On-the-fly high-resolution foregrounds simulations at scale with TOAST and PySM

Andrea Zonca - San Diego Supercomputer Center

Ben Thorne - Princeton University

Ted Kisner, Reijo Keskitalo, Julian Borrill - Lawrence Berkeley Lab

Tools

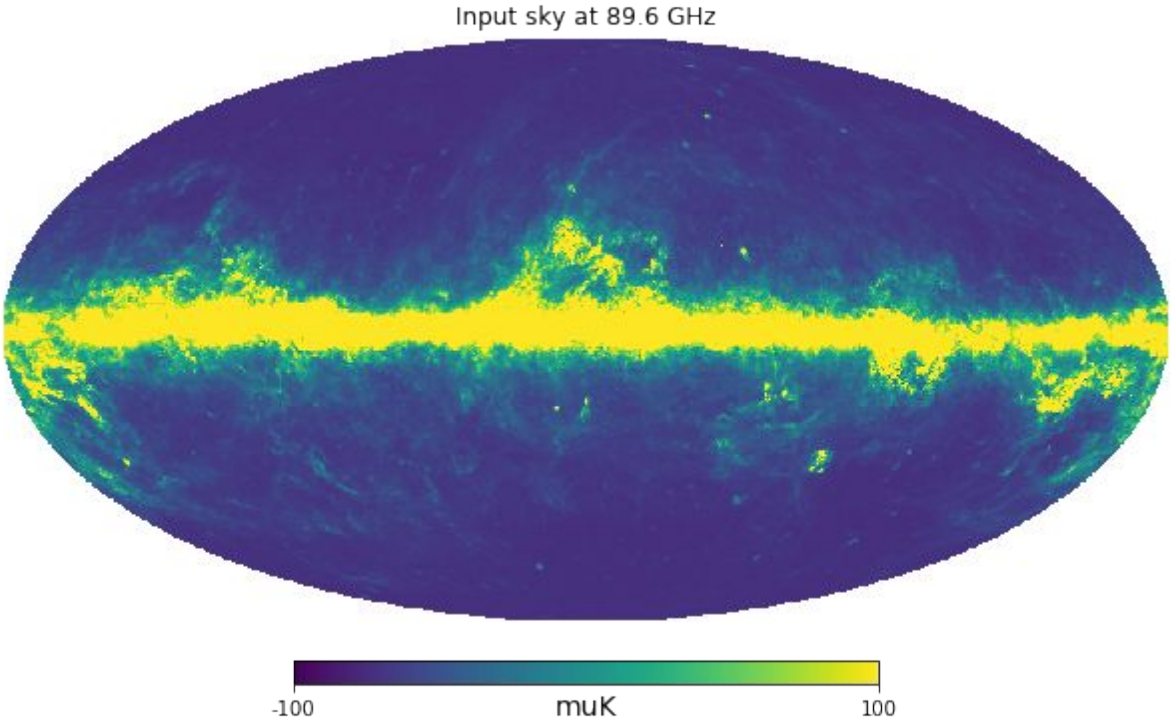
- **PySM**
  - Generate sky emission from models
  - Beam convolution
  - Bandpass integration
- **TOAST**
  - Simulate experiment scanning strategy
  - Generate realistic timelines (1/f noise, atmosphere, sky signal, dipole)
  - Distributed mapmaking

Generate input sky

PySM provides models for all components from literature

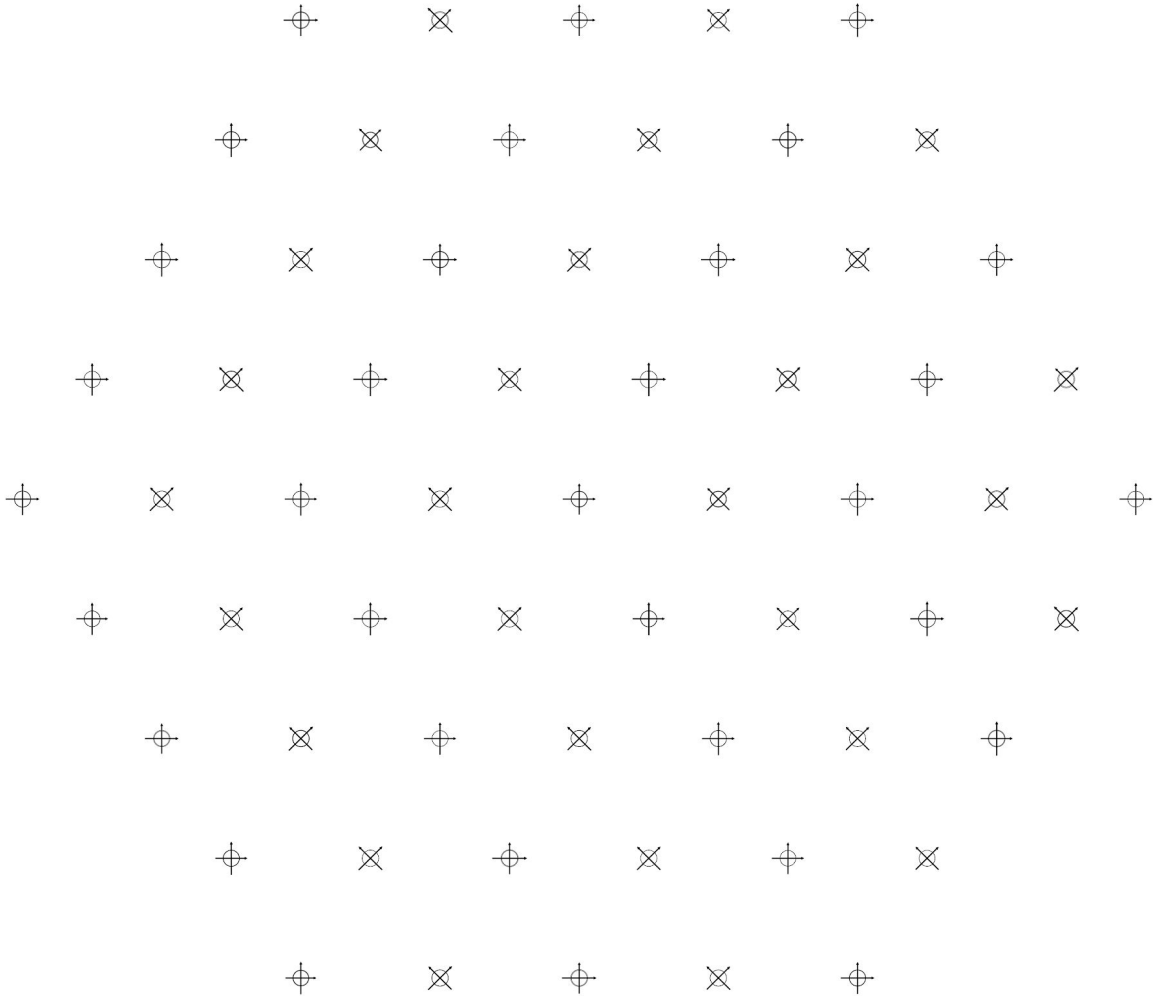
```
nside = 512
sky_config = {
    'synchrotron' : models("s3", nside),
    'dust' : models("d7", nside),
    'freefree' : models("f1", nside),
}
```

Generate input sky



Example first

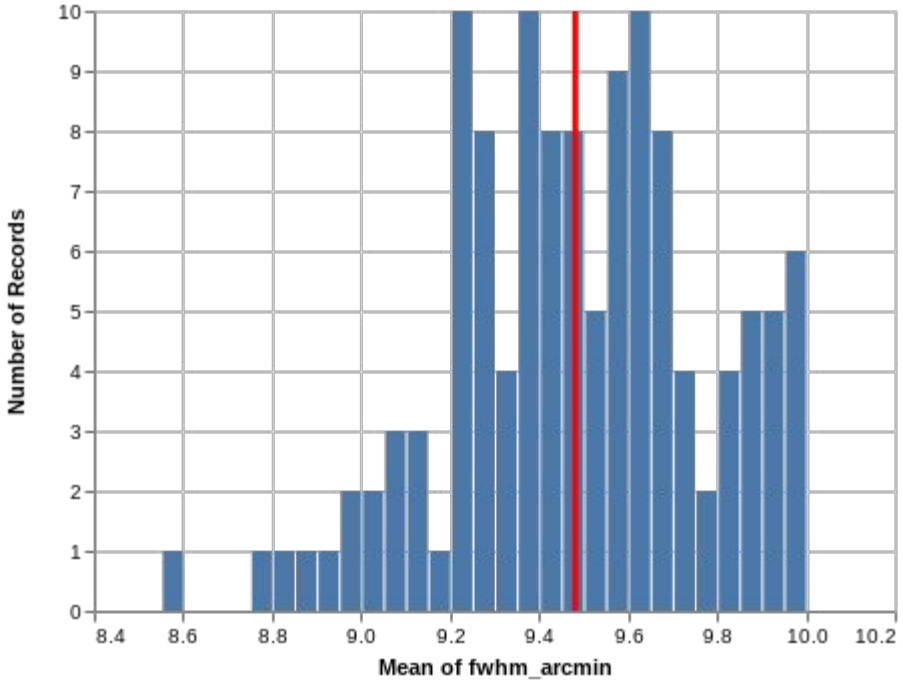
- **Satellite with hexagonal focal plane**
- **122 detectors**

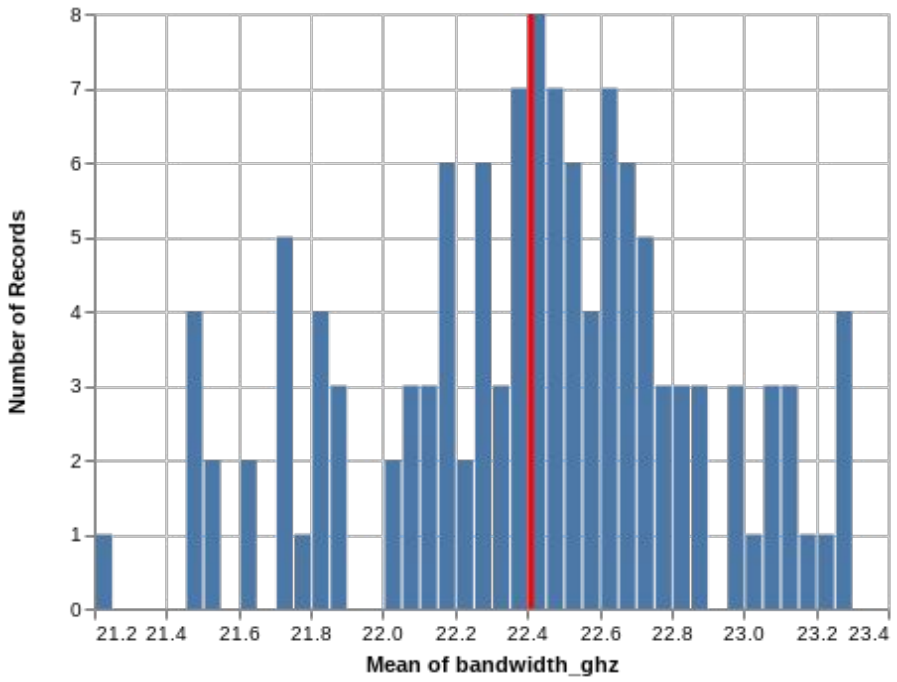


Study impact of non-idealities

- **beam 9.5 arcmin ± 3%**
- **bandpass center 89.6 GHz ± 1%**
- **bandwidth 22.4 GHz ± 2%**

Gaussian distribution around nominal values


Number of Records
0
1
2
3
4
5
6
7
8
9
10
8.4
8.6
8.8
9.0
9.2
9.4
9.6
9.8
10.0
10.2
Mean of fwhm_arcmin


Number of Records
0
1
2
3
4
5
6
7
8
21.2
21.4
21.6
21.8
22.0
22.2
22.4
22.6
22.8
23.0
23.2
23.4
Mean of bandwidth_ghz

Generate PySM input maps on-the-fly

- Integration with TOAST to run in parallel

- Implemented partial MPI support in PySM:
  - few MPI processes read input maps from disk
  - communicate to other processes

Generate PySM input maps on-the-fly

- Implemented support for partial sky in PySM:
  - Each process responsible for a fraction of the map

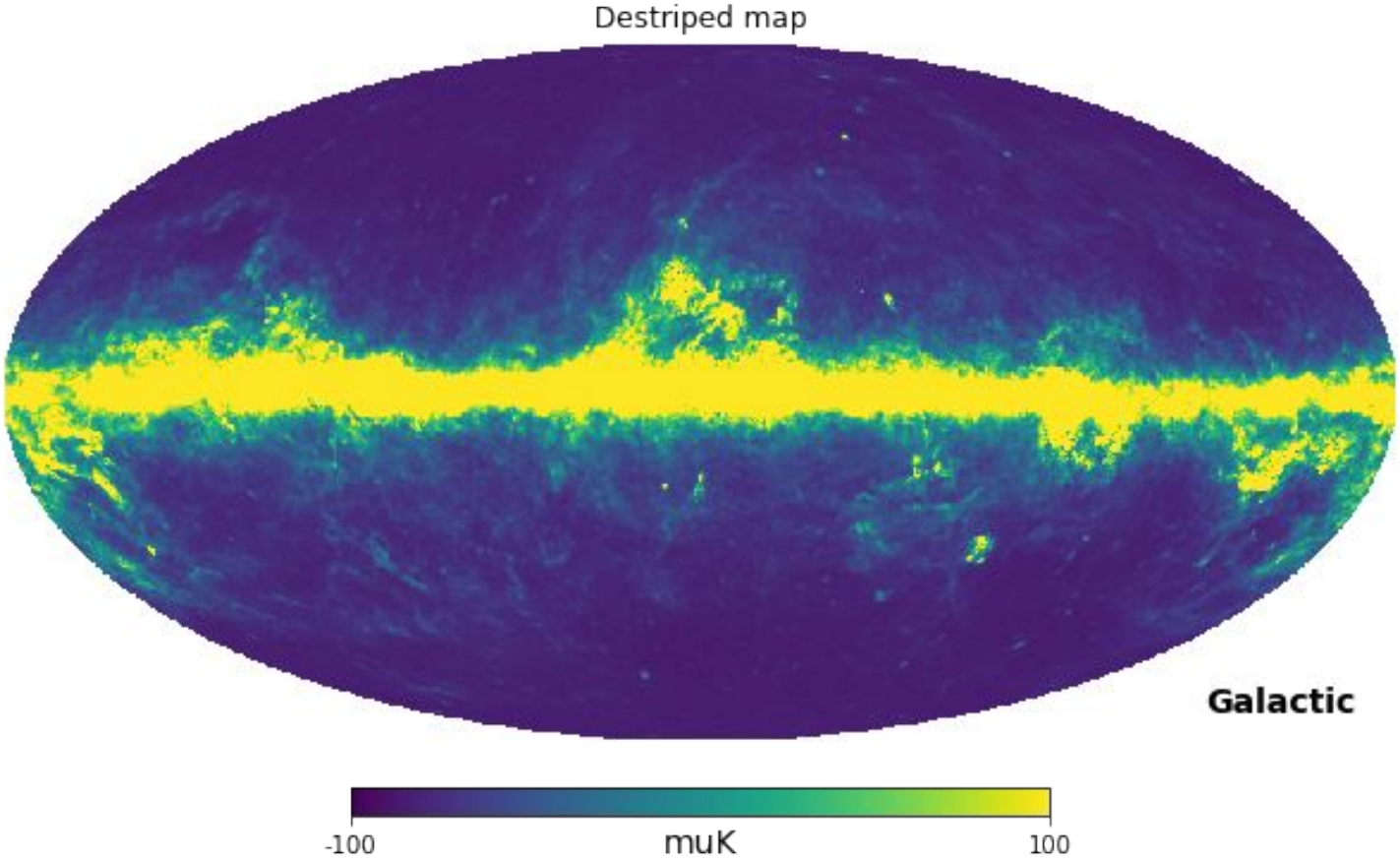
- PySM works independently on each process
  - process 1 channel at a time
  - bandpass integration

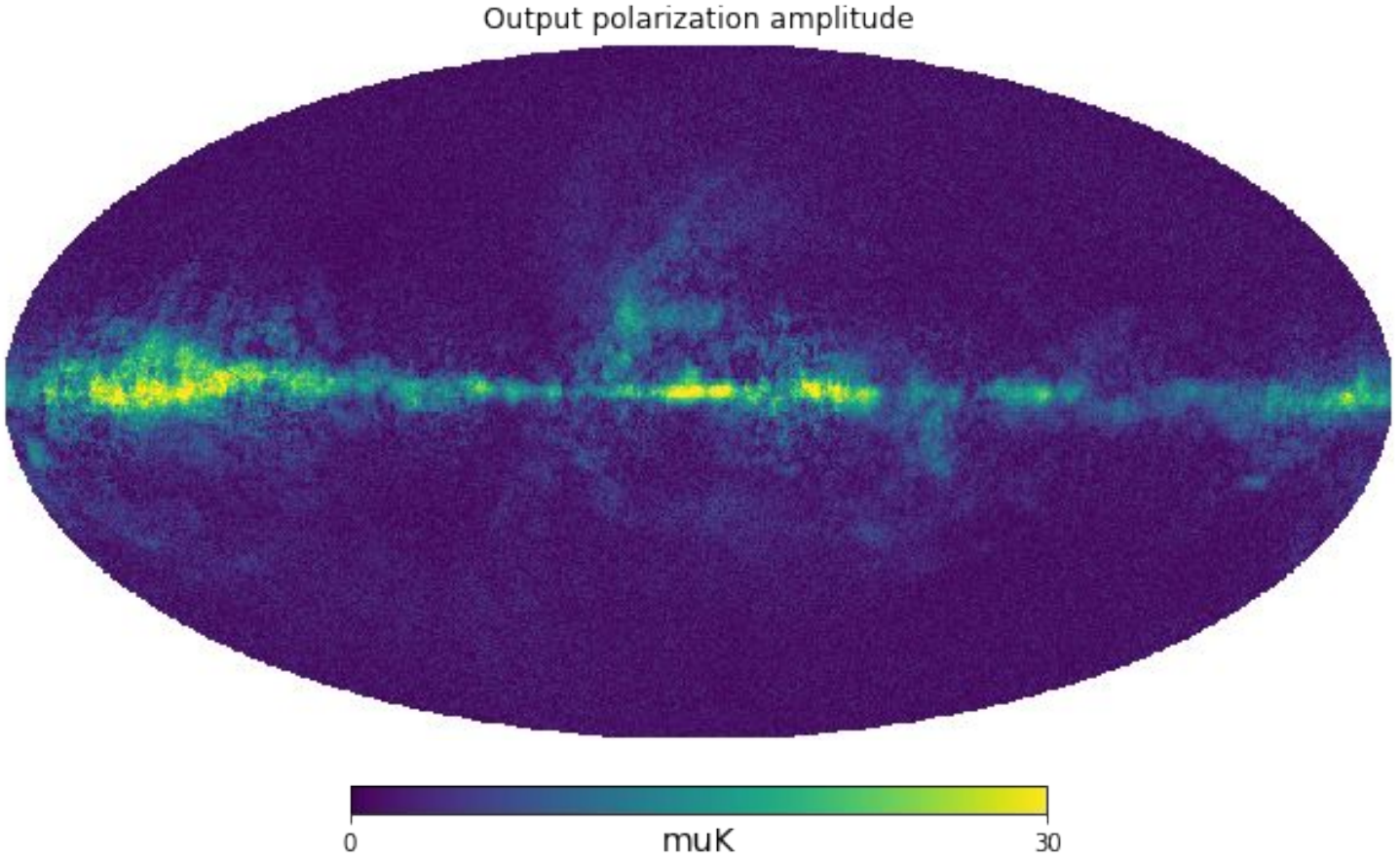
Distributed beam smoothing

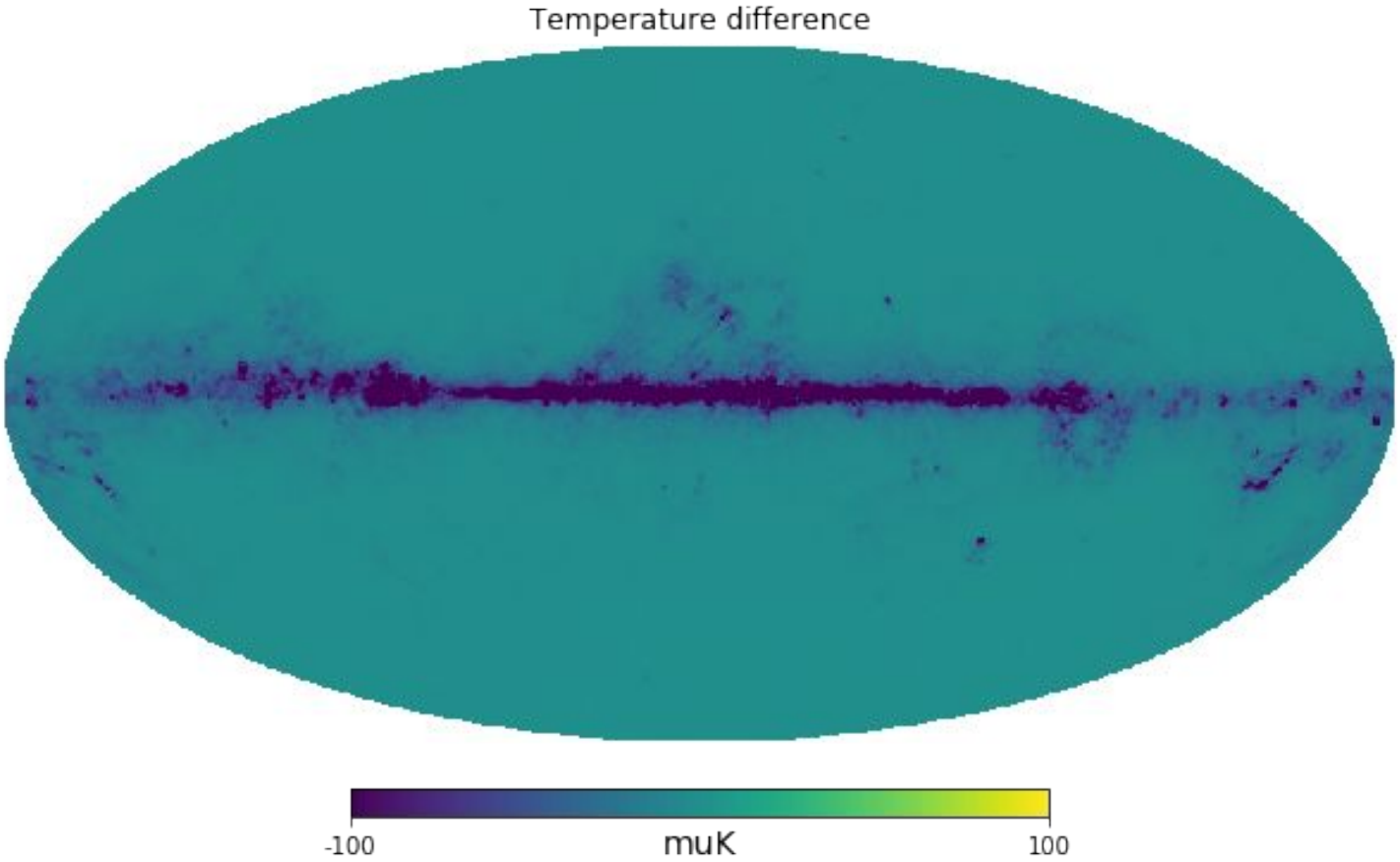
- Integration with libsharp (**distributed** spherical harmonics library by M. Reinecke)
- Contributed almxfl function to smooth alms

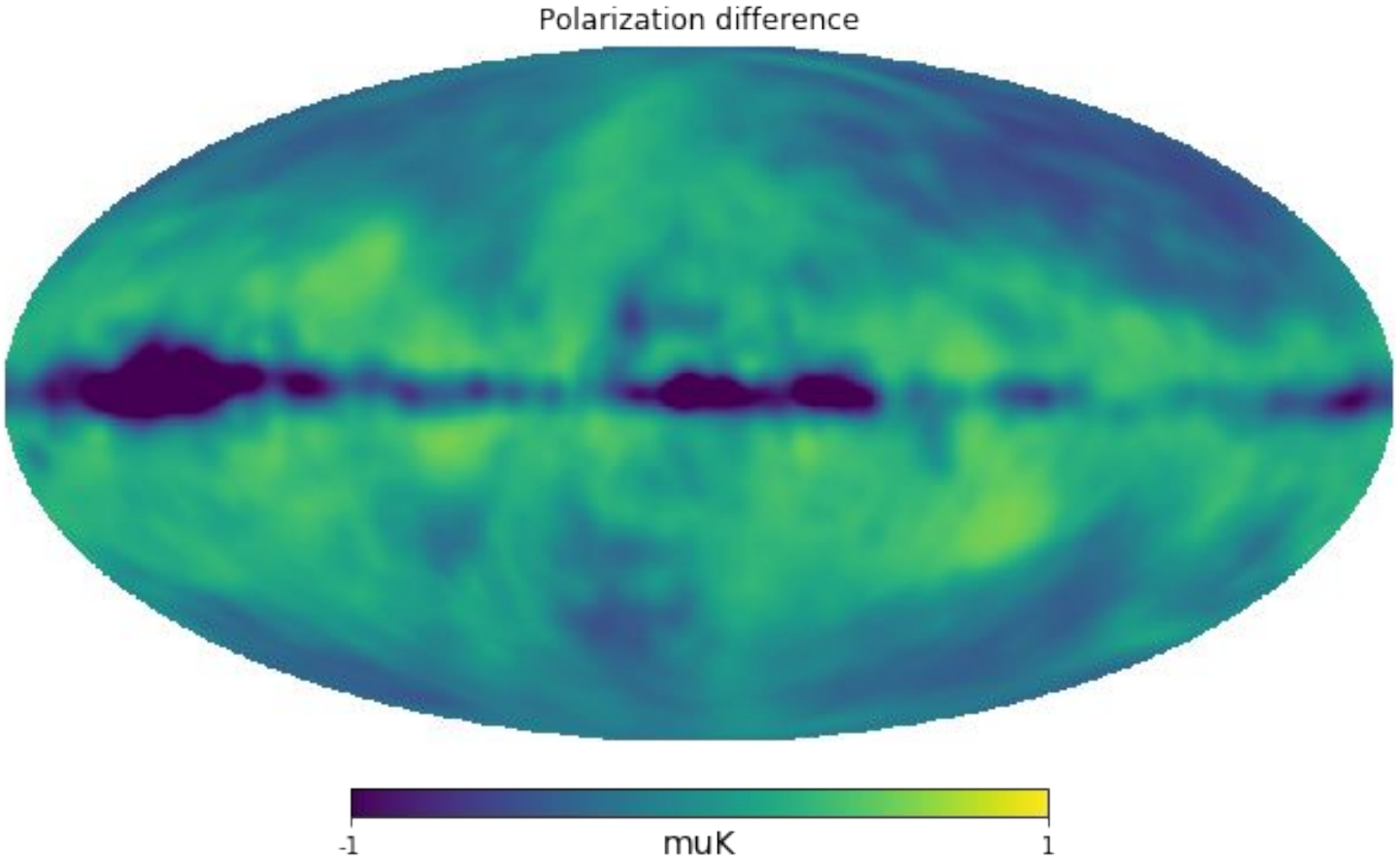
Distributed mapmaking at scale

- Maps scanned to distributed timelines (1 year)
- Noise
- Destriping with **libmadam**
- **730 nodes** on Cori, < 10 minutes
- TOAST tested on > 9000 nodes

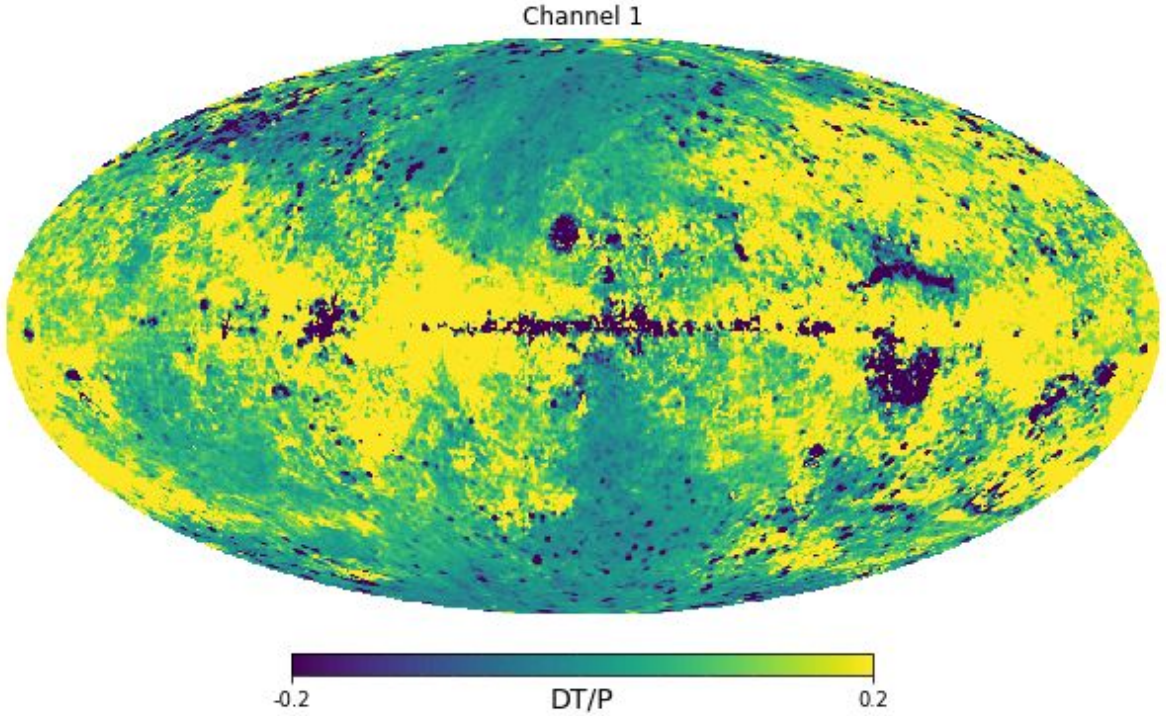

Destriped map
Galactic
-100
muK
100


Output polarization amplitude
0
muK
30


Temperature difference
-100
muK
100


Polarization difference
-1
muK
1

DT over P for each channel



Plans for PySM 3.0

- Run in serial or with MPI
- High resolution templates
- Optimize bandpass integration
- Download and cache input templates at multiple resolutions

Suggestions and feedback welcome!

Thank you!

- **TOAST configuration and SLURM files:** https://github.com/zonca/foregrounds2018_conference

- **Contact me:**
  - zonca@sdsc.edu, @andreazonca