A beamconv-based LiteBIRD simulation with HWP non-idealities

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Context

Developing simulations for LiteBIRD is clearly of great importance at this stage. In particular, having more than one pipeline is critical in order to have something to compare the results with.

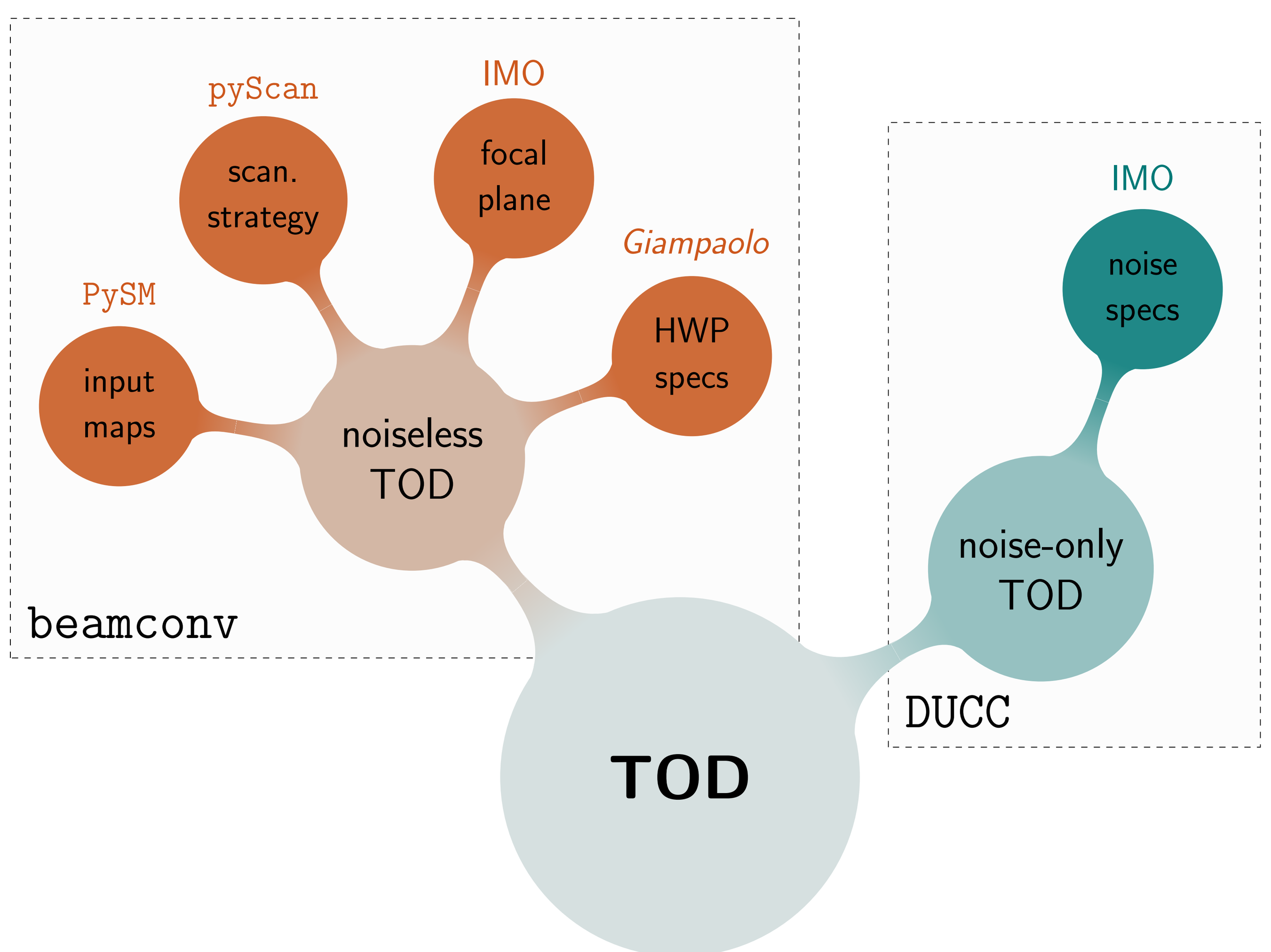
As part of my PhD, I'm working on a simulation pipeline for LiteBIRD, complementary to the one that is currently developed by the collaboration.

Dependencies and structure of the pipeline

My pipeline is strongly based on `beamconv` [1, 2]: a code that simulates CMB detector signal timelines, given realistic beams and scan strategies. The main inputs needed by `beamconv` are:

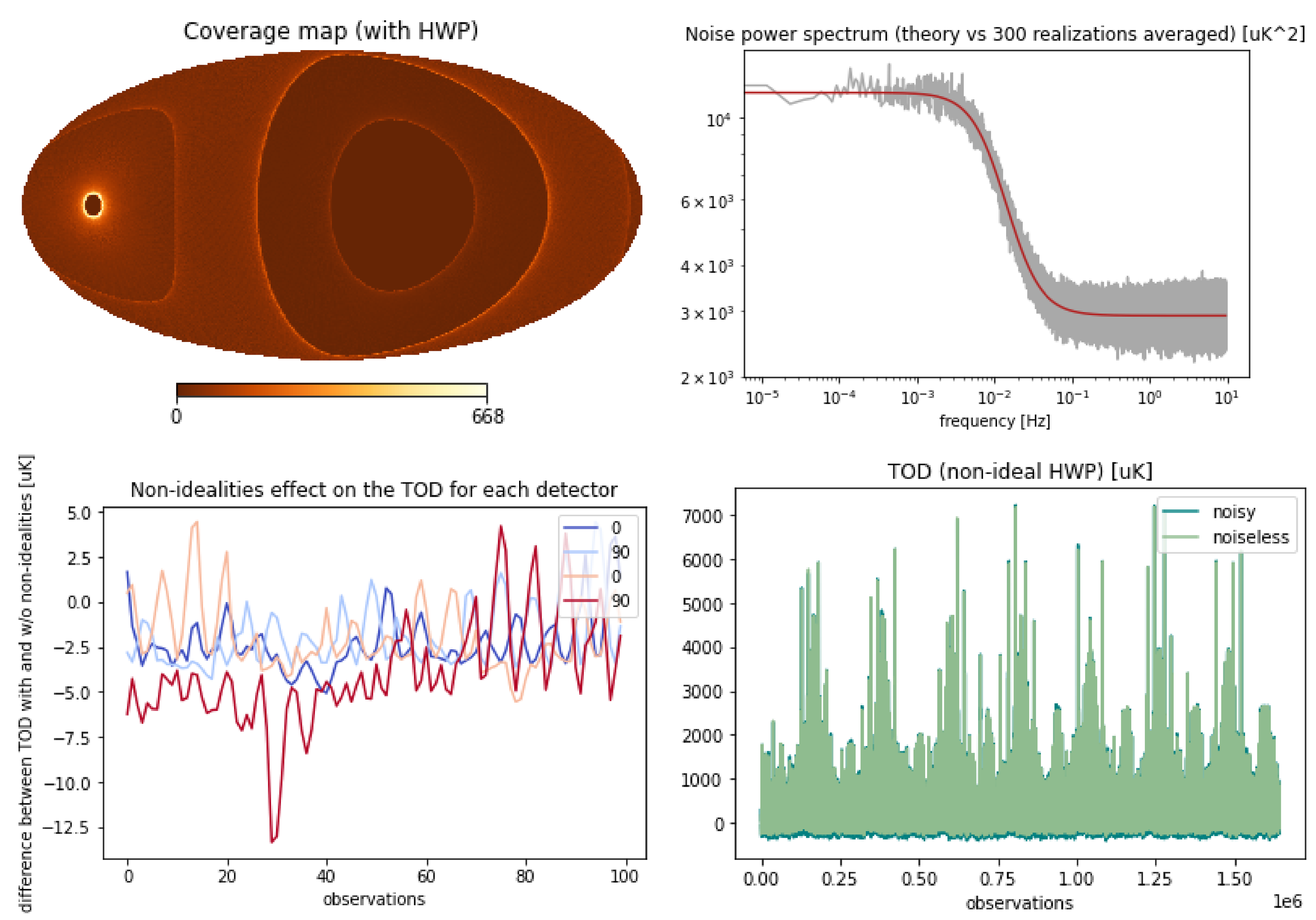
- **input maps:** obtained with `PySM 3` [3];
- **scanning strategy:** implemented as in `pyScan` [4];
- **focal plane specifics:** directly read from LiteBIRD's IMO;
- **HWP Mueller matrix:** calculated from the Jones matrix elements shared by Giampaolo.

Another feature implemented in the code is noise: the power spectrum's specifics in the IMO are fed to `DUCC` [5], which returns noise-only TODs. The output TODs of `beamconv` and `DUCC` are eventually summed together, as sketched below.



Simulation's output (4 detectors only)

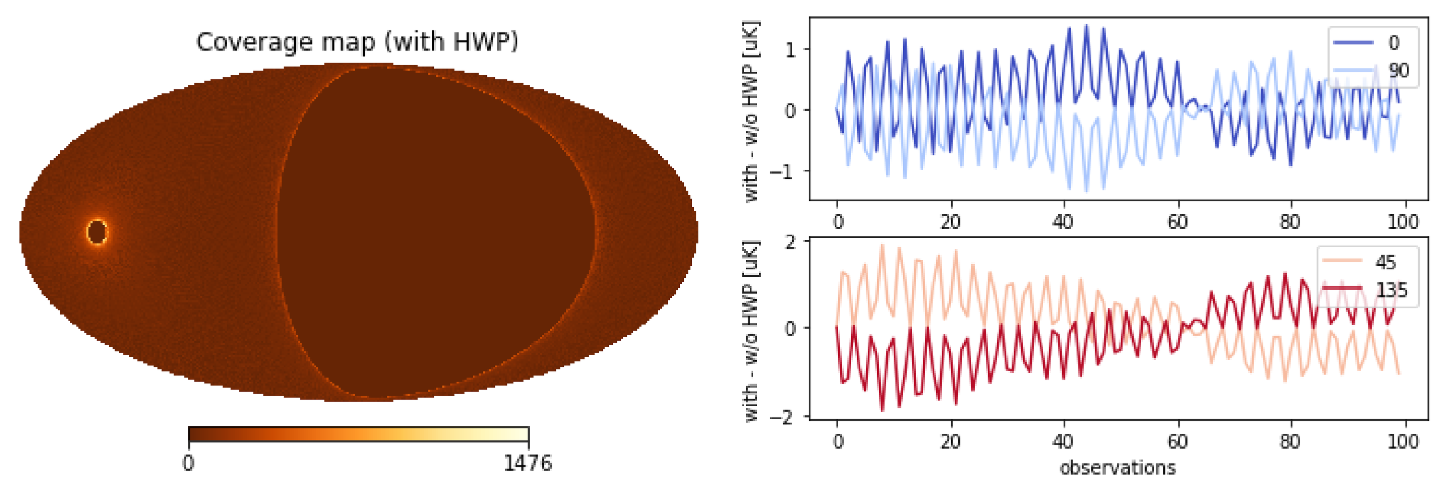
In this preliminary version of the code, the sky is observed with 4 detectors belonging to the M1-140 channel for 1 day. The detectors' positions on the focal plane are taken into account by feeding to the code the offset quaternions from the IMO. The HWP non-idealities are taken into account, but for a fixed frequency.



- The coverage looks good;
- Averaging noise realizations, we recover the theoretical $P(f)$;
- Non-idealities are clearly affecting the TOD.

As a simpler countercheck

Positioning all the detectors at boresight and assuming the HWP to be ideal, we recover the "usual" LiteBIRD's hits map. Also, without non-idealities, detectors sensitive to orthogonal polarization directions appear to be affected by the presence of the HWP in opposite ways.



Moving forward

There are a few steps that I'm planning on taking in order to make the simulation more realistic:

- Include frequency dependence of HWP non-idealities;
- Include realistic beam shapes;
- Include time-dependent dipole;
- Adapt the code for production purposes.

In order to take those steps, I need to answer some questions first:

- Are the scanning strategy specifics readable from the IMO?
- Are the Mueller matrix elements readable from the IMO?
- Which is the best way to include the frequency dependence?
- Am I interpreting the `pol` and `orient` parameters correctly?

Any feedback is much appreciated at this point since it would allow me to better organize the work in the following months.

Bibliography

[1] A. J. Duivenvoorden *et al.*, "Probing frequency-dependent half-wave plate systematics for CMB experiments with full-sky beam convolution simulations," *Mon. Not. Roy. Astron. Soc.*, vol. 502, no. 3, pp. 4526–4539, 2021.

[2] A. J. Duivenvoorden and J. E. Gudmundsson, "beamconv." `https://github.com/AdriJD/beamconv`, 2013.

[3] B. Thorne *et al.*, "The Python Sky Model: software for simulating the Galactic microwave sky," *Mon. Not. Roy. Astron. Soc.*, vol. 469, no. 3, pp. 2821–2833, 2017.

[4] T. Matsumura, "pyScan." `https://github.com/tmatsumu/LB_SYSPL_v4.3`, .

[5] M. Reinecke, "ducc." `https://gitlab.mpcdf.mpg.de/mtr/ducc`, .

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