CCAT-prime Galactic Disk Mapping

Simulation of the line emission from the Milky Way

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Introduction

Photon-dominated Regions (PDRs) are dominated energetically and chemically by the FUV radiation from nearby massive stars.
The KOSMA-τ model solves the thermal and chemical balance as well as the radiative transfer for a finite, spherical clumps.
Since the clouds in star forming regions follow a mass spectrum which can be best described by a power law, this offers the unique possibility to model complicated 3D geometry by composing clouds from ensembles of many different clumps. This extension is done in the KOSMA-τ 3D code.

Our KOSMA-τ 3D setup includes:

- 191 chemical species, including ([CI], [CII], CO, O and isotopologues), chemical rates from UDfA12
- Dust emission between 0.001 to 3100 micron
- Full line and continuum radiative transfer
- Dust distribution according to Weingartner & Draine (2001)

Model parameters - setting up the Model

We model the molecular gas in the Milky Way (MW). Its properties are as described as followed:

- Mass distribution over the MW follows Wolfire et al. (2003).
- Mass spectrum of the clumps: 0.01 to 100 M_o with $dN/dM \sim M^{-1.84}$.
- Systematic velocity follows M. J. Reid et. al. (2009).
- Velocity dispersion inside a volume element is added up from the internal velocity of single clumps by turbulence and a systematic velocity caused by the apparent non resolved systematic velocity differences inside a volume element.

The FUV-field inside a volume element follows:

- Its radial distribution follows Popescu et. al. (2011).
- Its absolute values at a Galactic radius of 4.5kpc is varied between $10\chi_D$ and $100\chi_D$.
  - The FUV-field is dominated by OB stars close to PDR clouds. The clouds are on average closer to young stars than what would follow from an equal distribution over the whole Milky Way. Therefore the FUV-flux is higher than the $1\chi_D$ at solar radius.

A second medium represents the more diffuse mass further away from the FUV sources. It is irradiated by a low FUV-fluxes of about $1\chi_{D,}$ has a low density, and is represented by very small clumps.

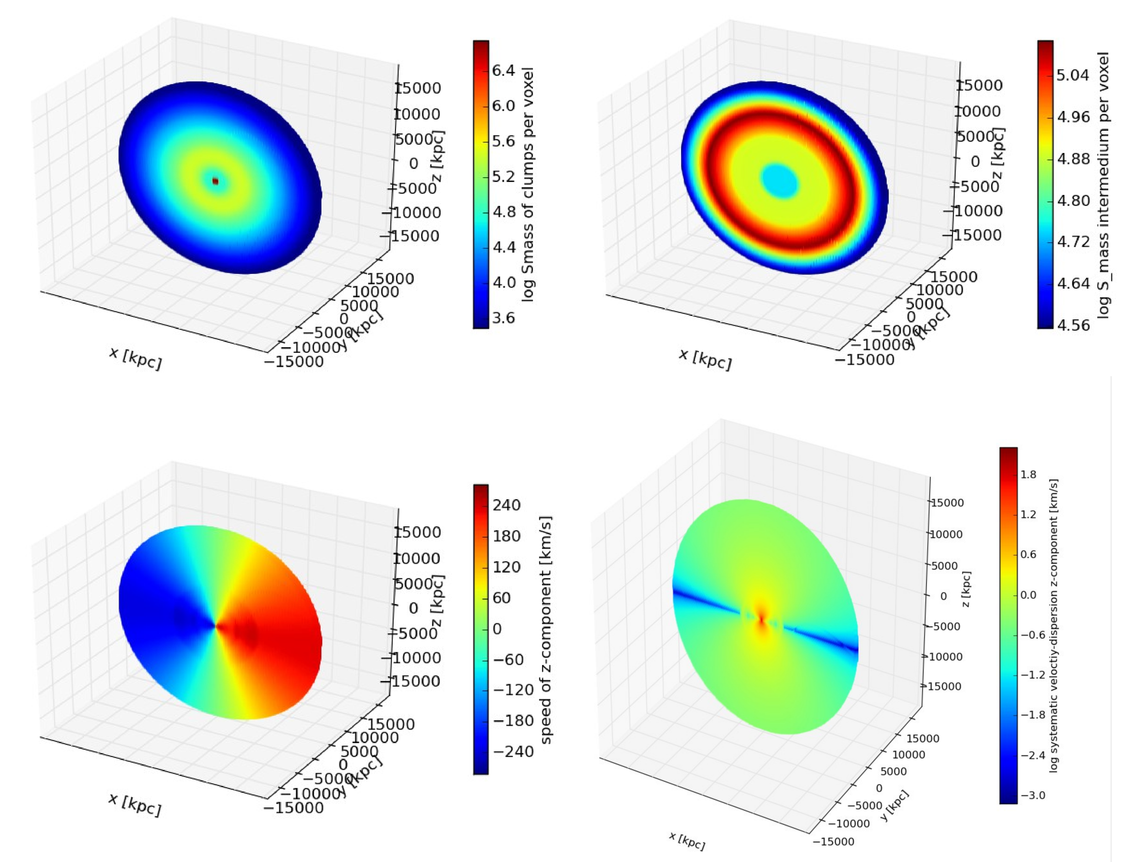

FIGURE 1: Mass distribution, in Galactic model representing molecular (top left) and atomic (top right), used for the simulation and apparent velocity (down left) and its dispersion (down right)

Results

As a first test we compare our results to Dame et. al. (2000, Fig.2) and Fixsen et. al. (1999, Fig.3).
The position-velocity diagram of CO 1-0 fits quite well. (Though the mass input is radial symmetric with no bar and arm structure) We see high intensity with high velocity dispersion in the galactic center, the molecular ring from about -50° to 50° and the arc of the outer regions.

The first media dominates the [CII] fluxes while the second dominates dust emission and its temperature in the outer parts of the MW.
We find that without the second medium the average dust temperatures are too high with 26K-30K for FUV fluxes of $10\chi_D$-$100\chi_D$. This is in contrast to Schlegel et. al. (1998) with dust temperatures in the range of 16K-20K. The second less irradiated medium provide temperatures of about 16K-17K.

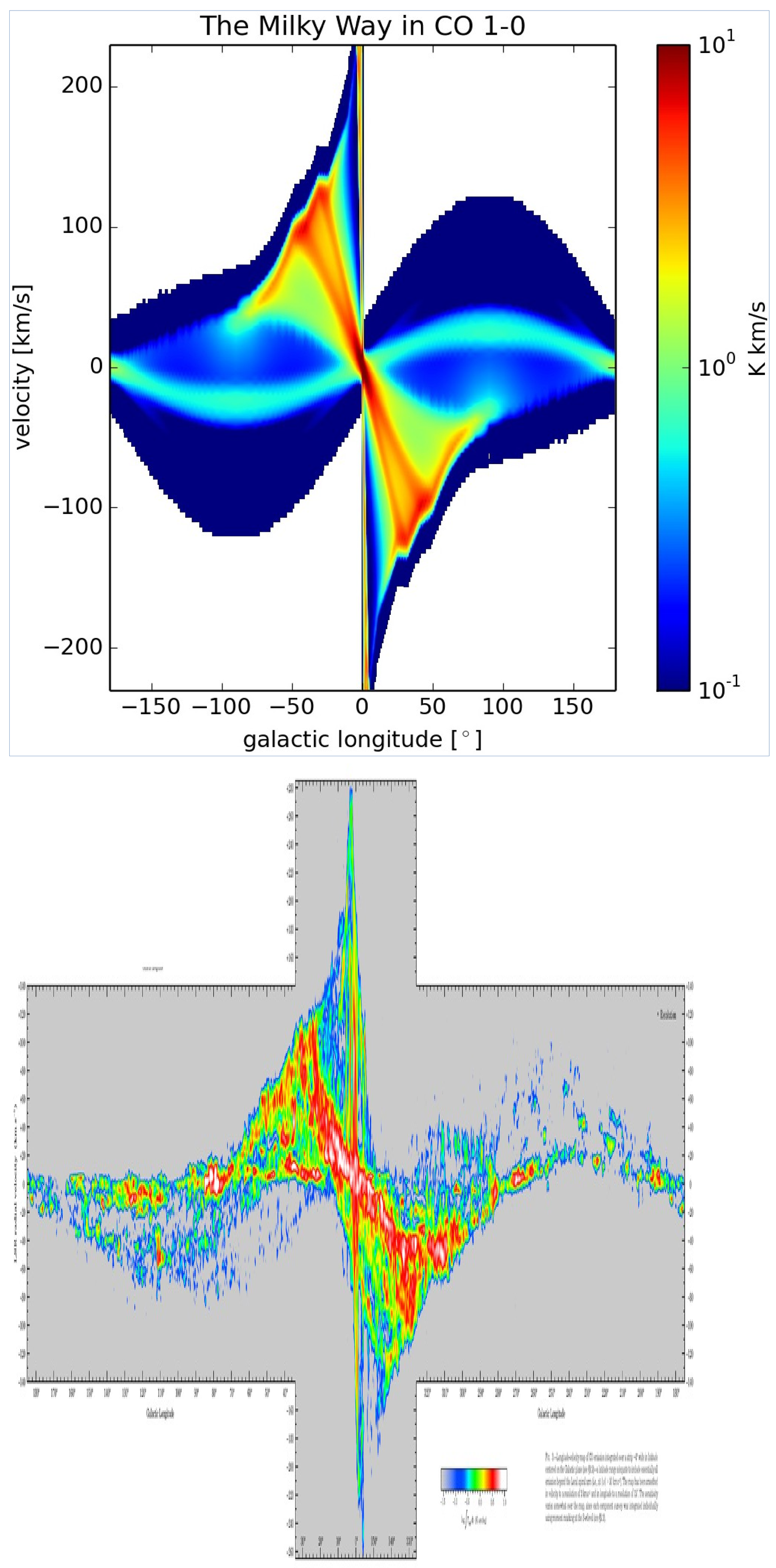

FIGURE 2: The best fit of the MW model in CO 1-0 (top) compared to "The Milky Way in Molecular Clouds" Dame et. al. (2000) (bottom)

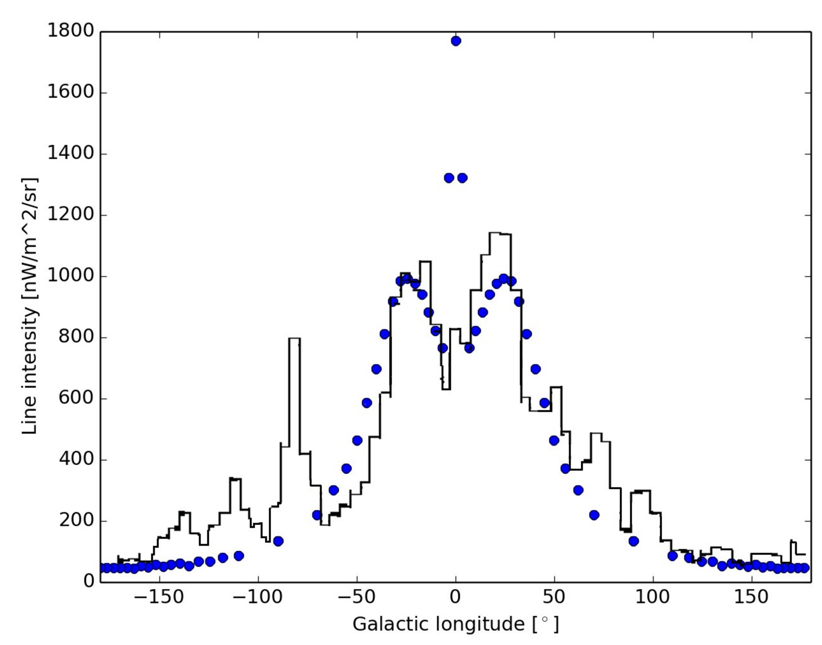

FIGURE 3: Integrated line of C[II] of best MW fit model (blue), with Kobe data (black)

With the KOSMA-τ 3D code we are able to build up a self consistent PDR model of the MW and reproduce several important line emissions.

Predictions for CCAT-prime: CI and CO line emission and observability

We calculate if CCAT-prime will be able to resolve them in a way to confirm our results.
The model provides the flowing predictions for these lines observable by CCAT-prime:

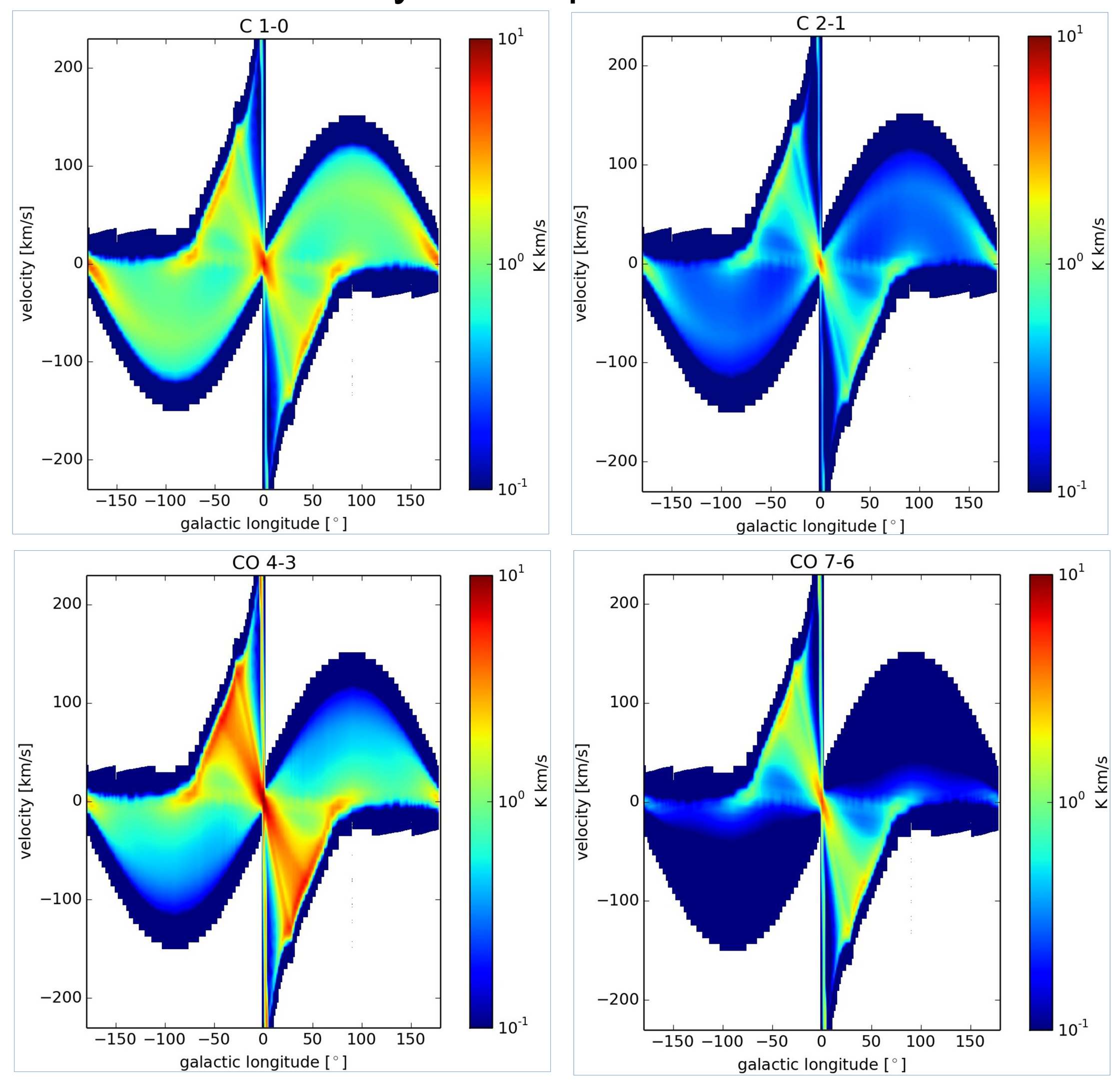

FIGURE 4: Integrated lines of the MW model. CO 4-3 and CO 7-6 lines and the two [CI] lines.

We plot several spectra at different lines of sight and determine the lower limit for T_rms under which all details could be still resolved.
We use the following general parameter for estimating the observing time for CCAT-prime:

- median weather
- main-beam efficiency = 1
- forward beam efficiency = 1
- velocity channel width = 3km/s
- observing efficiency = 0.8
- observing time per day = 6h
- survey area = b±1°
- observable fraction of MW = 2/3
- elevation 42°

Line	T_rms [K]	obs. time [h]	obs. time [days]
CI 1-0	0.07	1621	270
CO 4-3	0.09	381	63
CI 2-1	0.05	27615	4602[1,2]
CO 7-6	0.04	47394	7899[1,2]

Table 1: Estimated time needed for a MW survey with sufficient velocity resolution and integration time to trace the line features of our MW model.

[1] Since CI 2-1 and CO 7-6 can be observed simultaneously only the higher number applies

[2] If we assume the best quartile of the weather the observing time drops by a factor of 3.6.

Conclusion

The CI 1-0 and the CO 4-3 lines can be surveyed over the hole MW with CCAT-prime within reasonable time. This will provide all details of the line profiles.
The CO 7-6 and CI 2-1 can be observed together due to their close frequency but require much more integration time. A full MW survey resolving all the details of the line profiles would take a prohibitive amount of time. The time can be reduced by mapping only parts of the MW, lowering the velocity resolution, sacrificing some signal to noise, or only observing during good weather conditions.