A 3D model for CO emission

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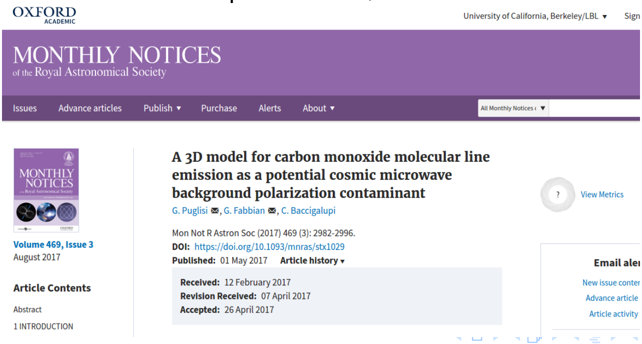

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Abstract

1 INTRODUCTION

A 3D model for carbon monoxide molecular line emission as a potential cosmic microwave background polarization contaminant

G. Puglisi, G. Fabbian, C. Baccigalupi

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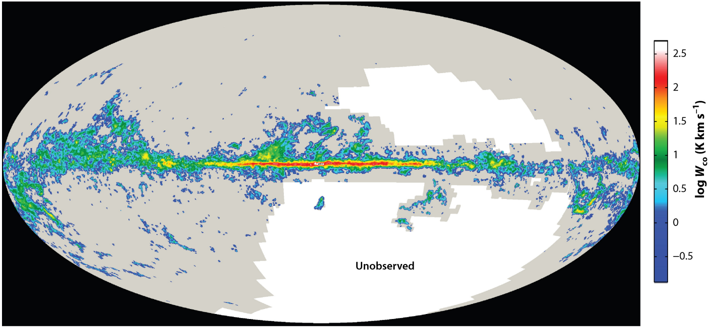
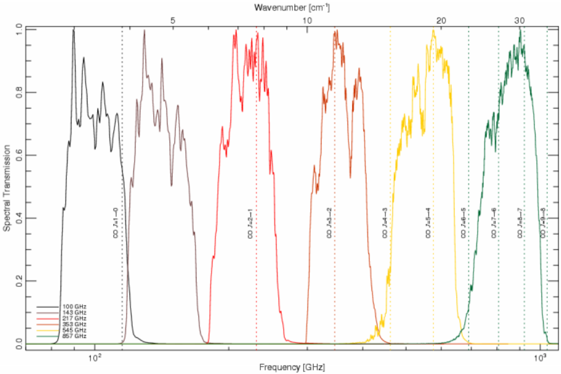
State of the art of CO survey



Heyer M, Dame TM. 2015.
Annu. Rev. Astron. Astrophys. 53:583–629

Assessing "potential" CO contamination

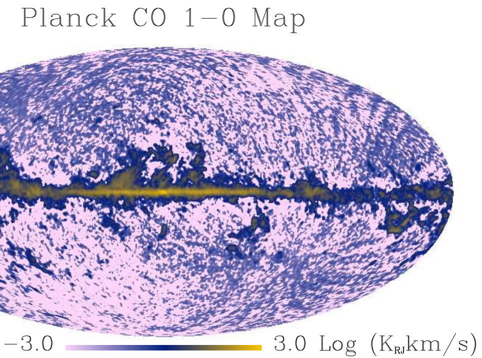
The first rotational lines coming from the monoxide carbonate (CO): $J = 1-0, 2-1, 3-2$ fall in the CMB frequency bands!



Analysis with Planck CO$1-0$ map

At $|b| < 30°$: the map is signal dominated;

At $|b| > 30°$: few regions with S/N>1, extremely dominated by the Planck noise;



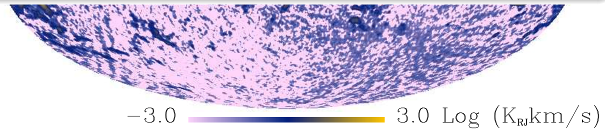
Analysis with Planck CO$1-0$ map

At $|b| < 30°$: the map is signal dominated;

At $|b| > 30°$: few regions with S/N>1, extremely dominated by the Planck noise;

Worries of Polarbear Collaboration:

To what extent a CO line should be avoided in designing the future Polarbear bands? Could an undetected CO cloud at high Galactic latitude mimic a Gravitational Wave signal B mode?



MCMOLE3D: *Digging into the Galaxy*

Monte-Carlo MOlecular Line Emissions 3D*is a `python` package which allows to draw a 3D model of molecular clouds distributed across the Milky Way via Monte-Carlo simulations, starting from some assumptions (Ellsworth-Bowers et al., 2015):

- molecular clouds: located in the Molecular Ring;
- $R < 3$ kpc: Molecular Central Zone
- The vertical profile (Bronfman et al., 1988);
- Size Distribution Function and Averaged Emissivity profile from Heyer and Dame (2015):

For further details see Puglisi et al. (2017)

*https://github.com/giuspugl/MCMole3D

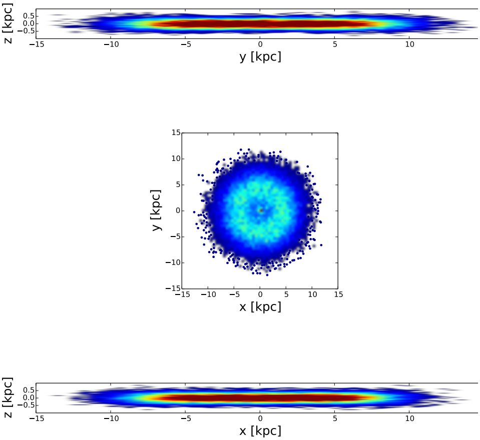
Parameters to the model

parameters to 1 MC simulation	
N_{clouds}	40,000(Ellsworth-Bowers et al., 2015)
R_{ring} [kpc]	5.3 (Ellsworth-Bowers et al., 2015)
L_{min} [pc]	0.3 (Roman-Duval et al., 2016)
L_{max} [pc]	60 (Roman-Duval et al., 2016)
$z_{1/2}$ [pc]	42.5 (Bronfman et al., 1988)
R_{bar} [kpc]	3 (Bobylev and Bajkova, 2013)
i [deg]	-13 (Davis et al., 2012)
ϵ_c $\left[\mathrm{K\,km\,s^{-1}}\right]$	240 (Heyer and Dame, 2015)
R_{em} [kpc]	6.6 (Ellsworth-Bowers et al., 2015)
$L_0{}^*$ [pc]	[5,50] Default: 20
$\sigma_{ring}{}^*$ [kpc]	[1,5] Default:2.5

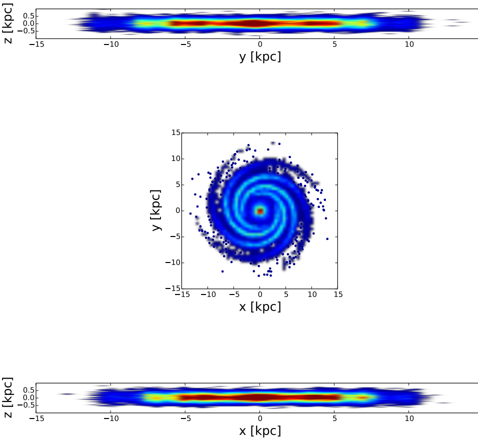
* Parameters allowed to range

Cloud geometrical distribution

Axisymmetric ring



4 Logspiral arms + bulge



Cloud geometrical distribution

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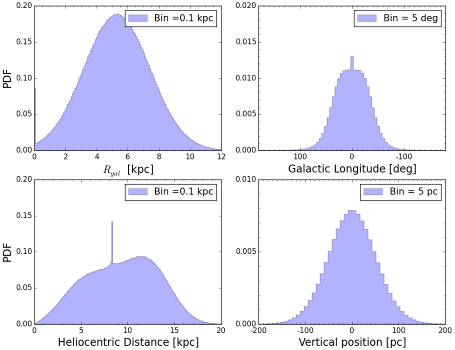
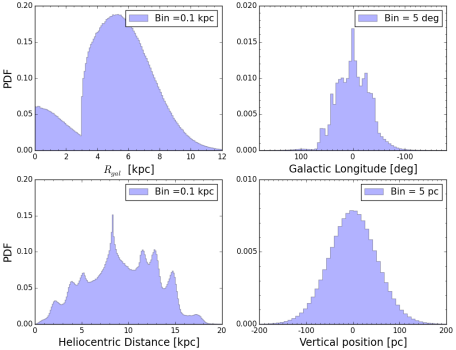


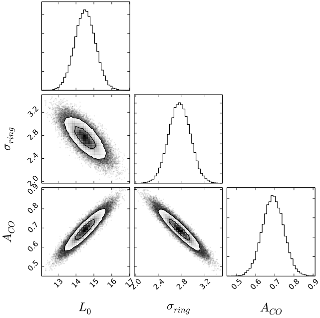
4 Logspiral arms + bulge

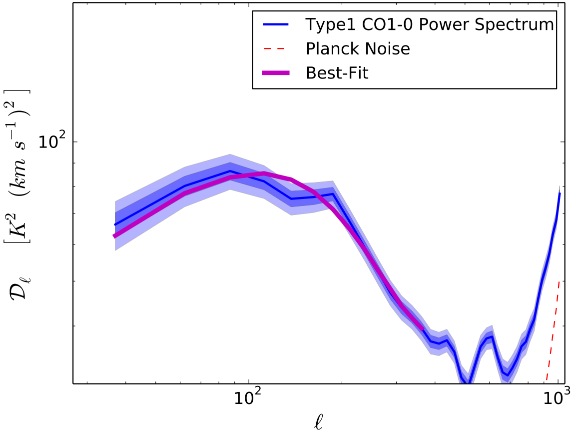


Best-fit on Planck CO map (@ $|b| < 30$ deg)

LogSpiral geometry Power-spectrum estimated via X2pure

$$L_0 = 14.50 \pm 0.58\,\mathrm{pc}$$
$$\sigma_{ring} = 2.76 \pm 0.19\,\mathrm{Kpc}$$
$$A_{CO} = 0.69 \pm 0.06$$
$$\tilde{\chi}^2 = 1.48$$
$$PTE = 0.13$$

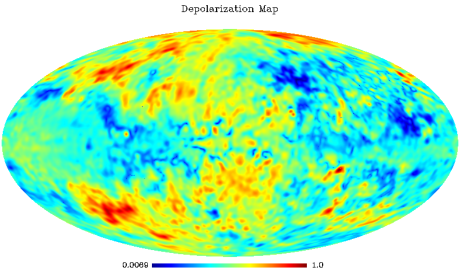


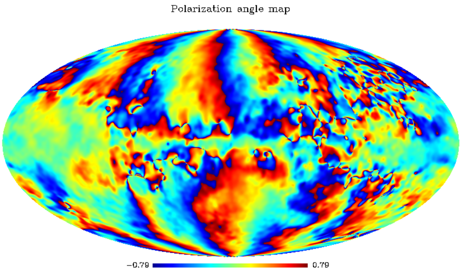


Polarization Forecasts @ high Galactic Latitudes (@$|b| > 30°$)

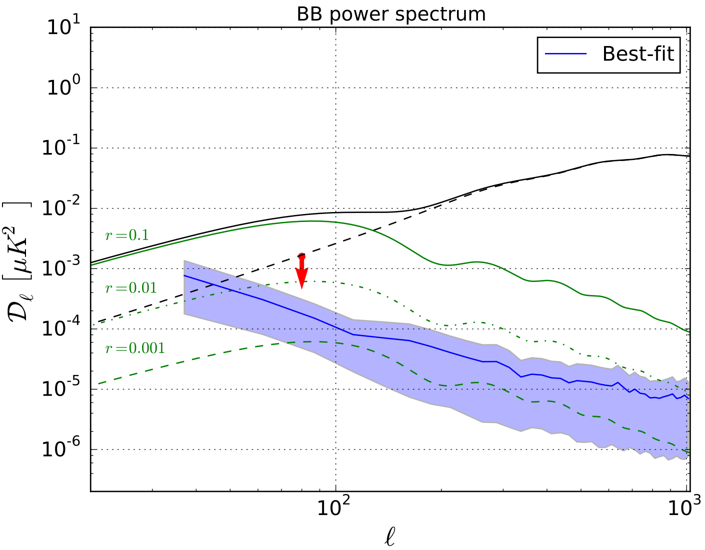
Compute Q and U maps from I ones (assuming $f = 1\%$) via:

$$Q(p) = I(p) f g(p) \cos(2\psi(p))$$
$$U(p) = I(p) f g(p) \sin(2\psi(p))$$





Polarization Forecasts @ high Galactic Latitudes ($|b| > 30°$)



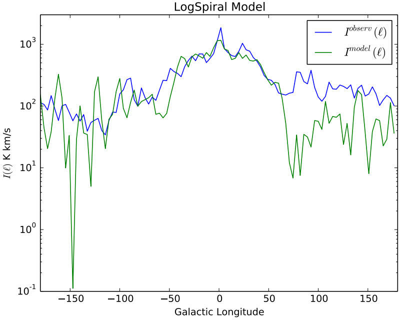
Summary

- the Axisymmetric geometry does not fit at all $\tilde{\chi}^2 = 7.3$
- we tested the model by considering only 2 parameters L_0 and σ_{ring};
- the bestfit values are within the *expected* ranges in the literature;
- `MCMole3D`reproduces well the observations at low Galactic latitudes and the power spectrum at high latitudes
- forecast on the expected level of CO contamination in B-modes $\ell \sim 80$:

$$r \lesssim 0.025$$

Future Outlooks

Constrained realizations: including Taurus, Orion, Cygnus cloud complexes
w/o Cyg X1 complex



Future Outlooks

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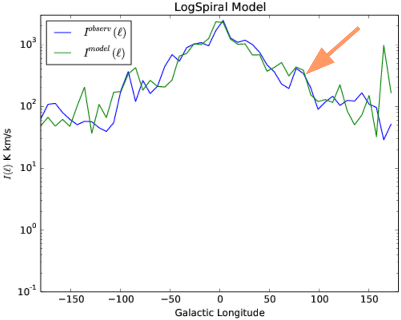

Future Outlooks

Constrained realizations: including Taurus, Orion, Cygnus cloud complexes
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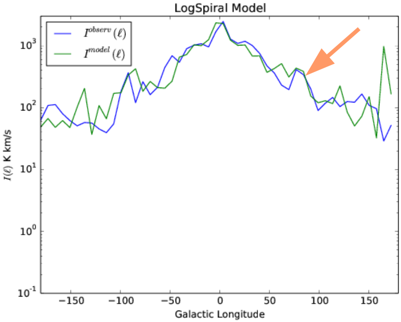


- Consider elliptical clouds: may effect the estimation at small scales;
- the vertical profile parameters $z_0, z_{1/2}$ may shape power spectrum,

backup slides

Best-fit on Planck CO map (@ $|b| < 30$ deg)

Axisymmetric geometry Power-spectrum estimated via X2pure

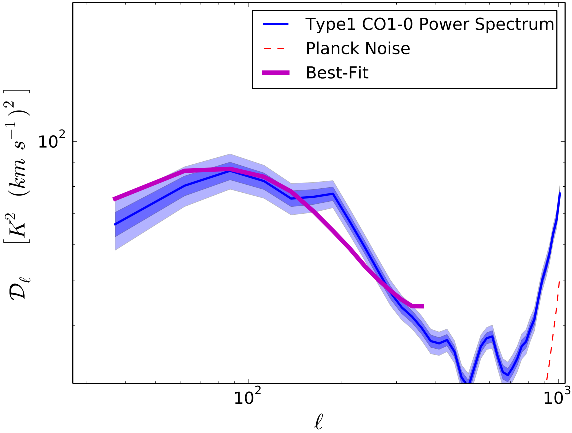
$L_0 = 19.50 \pm 12.7\,\mathrm{pc}$

$\sigma_{ring} = 2.1 \pm 0.2\,\mathrm{Kpc}$

$A_{CO} = 1.0 \pm 0.1$

$\tilde{\chi}^2 = 7.4$

$PTE = 0.00$

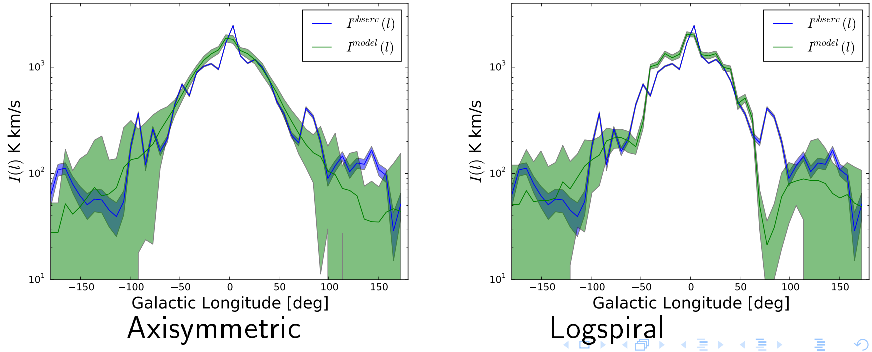


Comparison with Planck observations

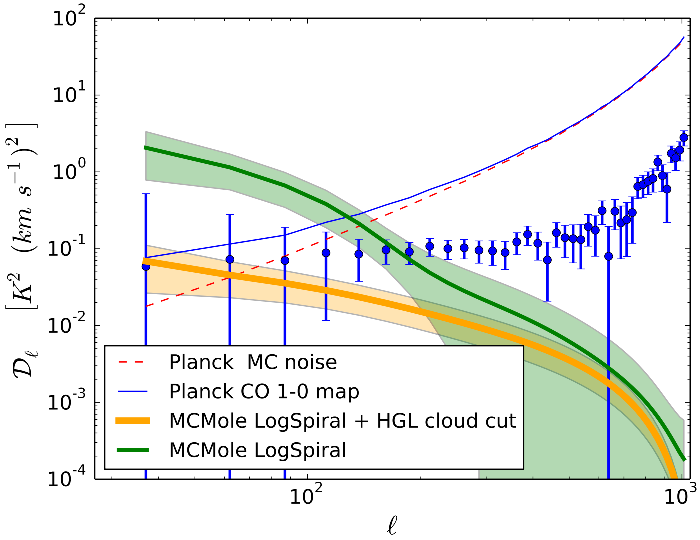
- Compute $I(\ell), I_{tot}$ (as in Bronfman et al. (1988)) the Galactic plane $|b| < 2^\circ$
- I_{tot}^{model} is then rescaled with the factor $f = I_{tot}^{observ} / I_{tot}^{model}$

$$I^X(\ell) = \int db I^X(b,\ell),$$

$$I_{tot}^X = \int d\ell db I^X(b,\ell) \qquad \text{with } X = model, observ$$



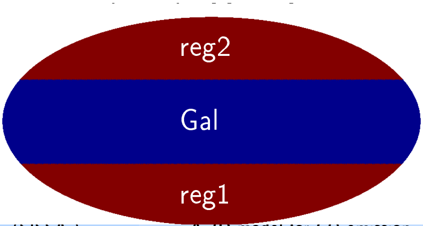
Power Spectra Comparison @ $|b| > 30$ deg



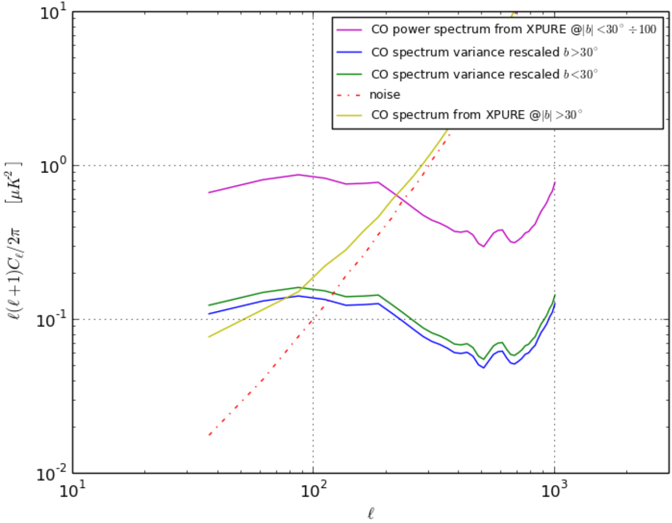
Rescaling CO$1-0$ power spectrum

To have a conservative estimation of the CO spectrum at $|b| > 30°$, (reg 1 and 2 in map) we rescale the one at low Galactic latitudes (Gal) by:

$$C_\ell^{reg} = C_\ell^{Gal} \frac{variance(reg)}{variance(Gal)}$$



Rescaling CO$1-0$ power spectrum



Rescaling CO$1-0$ power spectrum

- The spectra obtained by rescaling (green and blue)and the one from Xpure (yellow)are quite comparable (where the latter is reliable i.e. $\ell < 100$)
- A *very conservative* assessment of CO contamination at high Galactic latitudes around $\ell = 100$ (assuming molecular cloud polarized to 1%) yields to $r_{CO} = 10^{-3}$.

- to reduce the noise level, we degraded the map from `nside=2048` to `nside=64`
- compute the pixel variance in the regions :

region	Gal	1	2
variance $[\mu K^2]$	193.5	0.36	0.32

- rescale the power spectrum

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