The 3D Distribution of the Molecular Clouds in the Galactic Centre

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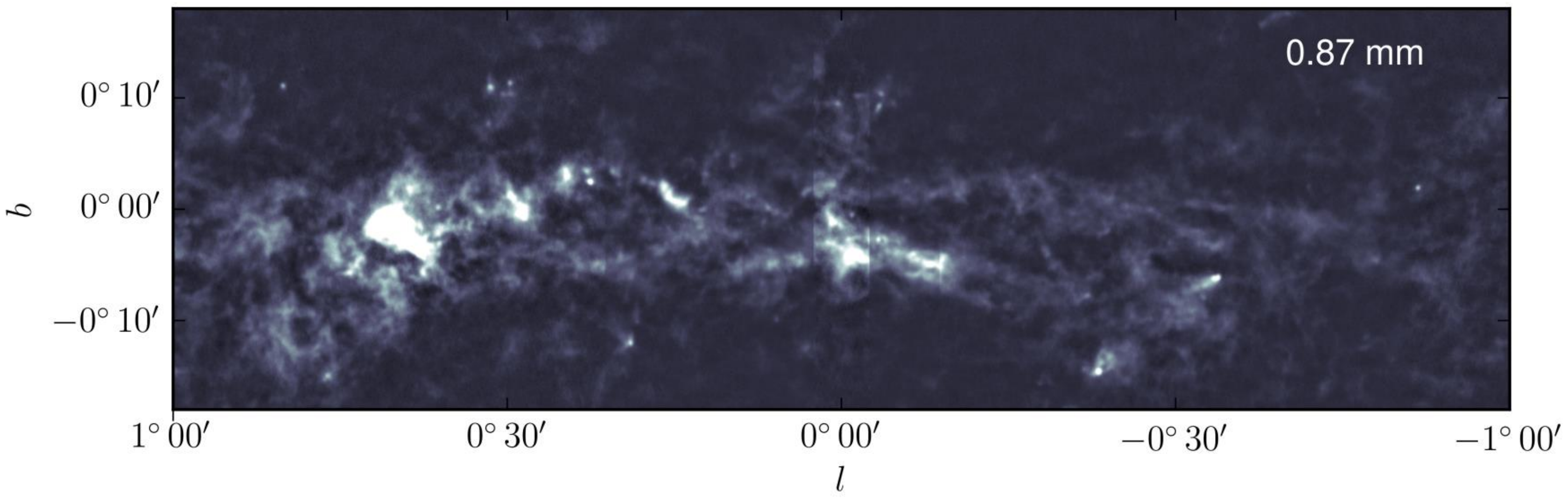
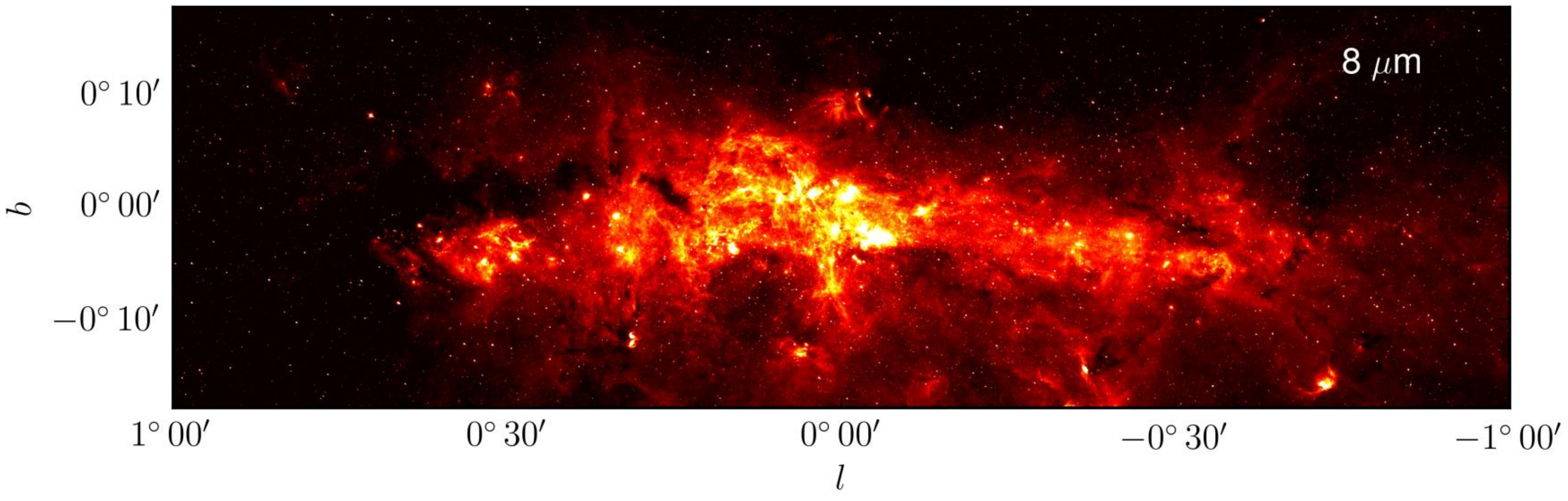
The Central Molecular Zone



ATLASGAL

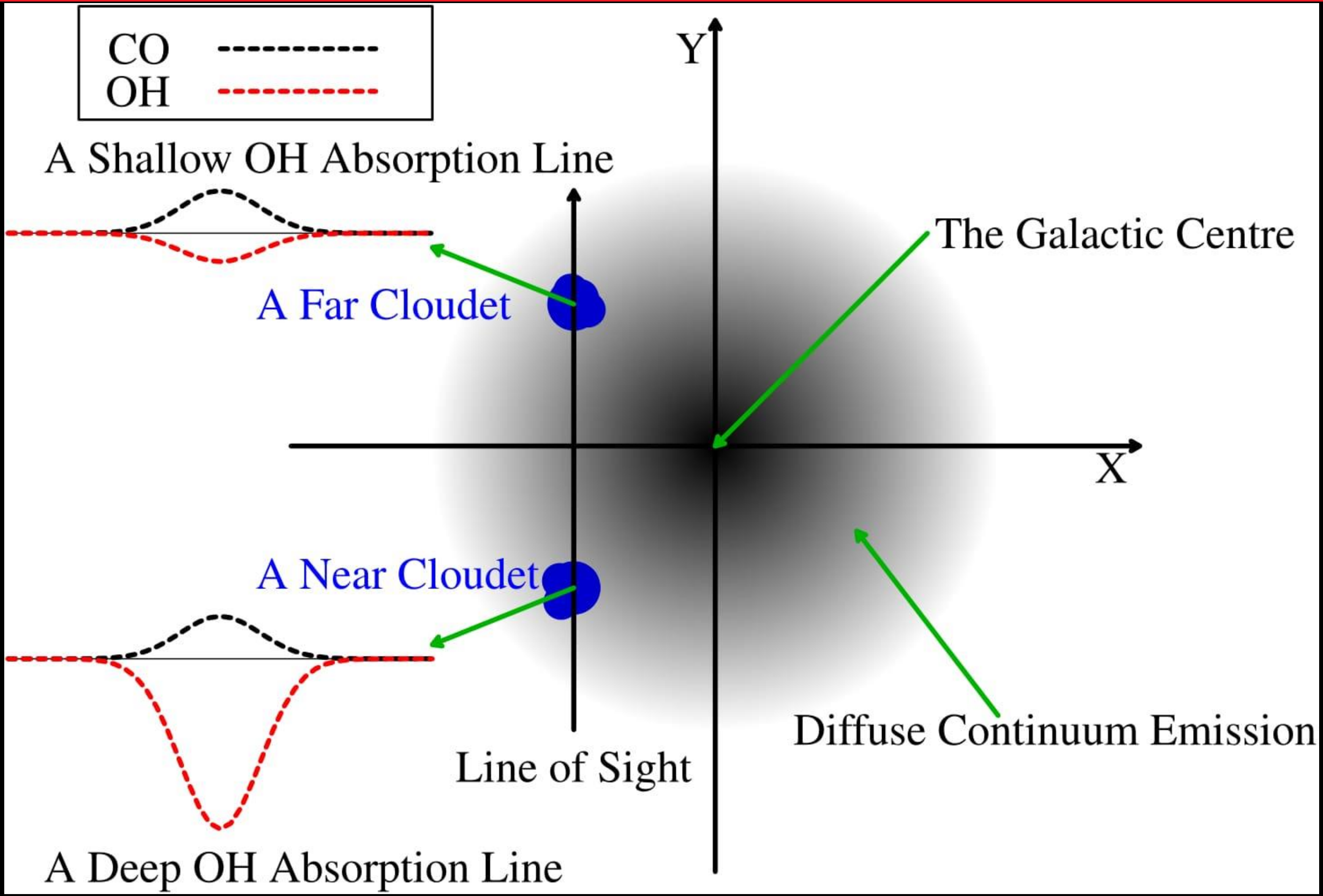


GLIMPSE

The Principle of Deriving a 3D Structure

Continuum behind clouds

$T_c = ?$



Sawada et al. (2004)

The Principle of Deriving a 3D Structure

Excitation temperature: $T_{\mathrm{ex}} = 4\ \mathrm{K}$

?

$$T_{\mathrm{b}} = (T_{\mathrm{ex}} - T_{\mathrm{c}})(1 - e^{-\tau})$$

Brightness Temperature: Observable

Optical depth: $\tau = 0.15 \times T_{\mathrm{CO}}$

Sawada et al. (2004)

The Excitation Temperature

$$\frac{N_{\mathrm{upper}}}{N_{\mathrm{lower}}} = \frac{g_1}{g_3}\exp\left(-\frac{hv}{kT_{\mathrm{ex}}}\right)$$

$$T_{\mathrm{ex}} = T_{\mathrm{ex}}\left(N_{\mathrm{upper}}, N_{\mathrm{lower}}\right)$$

The excitation temperature is a function of column densities.

The Optical Depth

$$\tau_{\upsilon} = A \frac{c^3}{8\pi {\upsilon_0}^3} \frac{g_{\mathrm{upper}}}{g_{\mathrm{lower}}} N_{\mathrm{lower}} \left(1 - \exp\left(-\frac{h\upsilon}{kT_{\mathrm{ex}}}\right)\right) \phi_{\upsilon}$$

$$\tau_{\upsilon} = \tau_{\upsilon}\left(N_{\mathrm{upper}}, N_{\mathrm{lower}}\right)$$

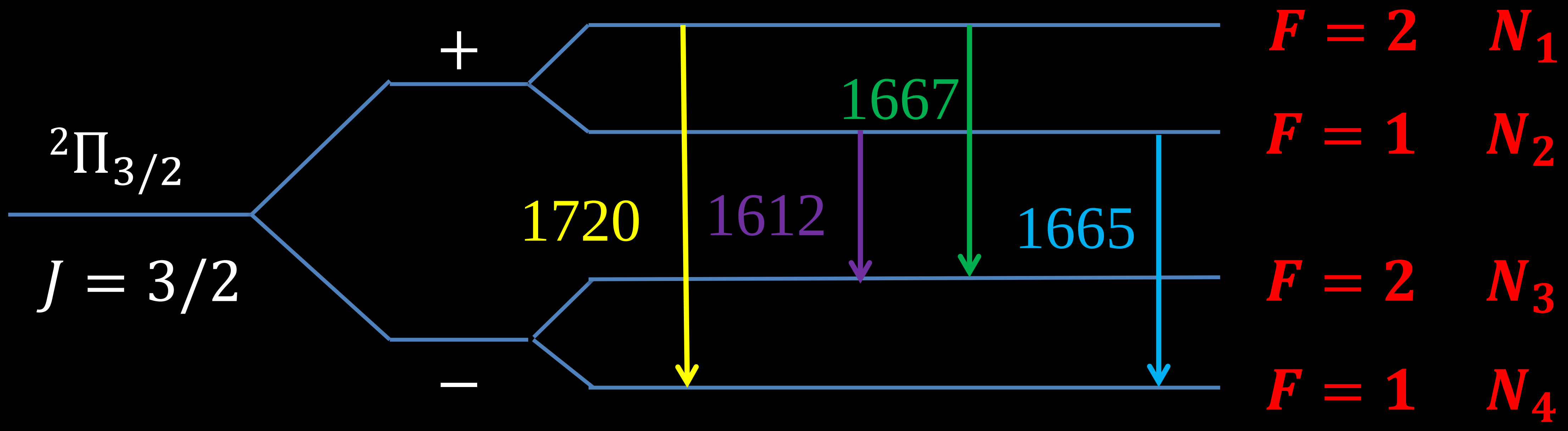
The optical depth is also a function of column densities.

Case of knowing background continuum

$$T_{\mathrm{b}} = \left(T_{\mathrm{ex}} - T_{\mathrm{c}}\right)\left(1 - e^{-\tau}\right)$$

The brightness temperature is a function of column densities.

OH Ground States



Observations of four lines can solve four column densities.

The Equations

$$T_{b1665} = \left(T_{ex\,1665}(N_2, N_4) - T_{c1665}\right)\left(1 - e^{-\tau_{v1665}(N_2, N_4)}\right)$$

$$T_{b1667} = \left(T_{ex\,1667}(N_1, N_3) - T_{c1667}\right)\left(1 - e^{-\tau_{v1667}(N_1, N_3)}\right)$$

$$T_{b1612} = \left(T_{ex\,1612}(N_2, N_3) - T_{c1612}\right)\left(1 - e^{-\tau_{v1612}(N_2, N_3)}\right)$$

$$T_{b1720} = \left(T_{ex\,1720}(N_1, N_4) - T_{c1720}\right)\left(1 - e^{-\tau_{v1720}(N_1, N_4)}\right)$$

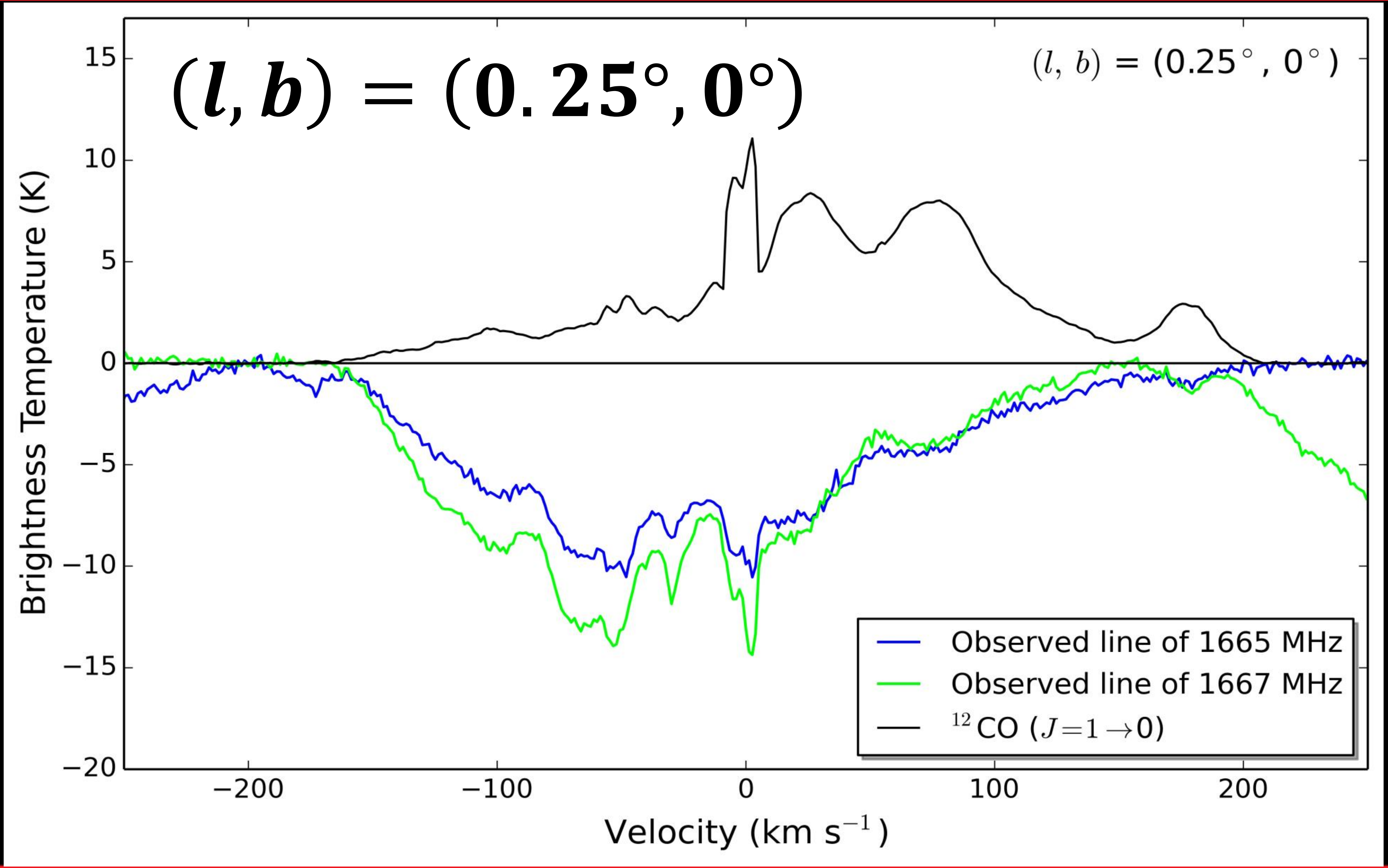
Background continuum

Case of the Galactic Centre

- $T_{\mathrm{b}} = (T_{\mathrm{ex}} - T_{\mathrm{c}})(1 - e^{-\tau})$
- 1665- and 1667-MHz lines blend together.

We need two more equations.

Case of the Galactic Centre



Assumption 1

The excitation temperatures of 1665- and 1667-MHz lines are equal.

$$T_{\mathrm{ex\,1665}} = T_{\mathrm{ex\,1667}}$$

Assumption 2

The column density of OH is proportional to the column density of ^{13}CO.

$$N_3+N_4=f \times T_{^{13}\mathrm{CO}}$$

$$4.7 \times 10^{18} \times [\frac{T_{\mathrm{co}}}{1\ \mathrm{K}}]\mathrm{m}^{-2}$$

Case of the Galactic Centre

$$T_{b1667} = (T_{ex\,1667}(N_1, N_3) - T_f T_{c1667})(1 - e^{-\tau_{v1667}(N_1, N_3)})$$

$$T_{b1612} = (T_{ex\,1612}(N_2, N_3) - T_f T_{c1612})(1 - e^{-\tau_{v1612}(N_2, N_3)})$$

$$T_{b1720} = (T_{ex\,1720}(N_1, N_4) - T_f T_{c1720})(1 - e^{-\tau_{v1720}(N_1, N_4)})$$

$$\frac{hv_{1665}/k}{\ln(N_4) - \ln(N_2)} = \frac{hv_{1667}/k}{\ln(N_3) - \ln(N_1)}$$

Fraction of continuum behind molecular clouds.

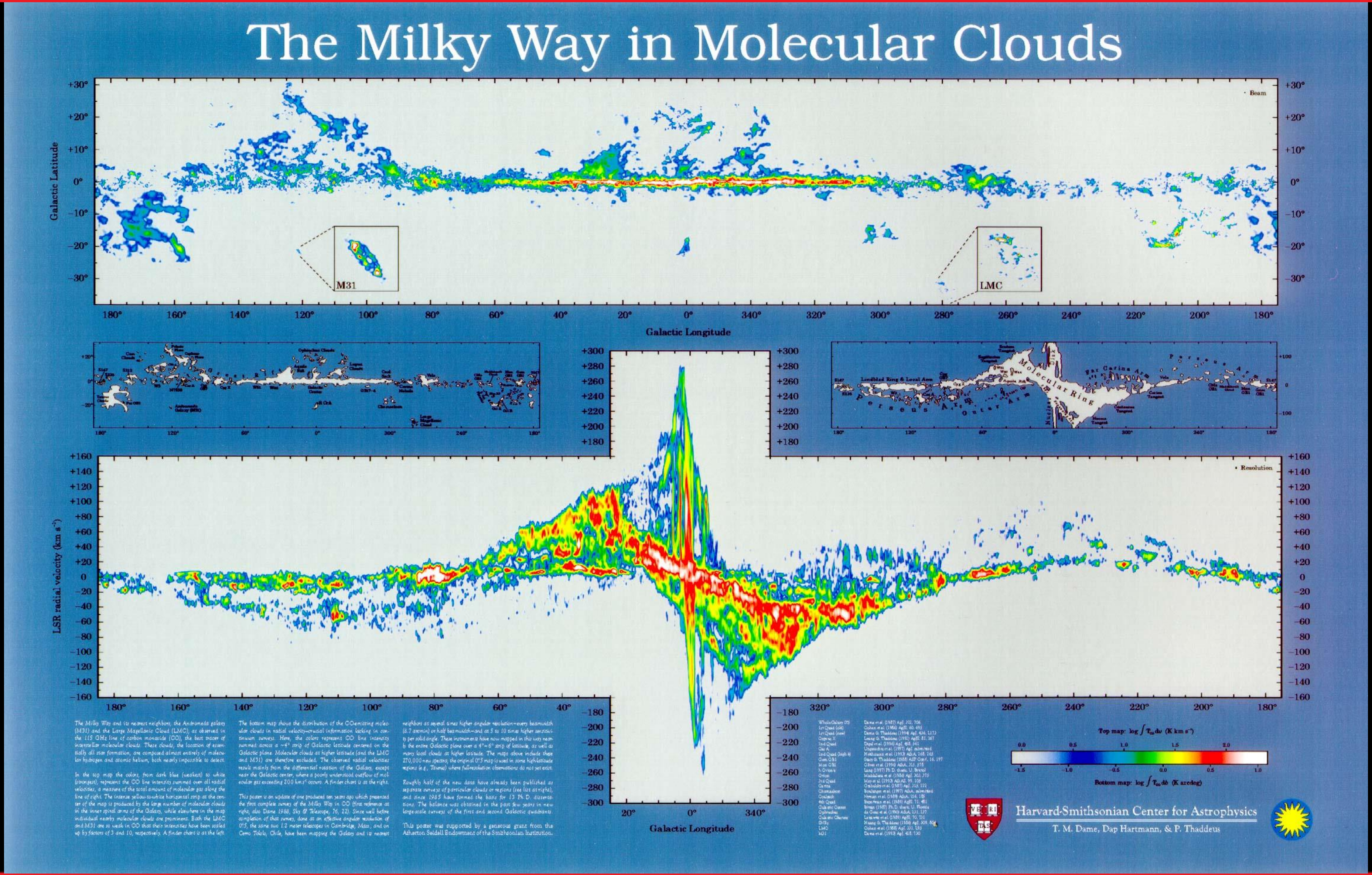
$$N_3 + N_4 = f \times T_{co}$$

OH Data (SPLASH, Dawson et al. (2014))

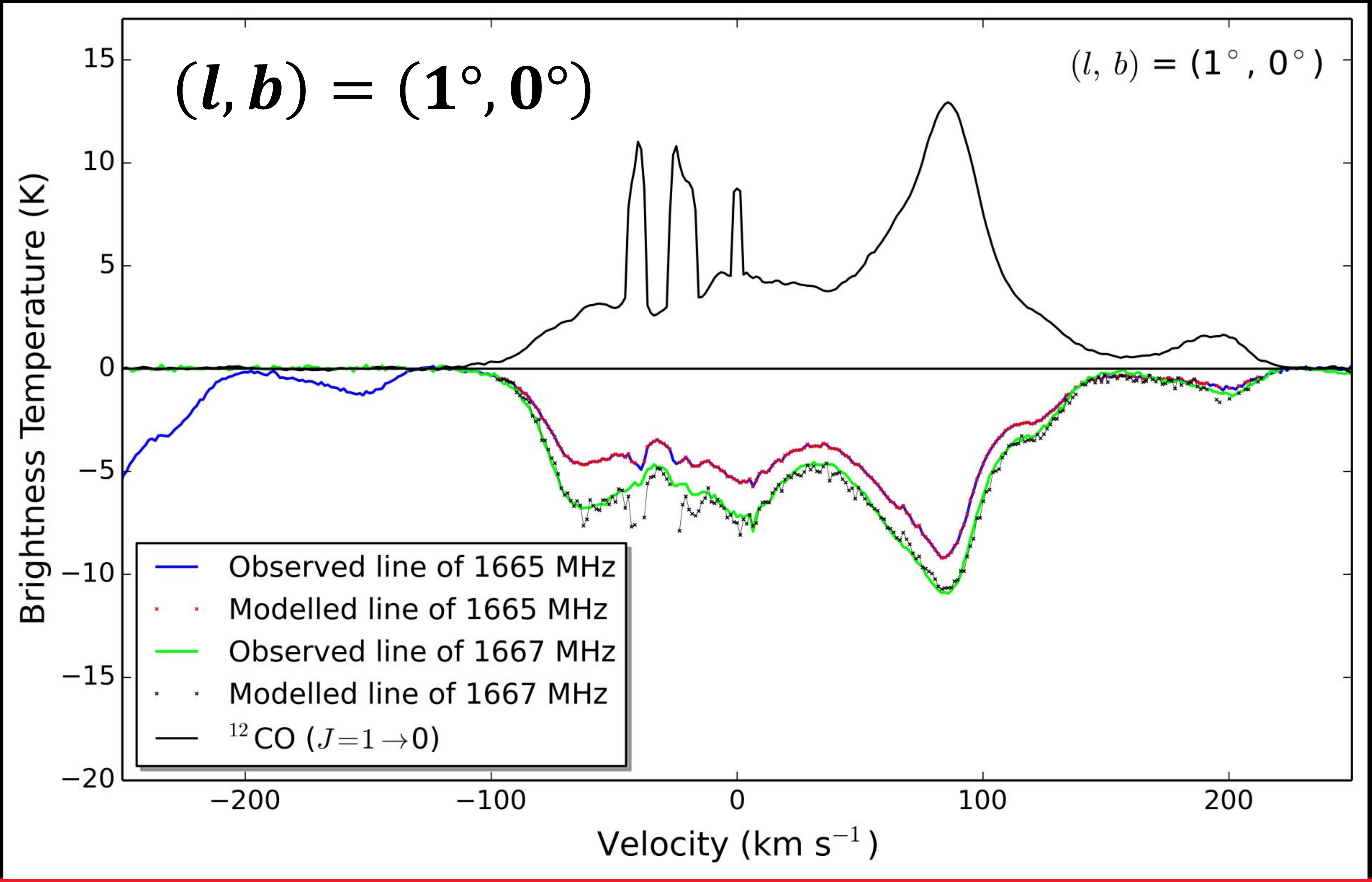
Parkes
64m

CO Data (Dame et al. (2001))

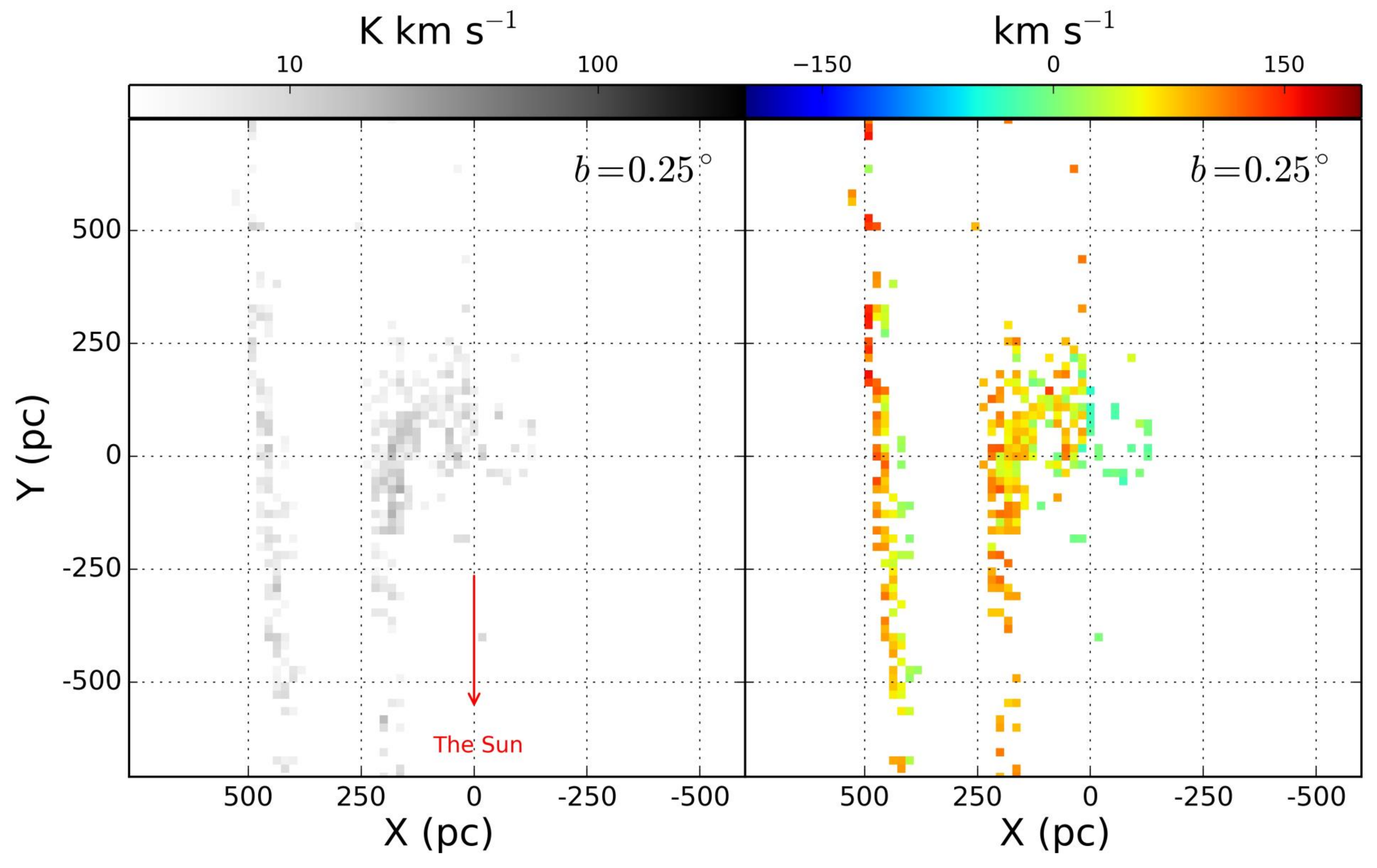
CfA
1.2m



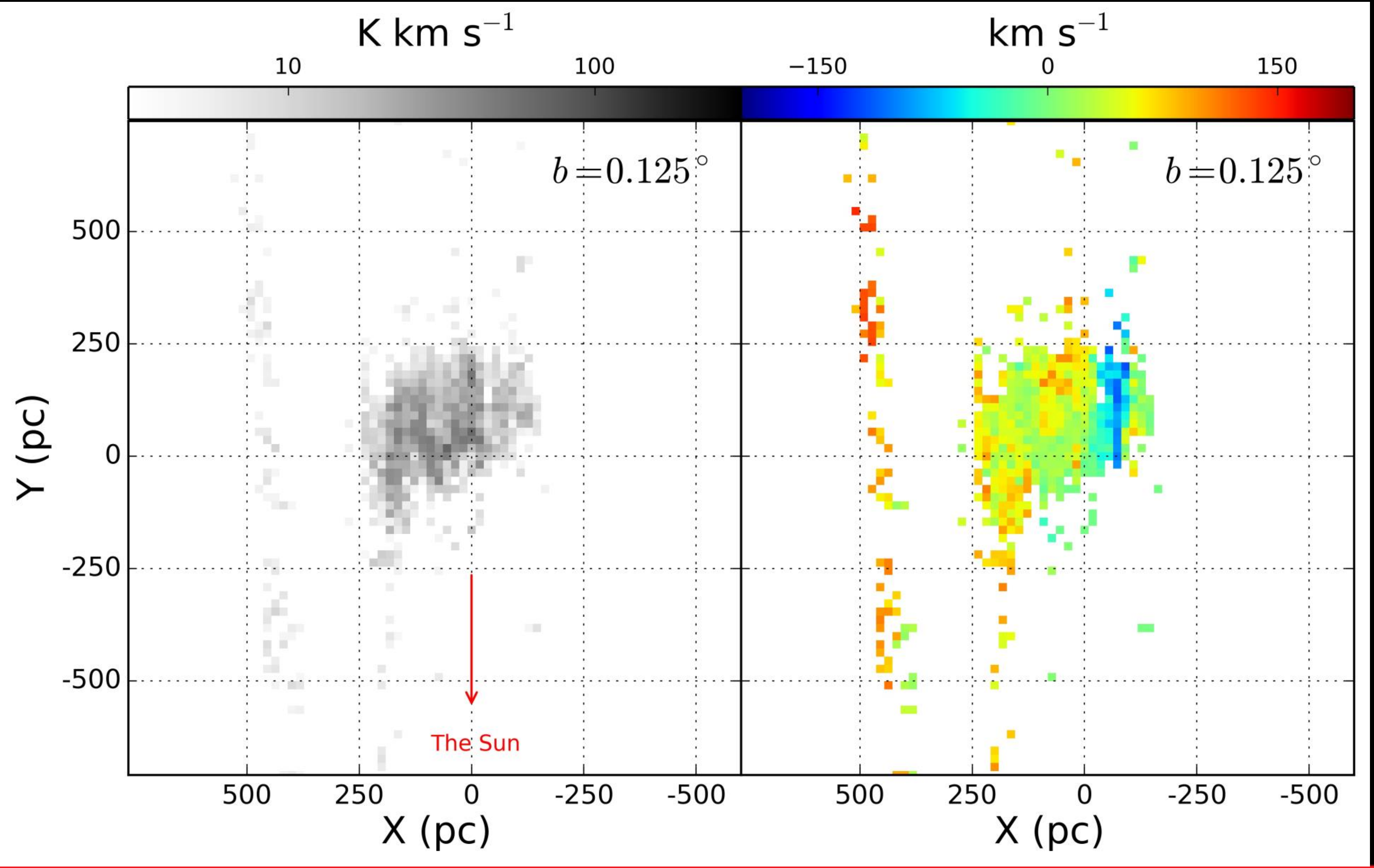
Testing the method



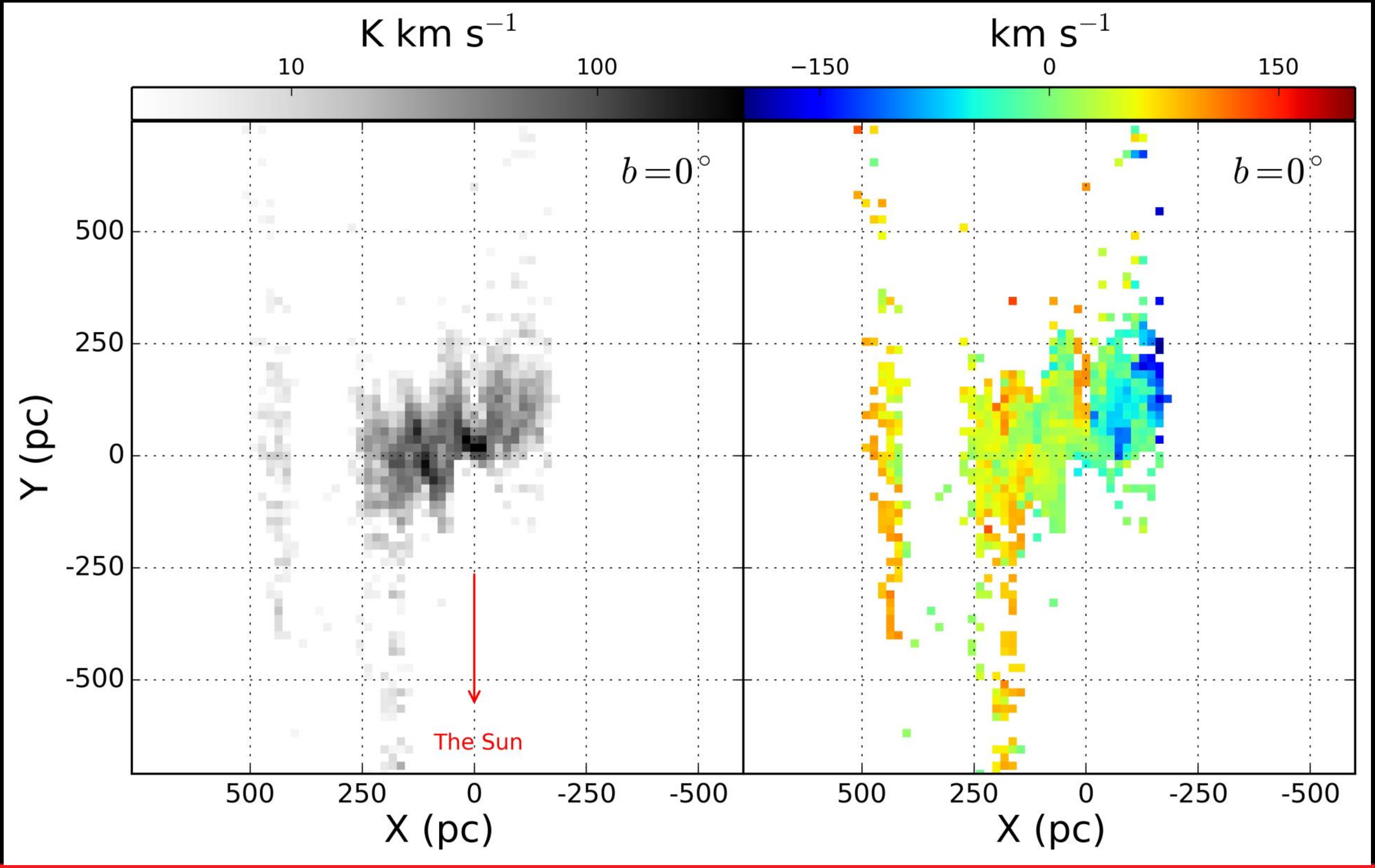
Face-On View (b = 0.25°)



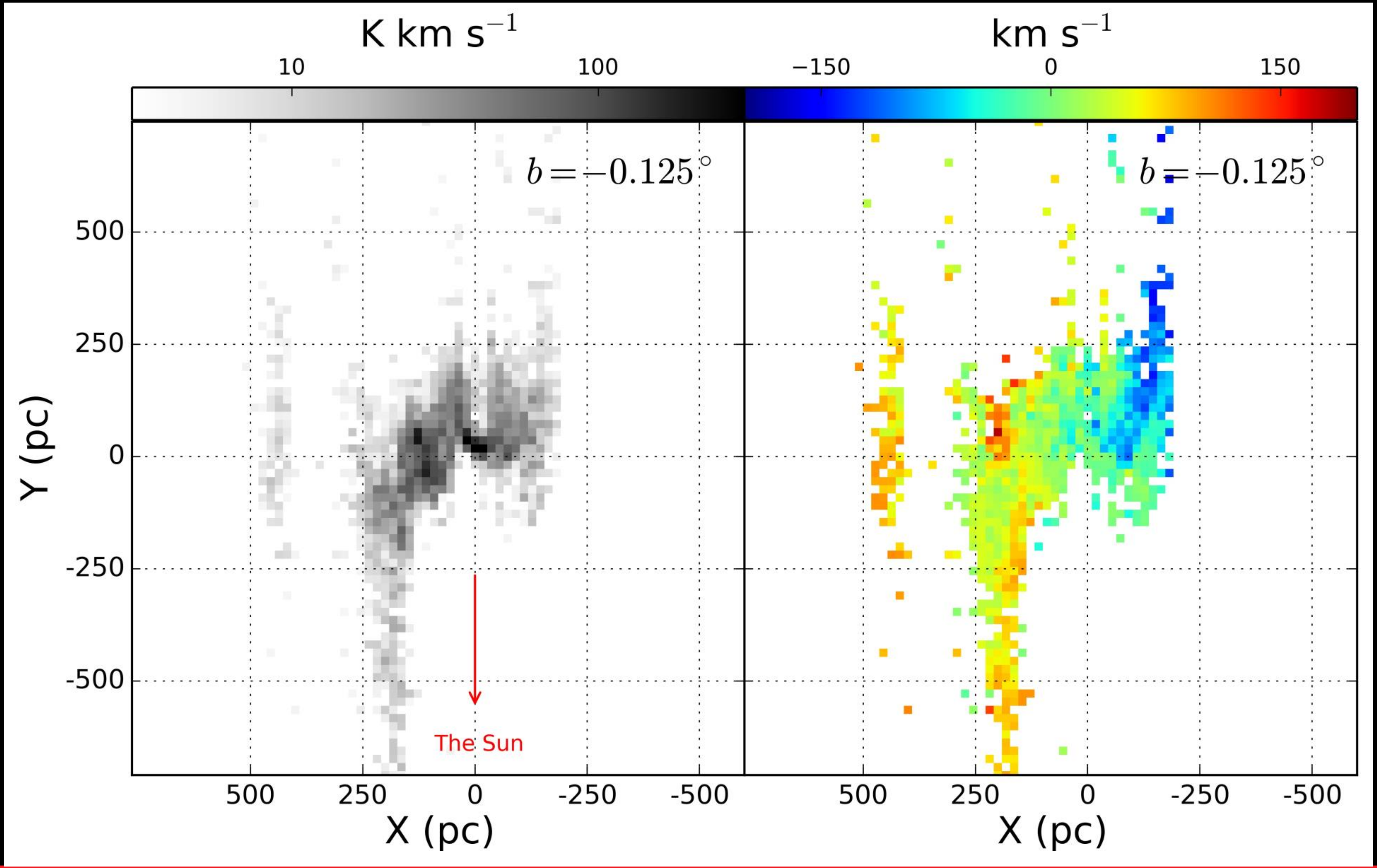
Face-On View (b = 0.125°)



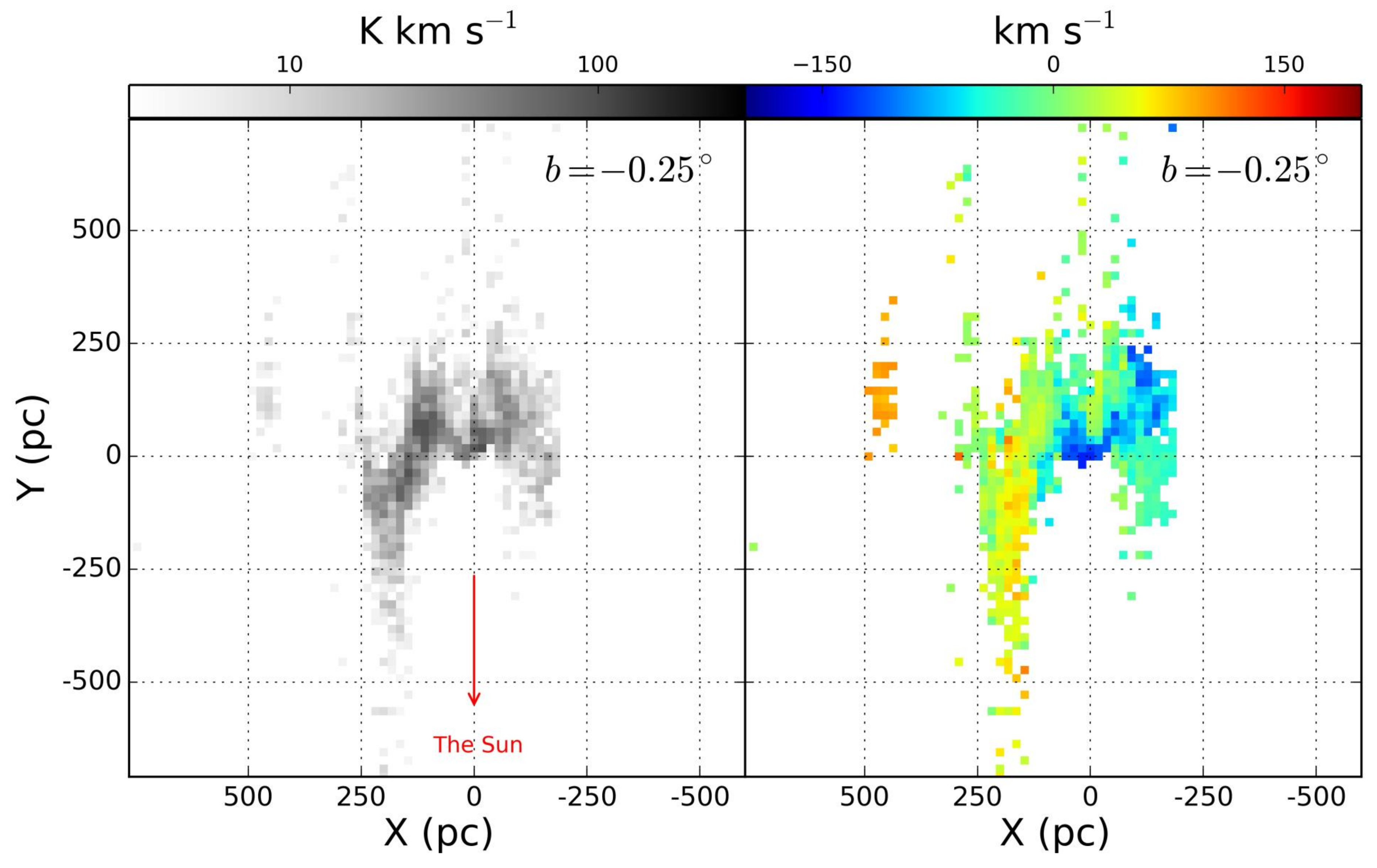
Face-On View (b = 0°)



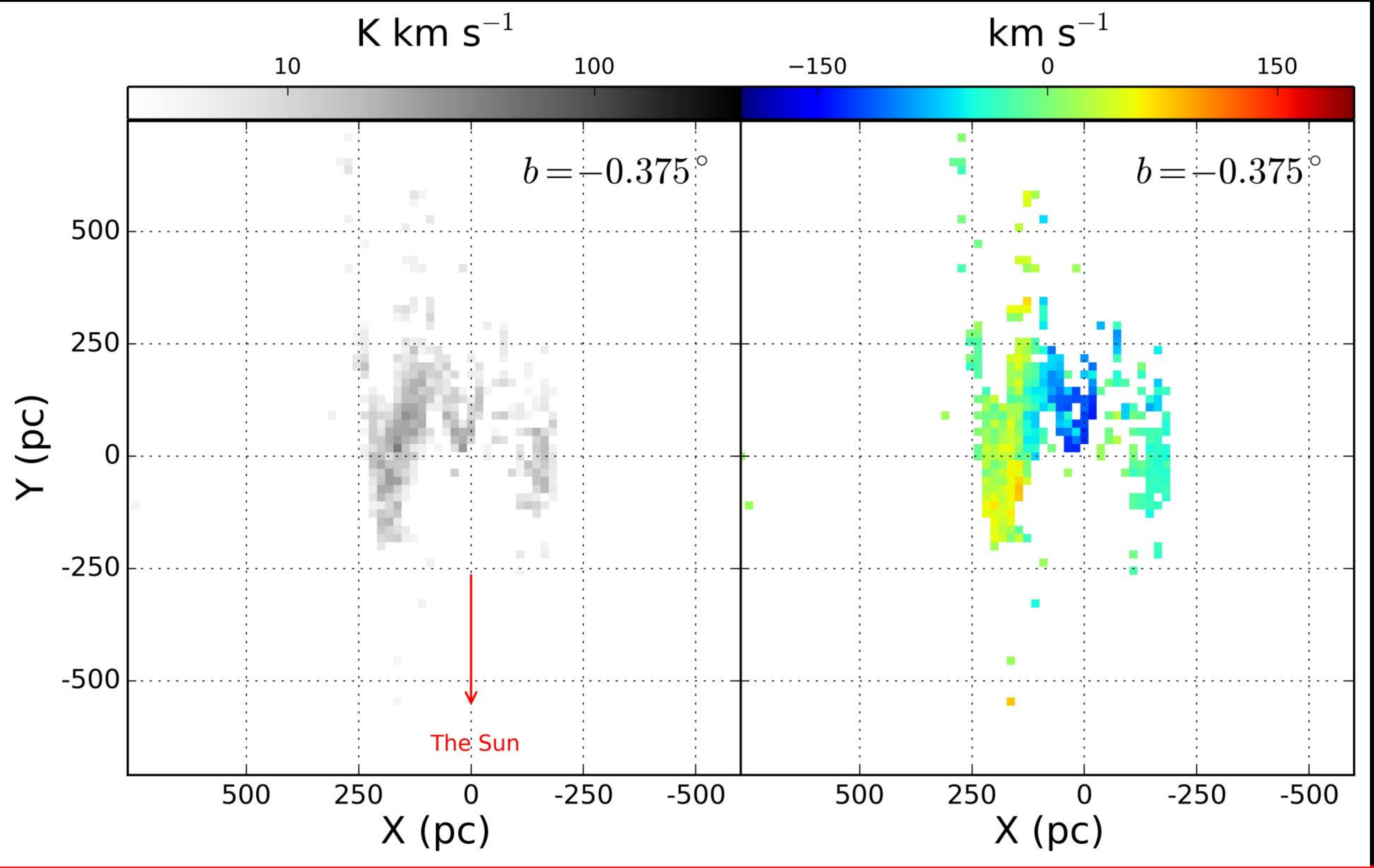
Face-On View (*b* = -0.125°)



Face-On View (b = -0.25°)



Face-On View (*b* = -0.375°)



Future studies

- **We have observed the OH spectral lines towards the CMZ with VLA.**

- **The data reduction of CO (Mopra) is ongoing.**

Summary

- **We found a new method of calculating OH column densities.**
- **We have derived a three-dimensional structure of the molecular clouds in the Galactic Centre.**