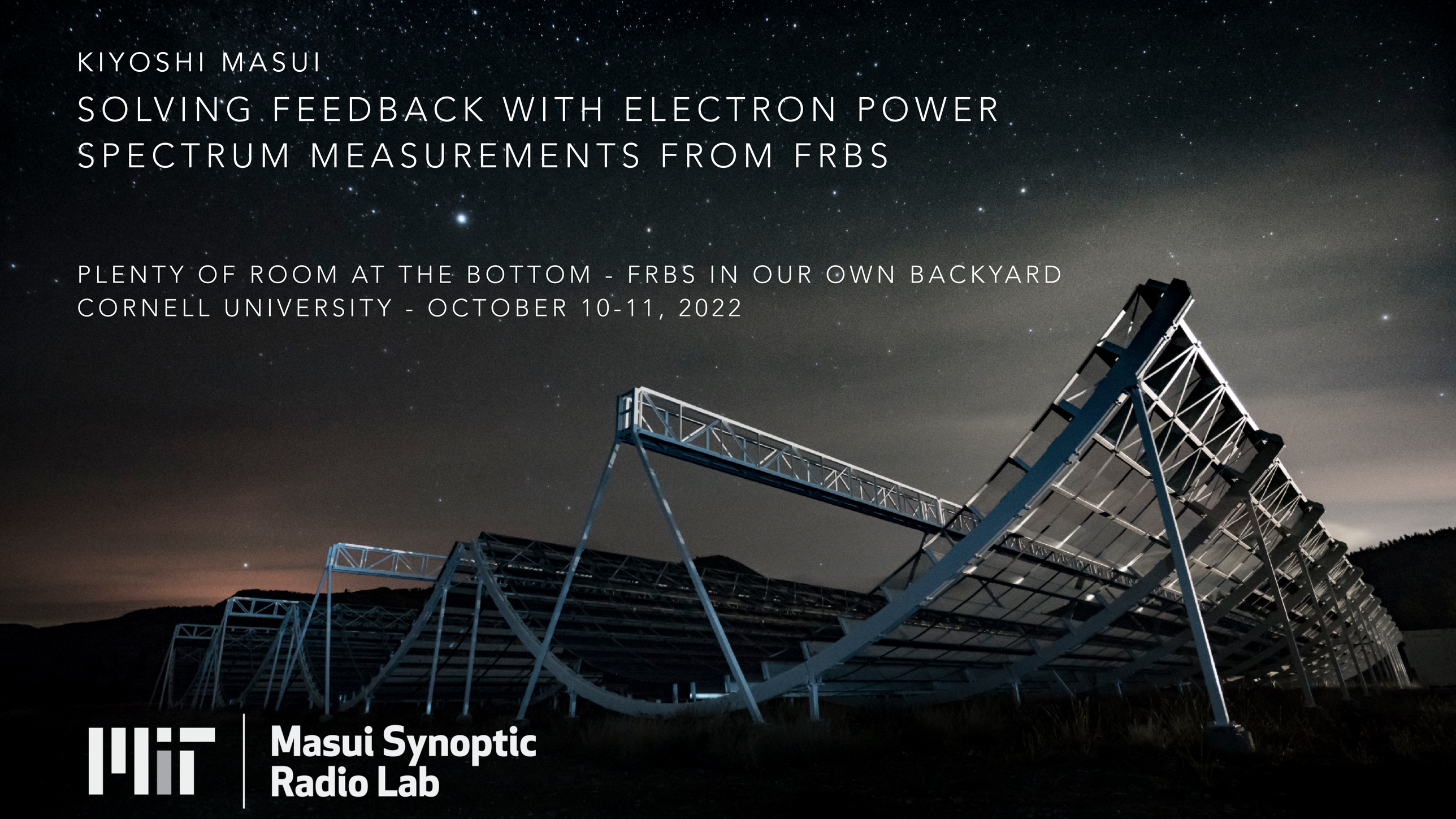
KIYOSHI MASUI

SOLVING FEEDBACK WITH ELECTRON POWER SPECTRUM MEASUREMENTS FROM FRBS

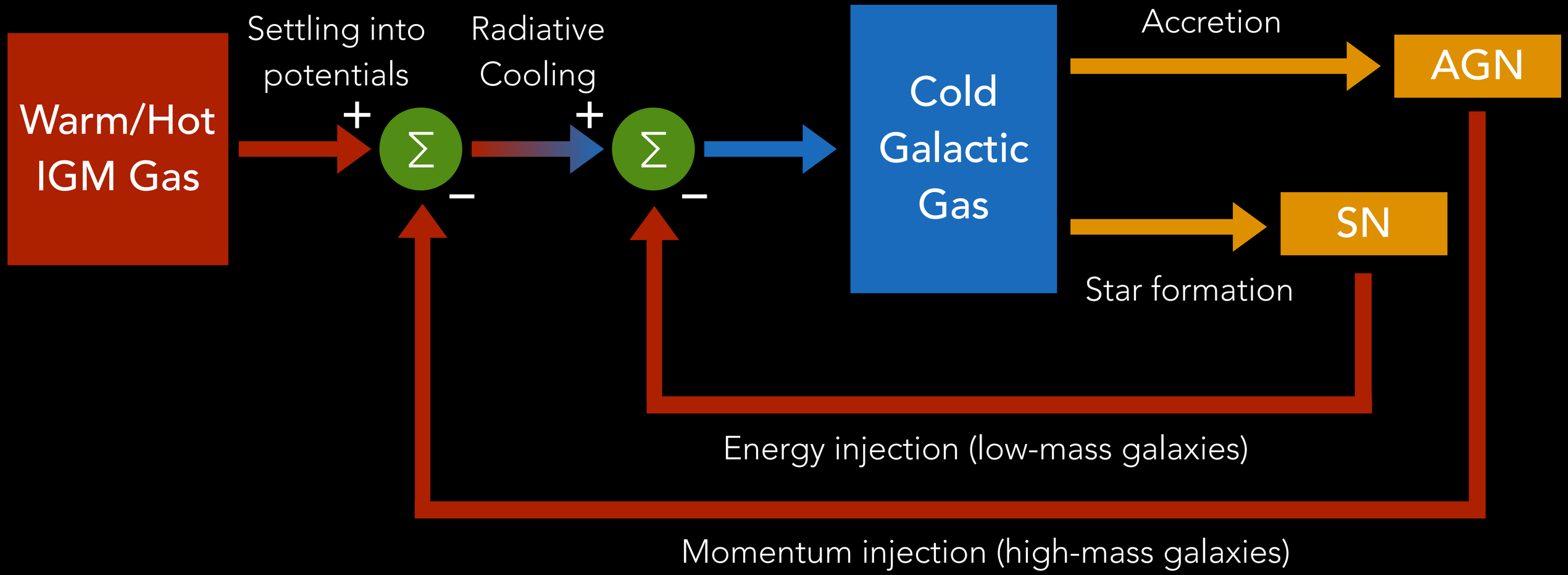
PLENTY OF ROOM AT THE BOTTOM - FRBS IN OUR OWN BACKYARD
CORNELL UNIVERSITY - OCTOBER 10-11, 2022



Masui Synoptic Radio Lab

WHAT IS

FEEDBACK IN GALAXY FORMATION



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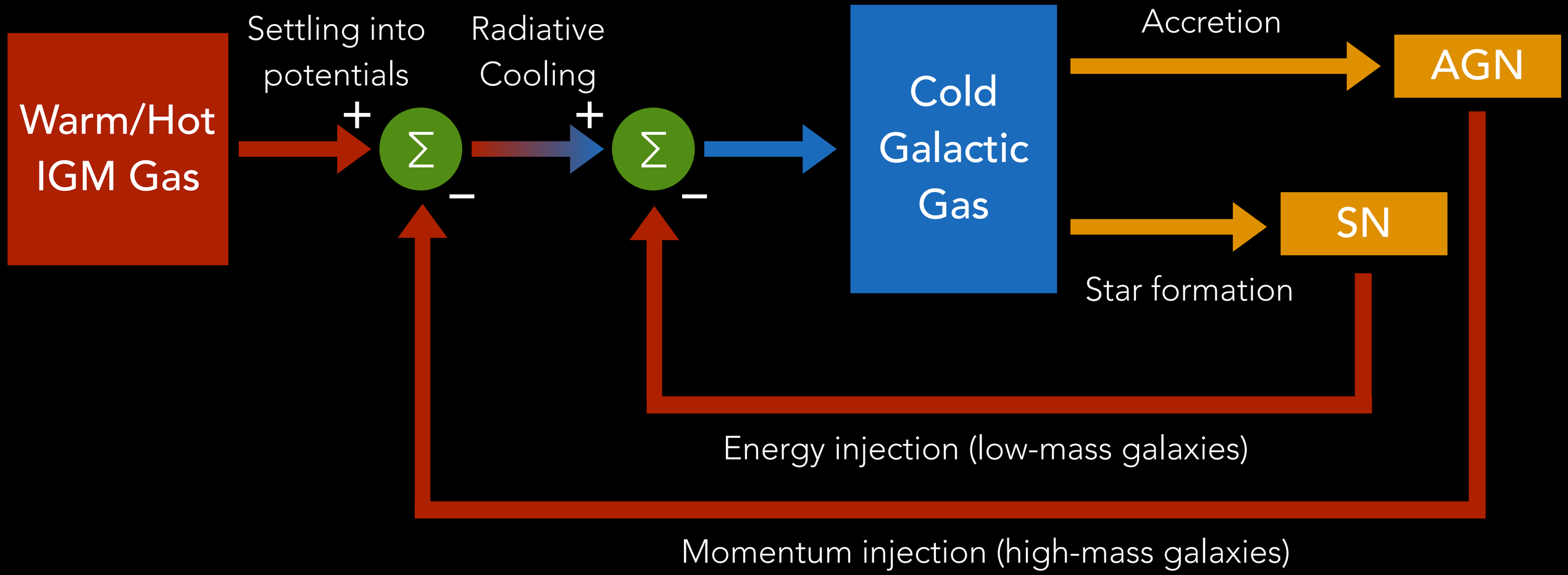

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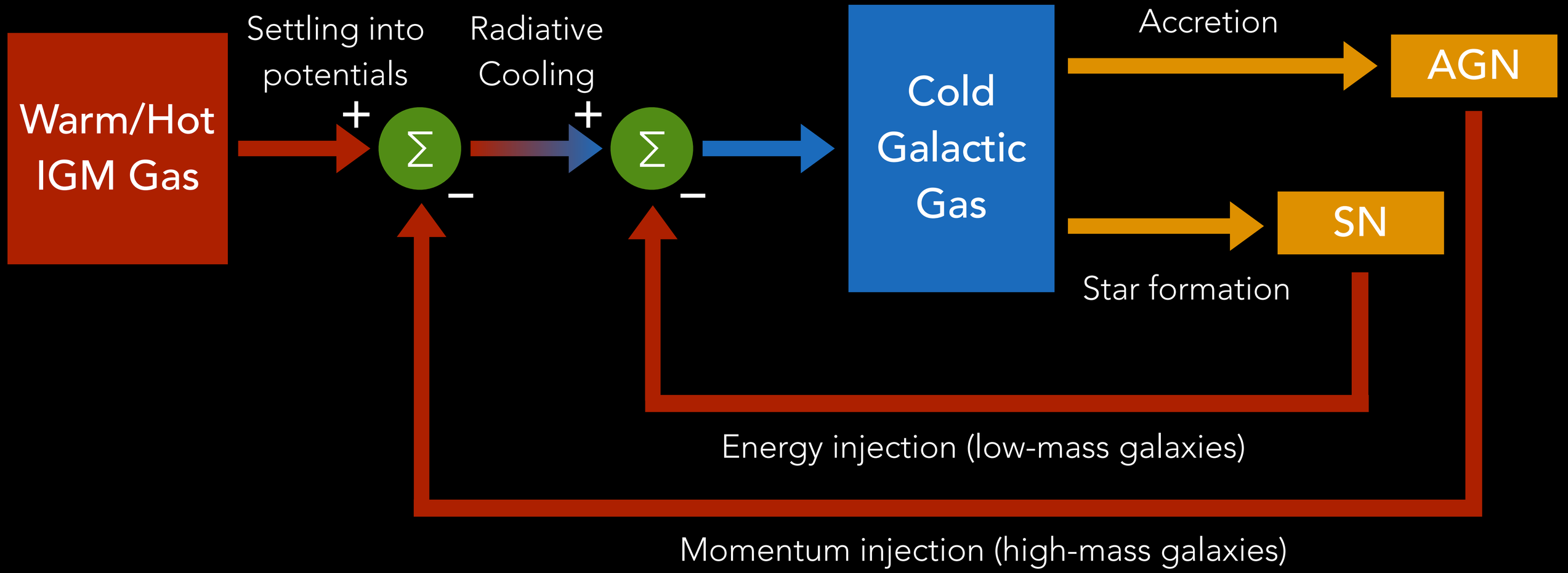

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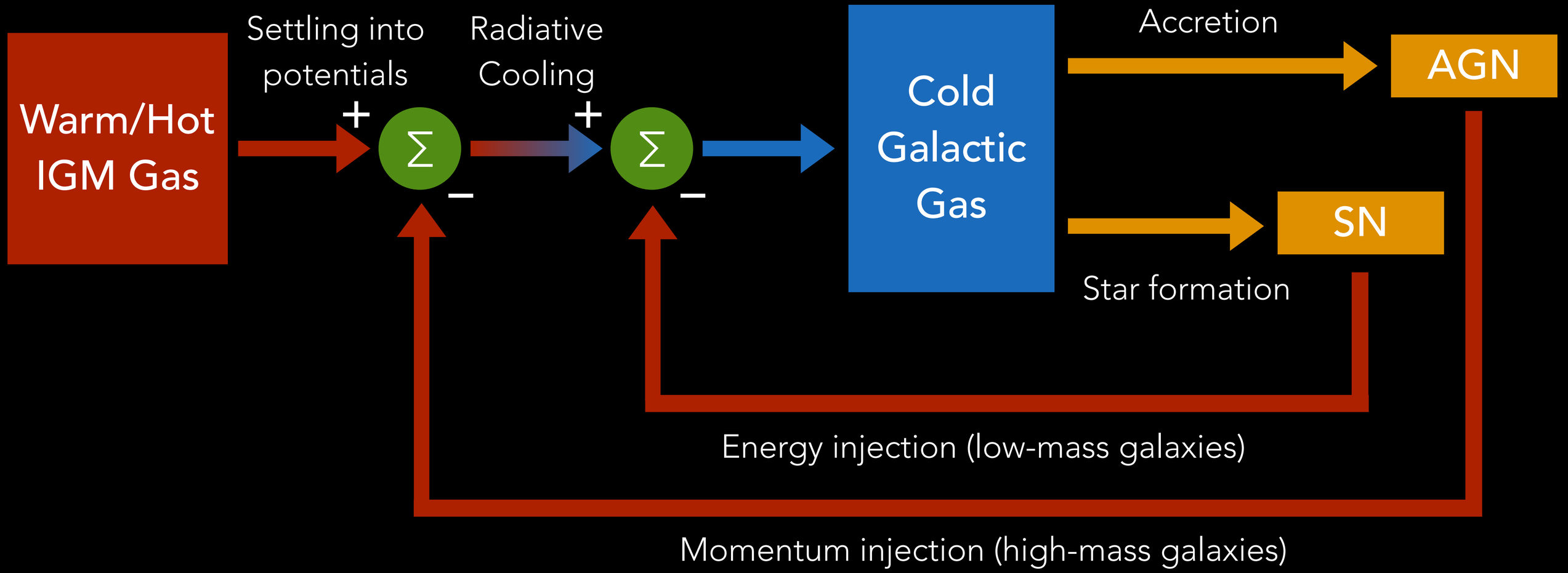

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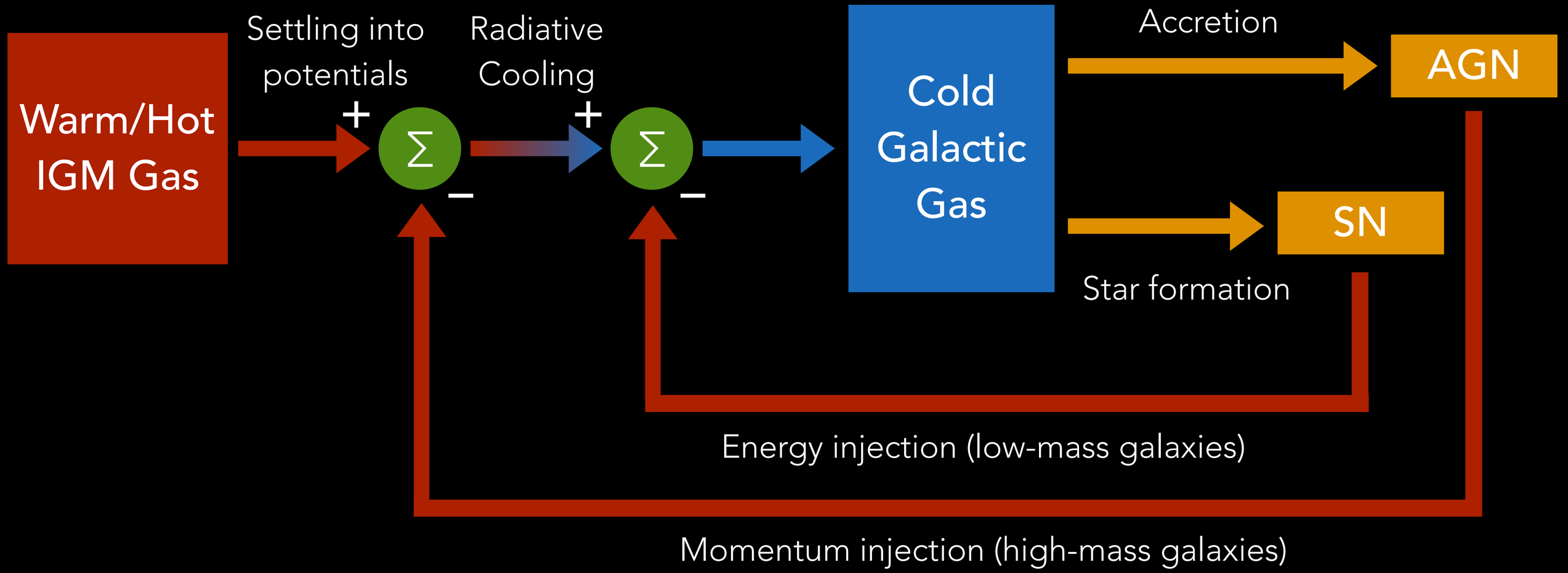

visualization Dylan Nelson

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Illustris — 1 Mpc TNG

WHY IS FEEDBACK POORLY CONSTRAINED?

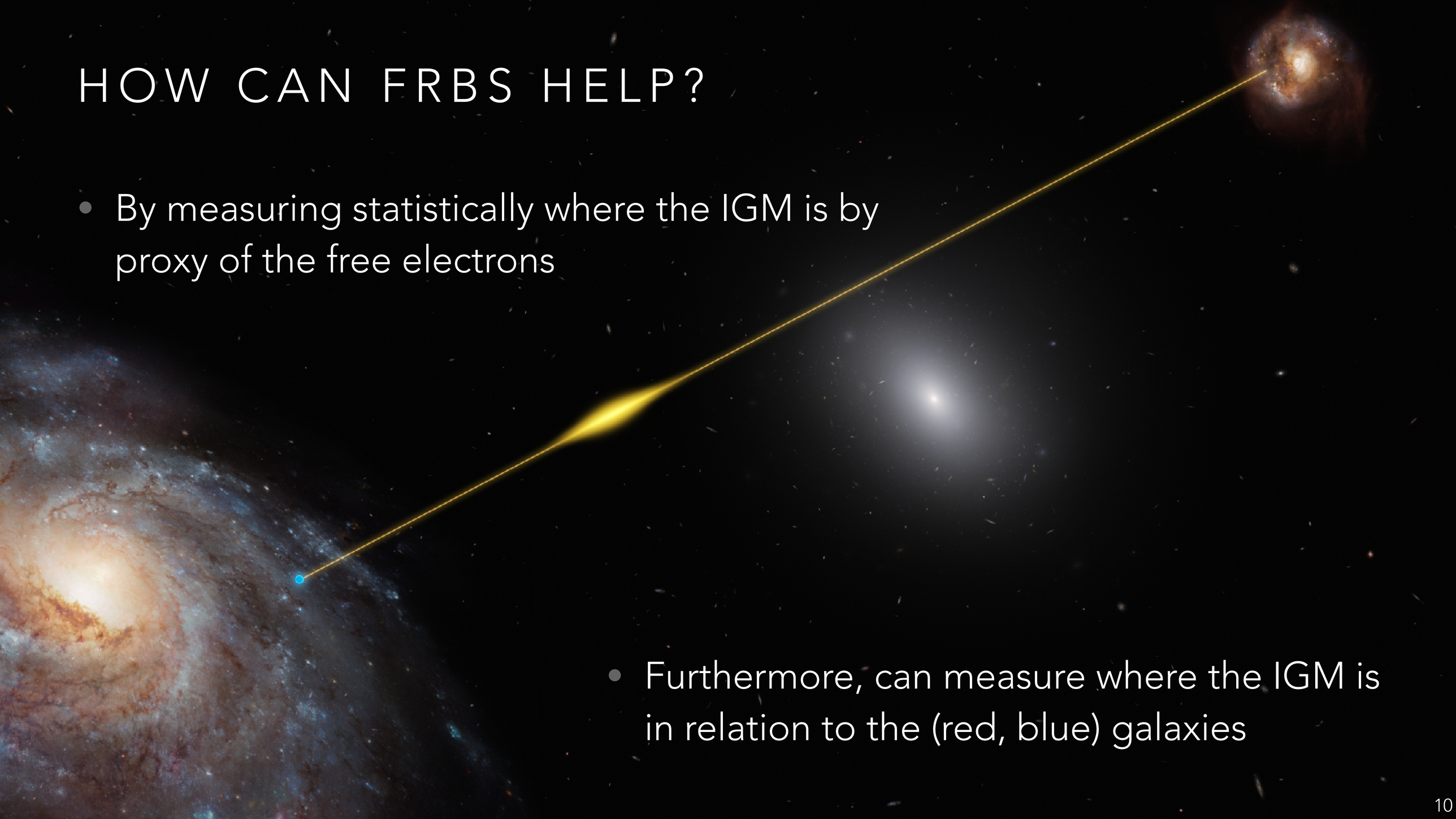
- Feedback disrupts cooling of the IGM
- Starves galaxies of the cold gas that feeds star formation
- But can only observe galaxy/stars/cold gas, secondary results of feedback
- Not the direct result, the IGM itself

ASIDE: THE MISSING BARYON PROBLEM

- This *is* the missing baryon problem:
  - IGM contains most of the baryons
  - Cannot be observed, cannot be reliably simulated
  - So we don’t know where they are

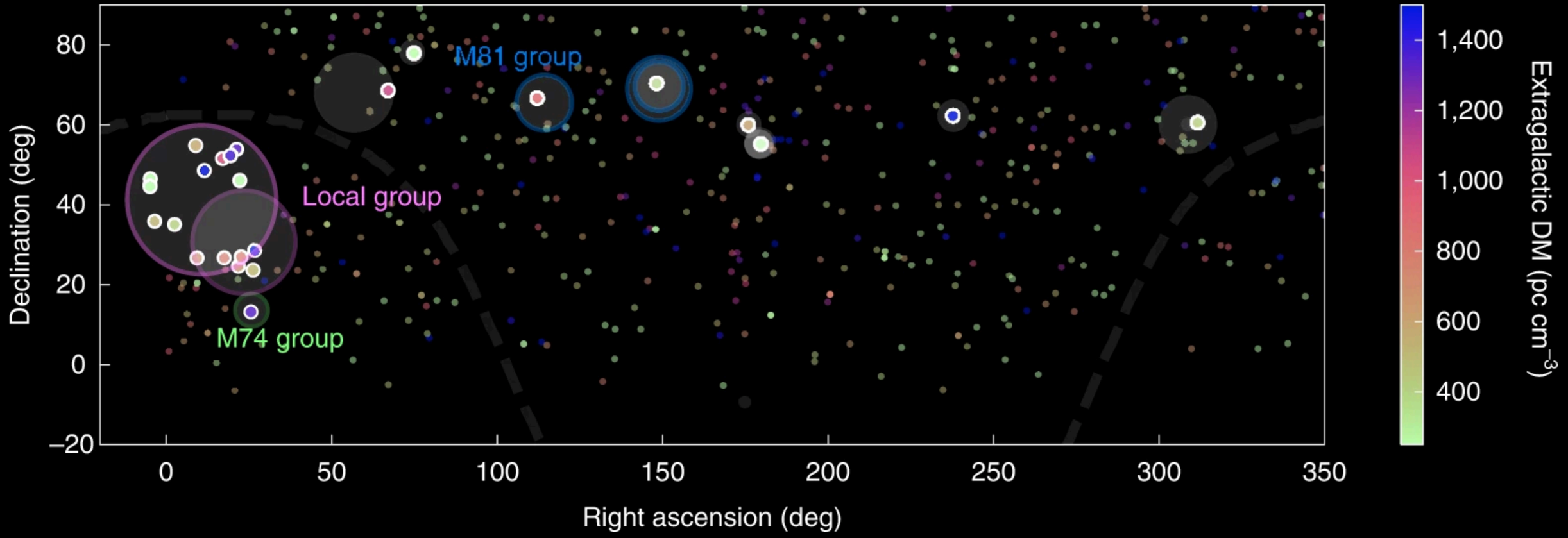
HOW CAN FRBS HELP?

- By measuring statistically where the IGM is by proxy of the free electrons

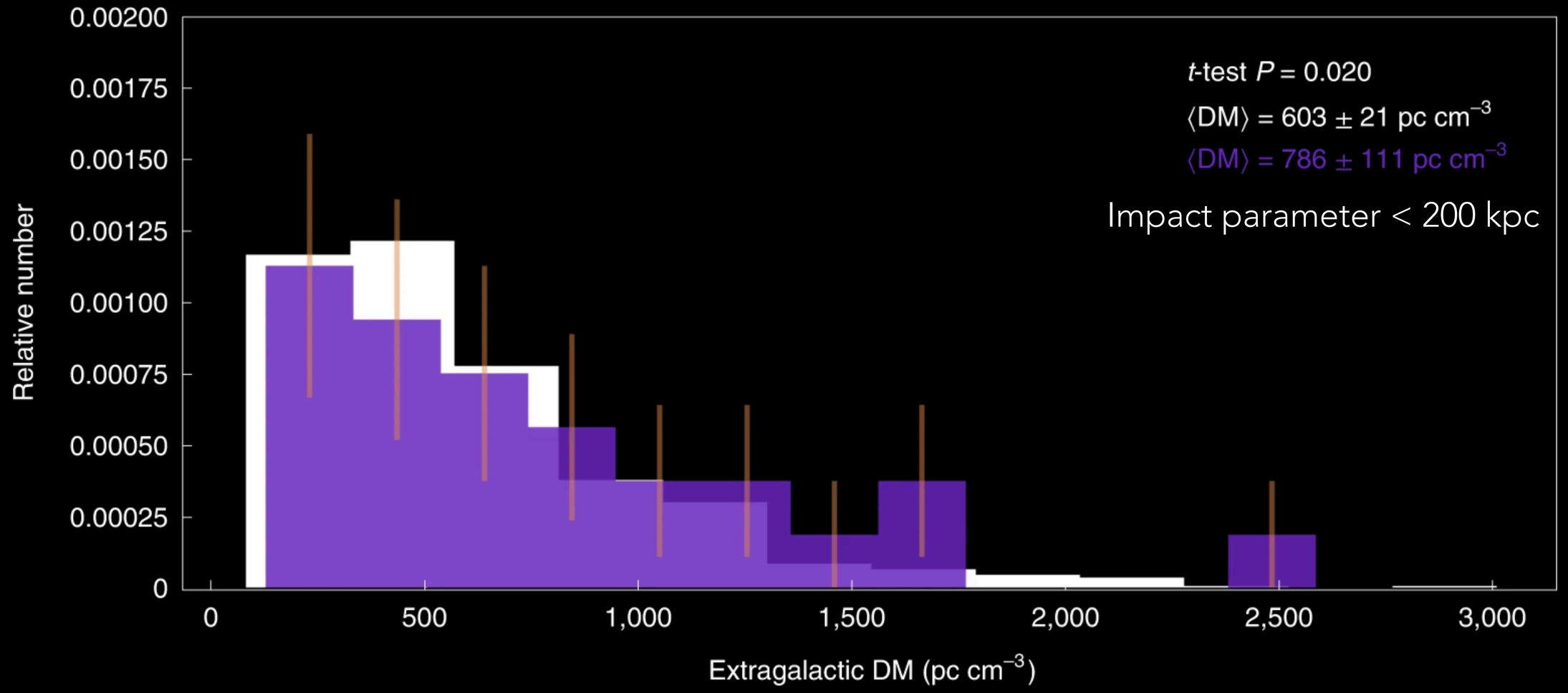


- Furthermore, can measure where the IGM is in relation to the (red, blue) galaxies

FIRST DETECTION: CONNOR & RAVI 2022



EXCESS DM ALONG LOS INTERSECTING HALOS



Impact parameter < 200 kpc

2-POINT STATISTICS: CONNOR & RAVI MEASURED THE

Excess DM along lines of sight intersecting galaxies, as a function of impact parameter

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Excess DM along lines of sight intersecting galaxies, as a function of impact parameter

[(LSS tracer 1) x (LSS tracer 2)](spatial scale)

2-POINT STATISTICS: CONNOR & RAVI MEASURED

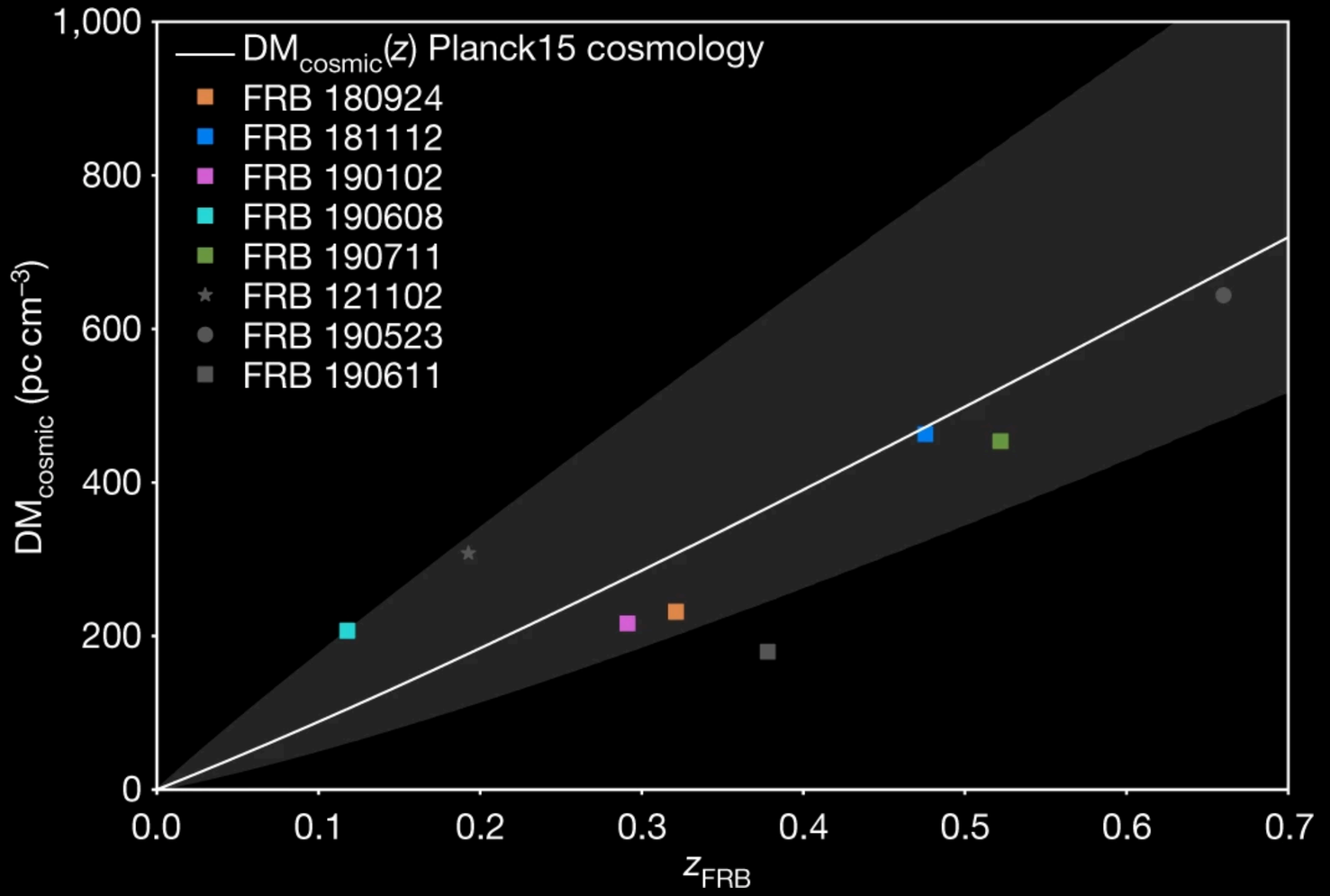
Excess DM along lines of sight intersecting galaxies, as a function of impact parameter

[(LSS tracer 1) x *(LSS tracer 2)](spatial scale)*

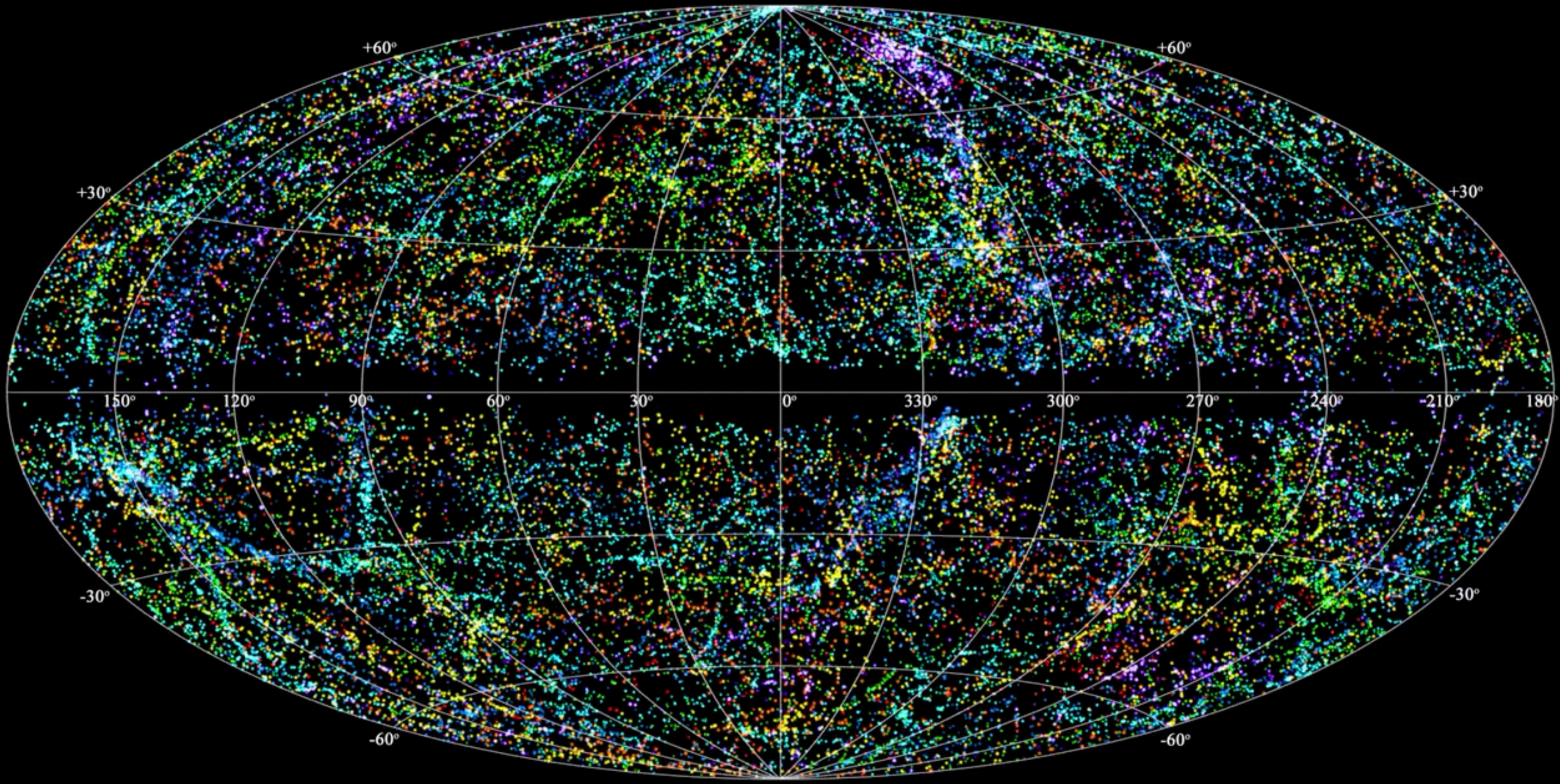
Examples: C_l^{TT} C_l^{TE} $P_{gg}(k)$

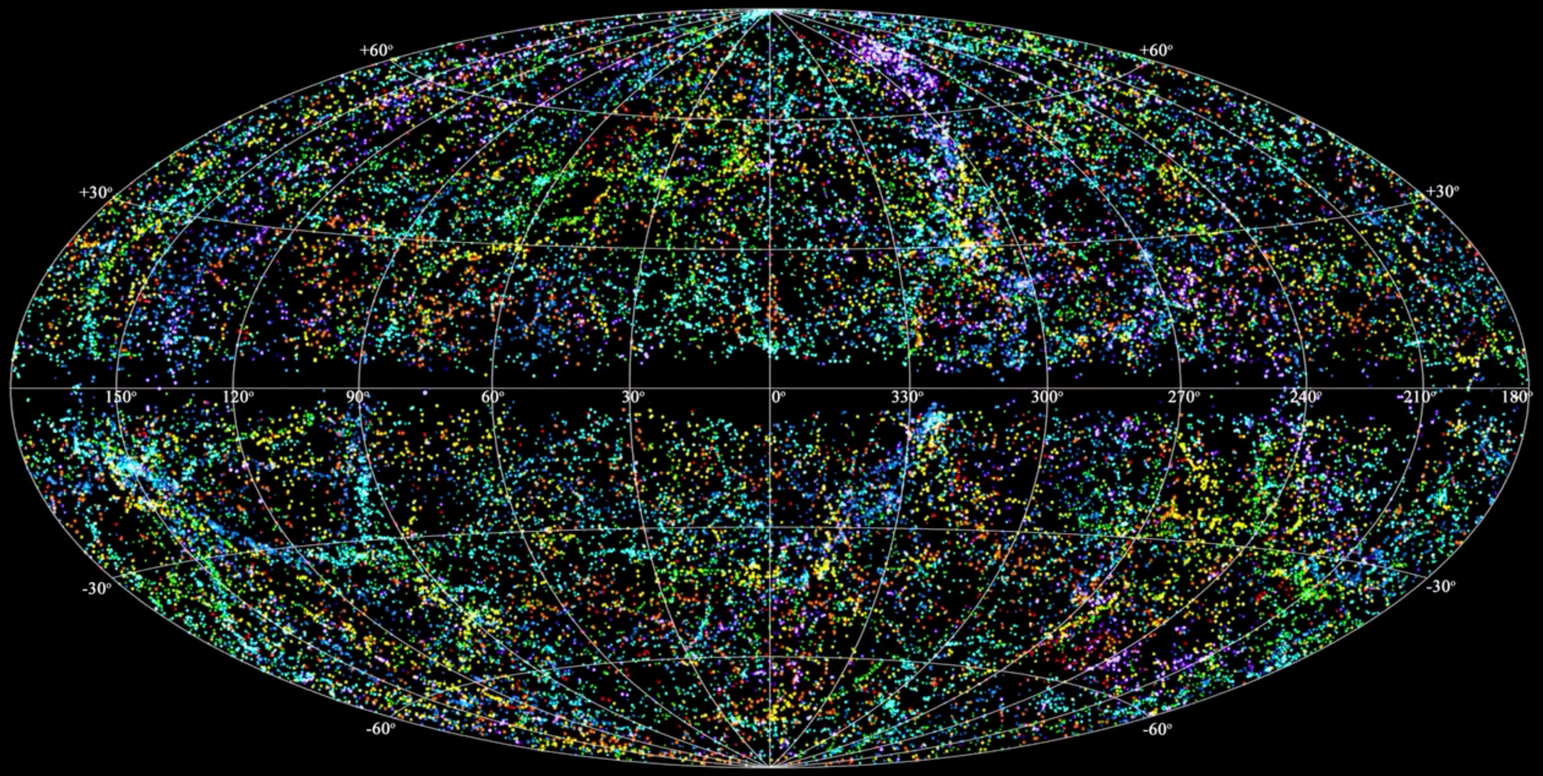
IN CONTRAST TO 1-POINT FUNCTIONS

Eg. P(DM | z)



Macquart et al. 2018


+60°
+60°
+30°
+30°
150°
120°
90°
60°
30°
0°
330°
300°
270°
240°
-210°
180°
-30°
-30°
-60°
-60°



DM map
and galaxy map

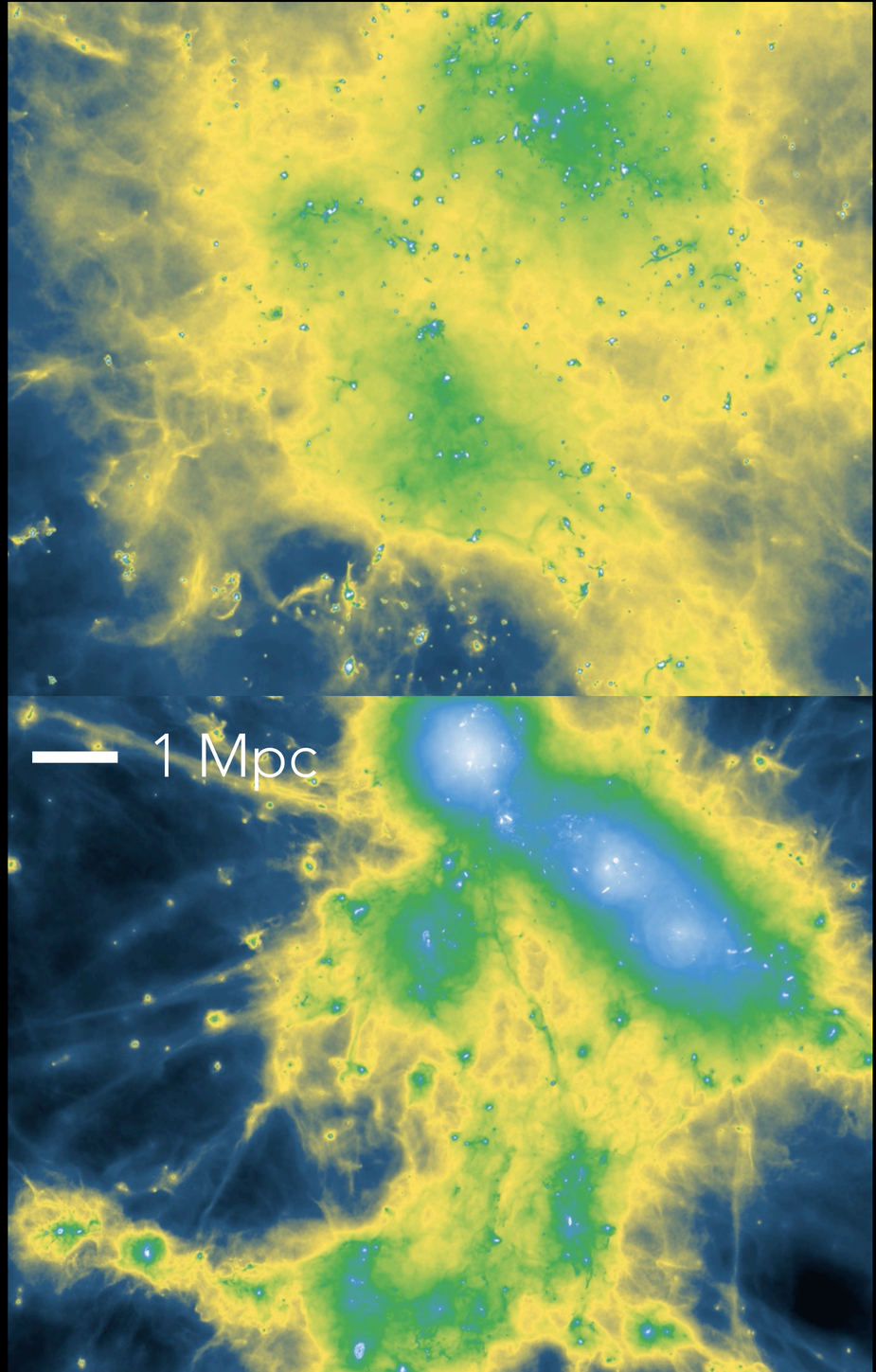
Spherical harmonic
transform

Cross correlate

Analysis proposed by Madhavacheril, Battaglia, Smith, and Sievers, 2019

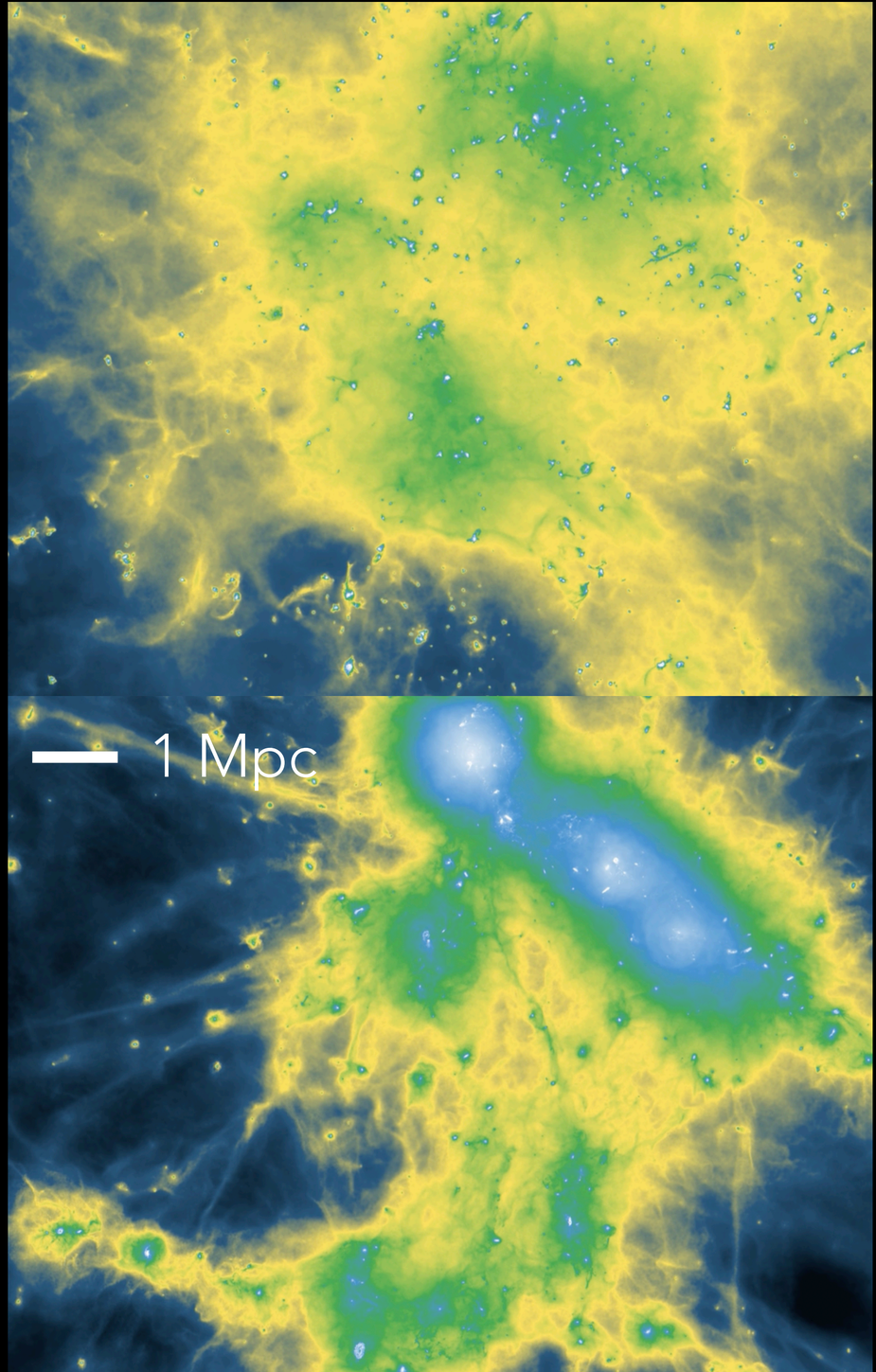
WHY [redacted]?

- We have a way to measure it
- Easy to extract from simulations
- Hyper sensitive to feedback physics
- Function of scale and galaxy type - lots of information



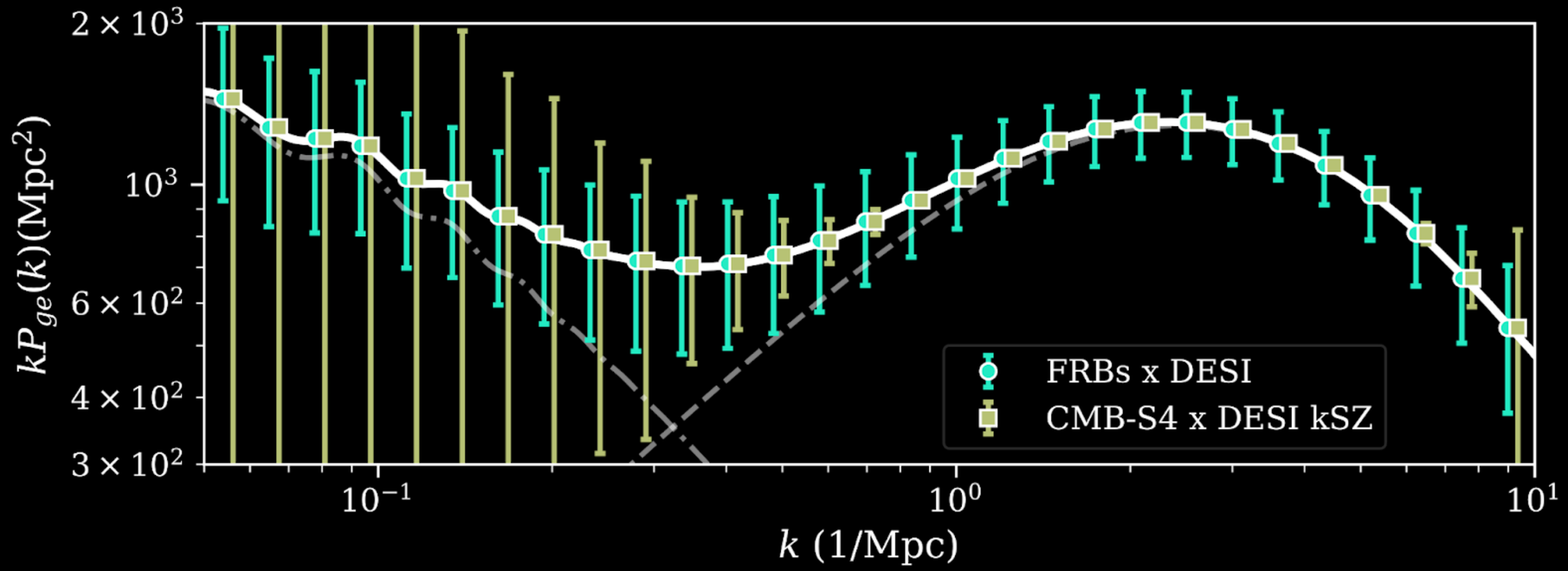
“SOLVING” FEEDBACK WITH [redacted]?

- **Pessimistically**: turn knobs on feedback models until sims match observations
- **Optimistically**: new qualitative insight and understanding
- **Either way**: major source of uncertainty in galaxy formation (and cosmology) eliminated



OBSERVATIONAL PROSPECTS: SENSITIVITY

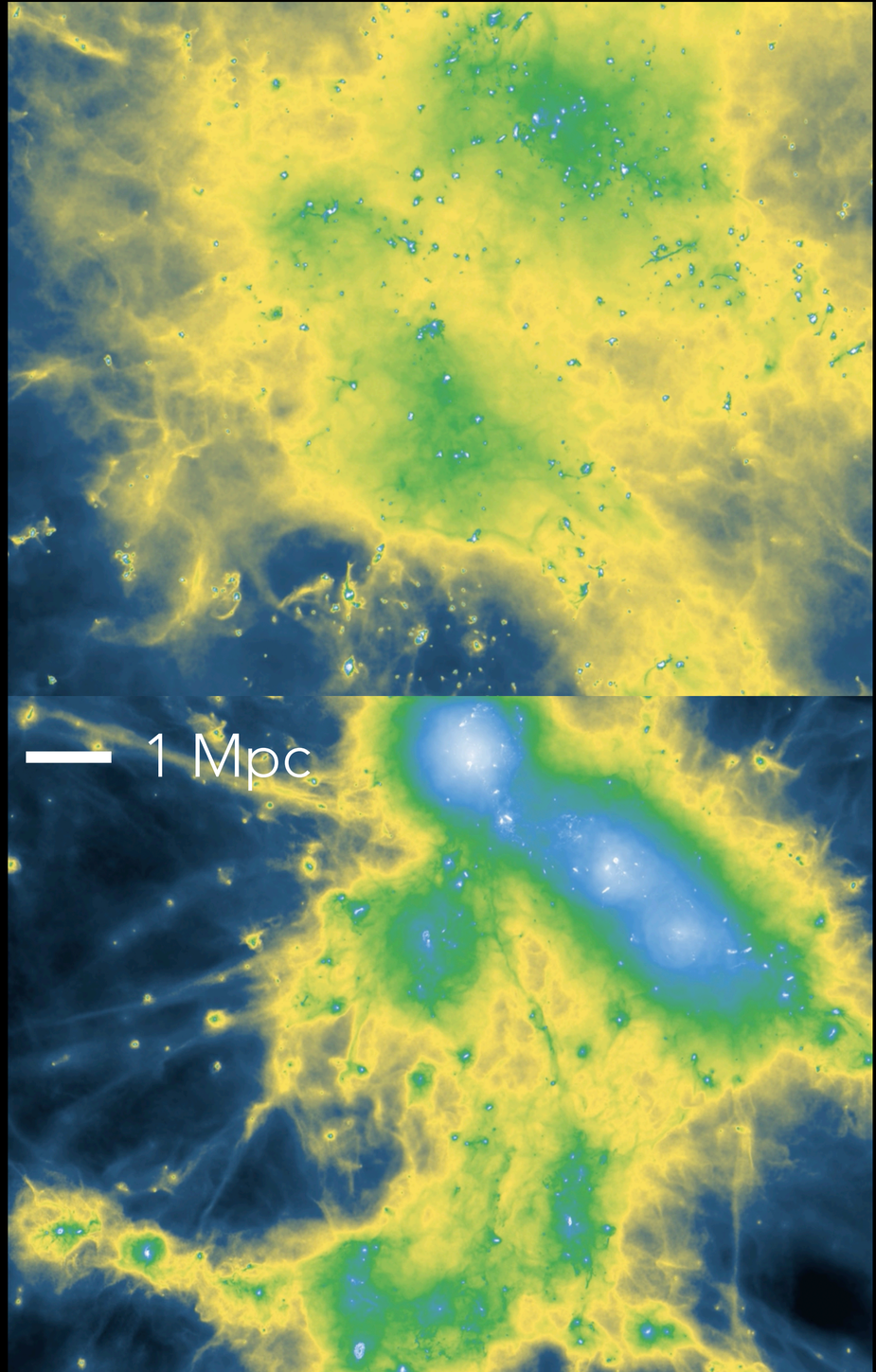
- Achieve ~10% measurements with 1000 background FRBs (with redshifts) cross-correlated with 10^7 galaxies at z = 0.5
- No forecasts at lower redshifts, but should be *much* easier



Forecasts by Madhavacheril et al. 2019

OBSERVATIONAL PROSPECTS: DATA

- There are several high-density, all-sky photo-z galaxy samples at z ~ 0.1 with ~ 10^7 objects
- At z = 0.1, 100 kpc = 1′. CHIME Baseband localizations good enough
- With FRB redshifts (CHIME/FRB Outriggers), can subtract off <DM>(z)



OBSERVATIONAL PROSPECTS: SYSTEMATICS

- DM_{host} correlating with galaxies
  - Probably not significant for initial measurements
  - Once redshifts available, only correlate far-separated pairs
- DM-dependent selection effects: should be able to calibrate and correct
- FRB foreground of galaxy: initially small, eliminate with redshifts

FINAL THOUGHT: COSMOLOGICAL IMPORTANCE

- Measuring [redacted] breaks a key degeneracy in the CMB kinematic Sunyaev–Zeldovich (KSZ) effect (Madhavacheril et al. 2019)
- The IGM contaminates weak gravitational lensing (Nicola et al 2022):
  - IGM is 14% of the matter, power spectrum is order-unity uncertain
  - Weak lensing mixes small and large scales - no avoidance
  - Unless we understand feedback, can’t do percent-level measurements of dark matter

CONCLUSIONS

- Feedback is the most pressing unsolved problem in the biggest sub-field of astrophysics
- FRB DM provides an observational probe of feedback's most direct effect: the distribution of the IGM
- In particular, measuring the electron–galaxy cross-power spectrum is:
  - Feasible
  - Robust to systematics
  - Highly informative of feedback