Observing the Dark Universe with Planck
(Baryons included)

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Collaboration:
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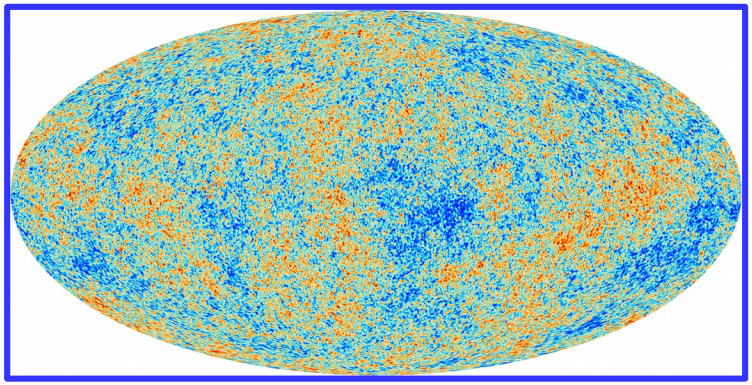
Stephen Turnbull (UoW), Jonathan Carrick

FM5.3.03 – The Legacy of Planck + Poster S319.p166

August 12th 2015

Secondary CMB anisotropies



Momentum field
(kSZ effect)

$$\Delta T \propto \int (1+\delta)(r\hat{r}) v_r(r\hat{r}) \mathrm{d}r$$

+

Gas profile in cluster
(individual analysis of
tSZ pressure profile)

$$\Delta T \propto \int (1+\delta)(r\hat{r}) T_e(r\hat{r}) \mathrm{d}r$$

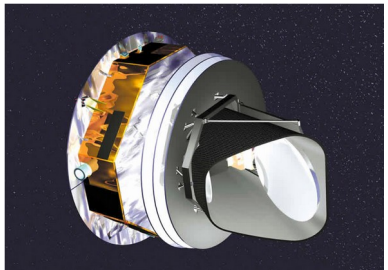
+

Rees-Sciama effect
(non linear density and
momentum field)

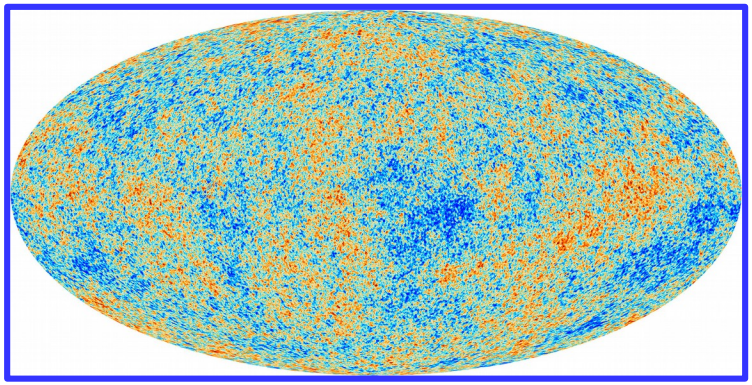
$$\Delta T \propto T \int \dot{\Phi}(\hat{r}, \eta) \mathrm{d}\eta$$

+

other (lensing, beaming, ...)



Secondary CMB anisotropies



Momentum field
(kSZ effect)

$$\Delta T \propto \int (1+\delta)(r\hat{r})v_r$$

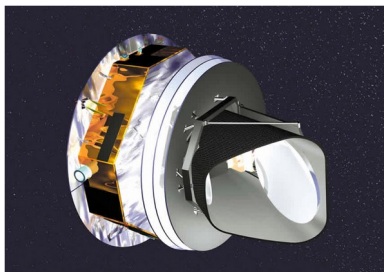
Rees-Sciama effect
(non linear density and
momentum field)

$$\propto T \int \dot{\Phi}(\hat{r},\eta)\mathrm{d}\eta$$

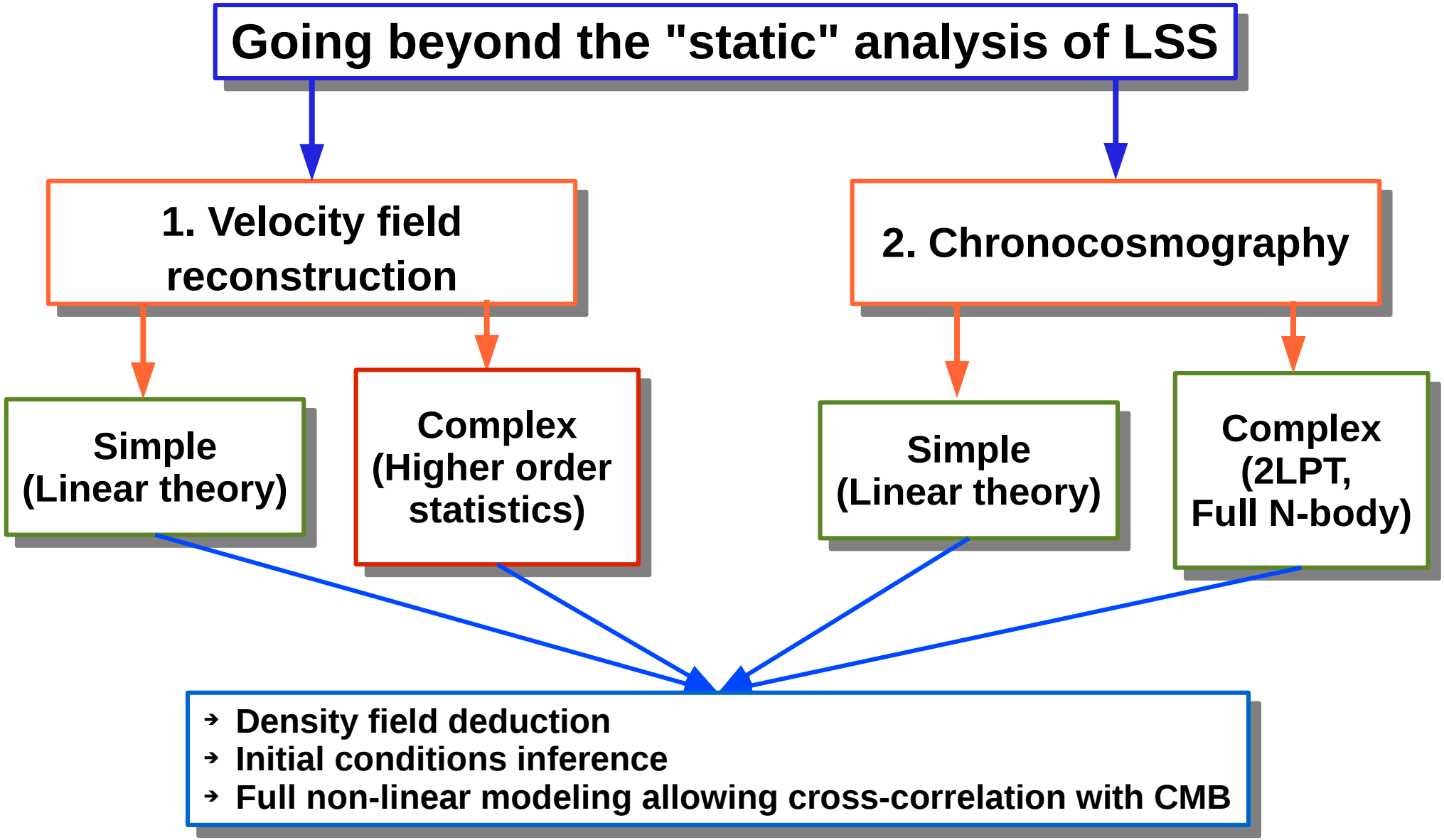
COMPLEX NON LINEAR DYNAMICS

Hand et al. 2012 (pairwise)
Lavaux et al. 2013 (template)
Planck 2015 [37] (pairwise+template)

all "**LINEAR**" methods

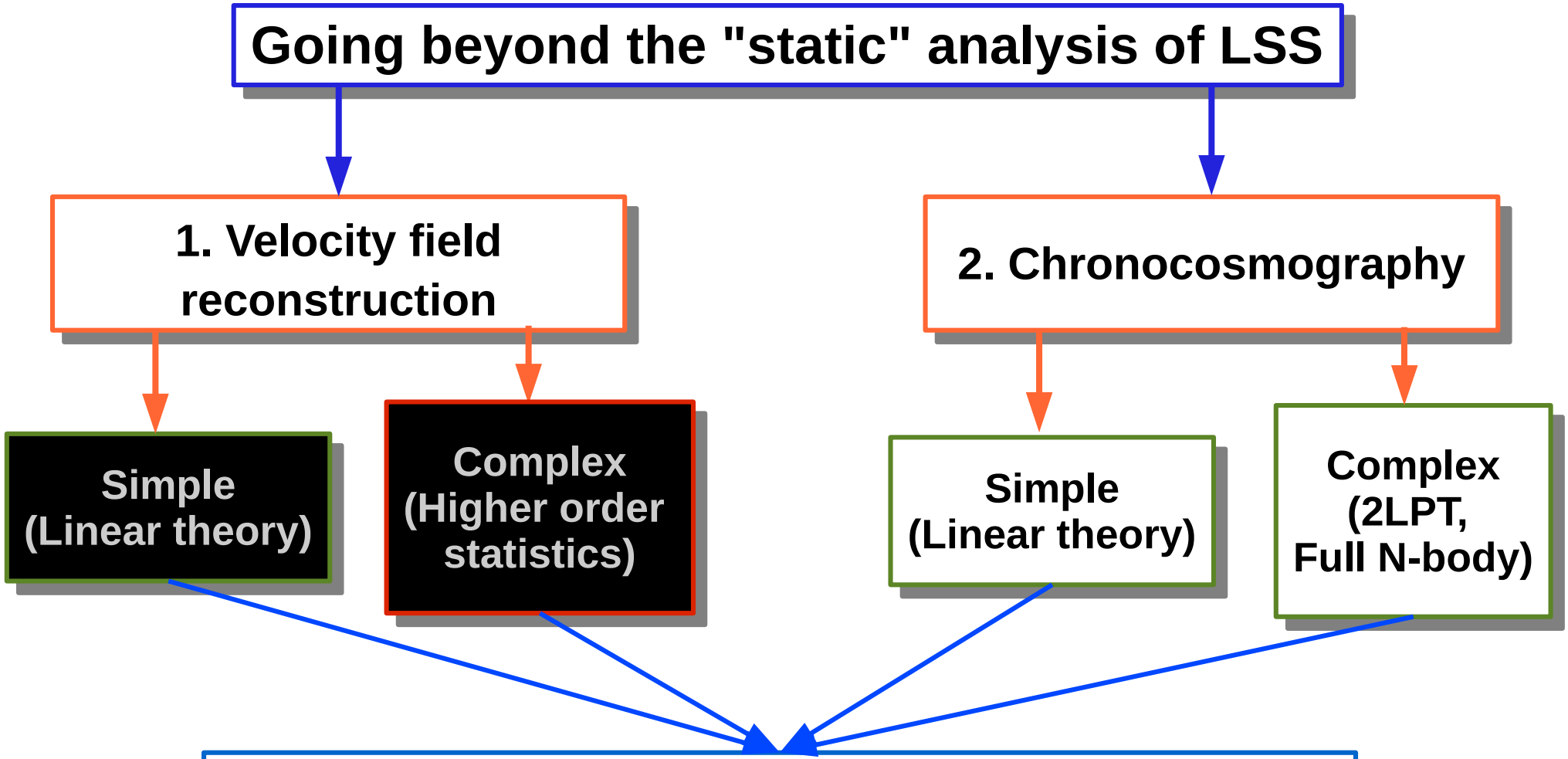


Modeling the dynamics



Joint endeavor: Jens Jasche, Florent Leclercq, Benjamin Wandelt, Mike Hudson

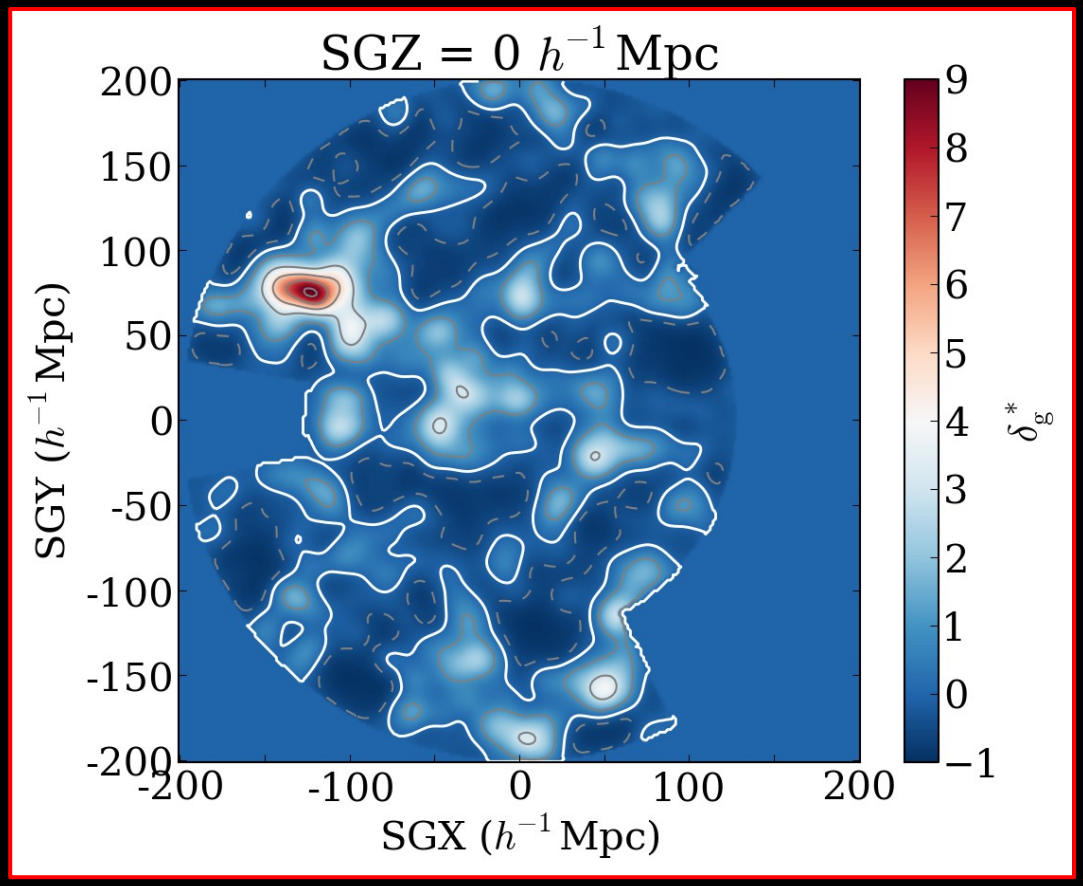
Modeling the dynamics



- Density field deduction
- Initial conditions inference
- Full non-linear modeling allowing cross-correlation with CMB
- Caveat: correlations to CMB data are Work in Progress

Joint endeavor: Jens Jasche, Florent Leclercq, Benjamin Wandelt, Mike Hudson

Large scale structure, linear cosmic flows (I)



Lavaux & Hudson (2011, MNRAS)

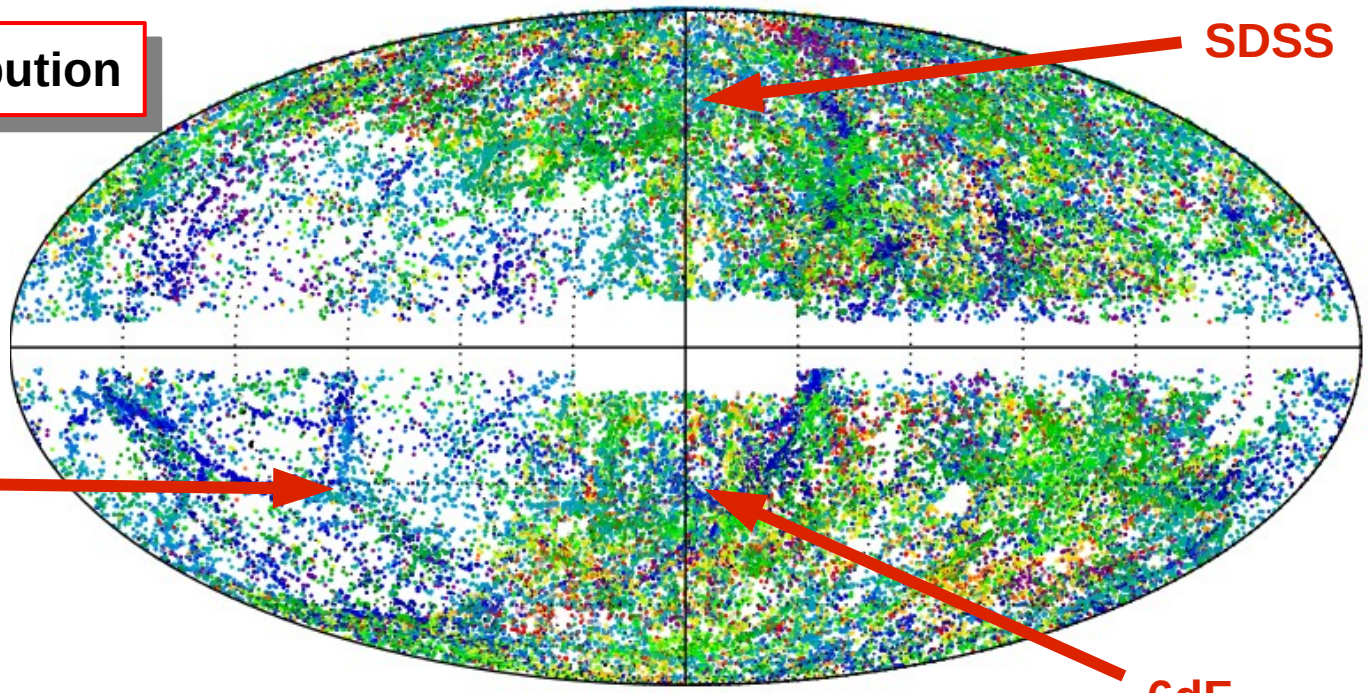
Carrick, Turnbull, Lavaux & Hudson (2015, MNRAS)

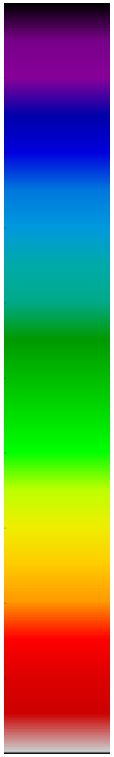
http://cosmicflows.iap.fr/

http://cosmicflows.uwaterloo.ca/

The 2M++ catalog

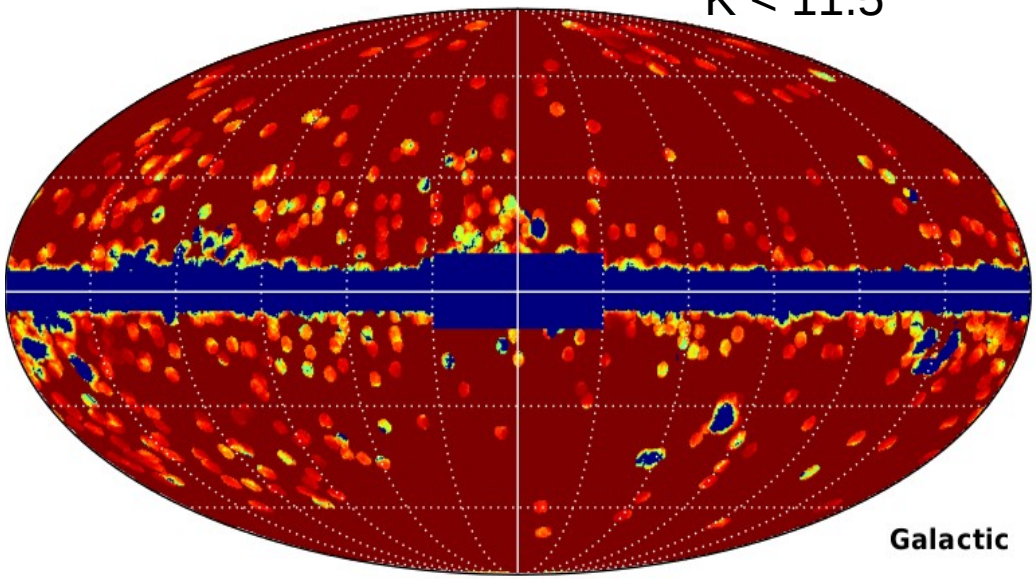
Galaxy distribution



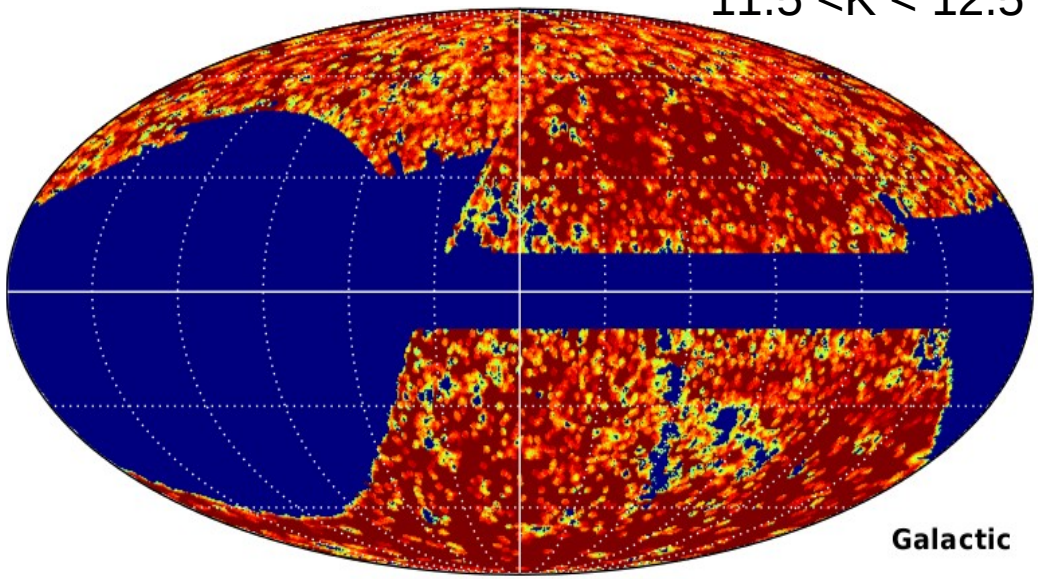


Redshift completeness

K < 11.5

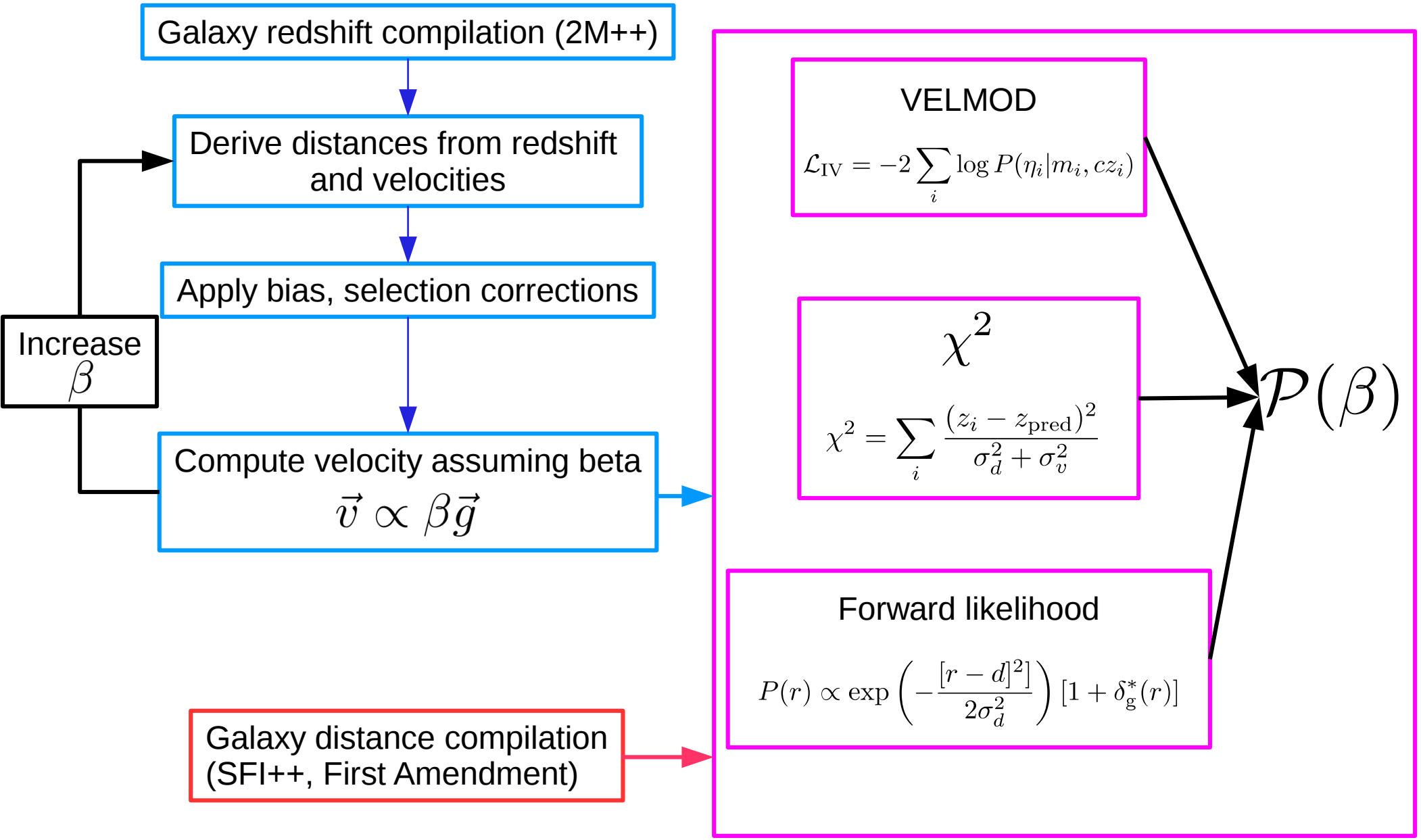


11.5 <K < 12.5



Analysis framework

velocity field reconstruction from density



Carrick, Turnbull, Lavaux & Hudson (2015, MNRAS)

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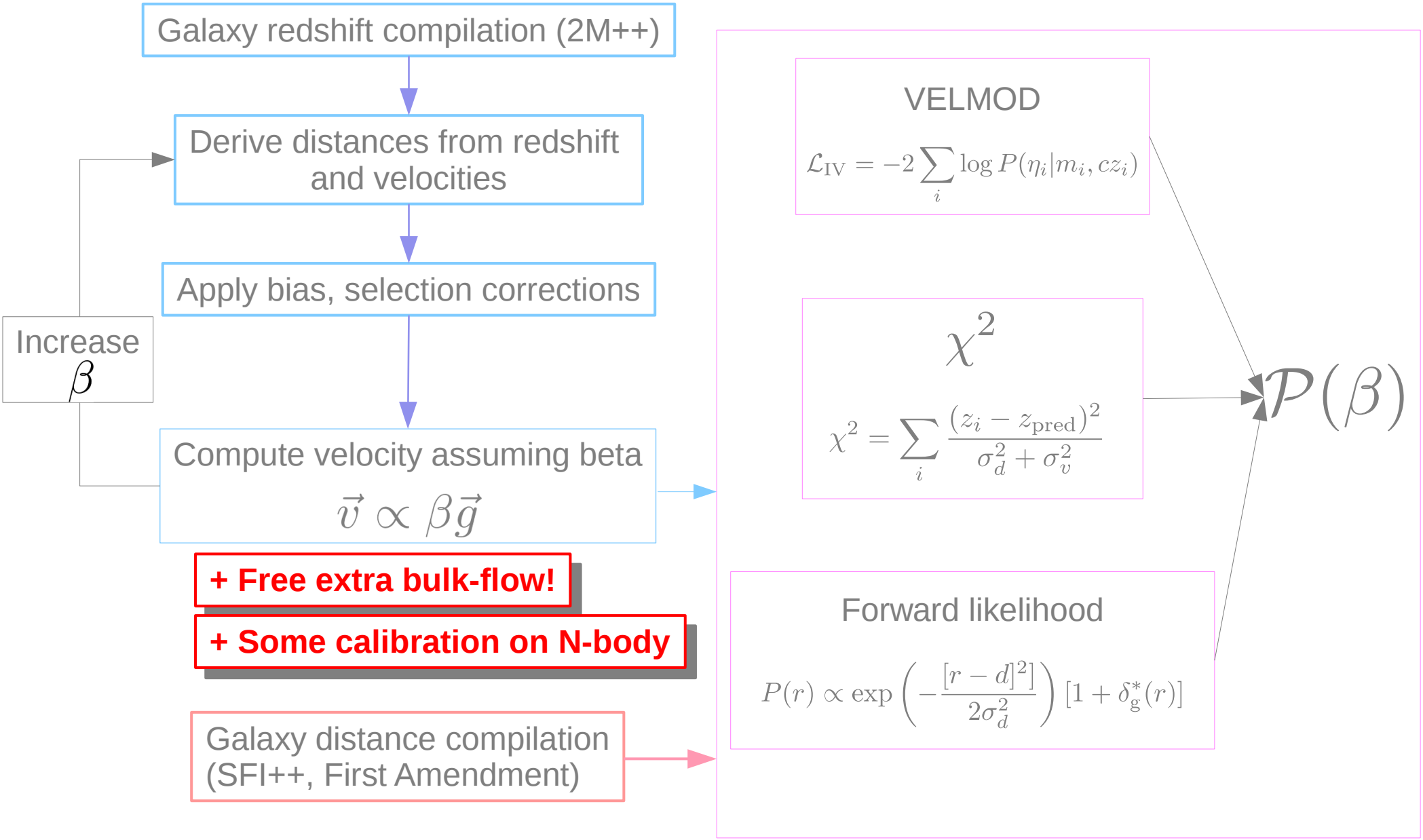
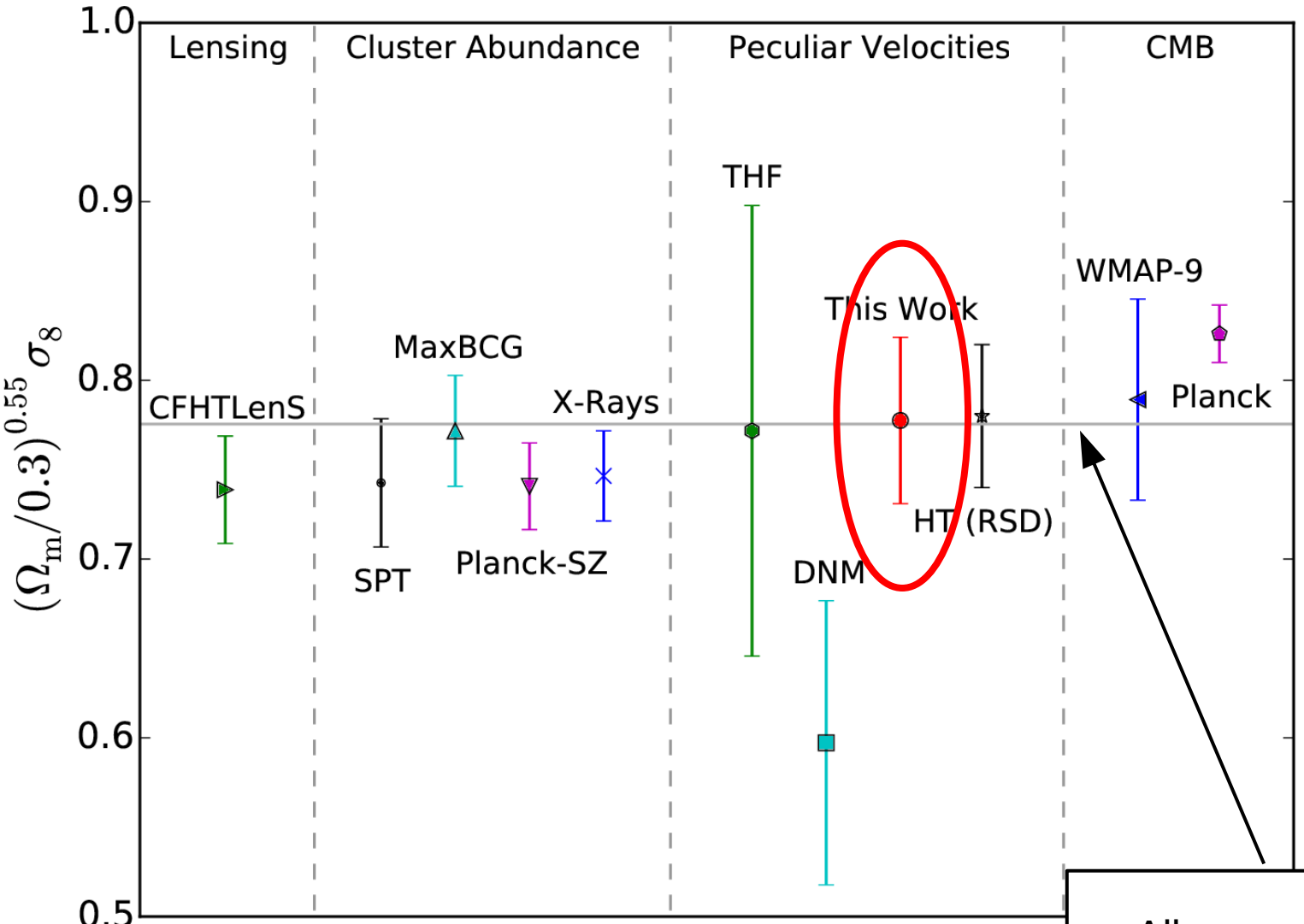


Carrick, Turnbull, Lavaux & Hudson (2015, MNRAS)

Results: gravity

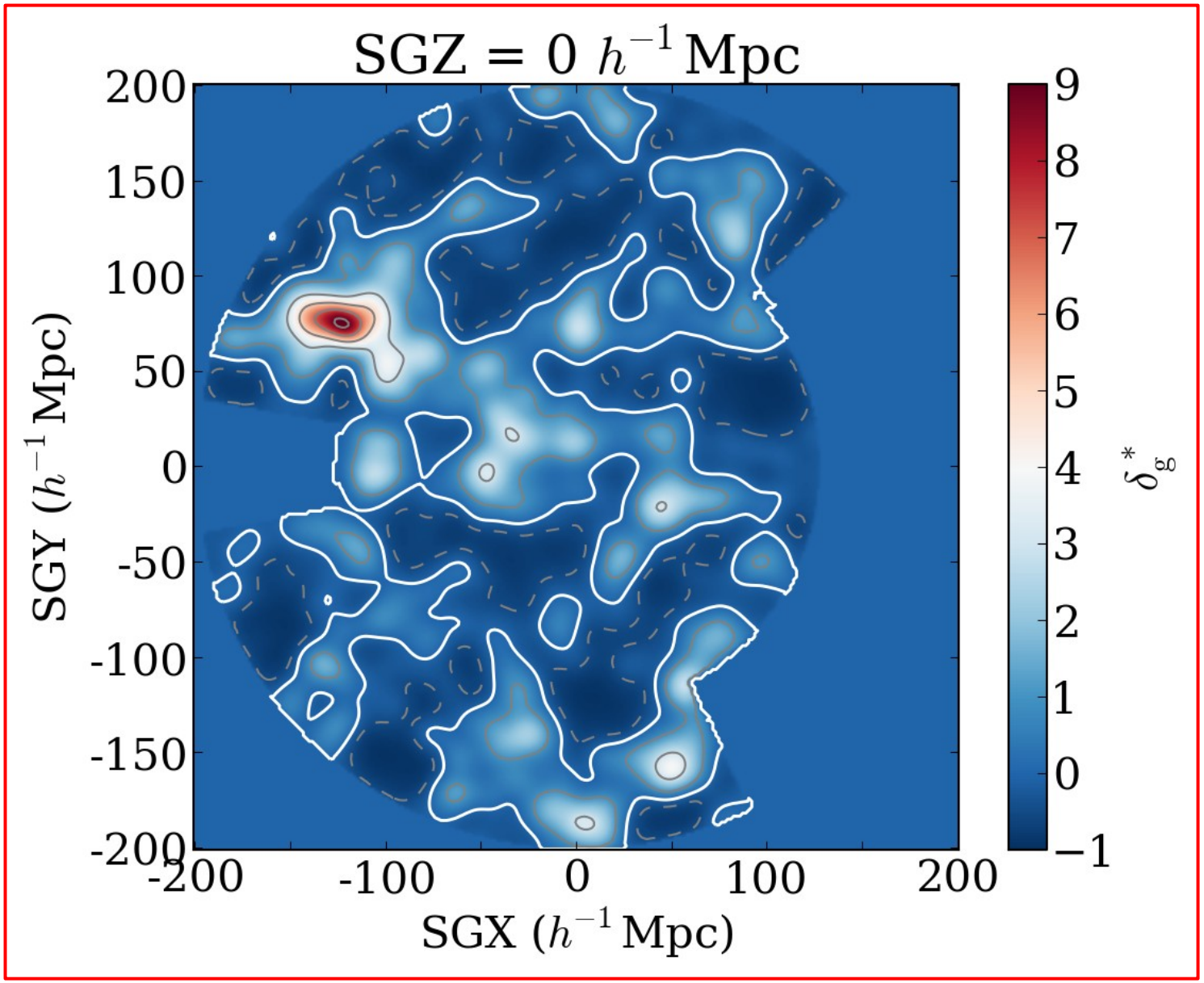


All measurements mean value

$$f\sigma_8 = 0.400 \pm 0.005$$

Carrick, Turnbull, Lavaux & Hudson (2015, MNRAS)

Large scale structure calibrated map



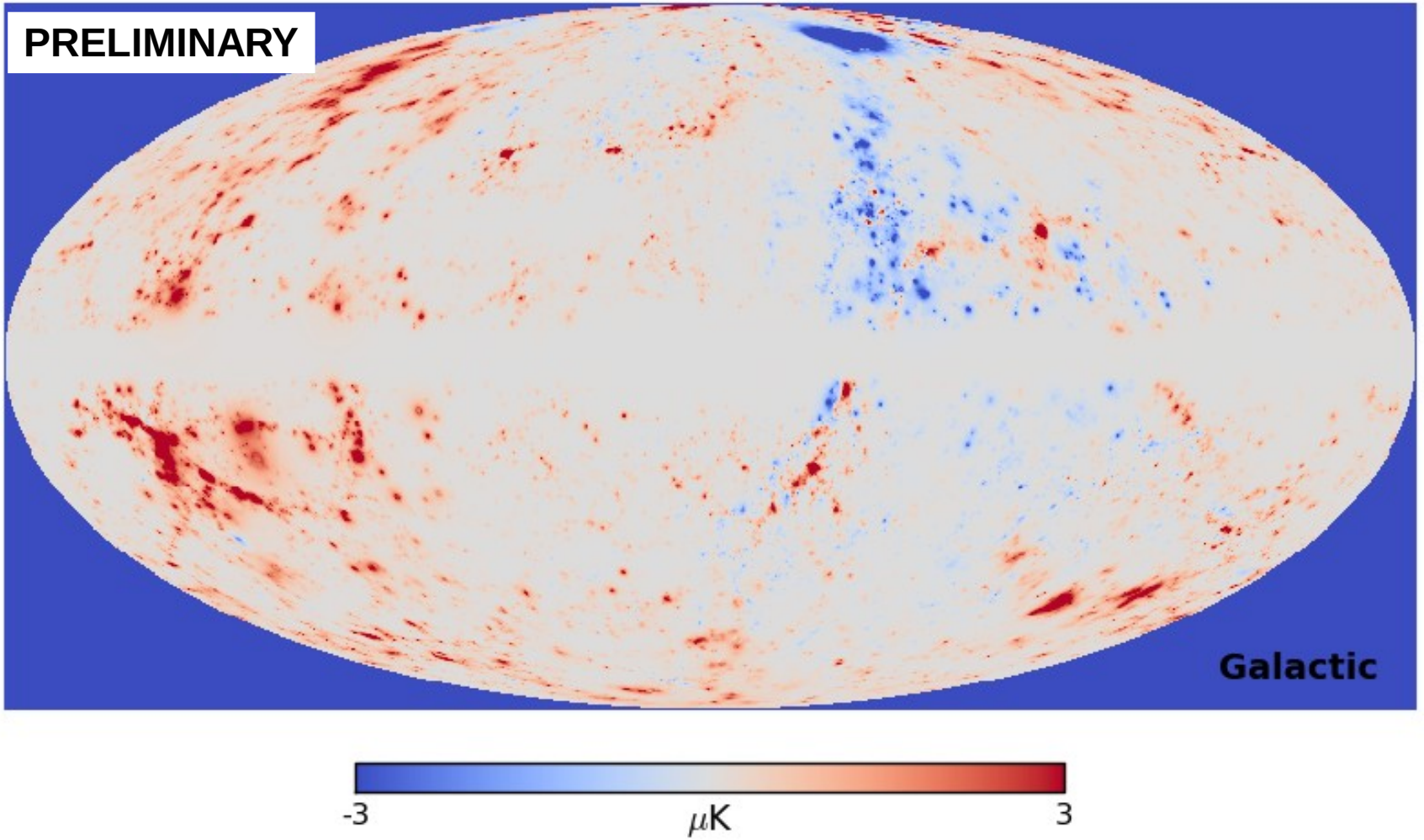
Carrick, Turnbull, Lavaux & Hudson (2015, MNRAS)

Summaries of results

- LG convergence as **expected** by LCDM
- Misalignment fluctuations **within** LCDM predictions
- $f\sigma_8$ in **agreement** with results from other probes
- **Bulk flow** still **high** but in **good agreement** with both observations and expectations

Calibrated velocities and maps at
http://cosmicflows.iap.fr and http://cosmicflows.uwaterloo.ca .

kSZ map using smoothed flows



Galaxy profile assumed (see Lavaux, Afshordi & Hudson 2012)

Projection of the first 200 Mpc/h

Large scale structure, full non-linear dynamic (II)

Algorithm for **RE**construction and **S**ampling (ARES)

Bayesian **O**rigins **R**econstruction from **G**alaxies (BORG)

Jasche & Wandelt (2013), Jasche & Lavaux (2014), Lavaux & Jasche (2015, submitted)

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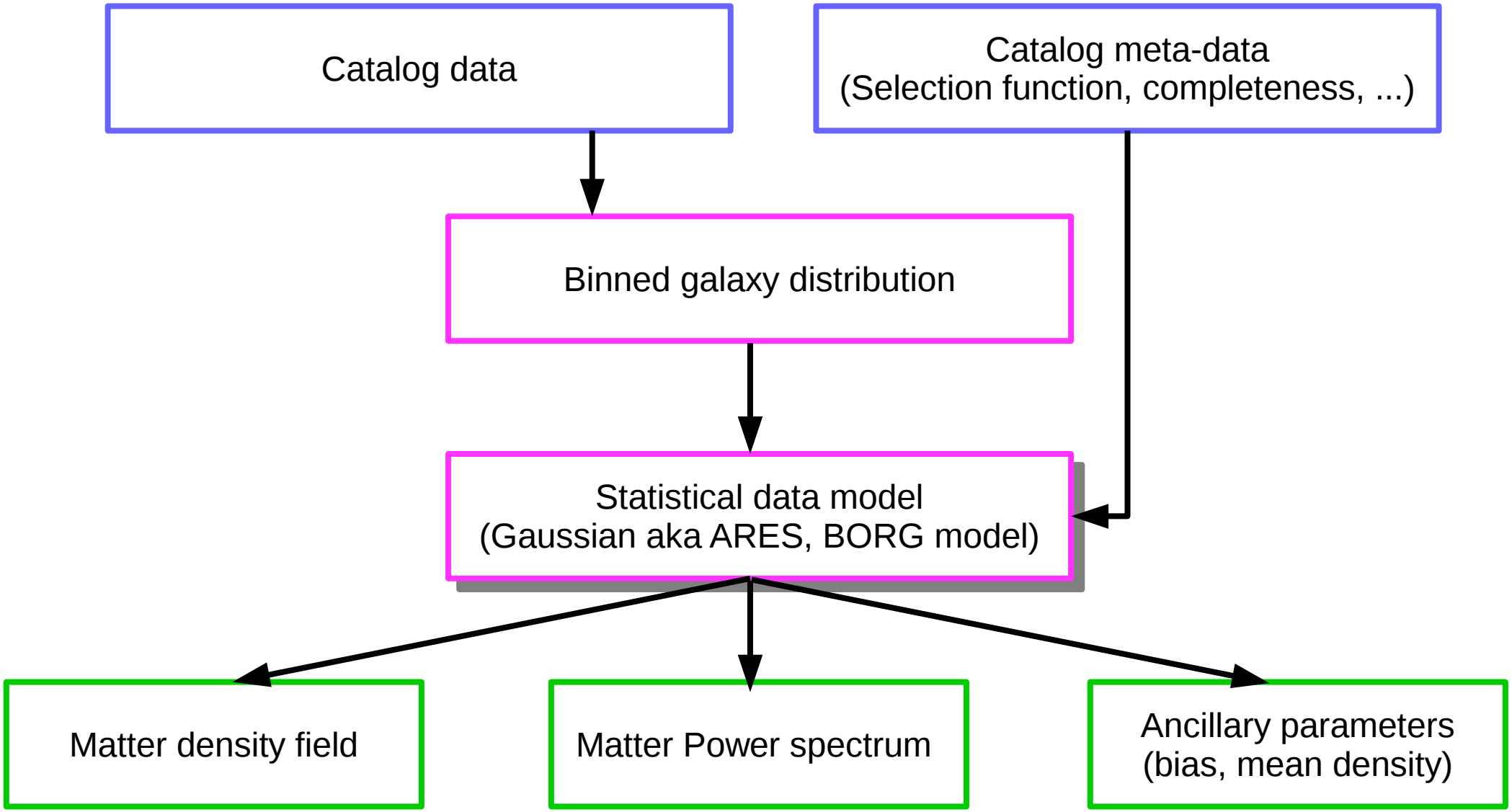
The analysis procedure



The **BORG** data model

Linear response operator (mask, radial selection)

« Mean » density of tracers

bias

$$-\log P\left(\delta,\alpha,\widetilde{n}\right)=A+\sum_i \widetilde{n}\,R_i\left(1+\delta_{\mathrm{NL},i}[\delta]\right)^{\alpha}-N_i\,\alpha\log\left(1+\delta_{\mathrm{NL},i}[\delta]\right)+\frac{\sum_k|\hat{\delta}_k|^2}{2\,P_k}$$

NGP binned data

Poisson probability

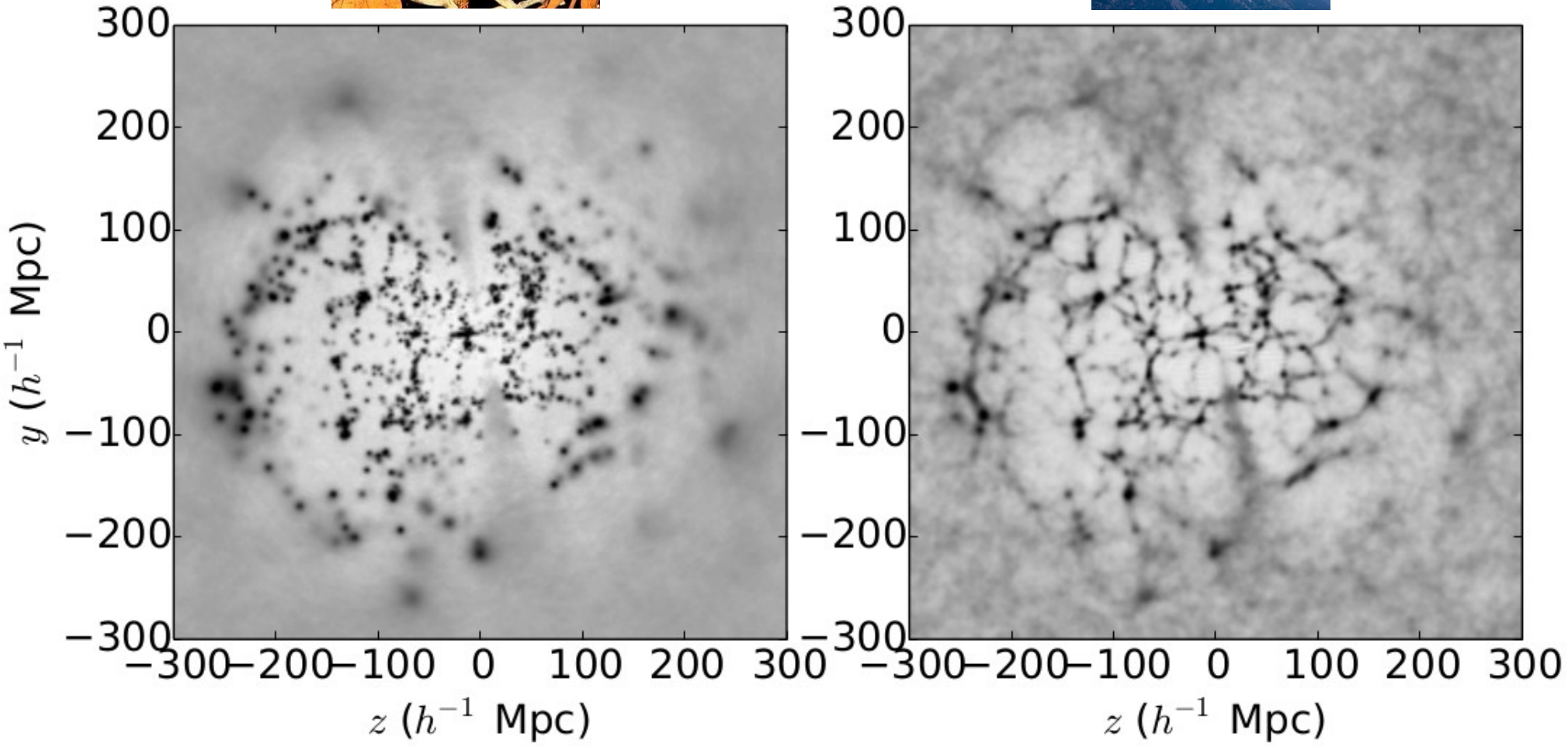
Gaussian prior

Field $\delta_{\mathrm{NL}}[\delta]$ derived from Cloud-In-Cell + 2LPT dynamics

δ sampled using Hamiltonian Monte Carlo algorithm

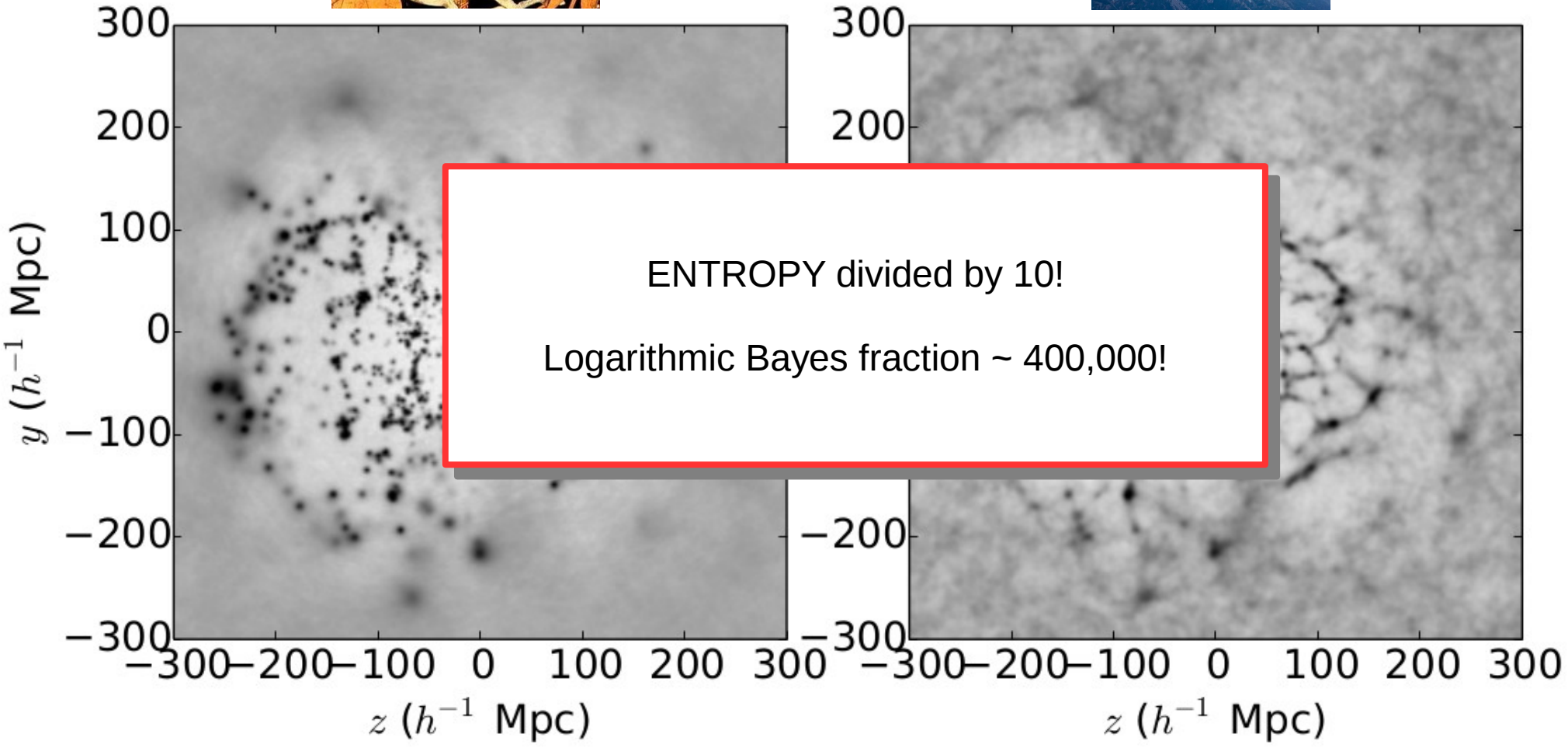
Jasche & Wandelt (2013)

Gaussian model vs BORG reconstruction



Jasche & Lavaux (2015, in prep)

Gaussian model vs BORG reconstruction



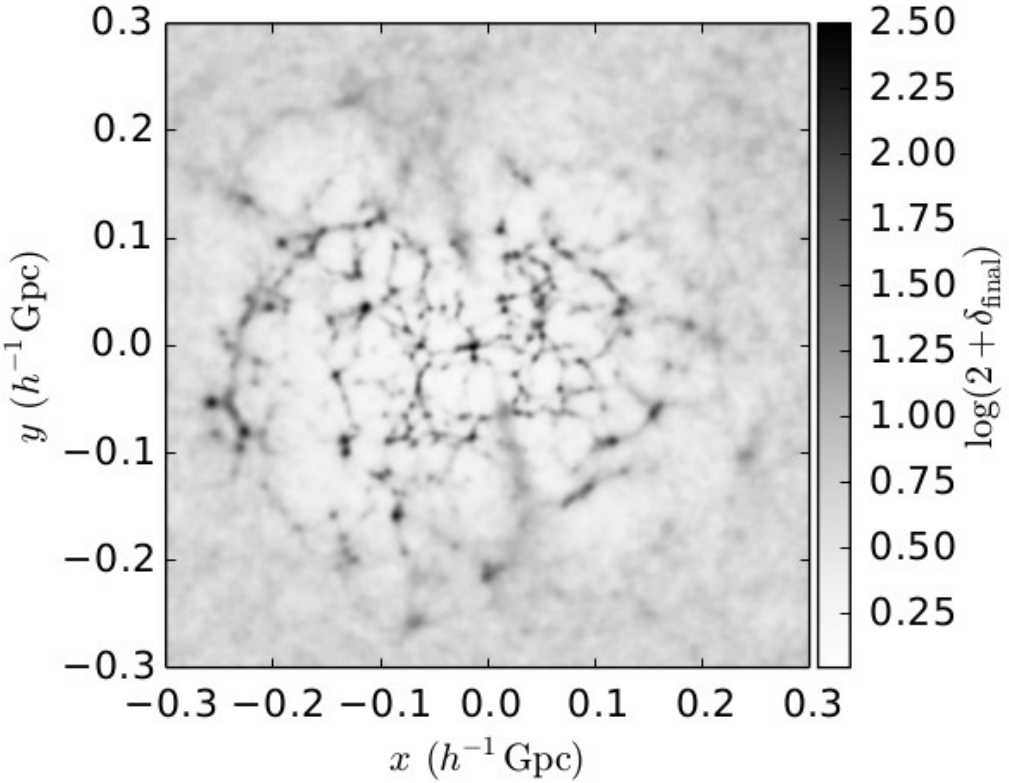
ENTROPY divided by 10!

Logarithmic Bayes fraction ~ 400,000!

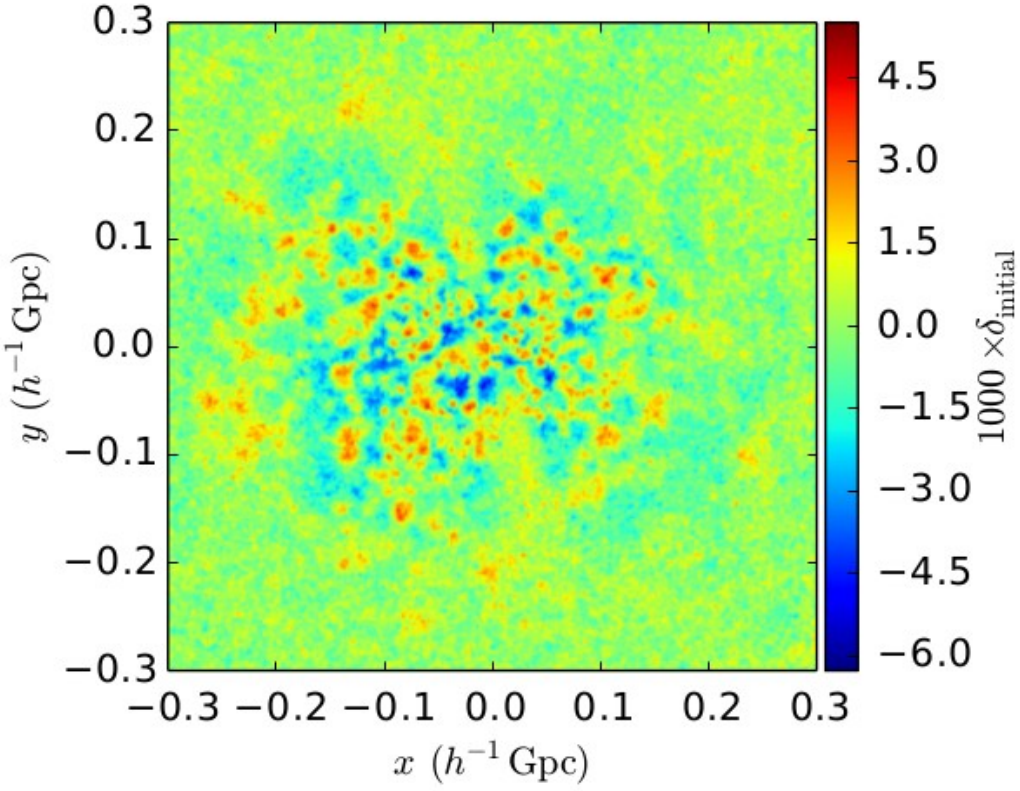
Jasche & Lavaux (2015, in prep)

Initial condition reconstruction

Ensemble mean density field at present time



Ensemble mean density field at z=1000



Lavaux & Jasche (2015, submitted)

Producing LSS/CMB observables

Initial conditions from BORG

Resimulations

Hard to compute non-linear dynamics

Momentum field
(kSZ effect)

$$\Delta T \propto \int (1+\delta)(r\hat{r}) v_r(r\hat{r}) \mathrm{d}r$$

Gas profile in cluster
(individual analysis of
tSZ pressure profile)

$$\Delta T \propto \int (1+\delta)(r\hat{r}) T_e(r\hat{r}) \mathrm{d}r$$

Rees-Sciama effect
(non linear density and
momentum field)

$$\dot{\Phi}(\vec{k},t) \propto \left(H(t)\hat{\delta}(\vec{k},t) + i\vec{k}.\hat{\vec{p}}(\vec{k},t) \right)$$

$$\Delta T \propto T \int \dot{\Phi}(r\hat{r}) \mathrm{d}r$$

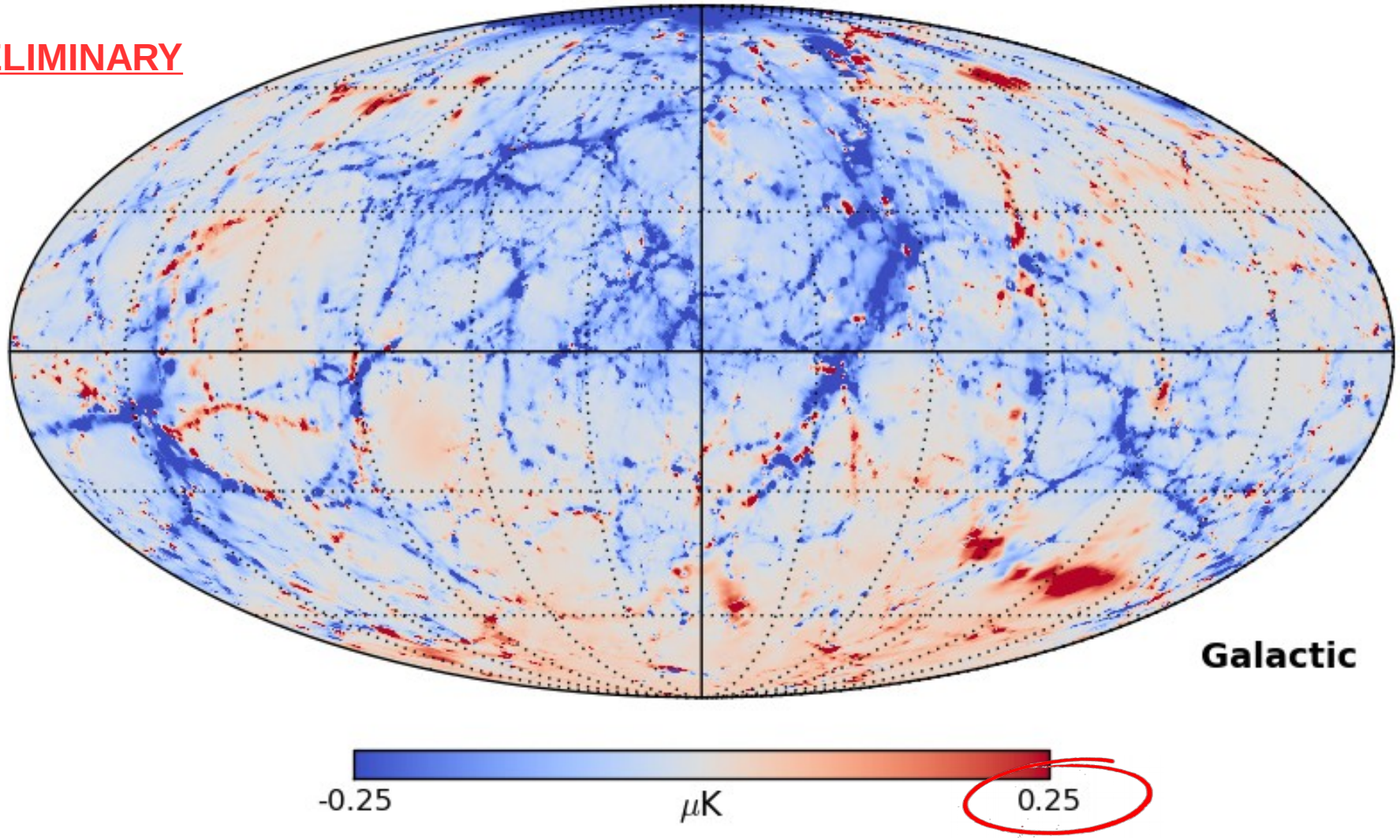
Better modeling yields higher
Signal/Noise

Two examples (PRELIMINARY MAPS)

Raytracing algorithm
Cai et al. (MNRAS, 2010)

kSZ maps

PRELIMINARY



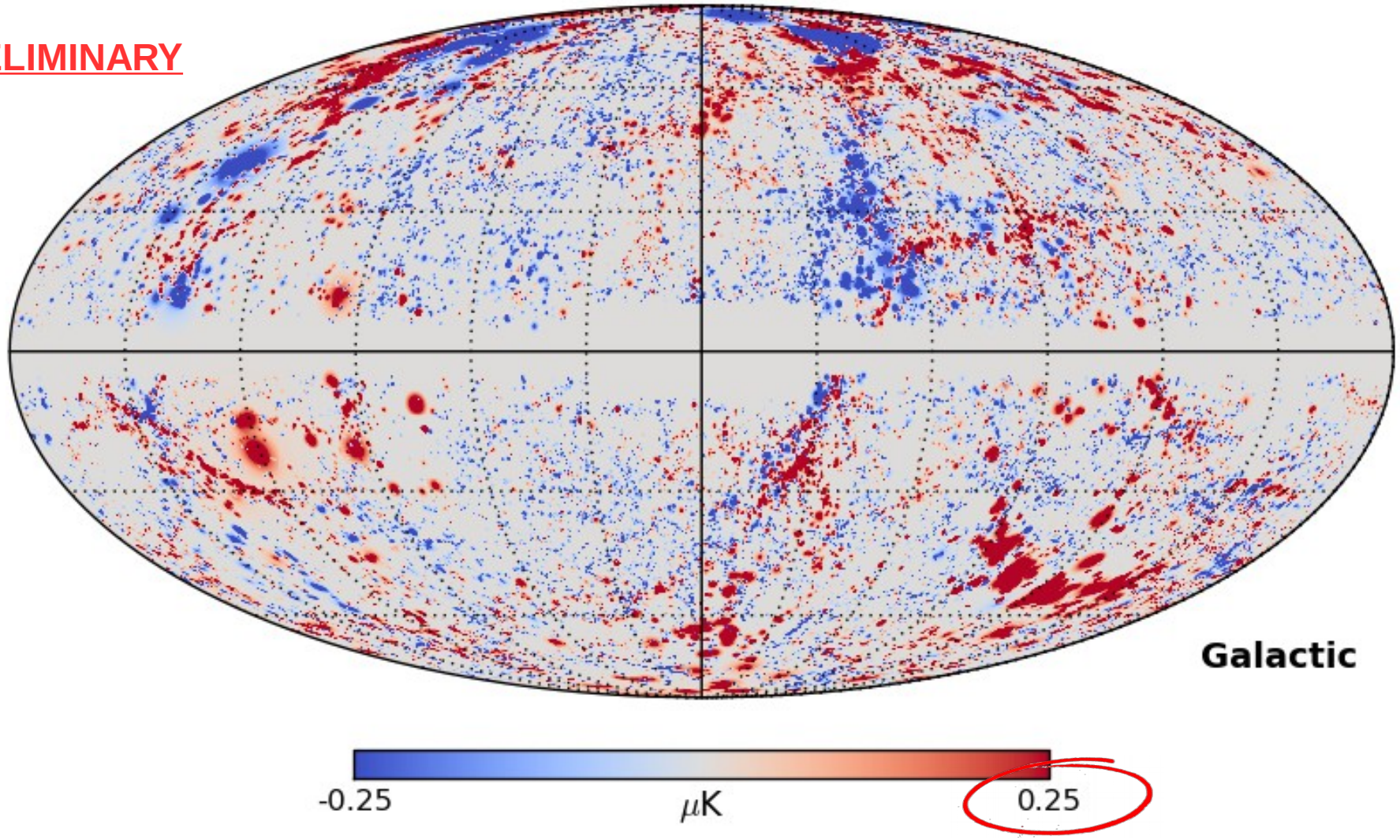
KSZ Simulation of **ONE(!)** BORG sample

Full posterior available for Hierarchichal Bayesian analysis

Raytraced from 0 to 100 Mpc/h

kSZ maps

PRELIMINARY



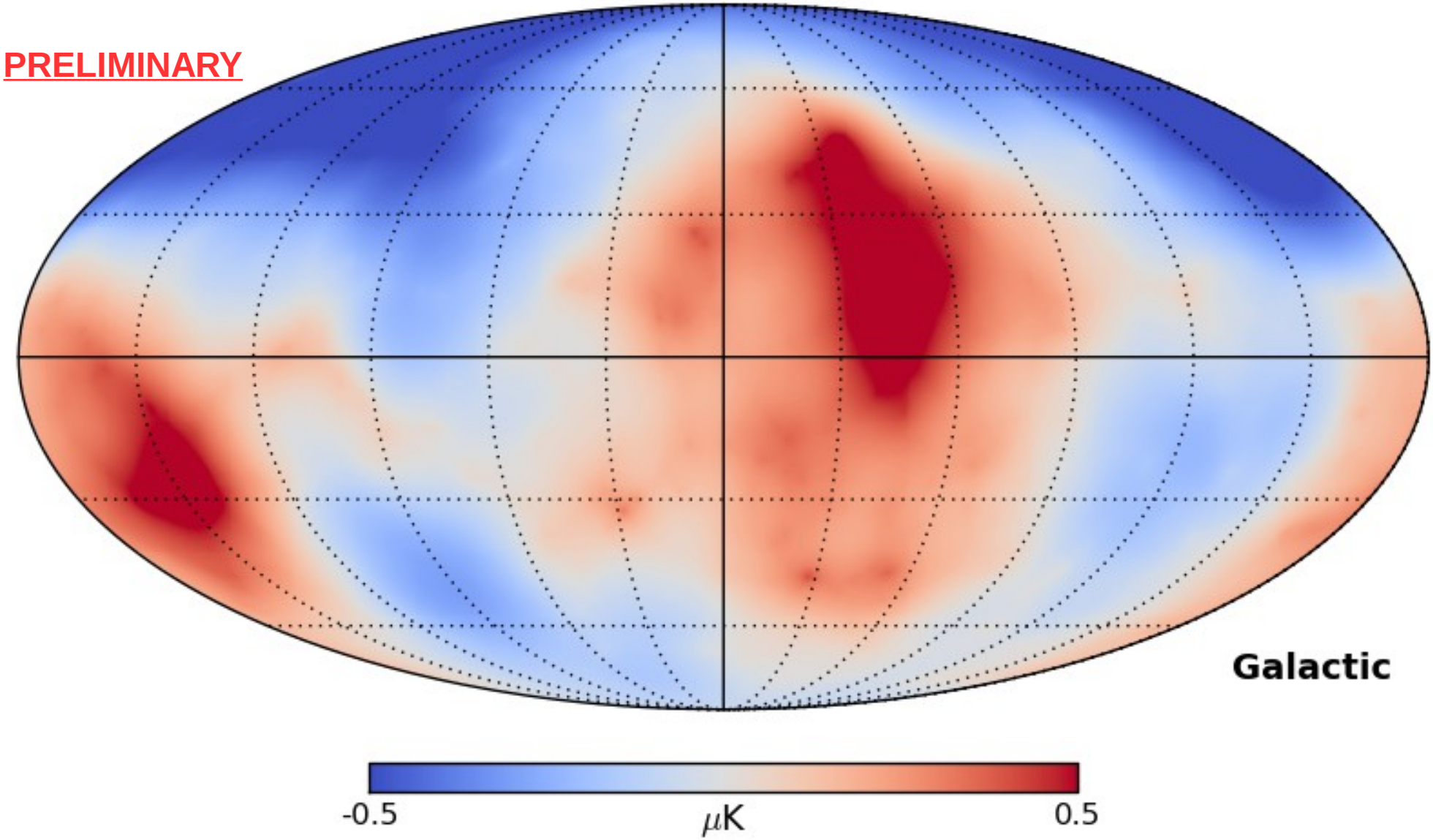
KSZ Simulation of **ONE(!)** BORG sample

Full posterior available for Hierarchichal Bayesian analysis

Raytraced from 0 to 100 Mpc/h

ISW map

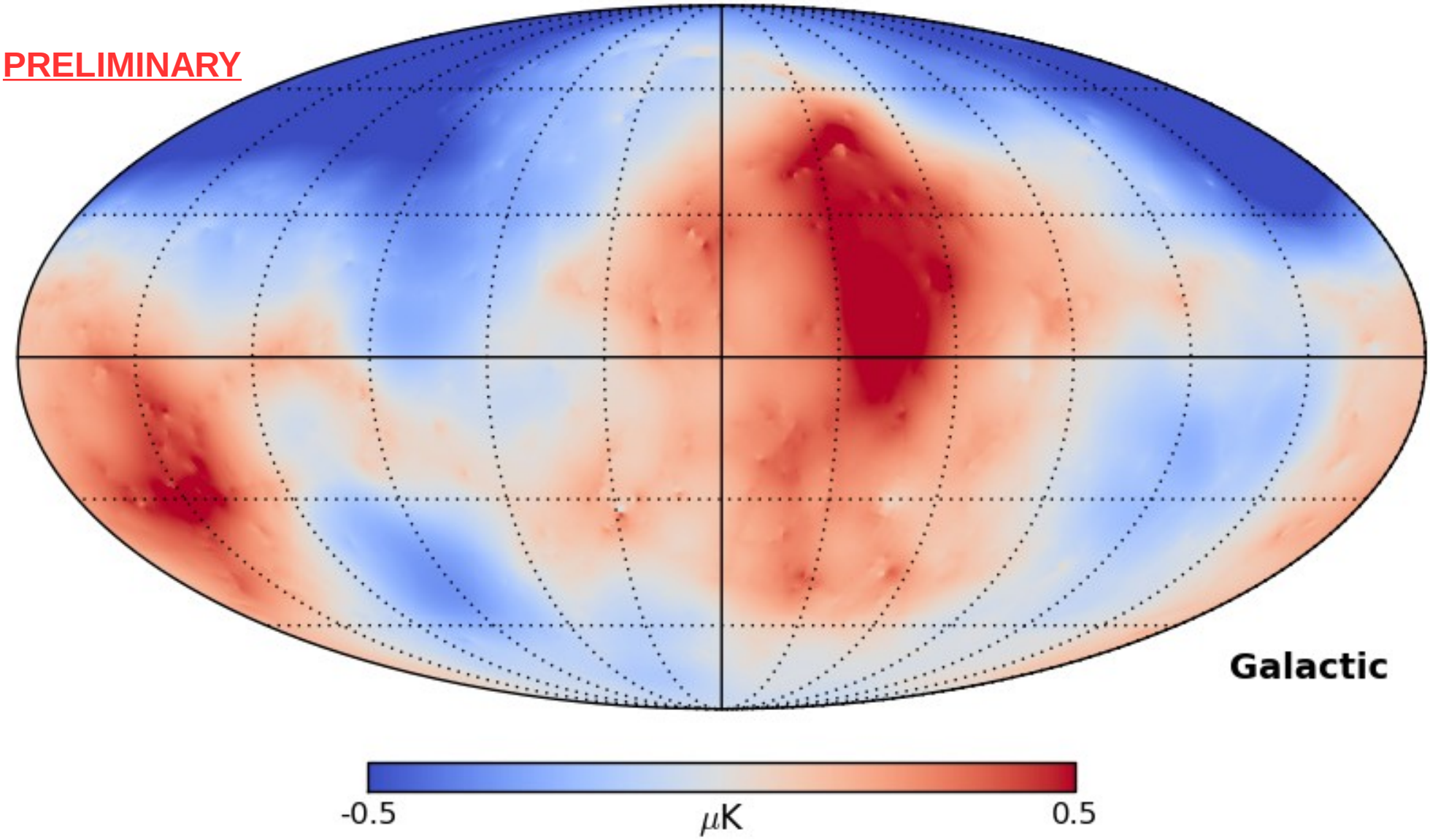
PRELIMINARY



Integrated Sachs Wolf effect, raytraced through the resimulation (0-100 Mpc/h)

Rees Sciama maps

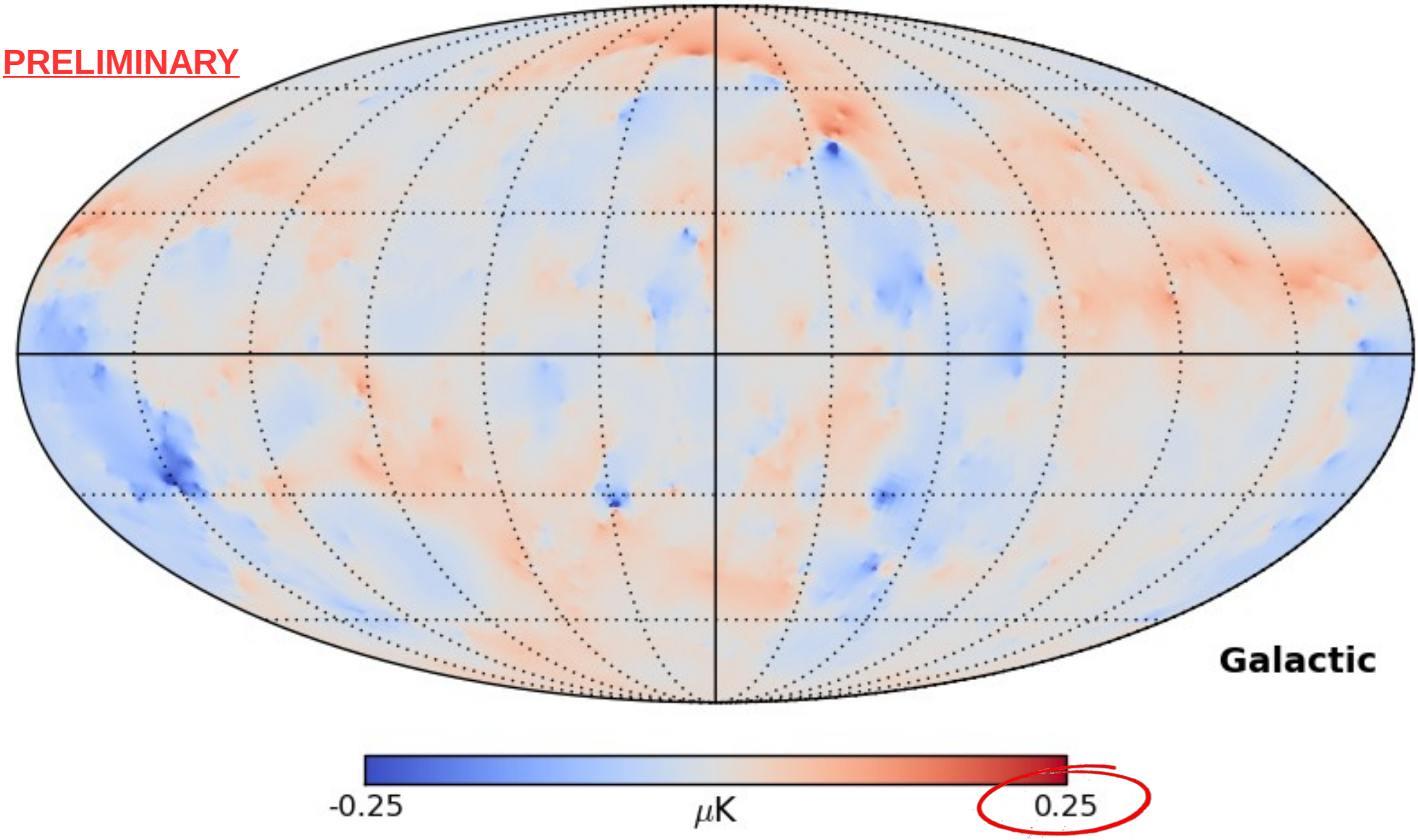
PRELIMINARY



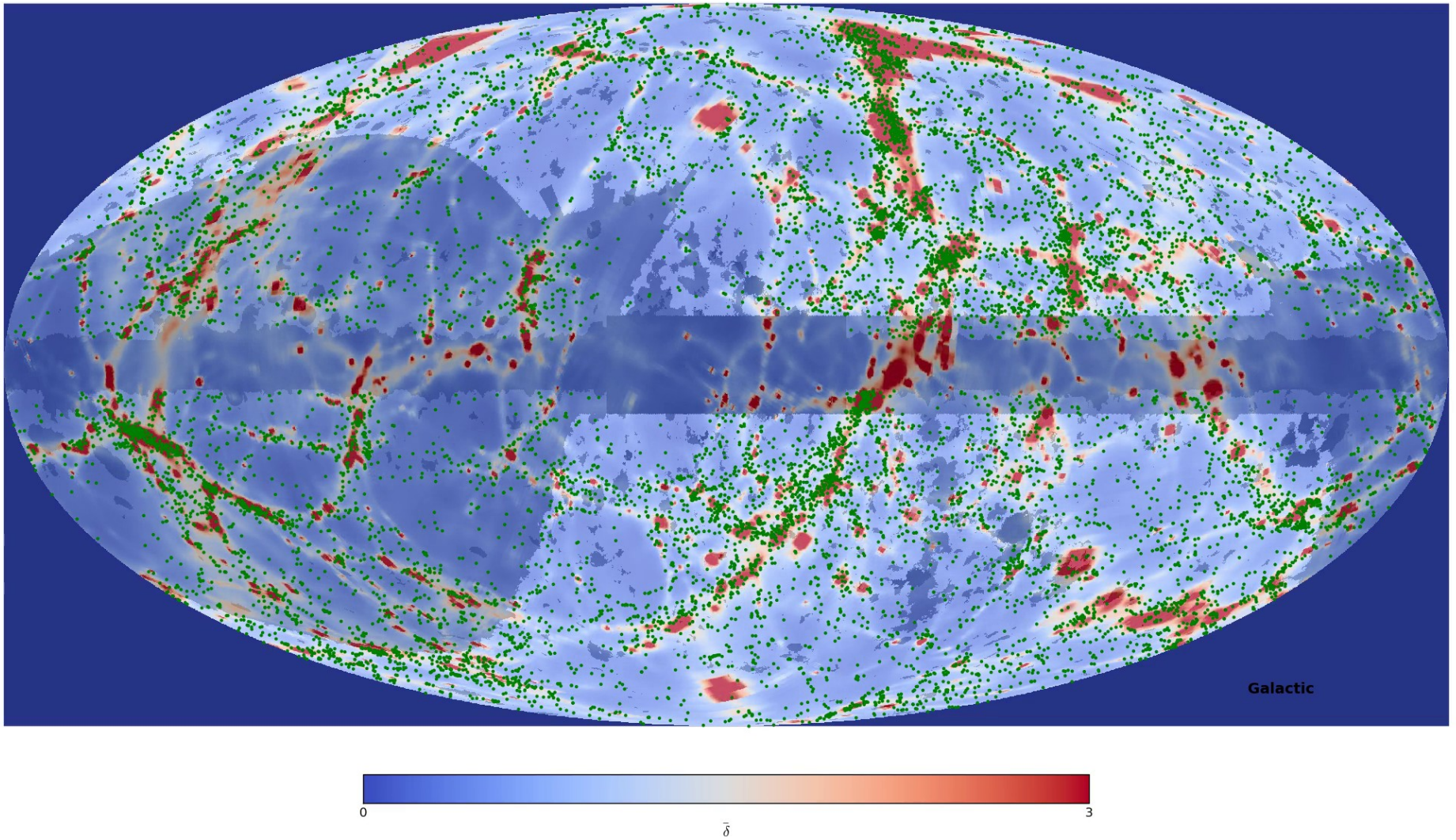
Rees-Sciama+ISW effect, raytraced through the resimulation (0-100 Mpc/h)

Only non-linear effects (RS - ISW)

PRELIMINARY



Pure Rees-Sciama effect, raytraced through the resimulation



600 Mpc/h, 60 Mpc/h projection, 2048^3 (512^3 shown here) dark matter (coll. S. Peirani, J. Jasche)

Conclusion

Conclusion

- **New methods** of analysis of Large Scale structures are coming online
- Offer a unique degree of **accuracy** in the reconstruction **non-linear** dynamics
- Methods will be applied to correlate galaxy surveys and CMB data through **kSZ/ISW/RS** effect, particularly **SDSS/LRG/LOWZ/CMASS**.
- **PLUS** will go further, investigate **precise tSZ** comparison