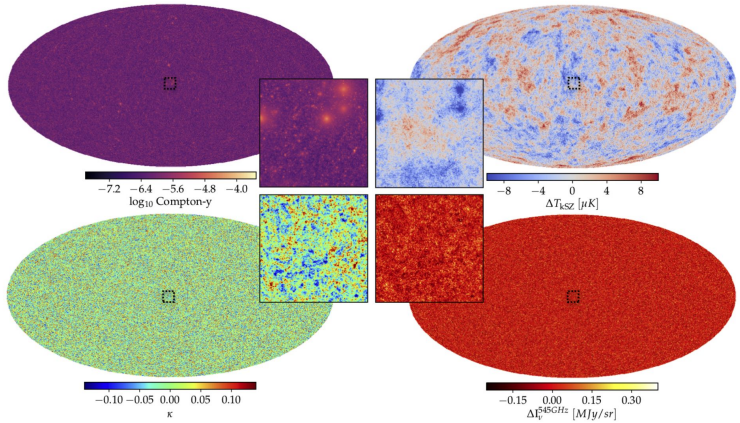
Extragalactic Sky Modeling For CMB (and LSS) Experiments

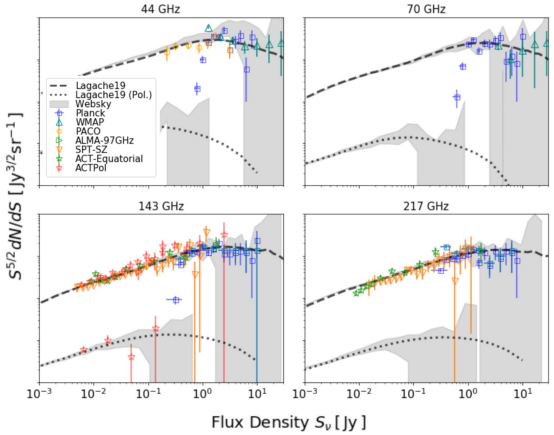
Jia Liu and Marcelo Alvarez

Introduction

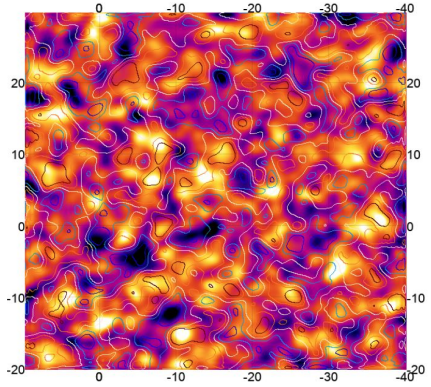
- Websky is a set of extragalactic CMB mocks of lensing, kSZ, tSZ, CIB, and radio source mock catalogs and maps from a periodic box 5 Gpc/*h* on a side at 6144^3 resolution
- A new set of CMB mocks is being developed based on the *FastPM* N-body code for
  - improved small-scale structure
  - inclusion of correlated galaxy mocks
  - a pipeline for multiple realizations

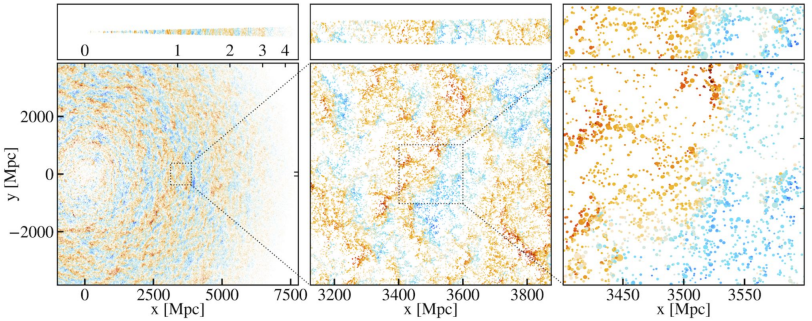
Stein et al. (2020)





Li, Puglisi, et al. (2022)





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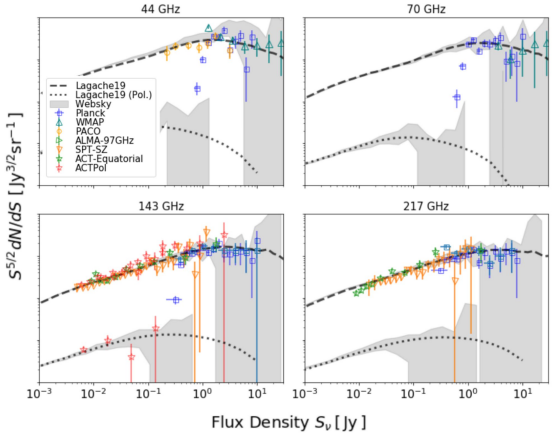

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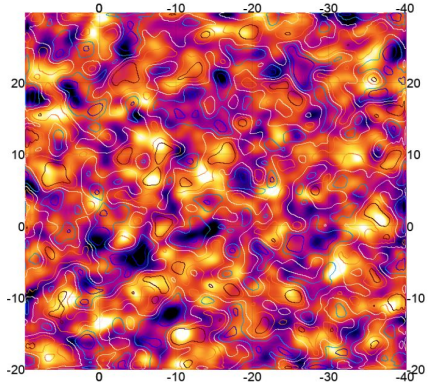

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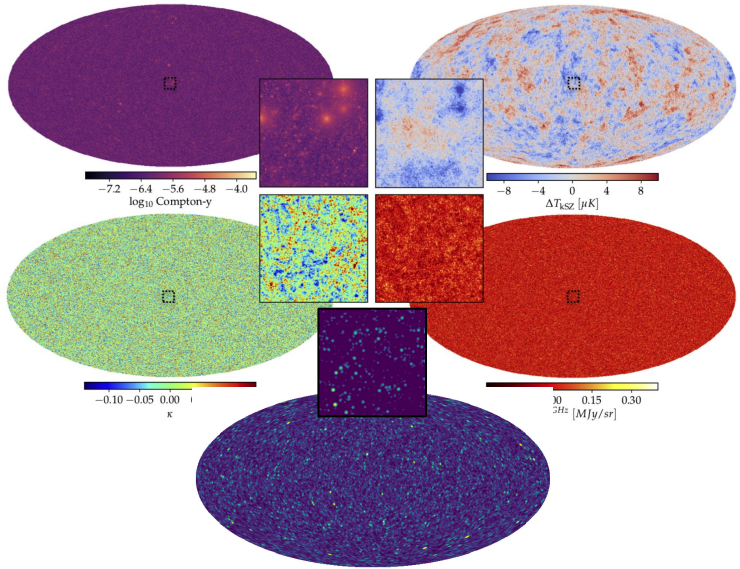


radio sources at 100 GHz

Li, Puglisi, et al. (2022)

radio source catalogs and maps at:
https://github.com/xzackli/WebskyRadioGalaxies

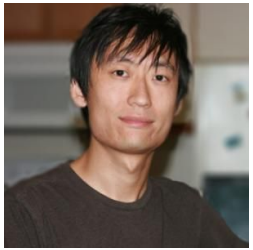
Current Status

- Testing N-body code for the FG
- Validating relaxed-FOF code to get to smaller halo mass
- Validating code for generating mass sheet for painting FG
  - Potential to replace halo-based painting methods
- Validating downsampling particle data (needed for e.g. kSZ, and cross-correlation with LSS surveys: LSST, DESI, PFS)
- Currently most things are validated at ½ of the final resolution
- (Almost) ready for the final resolution run!
  - 5 Gpc/h
  - 8192^3 particles
  - $M_{halo}^{min} = 10^{12}\ M_{sun}/h$
- Next: websky-like observables for tSZ, kSZ, CIB, radio

Development Team

- Full sky N-body with FastPM:
  Yici Zhong, Adrian Bayer, Yu Feng, Jia Liu






- Astrophysical modeling and observables:
  Zack Li, Mathew Madhavacheril, Giuseppe Puglisi, Jia Liu

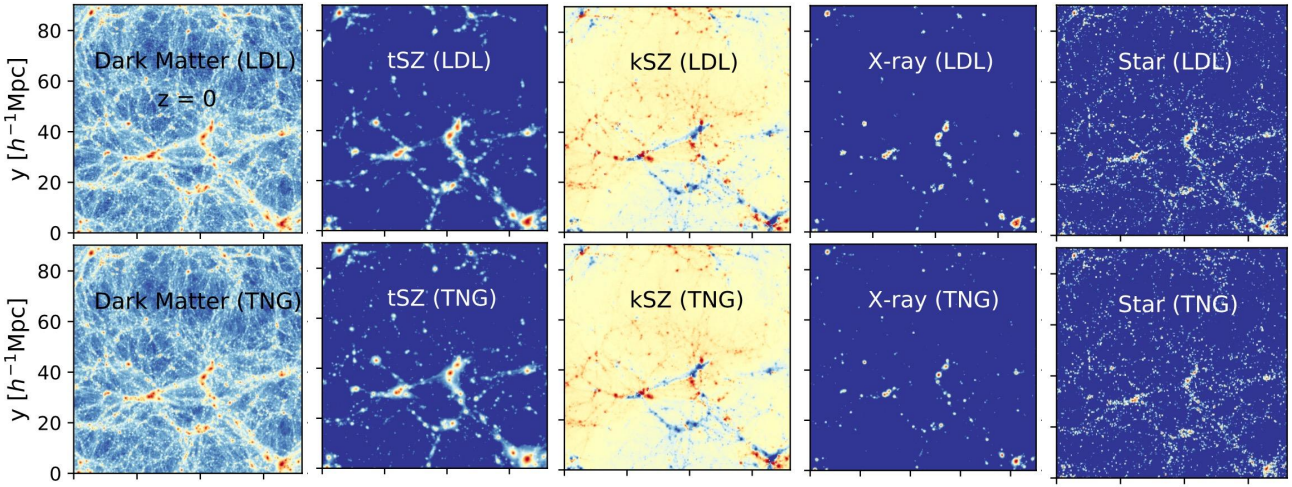


FastPM for the Gravity-only Simulations

Code: A particle-mesh gravity solver, with Potential Gradient Descent to improve small-scale clustering

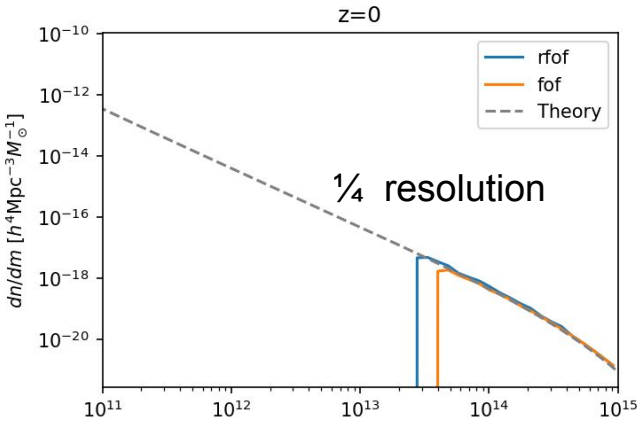
Performance: 10^7 faster than hydro simulation; **10^4 faster than tree-PM N-body simulation**; x10 slower than Websky (2LPT + peak-patch)

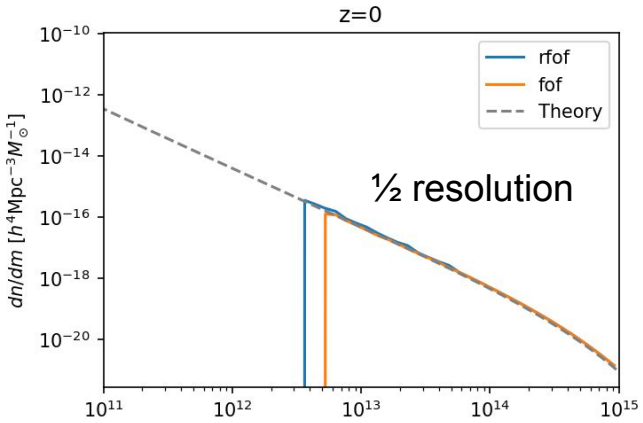
Opportunities: Lagrangian Deep Learning (astrophysics+painting); MADlens (differentiable lensing); flowPM (tensorflow-based/differentiability)

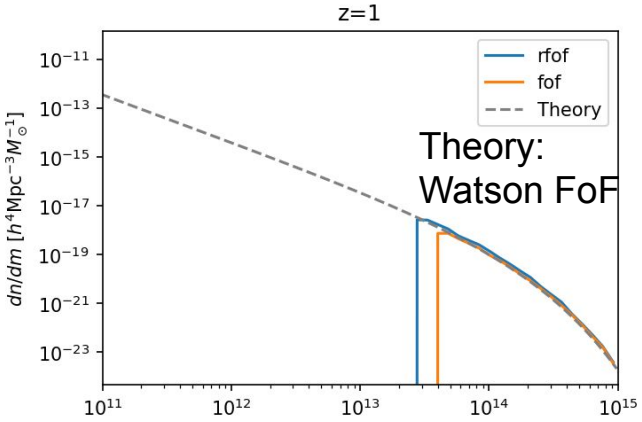


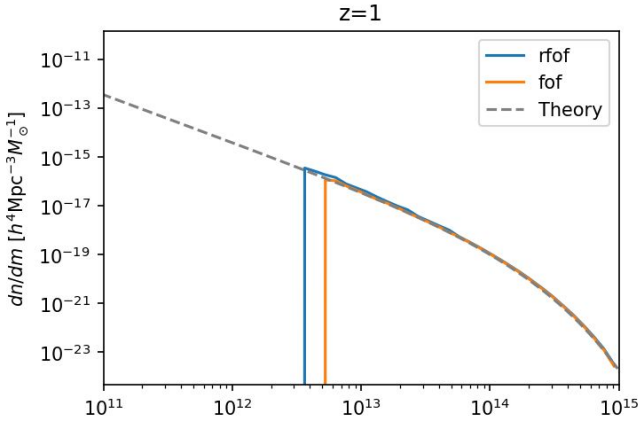
FastPM: Feng+2016
PGD: Dai+2018
LDL (*left img*): Dai & Seljak 2020
MADLens: Böhm+2020
FlowPM: Modi+2020

Validation of Halo Mass Function

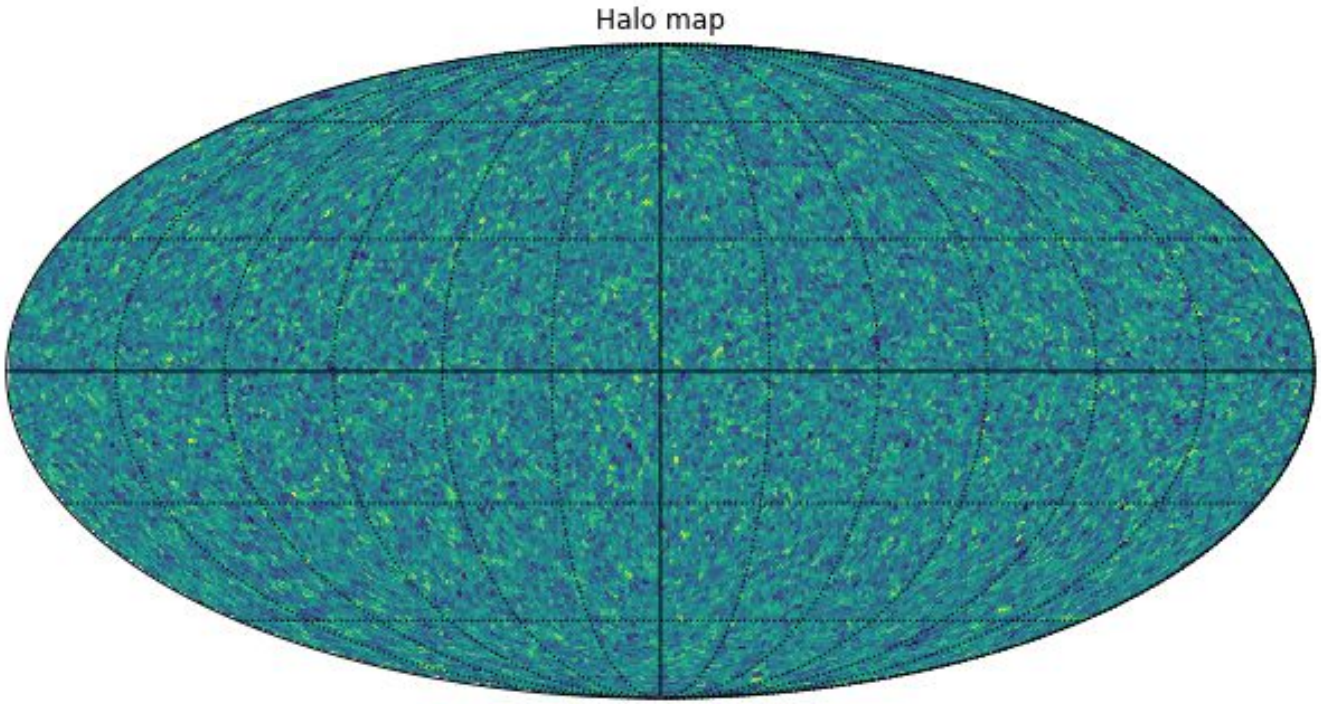




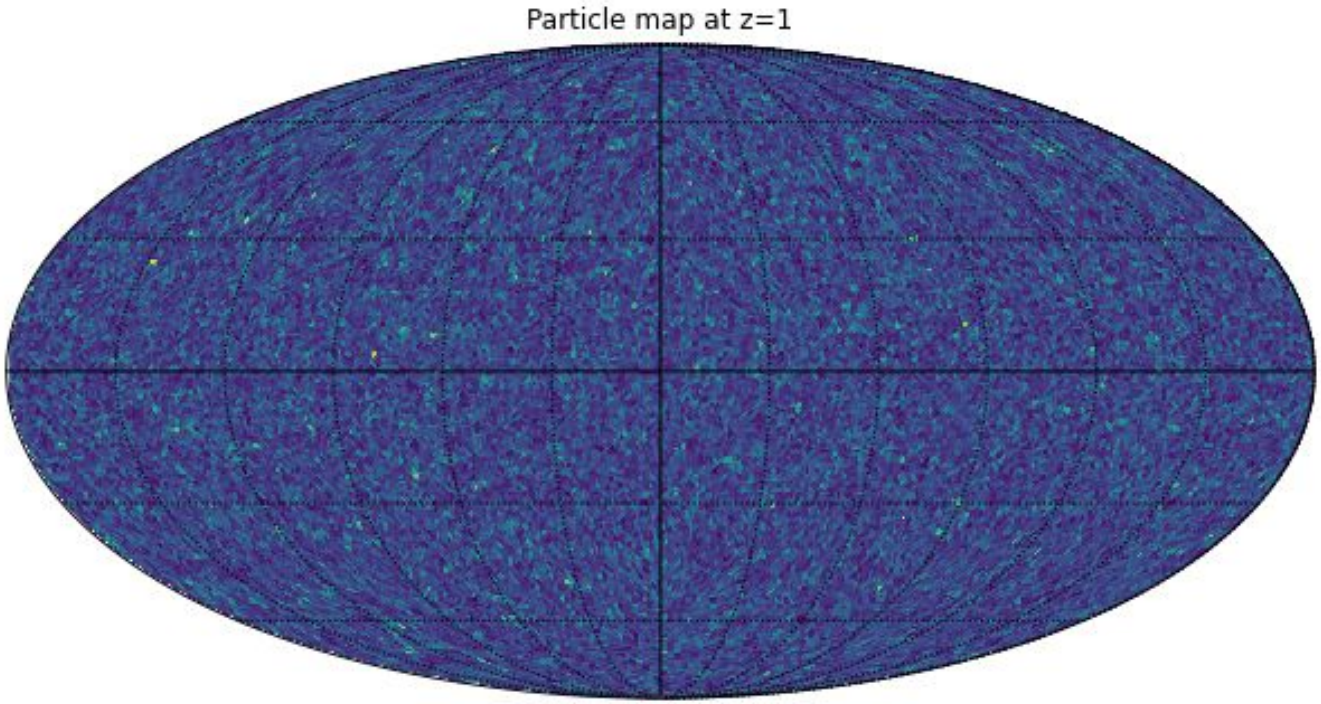




Full Sky Halo Density (½ final res.)



Full Sky Particle Density (½ final res.)



Challenges and Outlook

- Computing (e.g. 100 correlated simulations)
  - Large memory needs (e.g., ~½ of Cori KNL partition at NERSC)
  - 50-100 million CPU-hours
  - Mechanism exists for contributions from multiple collaboration computing allocations
- Storage (~10 PB)
  - Tradeoff between storage and computing, simulation → mock is lossy compression step
  - 500TB per run with 20% sampling rate
  - No mechanism exists for contributions from multiple collaboration storage allocations
- Joint requirements and validation
  - With limited resources, what are the key requirements, in order to cover all the science goals (e.g. fsky, resolution, redshift coverage)?
  - Validation can take a long time
- Organization and collaboration
  - Documentation for data release
  - Integration with DC2 and external collaborations
  - Training and career advancement of developer scientists