Density reconstruction via Bayesian large-scale structure inference

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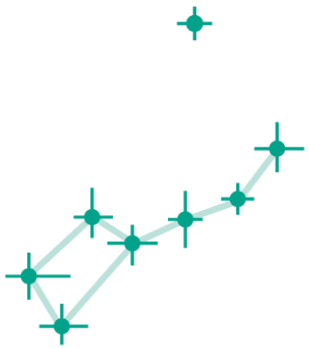

In collaboration with
the Aquila Consortium
www.aquila-consortium.org

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ICIC
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London

A disclaimer

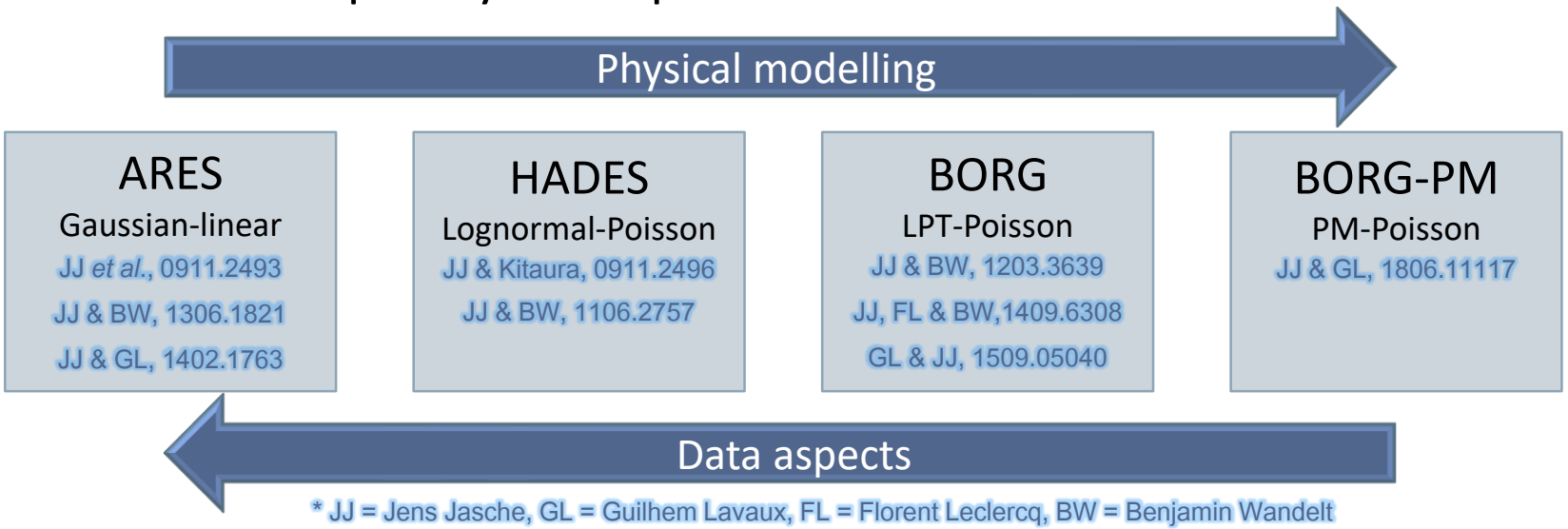
E. T. Jaynes (1922-1998)

"A previous acquaintance with probability and statistics is not necessary; indeed, a certain amount of innocence in this area may be desirable, because there will be less to unlearn."
— Edwin Thompson Jaynes (2003), *Probability Theory: The Logic of Science*

- For the purpose of this talk, please forget the following concepts:
  - "measurements" of power spectra / correlation functions, etc.
  - "mock" catalogues to measure frequencies
  - galaxy "weights" or any "correction" to the data
  - backward-modelling techniques for "BAO reconstruction"
  - any remaining frequentist concept (estimators / χ^2 / maximum likelihood, etc.)

Bayesian large-scale structure inference codes

- Codes developed by the Aquila Consortium:



* JJ = Jens Jasche, GL = Guilhem Lavaux, FL = Florent Leclercq, BW = Benjamin Wandelt

- Additional features:
  - Power spectrum inference
  - Galaxy bias (various models), redshift-space distortions, light-cone effects
  - Alcock-Paczyński effect and cosmological parameter inference

    Ramanah, Lavaux & Wandelt 2018, arXiv:1808.07496
  - Foregrounds and treatment of unknown systematics

    Jasche & Lavaux 2017, arXiv:1706.08971 • Porqueres, Ramanah, Jasche & Lavaux 2018, arXiv:1812.05113

Bayesian large-scale structure inference codes

```
github.com/AlDanial/cloc v 1.72  T=0.26 s (1649.8 files/s, 264776.5 lines/s)
-------------------------------------------------------------------------------
Language                     files          blank        comment           code
-------------------------------------------------------------------------------
C++                            191           7515           4704          23358
C/C++ Header                   235           6407           4066          22438
Julia                            4             92             64            366
-------------------------------------------------------------------------------
SUM:                           430          14014           8834          46162
-------------------------------------------------------------------------------
```

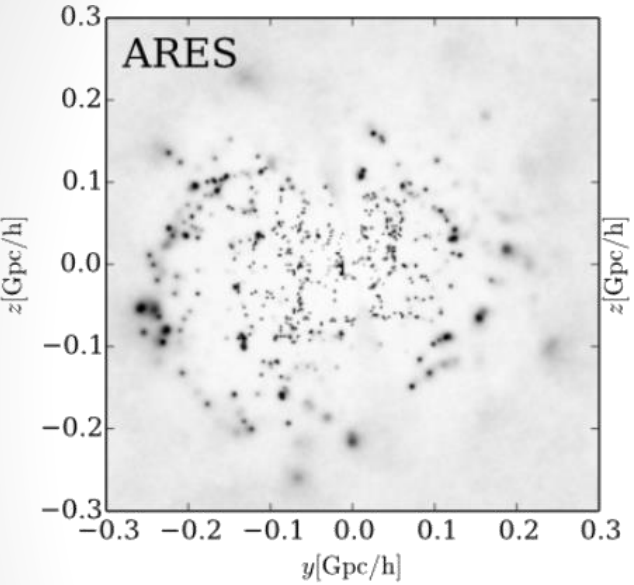
- Check ARES at https://bitbucket.org/bayesian_lss_team/

- All of these codes give samples of the respective posterior distributions.

  ⇒ Only one run of the code gives uncertainties!

Comparing BLSS methods

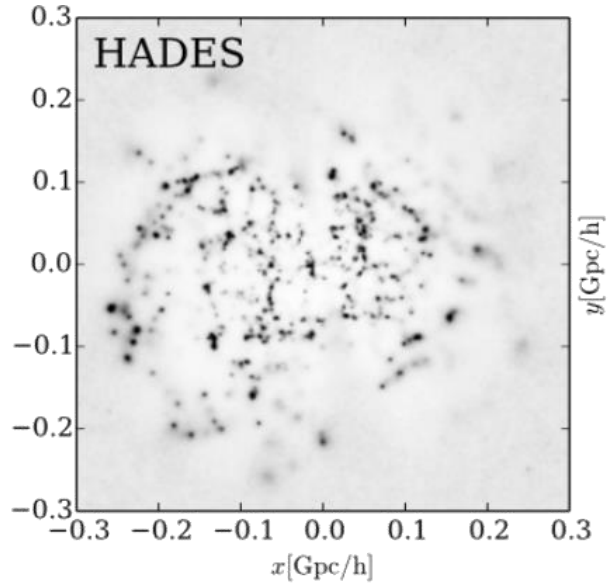
Gaussian (a.k.a. Wiener filter)



Jasche *et al.* 2010, arXiv:0911.2493

Jasche & Wandelt 2013, arXiv:1306.1821

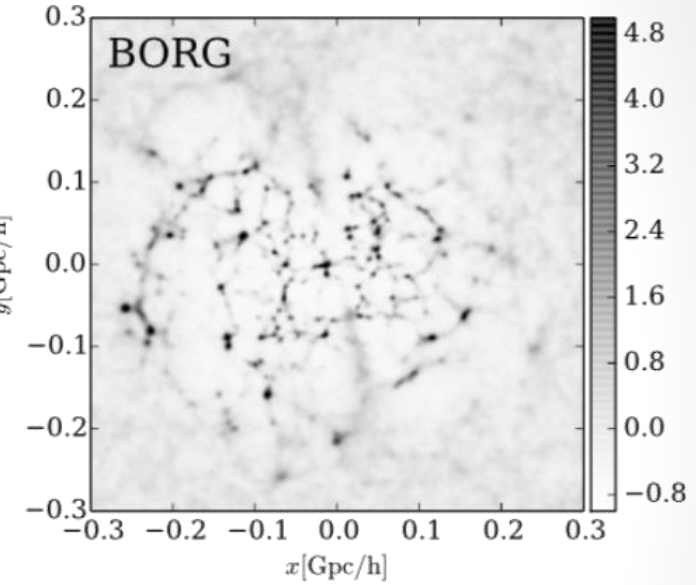
Lognormal – Poisson



Jasche & Kitaura 2010,

arXiv:0911.2496

2LPT – Poisson



Jasche & Wandelt 2013,

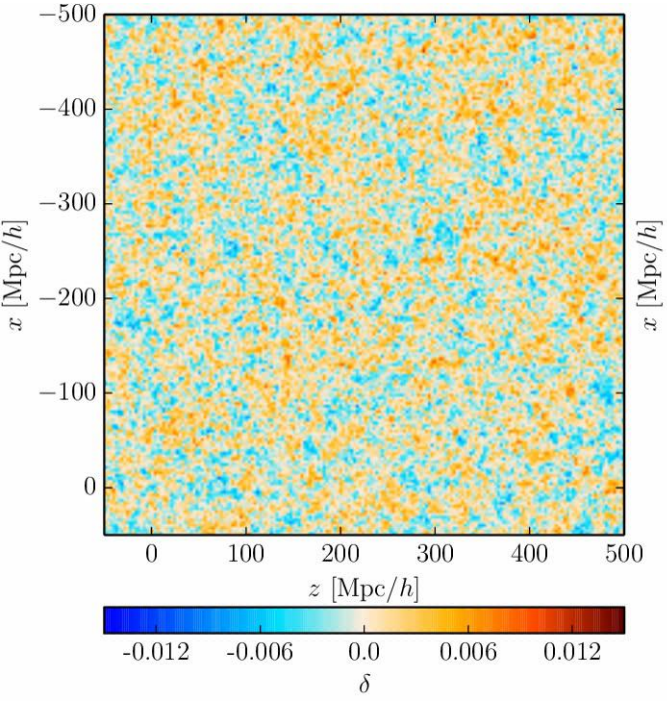
arXiv:1203.3639

- Which scheme performs best? Ask the data!

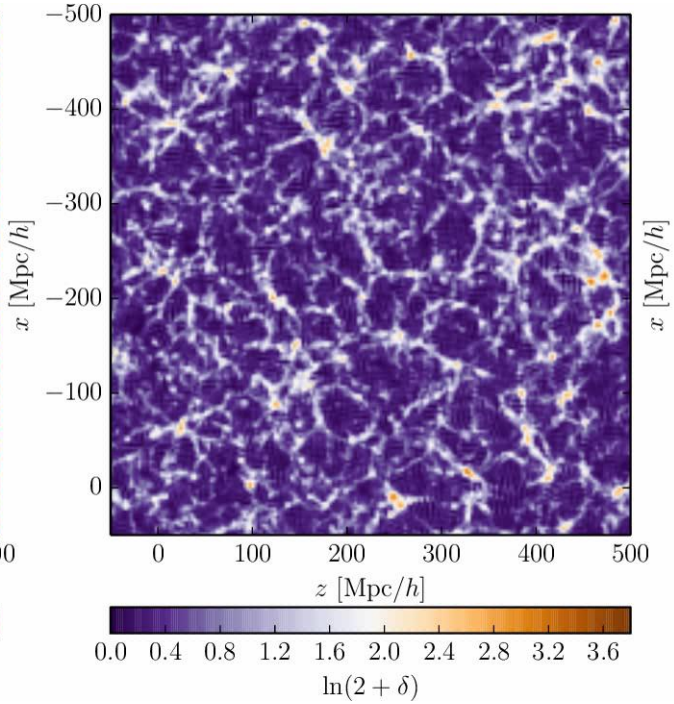
$$A_{ij} = \ln(\mathcal{P}(d|\delta_i)) - \ln(\mathcal{P}(d|\delta_j))$$

	ARES	HADES	BORG
ARES	0	-219580.31	-383482.25
HADES	219580.31	0	-163901.94
BORG	383482.25	163901.94	0.

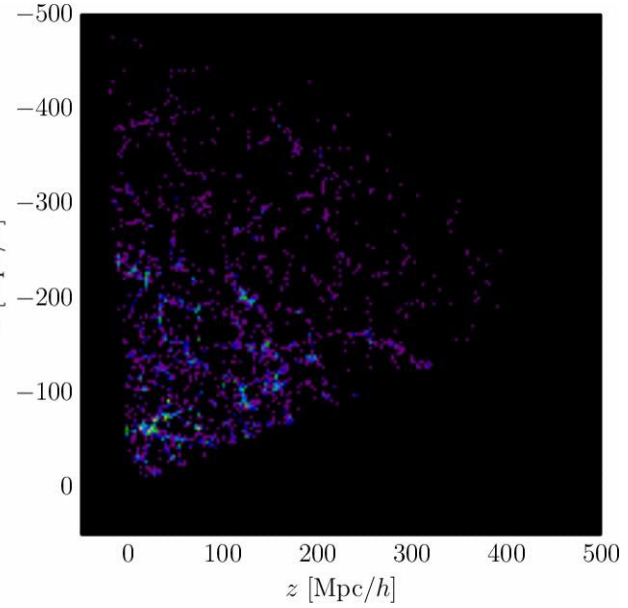
The BORG SDSS analysis



Initial conditions



Final conditions

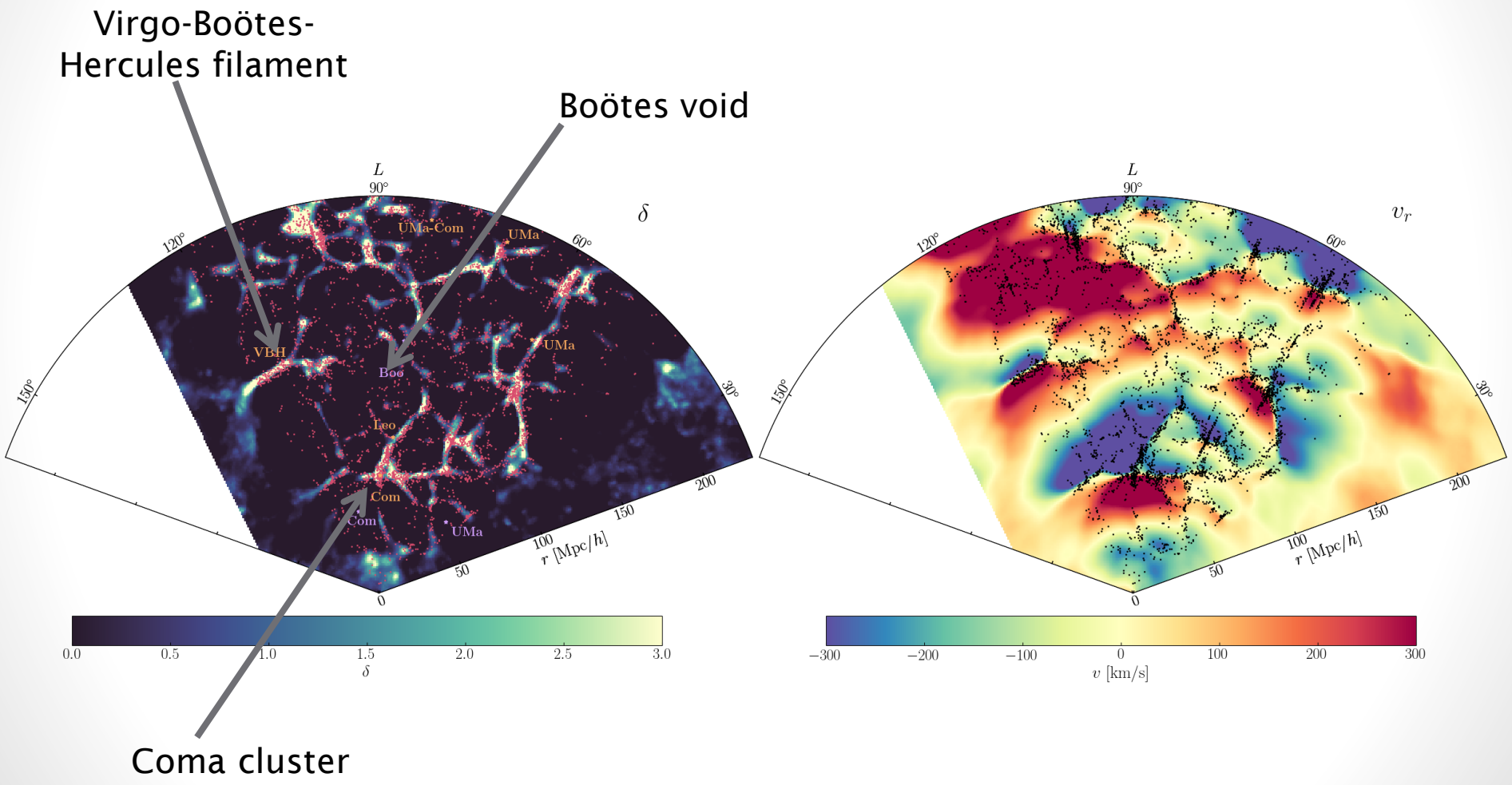


Observations

334,074 galaxies, ≈ 17 million parameters, 3 TB of primary data products,
12,000 samples, ≈ 250,000 data model evaluations, 10 months on 32 cores

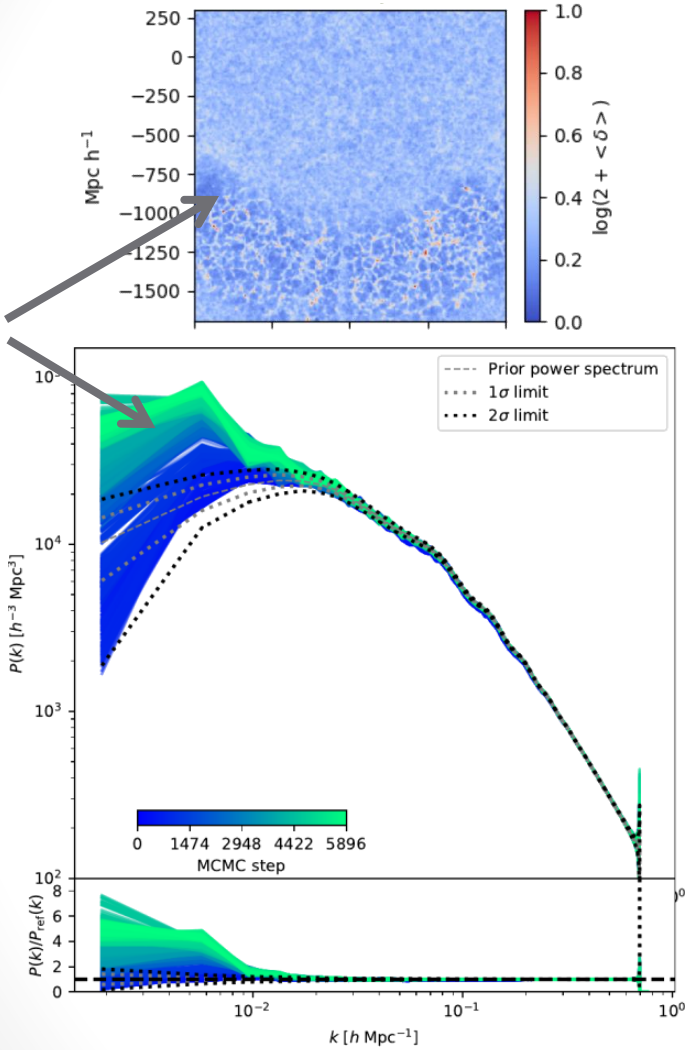
Jasche, FL & Wandelt 2015, arXiv:1409.6308

Cosmography in the supergalactic plane

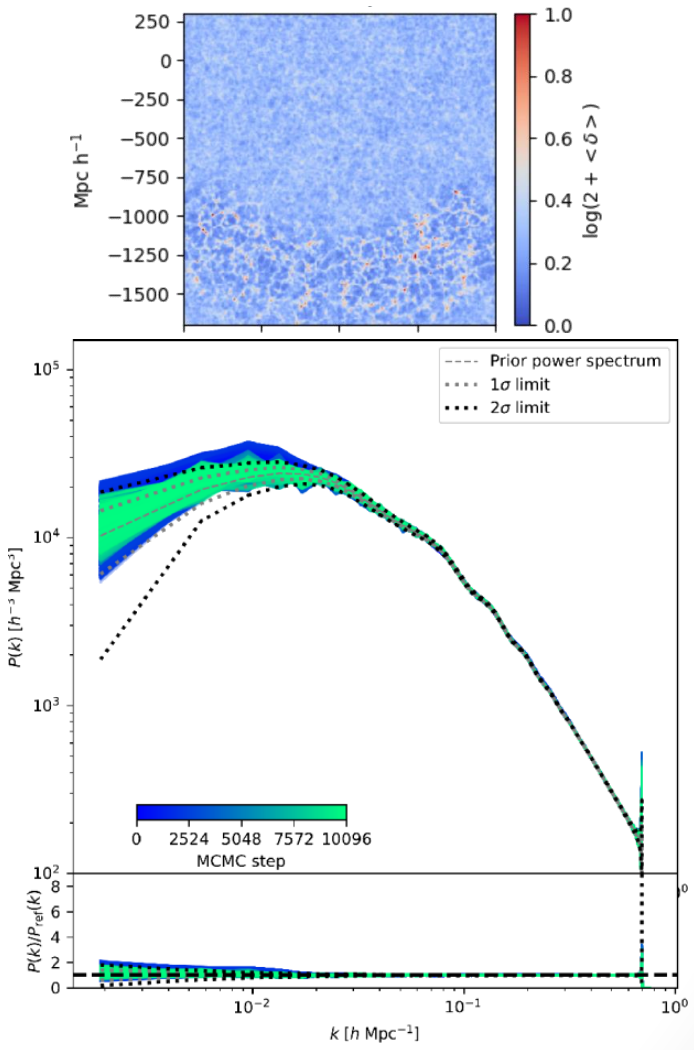


FL, Jasche, Lavaux, Wandelt & Percival 2017, arXiv:1601.00093

Unknown foreground contaminations



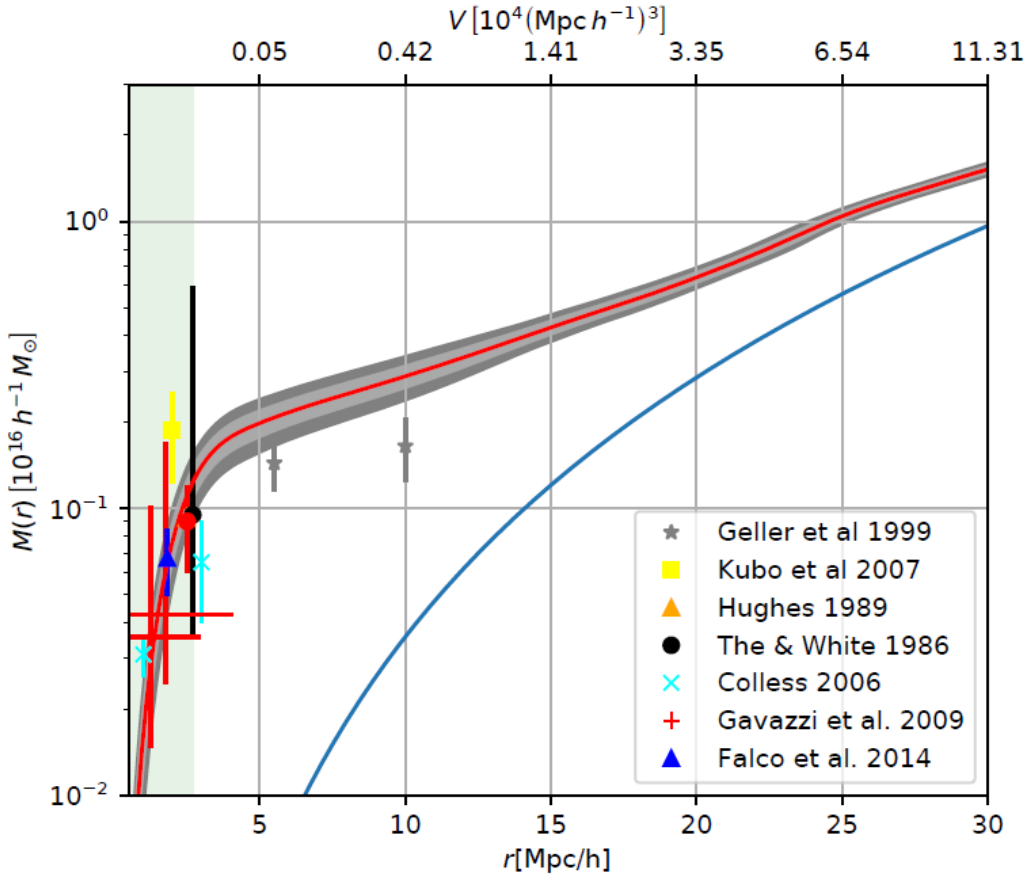
Standard Poisson likelihood



New robust likelihood

Porqueres, Ramanah, Jasche & Lavaux 2018, arXiv:1812.05113

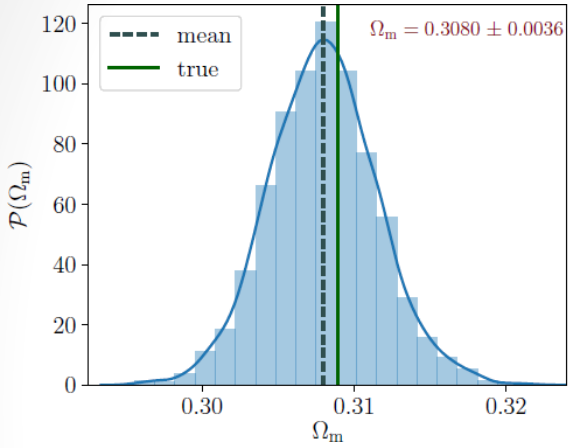
BORG-PM: full non-linear dynamics

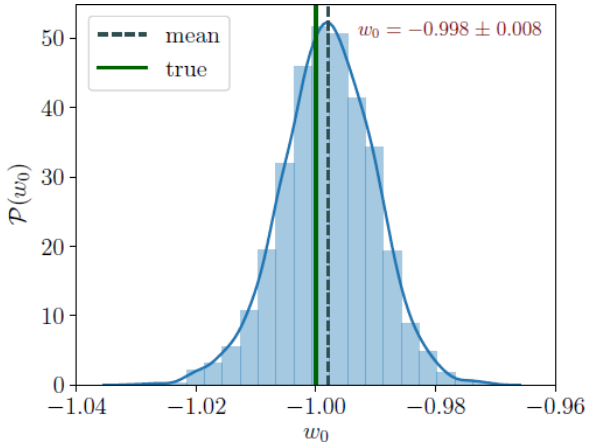


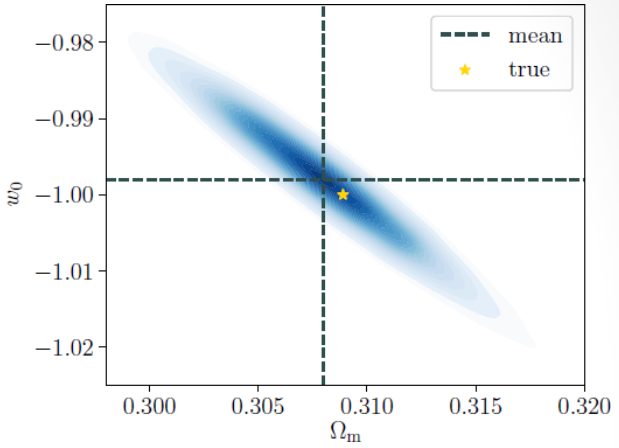
Mass profile of the Coma cluster, in agreement with gravitational lensing and X-ray observations down to a few Mpc.

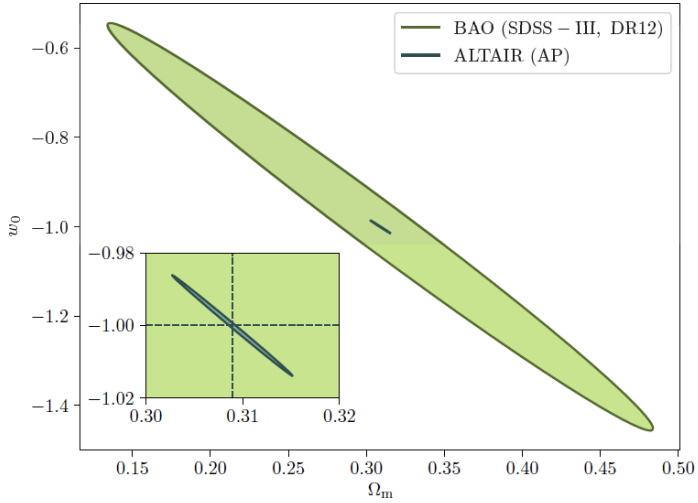
Jasche & Lavaux 2018, arXiv:1806.11117

ALTAIR: Cosmological inference from AP effect







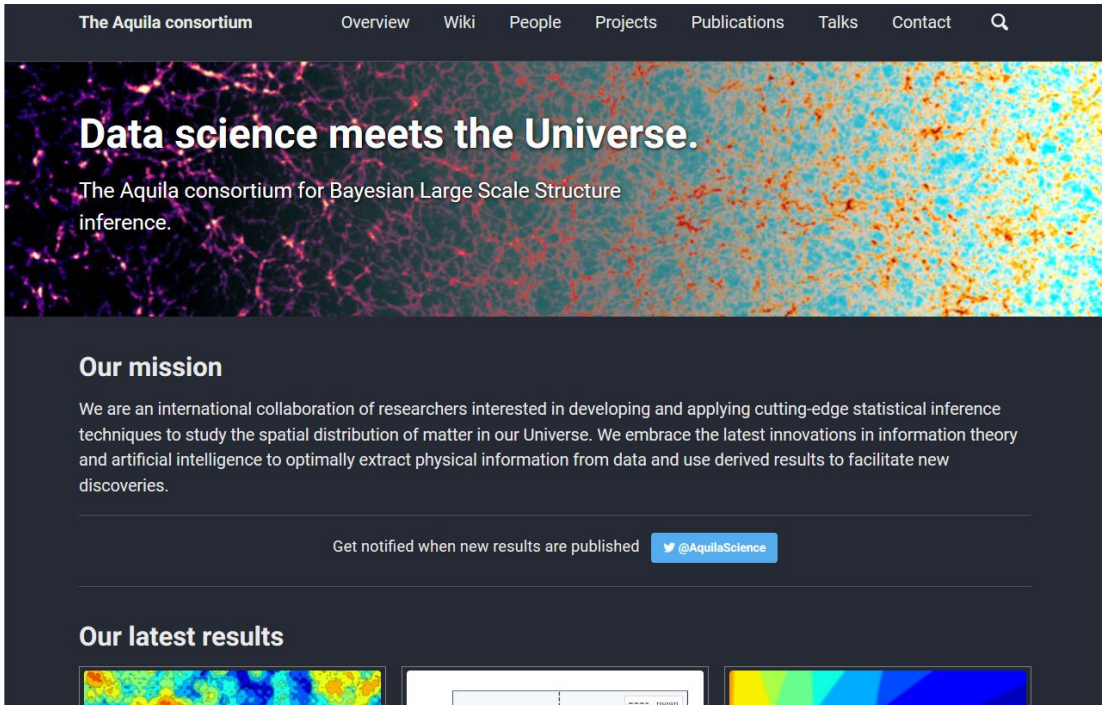


Joint map-cosmology inference is becoming feasible.

Ramanah, Lavaux & Wandelt 2018, arXiv:1808.07496

The Aquila Consortium

- Created in 2016. Members from the UK, France, Germany & Sweden.
- Gathers people interested in developing the Bayesian pipelines and running analyses on cosmological data.



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Conclusions

- Bayesian large-scale structure inference is not an impossible task!
- This work is on-going in the Galaxy Clustering Science Working Group – work package "Additional probes"
- The future: great science and challenges