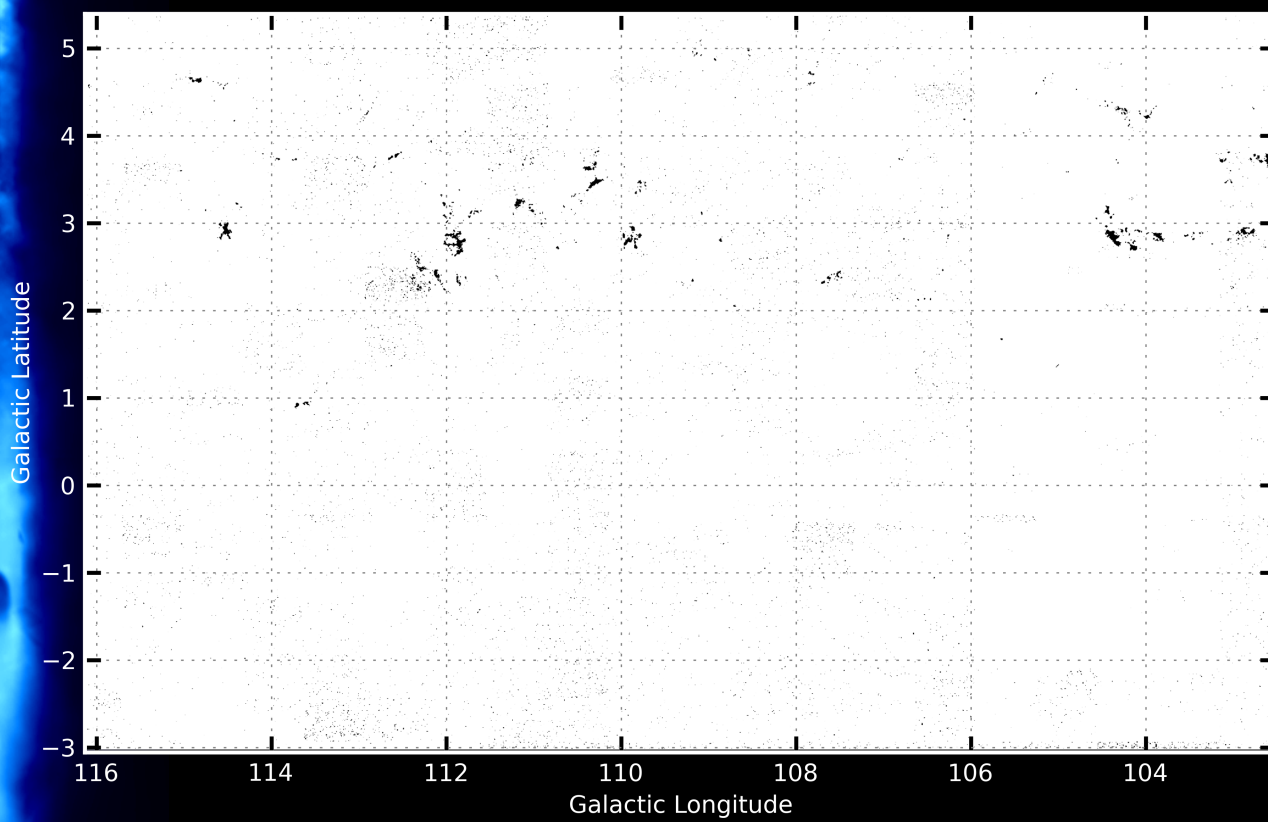
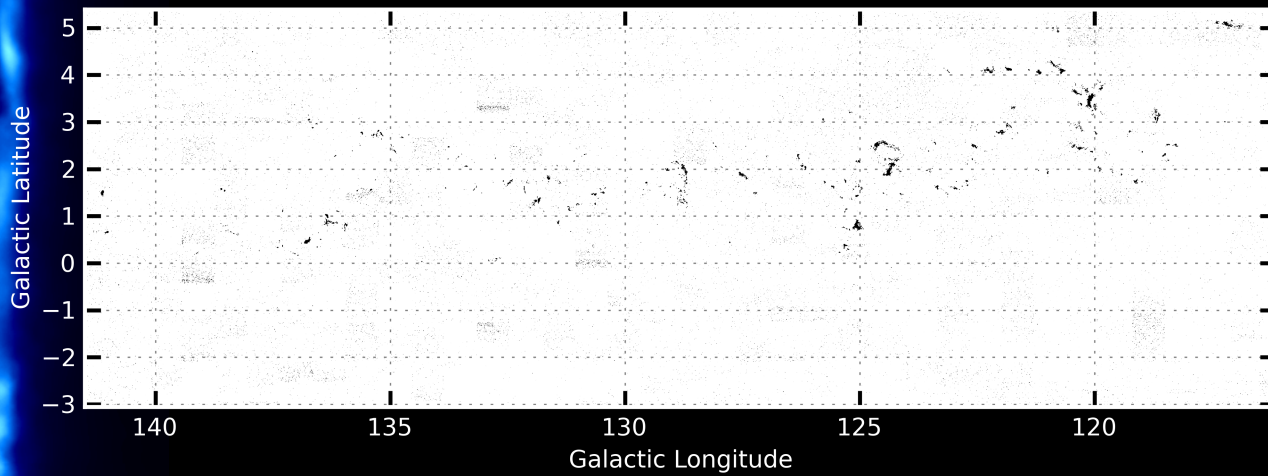
# Arm Centric Mapping (ii)



# Arm Centric Mapping (iii)

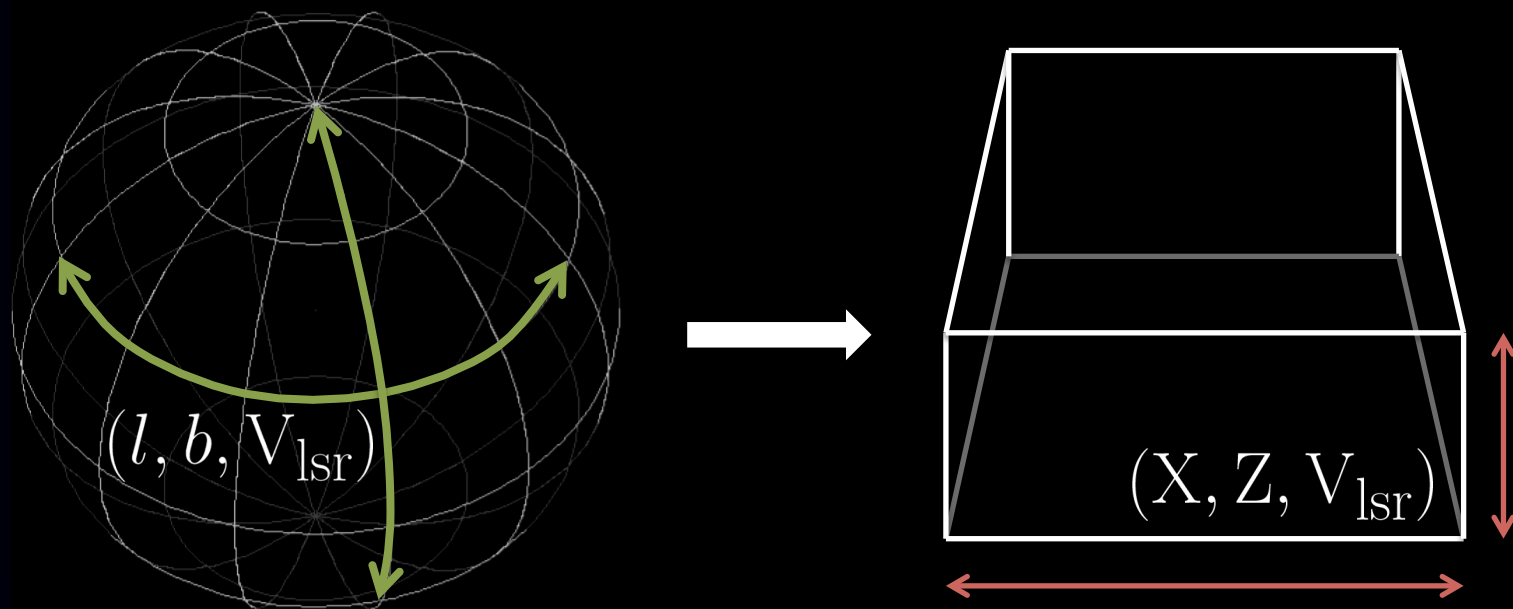


# Arm Centric Mapping (iii)



# Common Res. Mapping (i)

- Coordinate transform

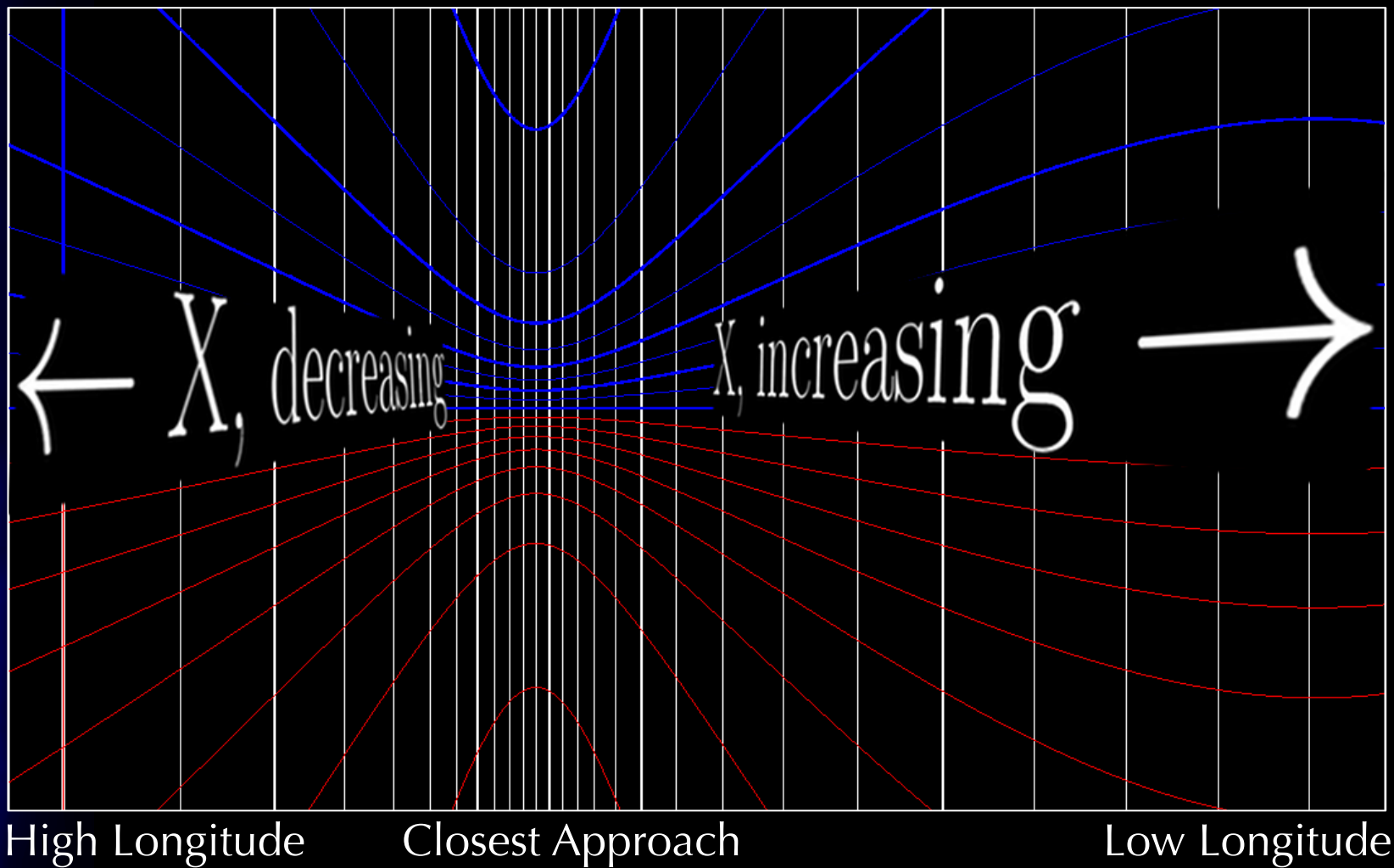


$$l(180^\circ) \equiv X(0\text{pc})$$

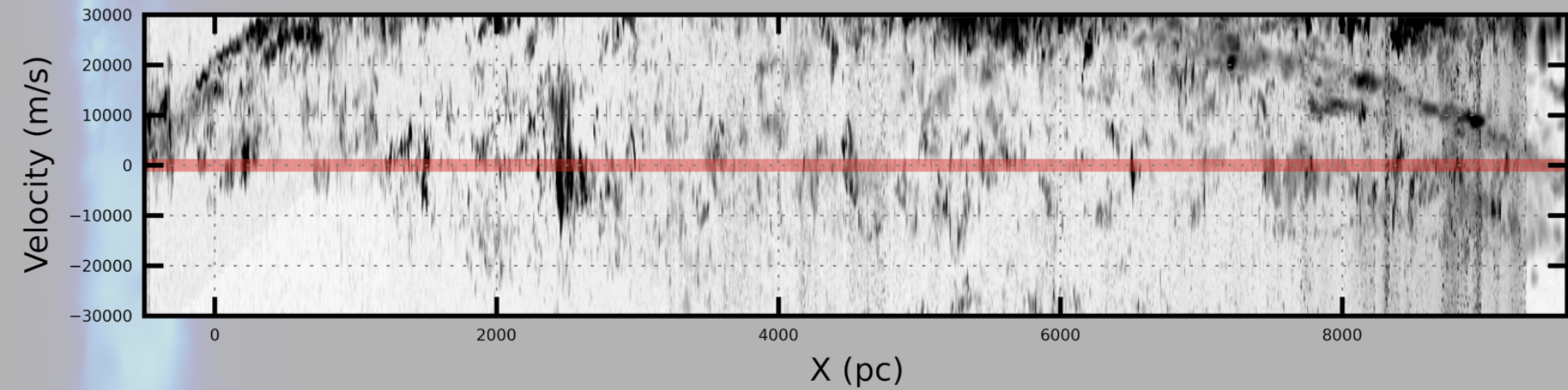
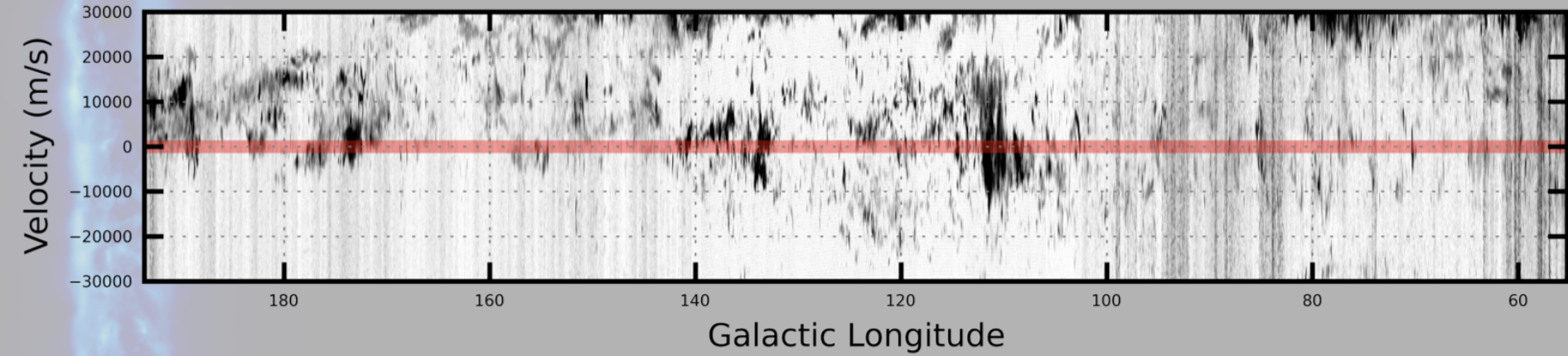
$$b(0^\circ) \equiv Z(0\text{pc})$$

# Common Res. Mapping (ii)

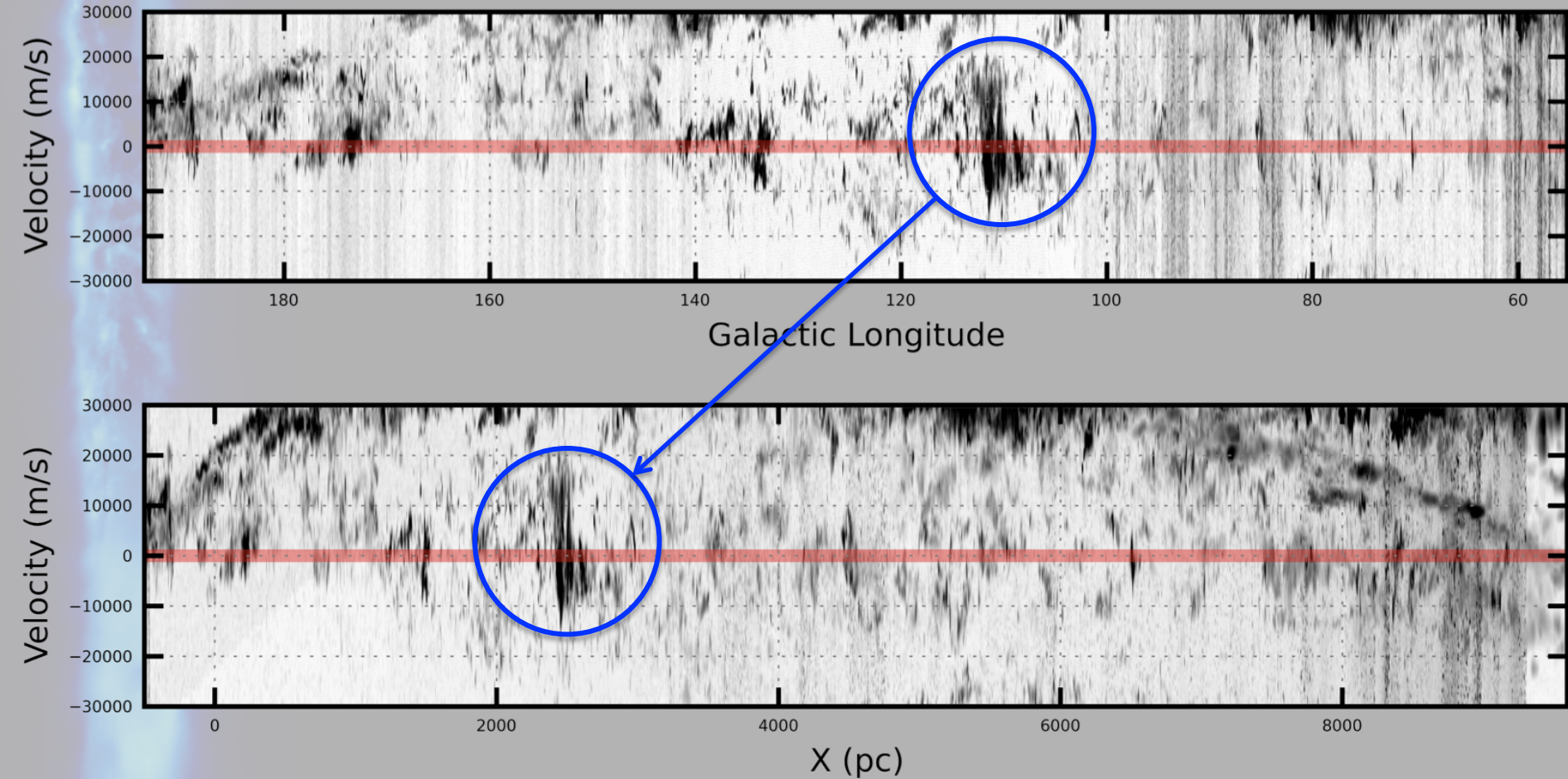
- Smoothing kernel



# Common Res. Mapping (iii)

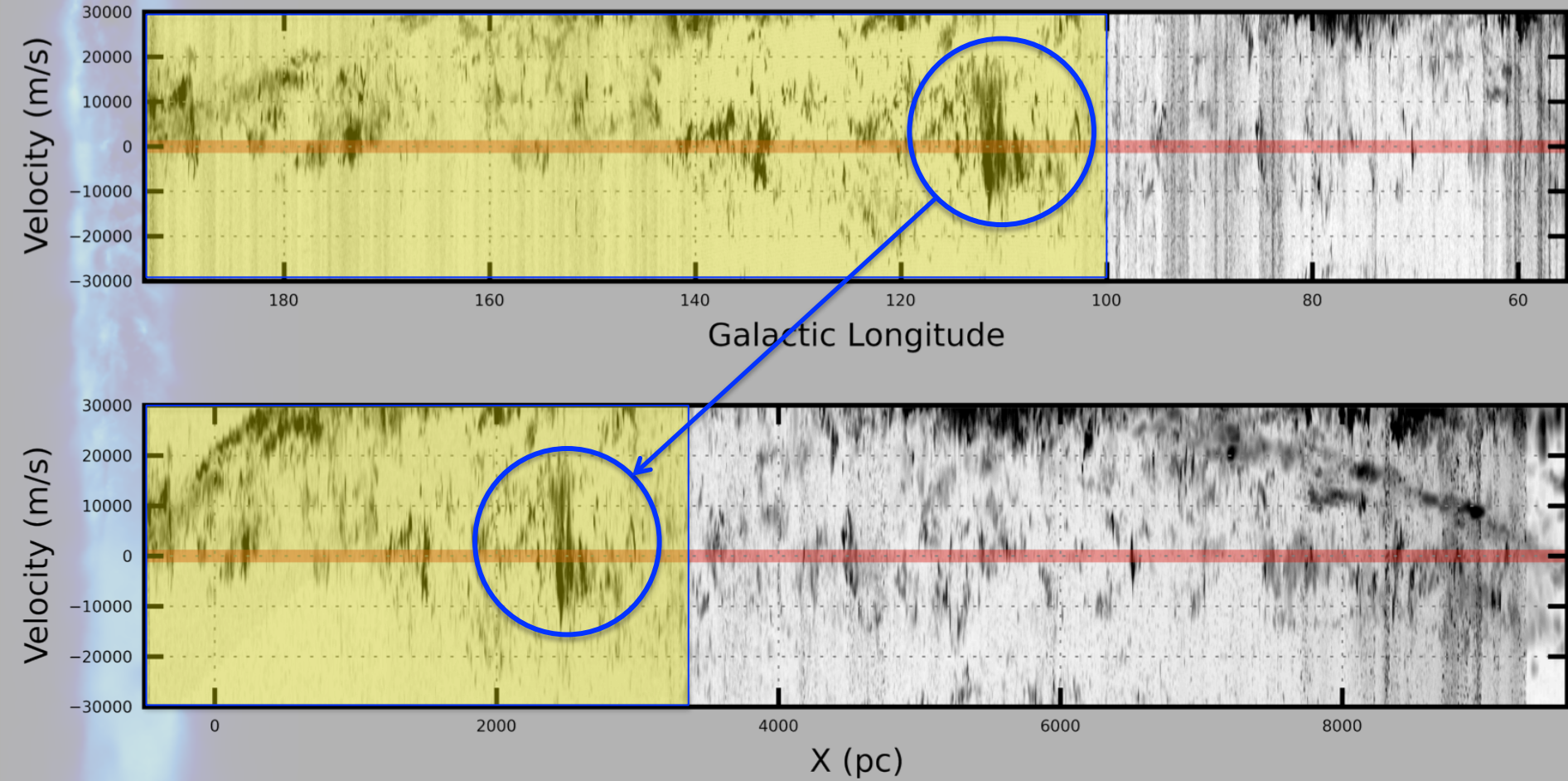


# Common Res. Mapping (iii)





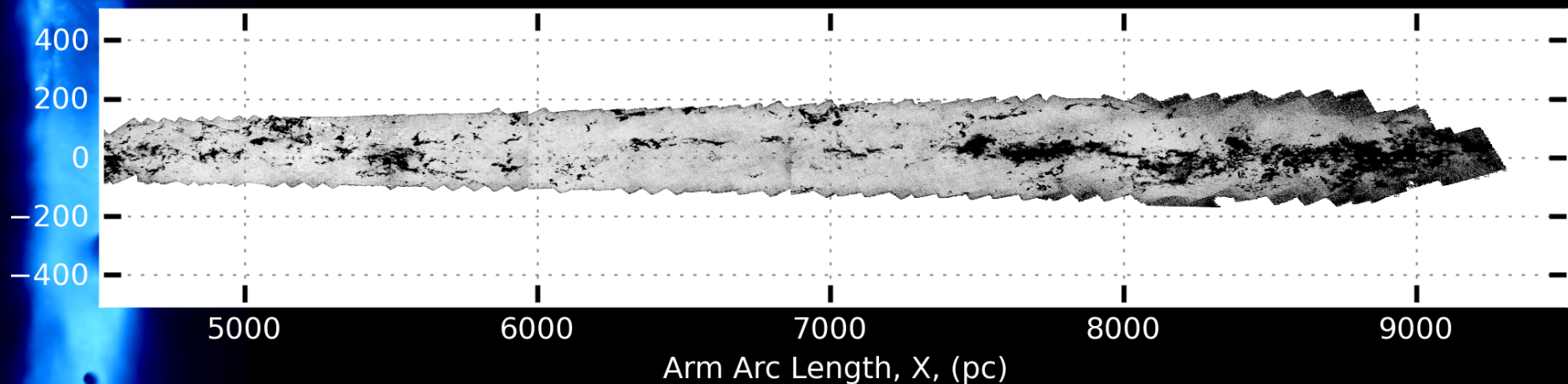
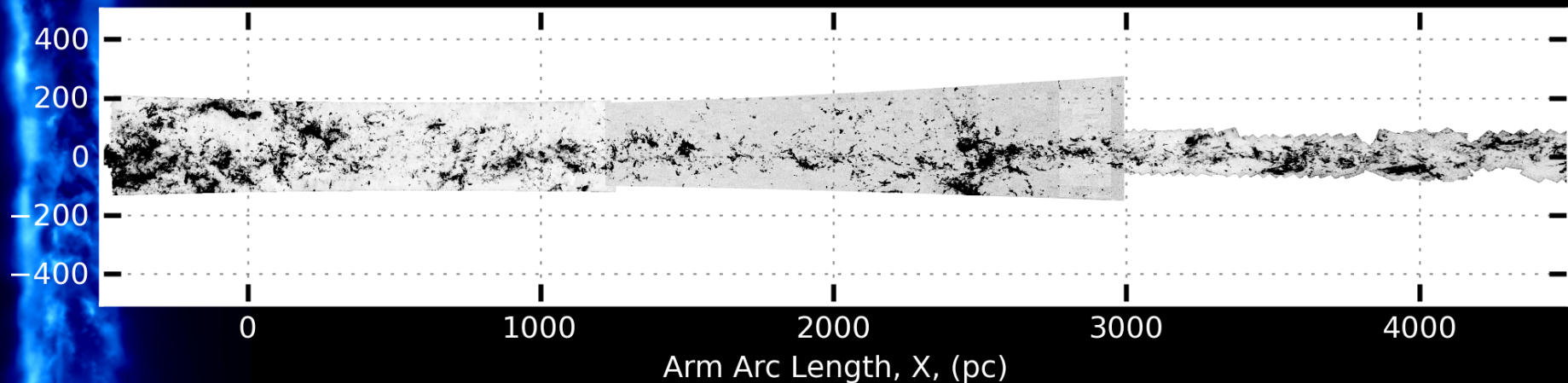
# Common Res. Mapping (iii)



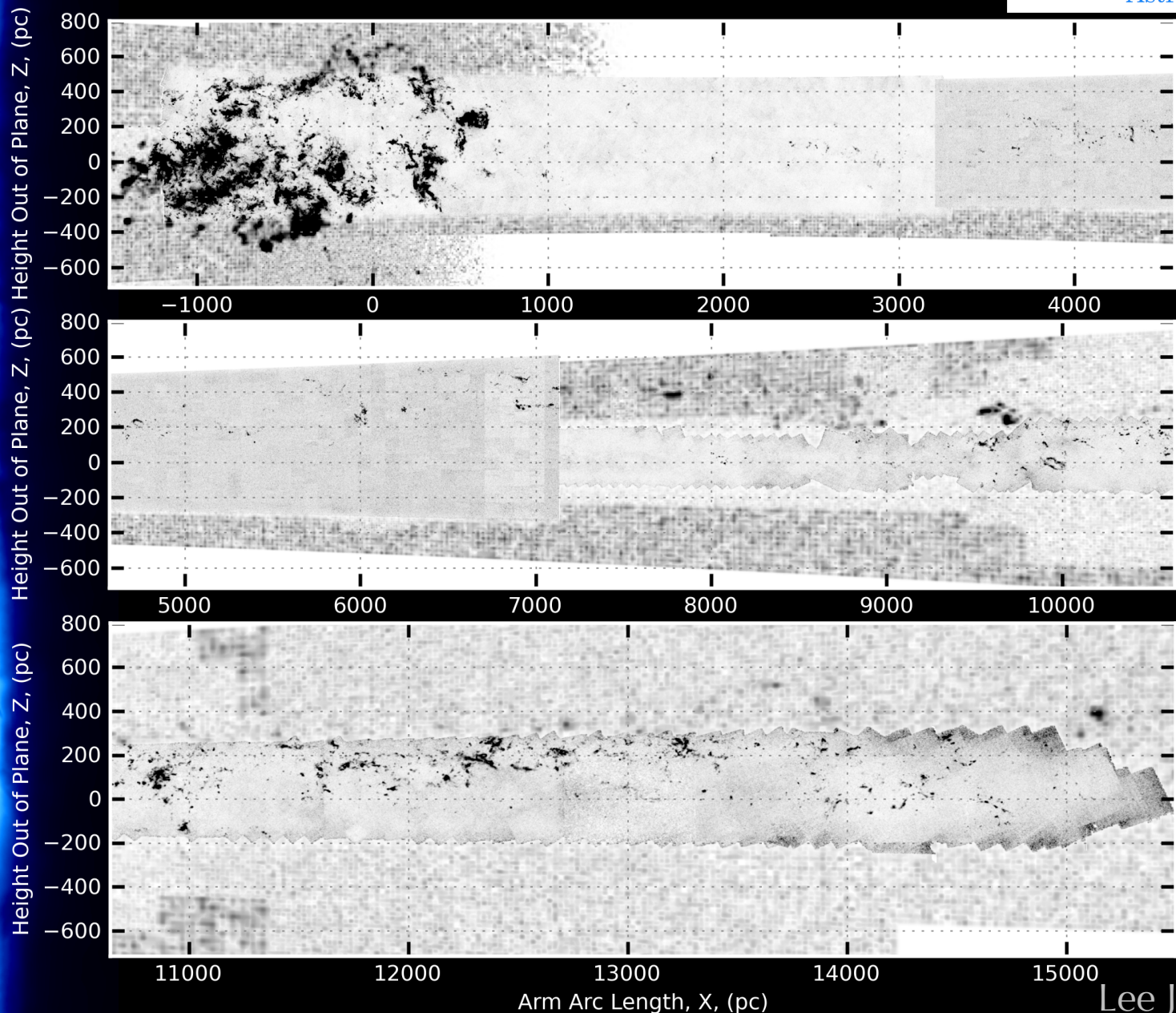
# Common Res. Mapping (iii)

Perseus

Height Out of Plane, Z, (pc)



# Common Res. Mapping (iii)



Outer

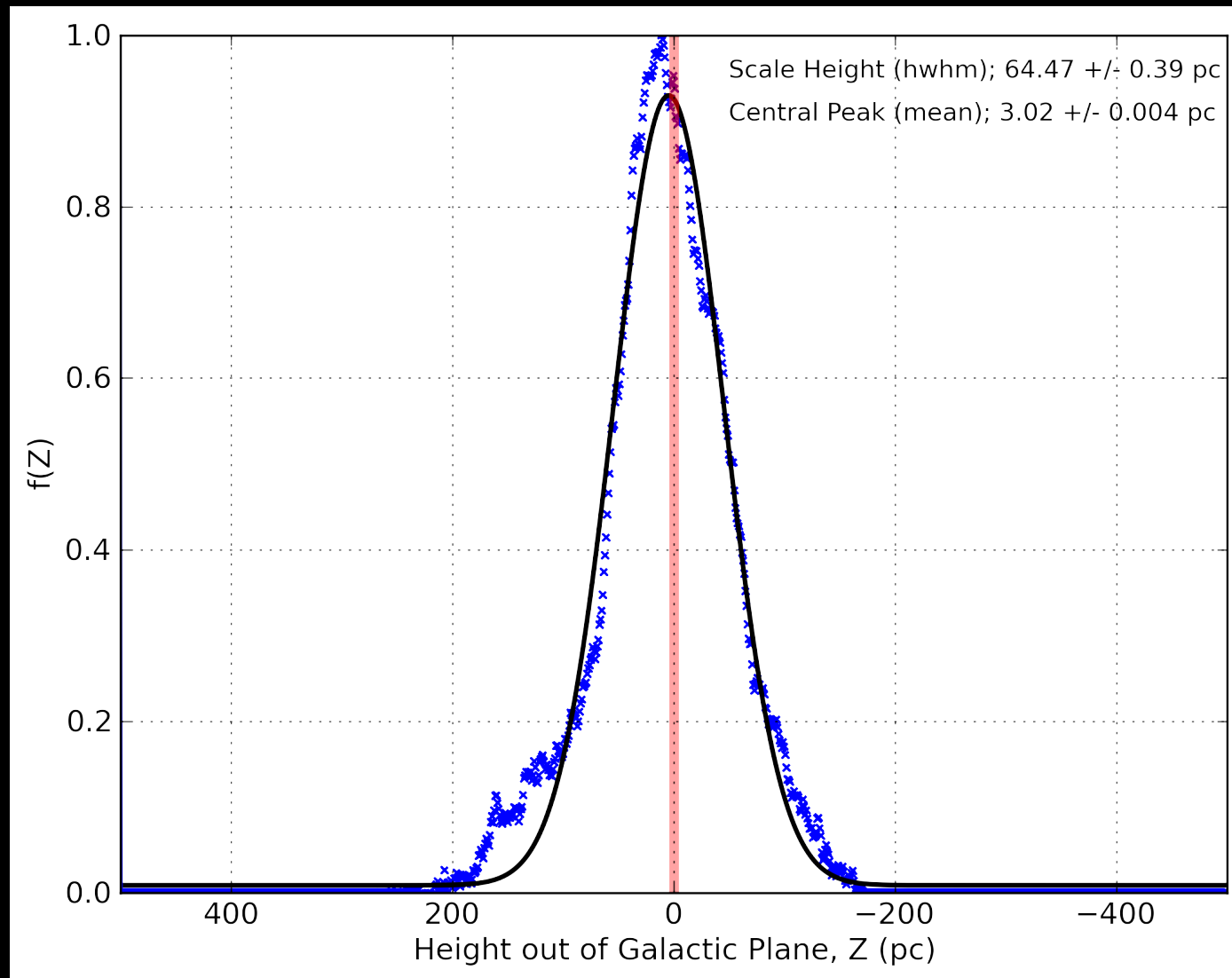


So, what now?

# Analysis

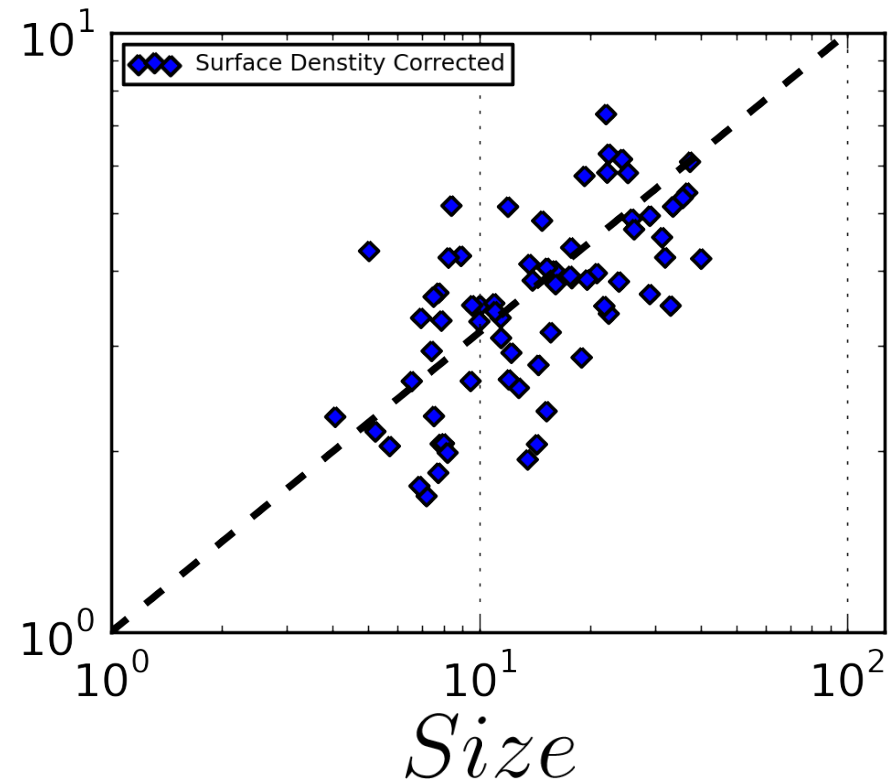
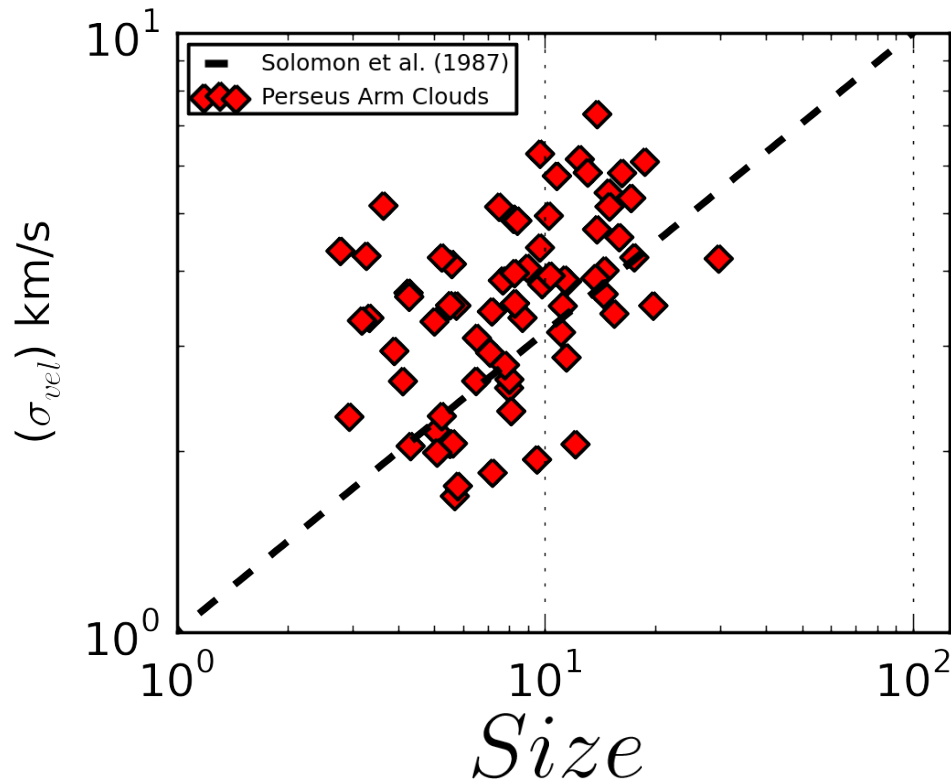
- What is the scale height of arm material?
- Do the Larson relations still hold true?
  - Size-line width (Solomon et al. 1987)
  - Surface density dependence? (Heyer et al. 2009)

# Analysis – Scale Height



# Analysis – Size:line-width

- Solomon's Size definitions



- All clouds on the same linear scale across the full extent of the Perseus arm.

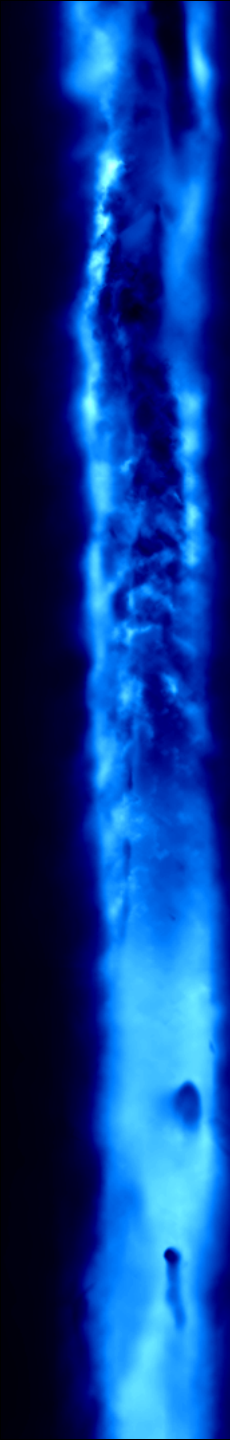
# What have we achieved?

- Modeled the spatial-velocity field of spiral features in the Milky Way.
- Accounted for non-circular motion using a shocked modification to the circular velocity field.
- The modelled radial & circular perturbations are consistent with their measured counterparts
- Produced a series of Arm-Centred maps for Perseus & Outer arms.
- Creating a cloud sample measured at a common distance
- Produced a series of maps at a single common resolution over the full extent of the arms.



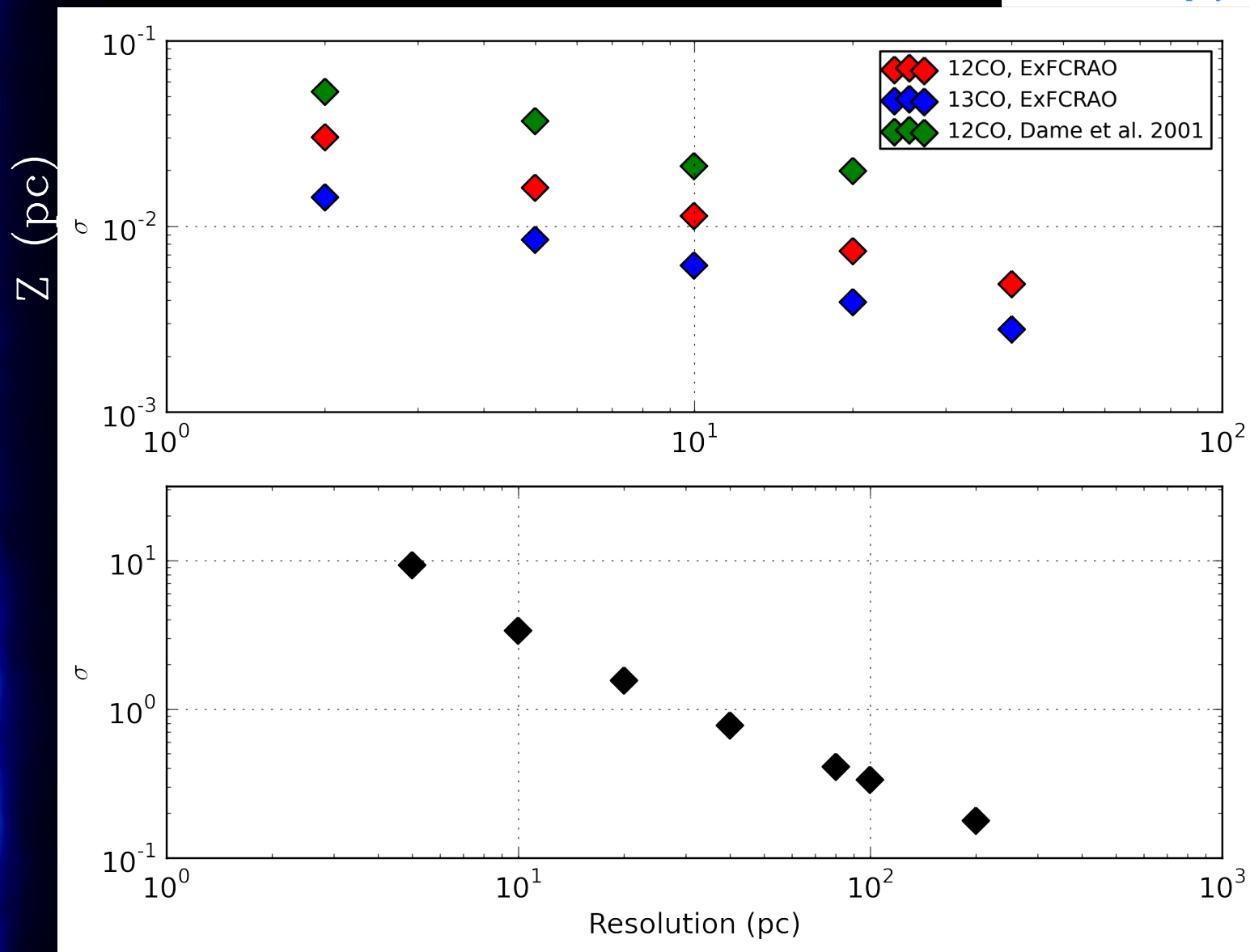
# On-going Work

- Perform full cloud decomposition & analysis
  - Mass spectrum
  - Size linewidth
  - etc
- Comparison with Galactic & Extragalactic cloud catalogues
- Cloud properties dependent of resolution
- Map other arms?



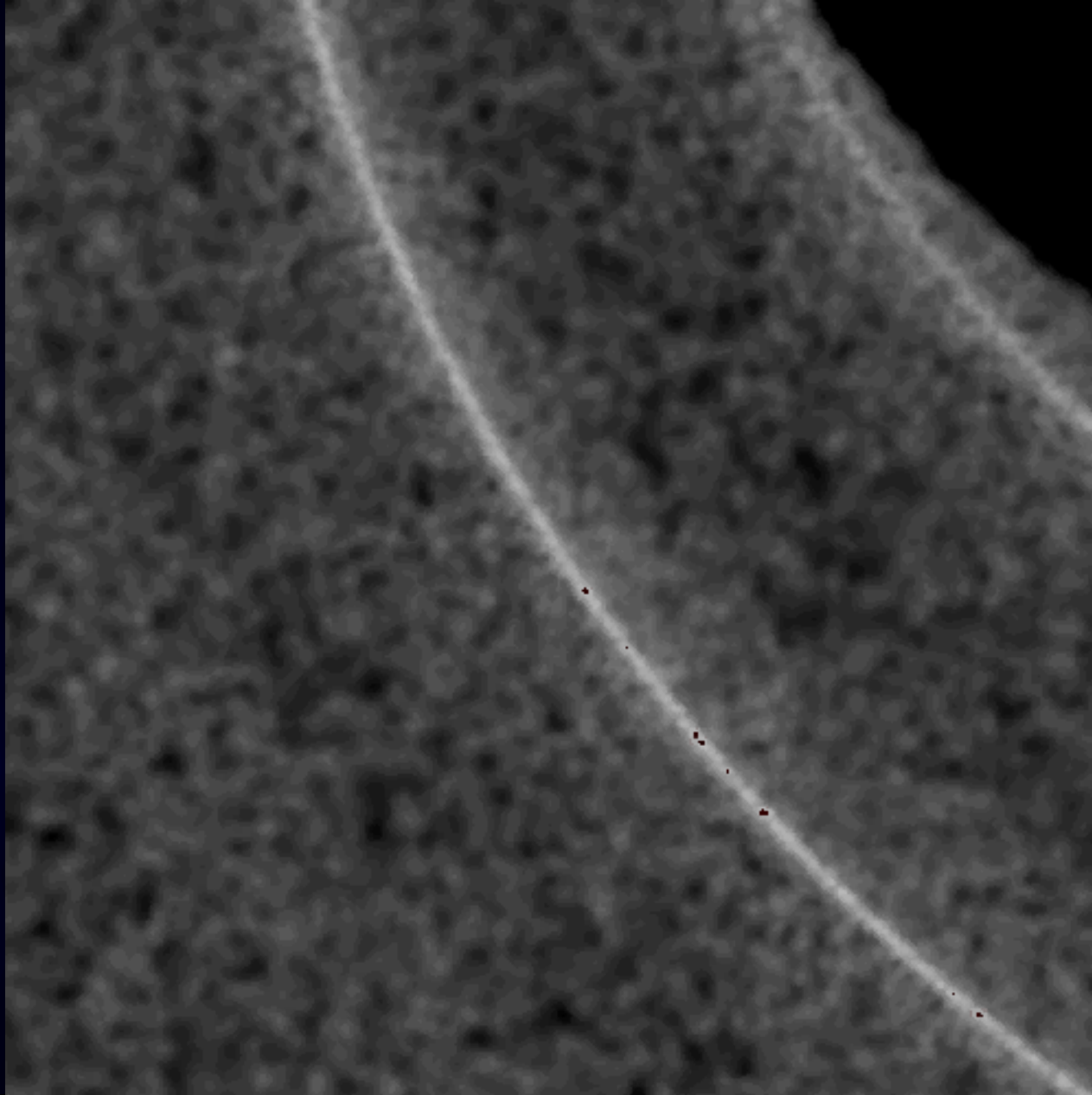
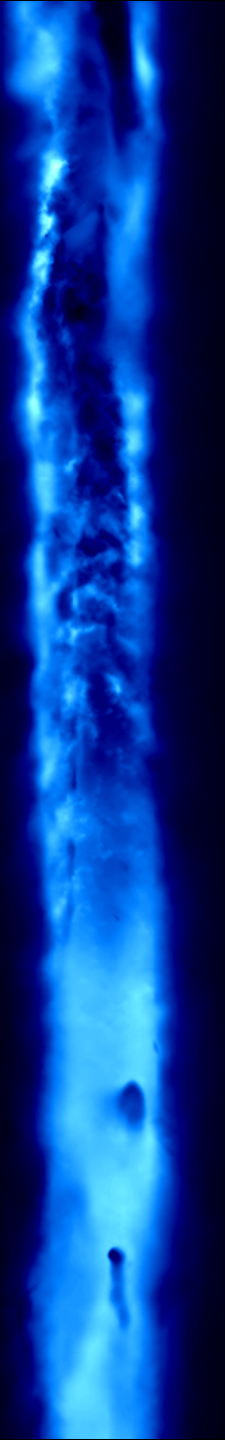
Thank You  
Any Questions?

# Analysis – The Kernel



K

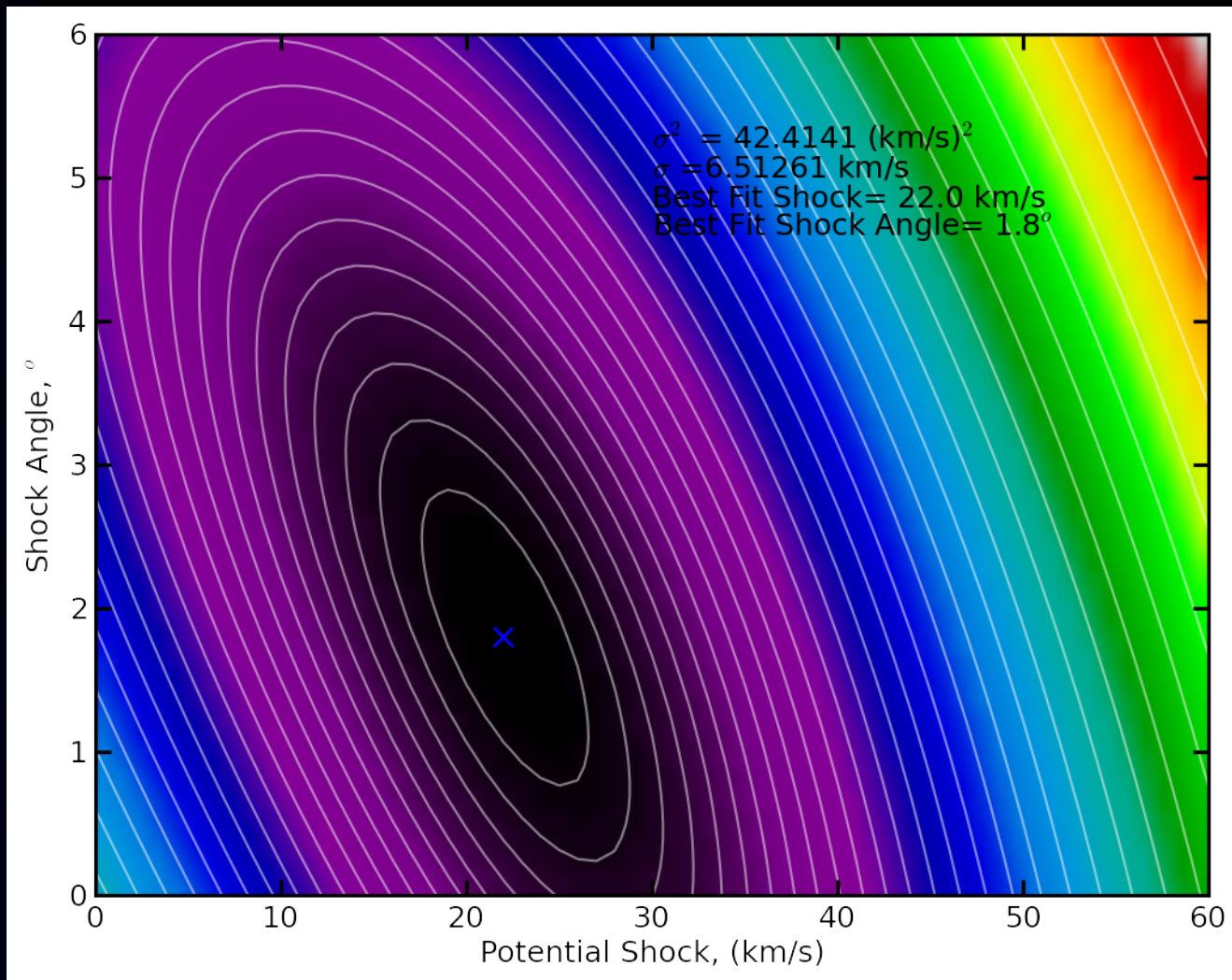
# Gas > Clouds > Stars



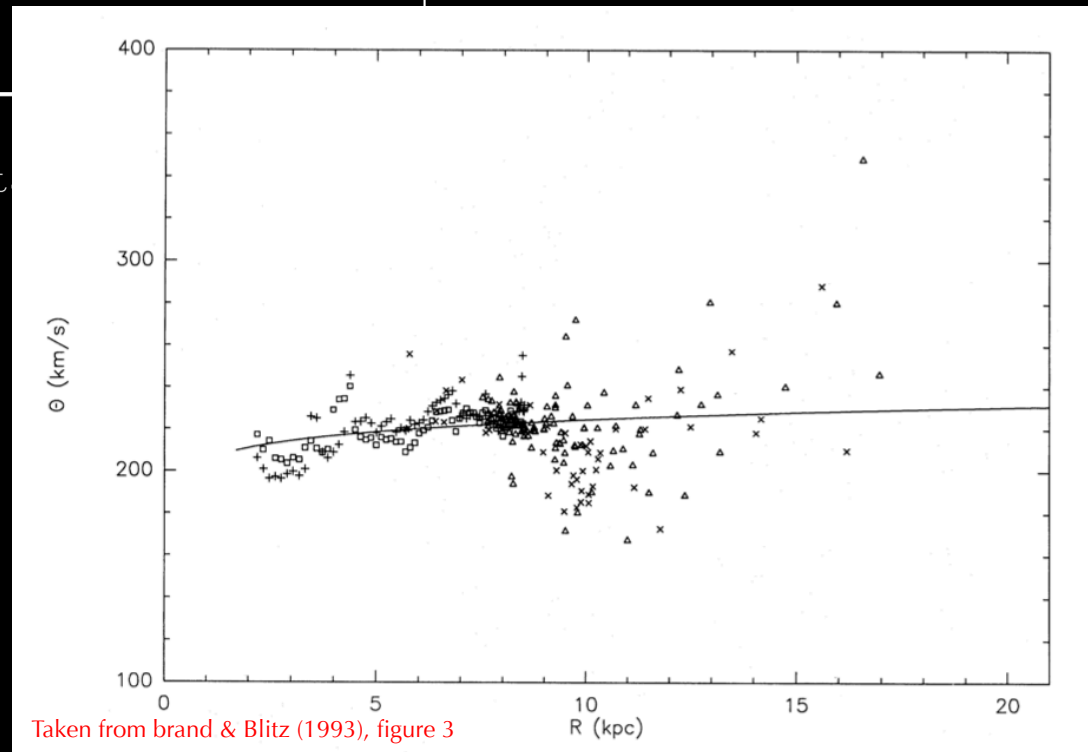
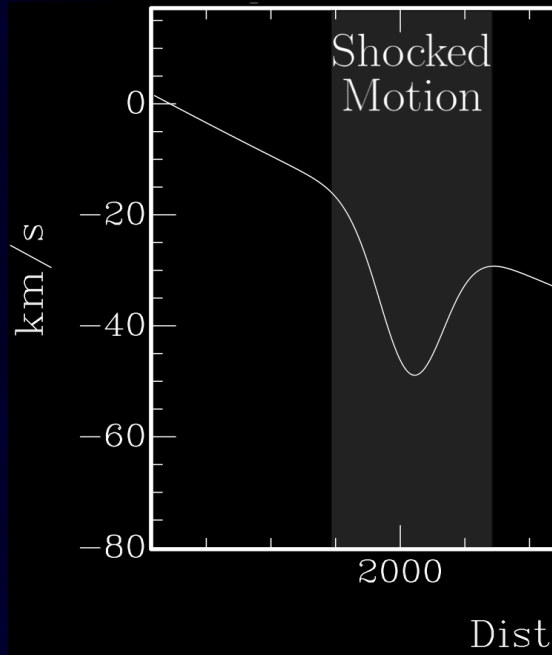
Movie credit : Claire Dobbs

Lee J. Summers

# Analysis – Error Ellipse

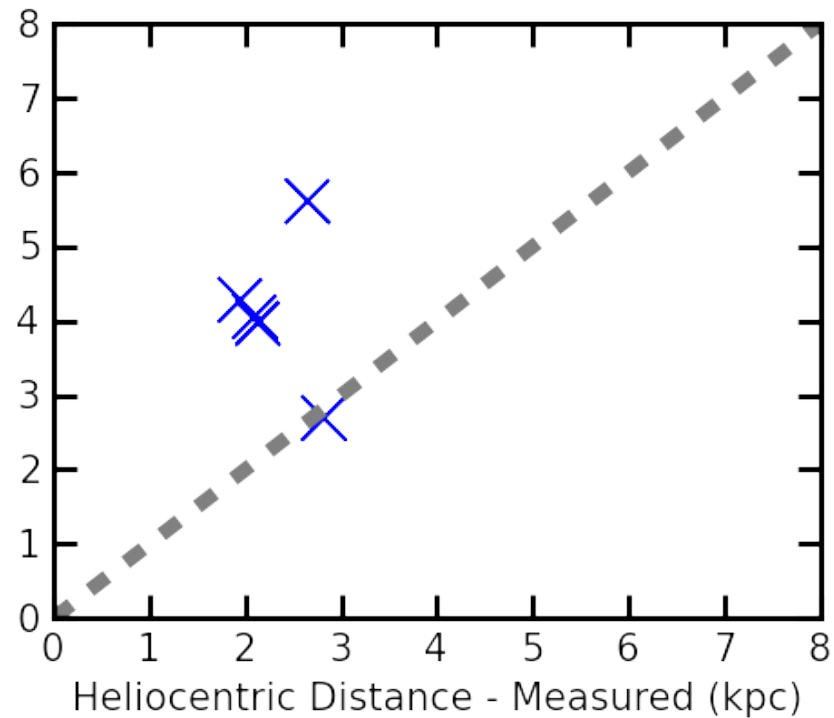
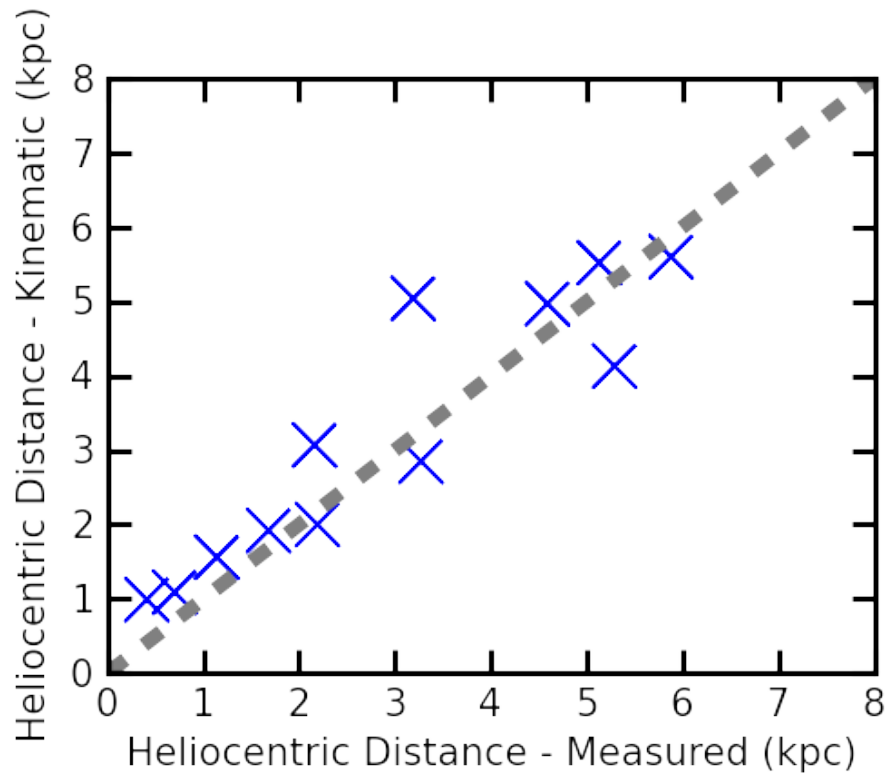


# Circular vs Shocked Motion



Taken from brand & Blitz (1993), figure 3

# Correcting Distance



# Correcting Distance

