# A systematic-free Bayesian analysis of SDSS3/BOSS and its correlation with CMB lensing

Guilhem Lavaux (IAP/CNRS) for the Aquila Consortium

KICC 10<sup>th</sup> anniversary, September 16<sup>th</sup> 2019

Aquila consortium (https://aquila-consortium.org)

# **Example 2** Bayesian analysis of S S 2 BOSS and its correlation with CMB Letters

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Ultimately: we want to fit a model to this kind of picture, and the pixel by pixel spectrum That's very challenging, probably impossible  $\rightarrow$  we reduce those datasets

A proposal to model observations of the Universe

#### Different analysis pathways...



#### The ideal scheme



#### The more pragmatic scheme: BORG3



#### A growing software basis

Language	files	blank	comment	code
 C++	 191	 7370	4123	26480
- C/C++ Header	268	7309	4657	26413
Julia	10	187	208	1022
CMake	25	142	21	532
Python	5	68	129	139
INI	1	20	Θ	89
Markdown	2	18	Θ	27

Check ARES at https://bitbucket.org/bayesian\_lss\_team/



#### The inference chain



#### The inference chain



#### SDSS-III/BOSS data



#### Non exhaustive list of contaminants

11 foregrounds (here only 8)... still much less than Leistedt & Peiris (2014) but improving



How to handle the unknown systematics?

## Accounting for unknown systematics

Each count in 3d patch 🖍 Poisson probability

Yield a new effective likelihood

$$P(\{N\}|\{\lambda\}) \propto \prod_{\text{patch}} \prod_{i \in \text{patch}} \left(\frac{\lambda_i}{\sum_{j \in \text{patch}} \lambda_j}\right)^{N_i}$$



Porqueres, Ramanah, Jasche & Lavaux (2018)

#### Results on mock SDSS3 data





What about the bias model?

#### Expected number of galaxies



Simple, but capture non-local information about galaxy formation

Major improvement with neural bias: Charnock et al. (2019, submitted, arXiv tomorrow)

The final model and results

#### The inference chain



#### The inference chain



Lavaux, Jasche & Leclercq (2019, submitted)

#### Results on SDSS-III/BOSS: density and P(k)

Ensemble mean density

Standard deviation



## Results on SDSS-III/BOSS: density and P(k)



No apparent contamination

#### Results on SDSS-III/BOSS: density and P(k)



#### BORG a posteriori powerspectrum

Lavaux, Jasche & Leclercq (2019 submitted)

Kalus, Percival et al. (2018, MNRAS)

## CMB Lensing



#### Application to CMB lensing



#### Systematic map inference



## Systematic map inference



#### Conclusion

### Take home message



Automated cosmological inference Eliminating systematic effect Gravity model validated with lensing





Need to increase resolution Not laptop computing





Bias model to be improved See tomorrow's arxiv paper by Charnock et al.



### The Aquila consortium

- Founded in 2016
- Gather people interested in working with each other on developing the Bayesian pipelines and run analysis on data.

https://aquila-consortium.org/

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The Aquila consortium	Overview	Wiki	People	Projects	Publications	Talks	Contact	Q,

#### Data science meets the Universe

The Aquila consortium for Bayesian Large-Scale Structure inference

#### Our mission

We are an international collaboration of researchers interested in developing and applying cutting-edge statistical inference techniques to study the spatial distribution of matter in our Universe. We embrace the latest innovations in information theory and artificial intelligence to optimally extract physical information from data and use derived results to facilitate new discoveries.