Building 3D Galactic Models: the case of CO

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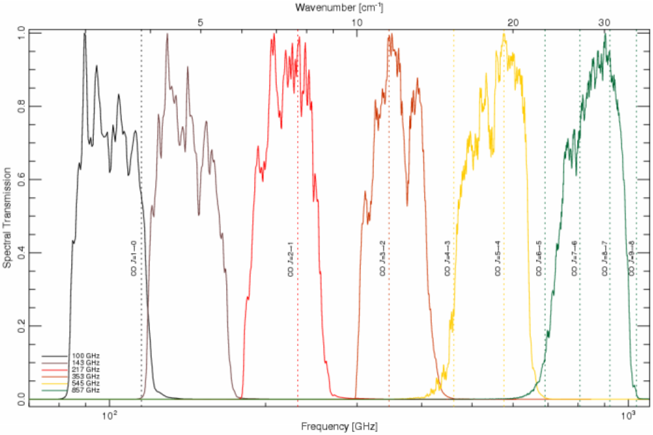
Carbon Monoxide (CO) rotational lines

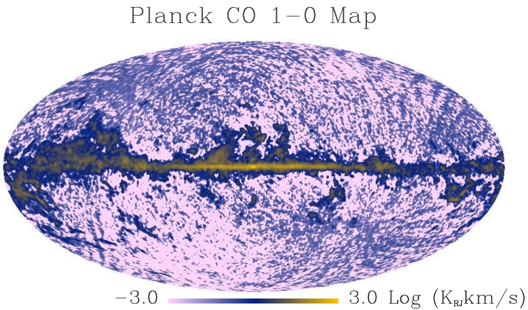
The first rotational lines coming from the monoxide carbonate (CO): $J = 1-0, 2-1, 3-2$ fall in the CMB frequency bands!

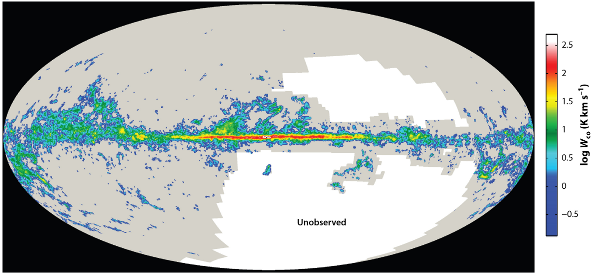


Planck $CO1-0$ map

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

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





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

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$3 \div 5\%$ fractional polarization has been already measured Greaves et al. (1999)

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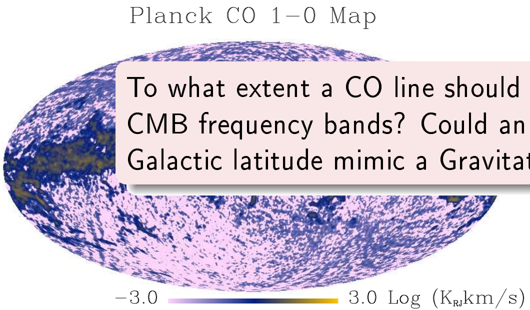

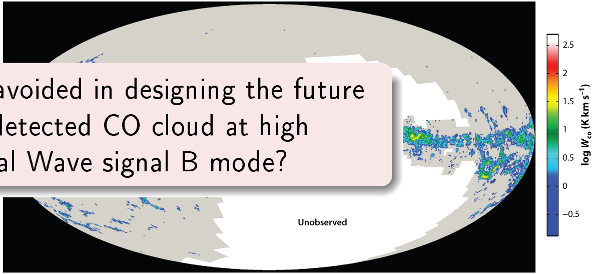

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To what extent a CO line should be avoided in designing the future CMB frequency bands? Could an undetected CO cloud at high Galactic latitude mimic a Gravitational Wave signal B mode?

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MCMOLE3D: *Digging into the Galaxy*

Monte-Carlo MOlecular Line Emissions 3D[1] 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
- Gaussian vertical profile (Bronfman et al., 1988);
- Size Distribution Function dN/dL and Averaged Emissivity profile $\langle \epsilon(R) \rangle$ from Heyer and Dame (2015):

For further details see Puglisi et al. (2017)

[1] `https://github.com/giuspugl/MCMole3D`

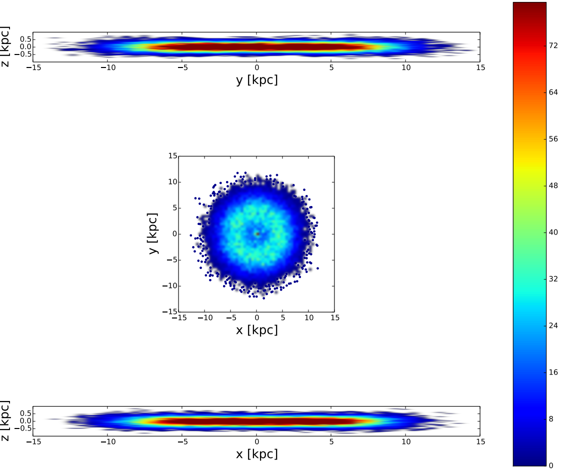
Parameters to the model

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
σ_{ring} * [kpc]	[1,5] Default:2.5

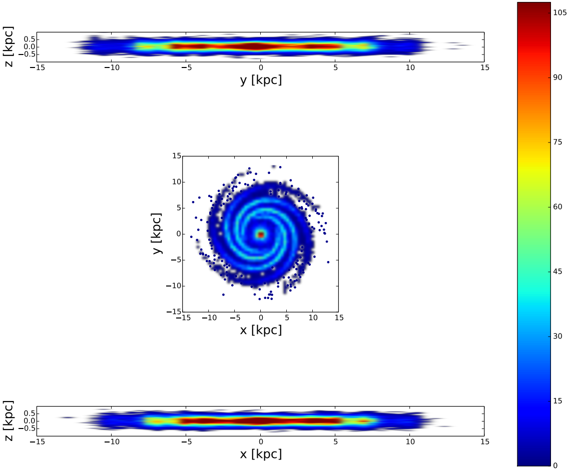
* Parameters allowed to range

Cloud geometrical distribution

Axisymmetric ring



4 Logspiral arms + bulge



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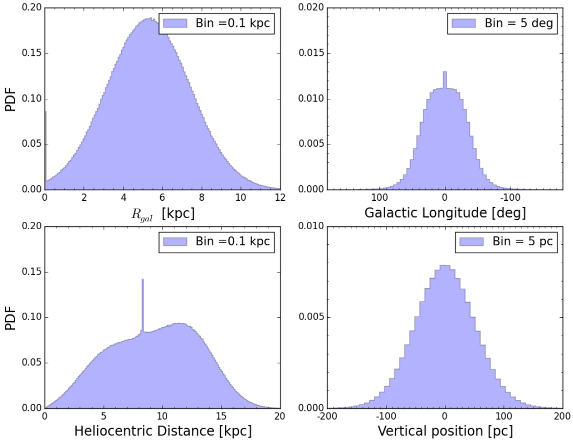

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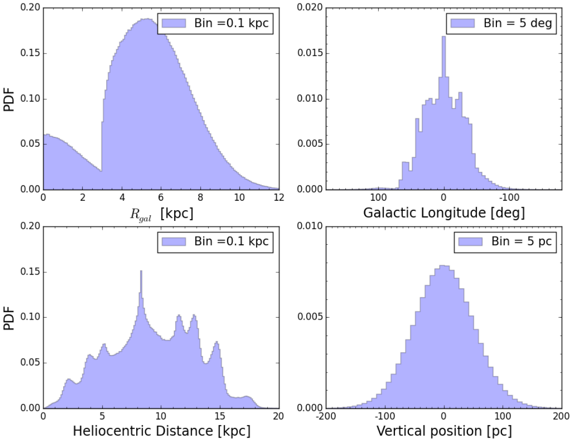
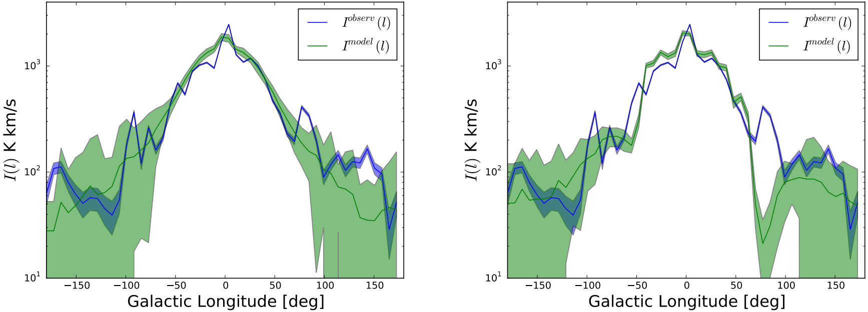


Comparison with Planck CO intensity map

$I(l)$ estimated (as in Bronfman et al. (1988)) within the Galactic plane$|b| < 2^\circ$

$$I^X(l) = \int db I^X(b,l), \text{ with } X = model, observ$$



Axisymmetric Logspiral

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

LogSpiral geometry typical cloud size: $L_0 \in [10, 30]$ pc
width of molecular ring: $\sigma_{ring} \in [2, 4]$ kpc

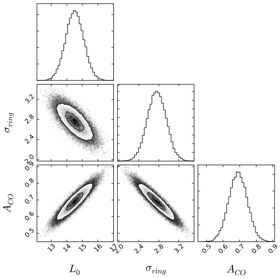
$$L_0 = 14.50 \pm 0.58\,\text{pc}$$

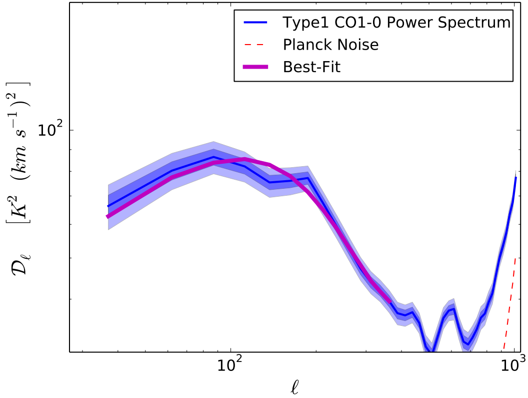
$$\sigma_{ring} = 2.76 \pm 0.19\,\text{Kpc}$$

$$A_{CO} = 0.69 \pm 0.06$$

$$\tilde{\chi}^2 = 1.48$$

$$PTE = 0.13$$





Axisymmetric geometry does not fit Planck CO power spectrum

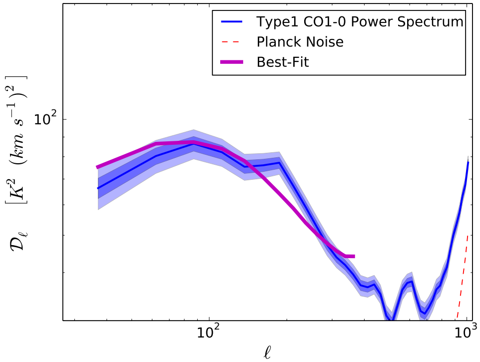
$L_0 = 19.50 \pm 12.7\,\mathrm{pc}$

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

$A_{CO} = 1.0 \pm 0.1$

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

$PTE = 0.00$

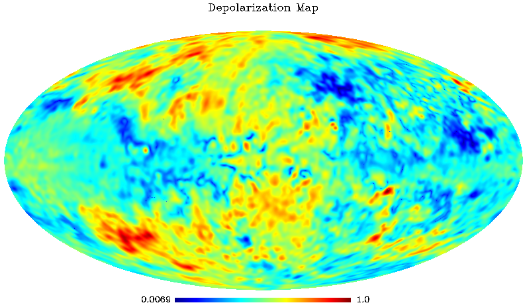


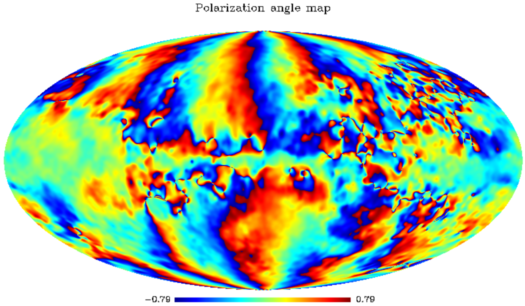
Polarization Forecasts

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

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

with g and ψ respectively depolarization and polarization angle maps coming from Dust template at 100 GHz.





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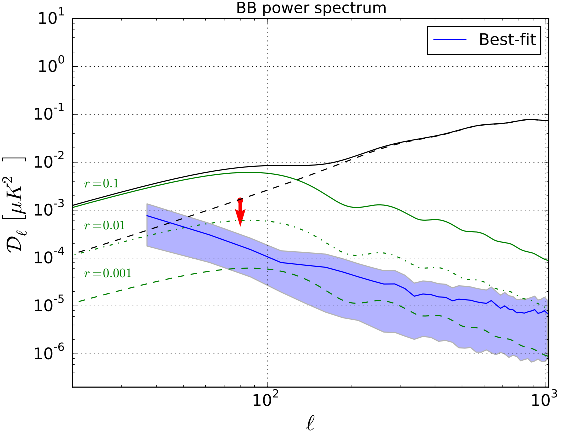


Compute B-mode power spectrum @ high Galactic Latitudes ($|b| > 30°$) from 100 realizations of `MCMole3D` polarization maps

Summary

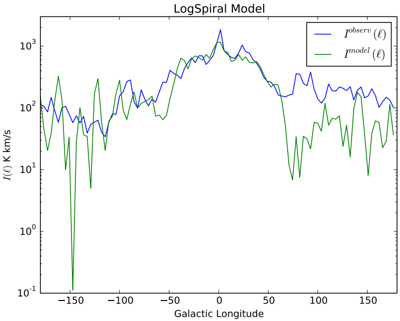
- `MCMole3D` is able to reproduces the overall emission at low Galactic latitudes by means of 2 free parameters L_0 and σ_{ring} with 100 MC simulations;
- 40,000 spherical molecular clouds (with a gaussian profile) have been considered so far
- the bestfit values are within the *expected* ranges in the literature;
- the expected level of CO polarization contamination to B-modes is forecasted to be $r \lesssim 0.025$

ToDOs:

- Consider elliptical clouds: may effect the estimation at small scales;
- the vertical profile parameters $z_0, z_{1/2}$ may play a role in shaping the angular power spectrum
- Constrained realizations

Constrained realizations

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



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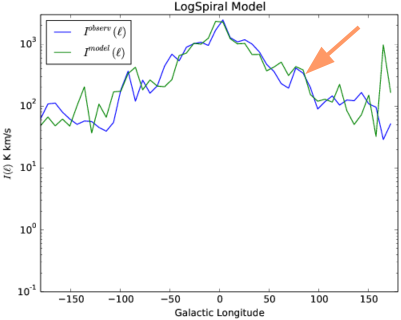

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