**Title:** Closing Talk: What have we learnt?

**Speakers:** Peng Oh

**Collection/Series:** Cosmic Ecosystems

**Subject:** Cosmology

**Date:** August 01, 2025 - 3:30 PM

**URL:** https://pirsa.org/25080011

# What have we learnt?

Peng Oh (UCSB)

# THANK YOU to the organizers!!

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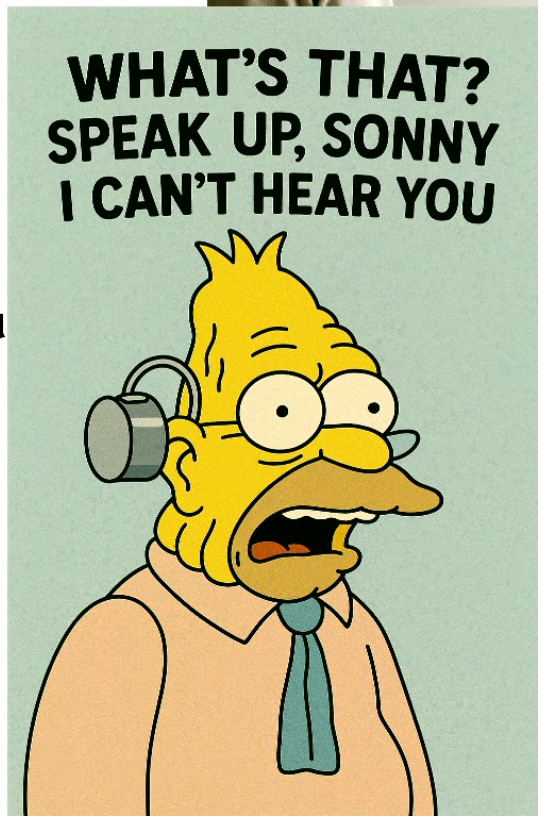
“The tragedy of old age is not that one is old, but that one is young” — Oscar Wilde

Can you give a research talk?


Actually, how about a review talk?


Sorry, can you give the conference summary?



# Mea Culpa, Mea Culpa, Mea Maxima Culpa

**I'm like, the worst person to be doing this**

## Teaching Statement

**S. Peng Oh**

### Classroom Teaching

I tell students it is great that they have a variety of lecturers, because everyone has different strengths and weaknesses. For my part, I am the sort of person where after I walk out of a talk or lecture, $> 80\%$ of the detailed content immediately evaporates from my brain (or, more likely, it never penetrated my skull in the first place). So, the actual information delivery aspect of a talk is completely wasted on me. I just remember if something was cool

# Why do YOU care about cosmic ecosystems?


- They introduce systematic errors when trying to measure fundamental cosmological parameters
- They constrain feedback, arguably the most important unsolved problem in galaxy formation
- They are the biggest, baddest laboratory in the universe for cool gastrophysical processes

# An Old Chestnut

**(Halo) Cosmology is either ...**

Chess

or

Mud-wrestling

Similar splits in supernova cosmology, dark matter annihilation, etc...

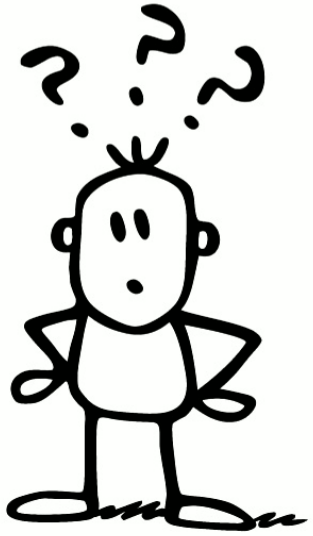
# First Impressions: the cool kids in cosmology speak a secret language

**... to keep out the unwashed masses**

Baryonification: A ‘glow-up’ beauty regime for dark matter halos

$f_{\rm gas} - 8\sigma$ The loser halo with the least gas out of $\sim 10^{29}$ halos

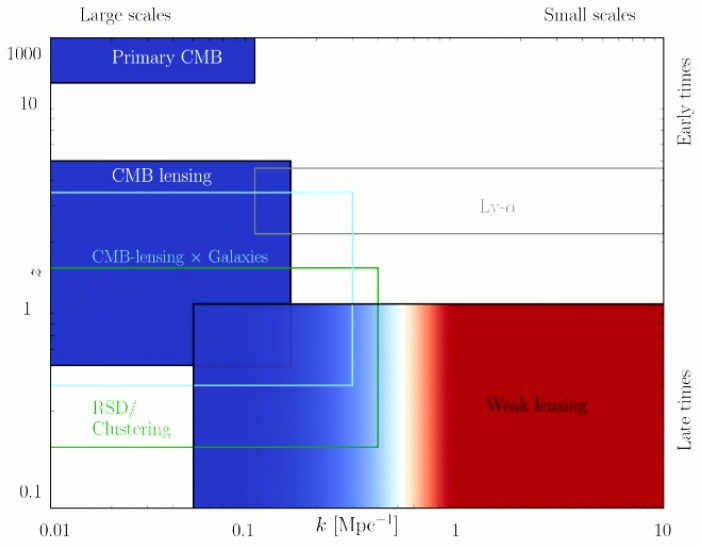
Extreme feedback: An insanely powerful form of feedback,
where feedback power is unchanged.



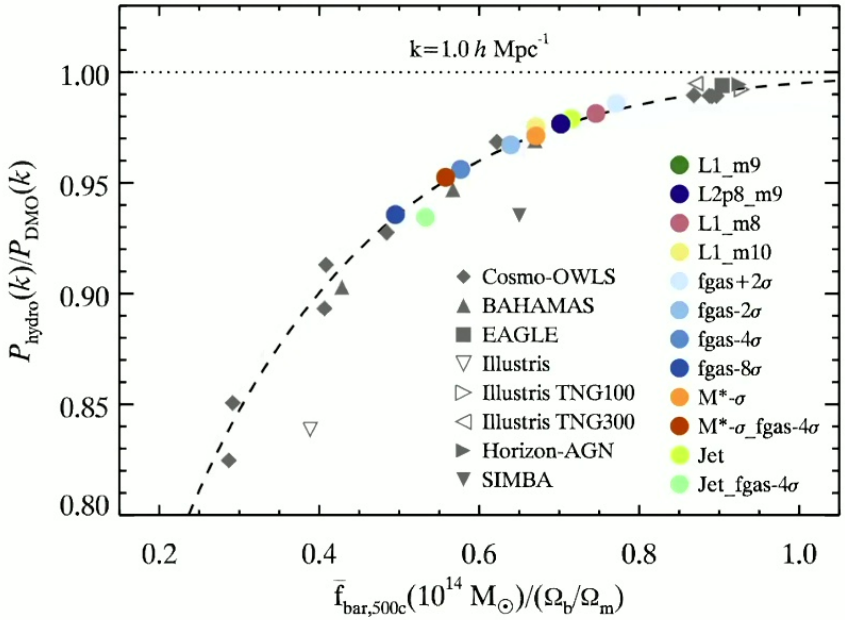
# The S8 tension is gone?? (maybe...)

- $S_8$ tension between large-scale structure and primary CMB disappearing (Wright+25, Efstathiou+25) and could probably not be solved by feedback in any case (McCarthy+18, 23)

Schaye+23




Preston+25




This is the problem child

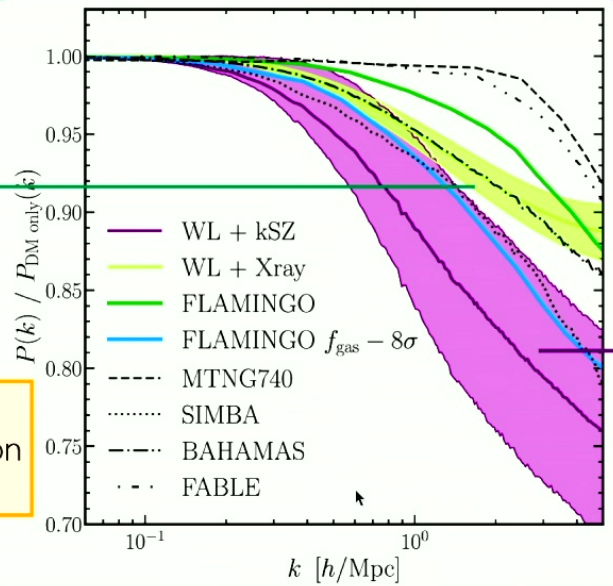
(changes depending on optical vs X-ray selection ...)

# Much ado about whether feedback is


X-ray hot gas fractions:

DES Y3 cosmic shear
+ XMM X-ray gas fractions

kSZ inconsistent with simulations & the expectation from X-ray gas fractions.




kinetic SZ effect profiles:

DES Y3 cosmic shear
+ ACT-BOSS kSZ

[*Bigwood, Amon+ 24*]

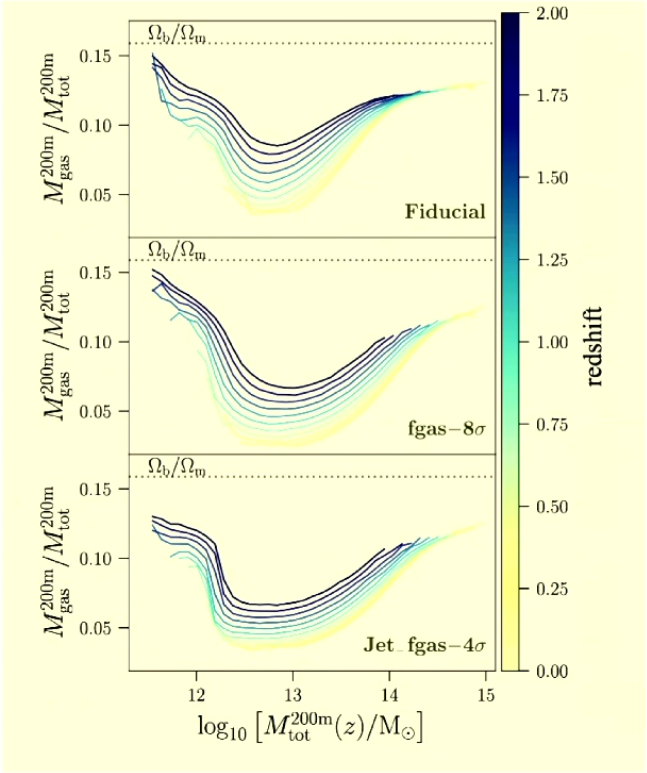
Amon | Princeton

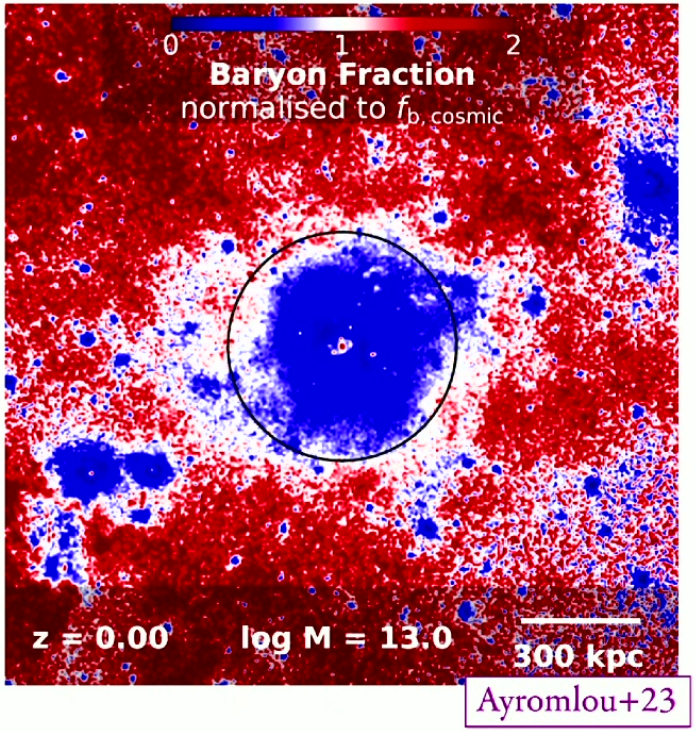
But: is this consistent with large amounts of cool gas around (Steidel?)...

Why doesn't CUBs see more evidence of feedback?

# Baryons getting rearranged on very large scales?!

Potentially out to 3 r_vir



# It's not about energy, it's about coupling


Need to either change timing (early, preventative) or strength of coupling

Would be nice to

- poke around old pre-heating models again
- refine cosmo feedback recipes with small scale idealized sims of cluster AGN feedback

Surprisingly little discussion of turbulence at this conference...

XRISM

# Like eco-systems, observations can evolve...

## Sunyaev–Zeldovich fluctuations from the first stars?

S. Peng Oh,★ Asantha Cooray and Marc Kamionkowski
*Theoretical Astrophysics, Mail Code 130-33, Caltech, Pasadena, CA 91125, USA*

Accepted 2003 April 11. Received 2003 April 16; in original form 2003 March 7

**Both** observations didn't hold up... oops

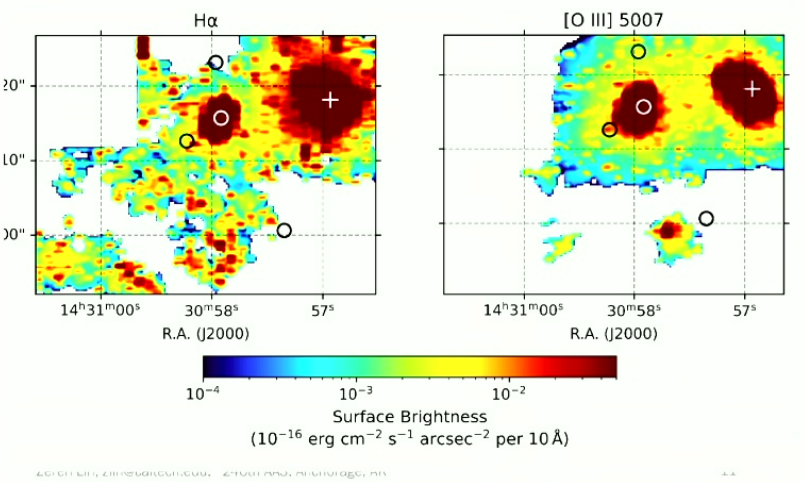
**ABSTRACT**

WMAP's detection of high electron-scattering optical depth $\tau_e$ suggests substantial star formation at high redshift $z \sim 17 \pm 5$. On the other hand, the recovered $\sigma_8 \sim 0.84 \pm 0.04$ argues against a cluster Sunyaev–Zeldovich (SZ) origin for the observed small-scale cosmic microwave background (CMB) fluctuation excess, which generally requires $\sigma_8 \sim 1.1$. Here we consider the effects of high-redshift star formation on the CMB. We derive a fairly model-independent relation between $\tau_e$ and the number of ionizing photons emitted per baryon $N_\gamma$, and use this to calibrate the amount of high-redshift supernova activity. The resulting supernova remnants Compton cool against the CMB creating a Compton $y$ distortion $y \sim$ few $\times 10^{-6}$ within observational bounds. However they also create small-scale SZ fluctuations, which could be comparable with SZ fluctuations from unresolved galaxy clusters. This raises the exciting possibility that we have already detected signatures of the first stars not just once, but twice, in the CMB.

**Key words:** galaxies: formation – intergalactic medium – cosmic microwave background.

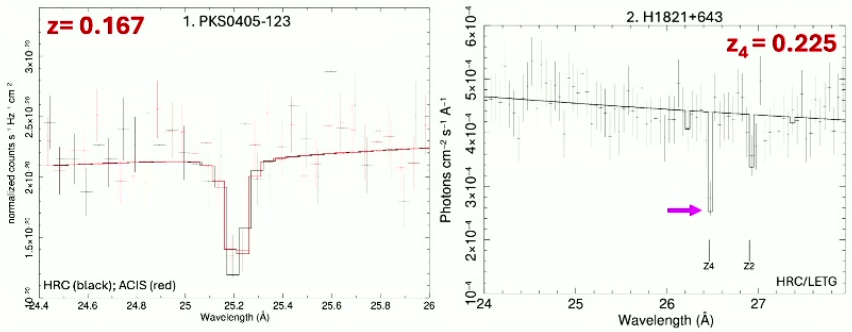
Observers should *always* be skeptical of theorists, but theorists should *sometimes* also be skeptical of observers...

# Brighter prospects for studying halo gas at lower masses

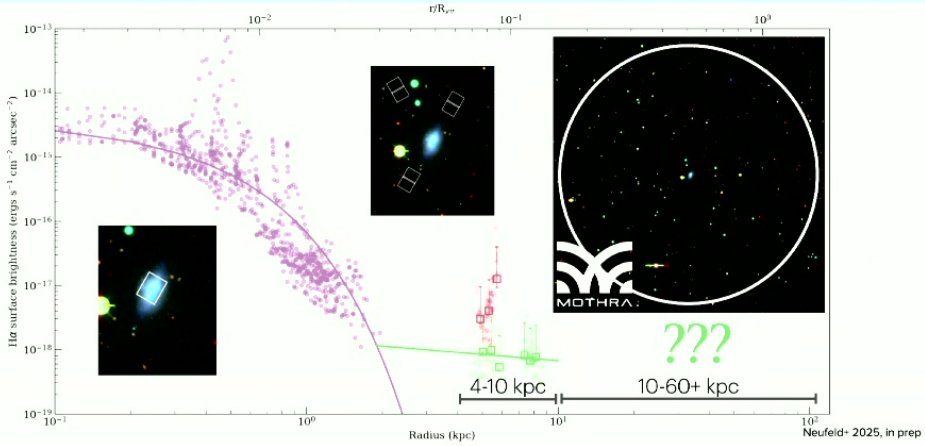



## Hot CGM of external galaxies: X-ray absorption

Look for O VII absorption at the same redshift as the "unusually broad" O VI absorption toward the same QSO



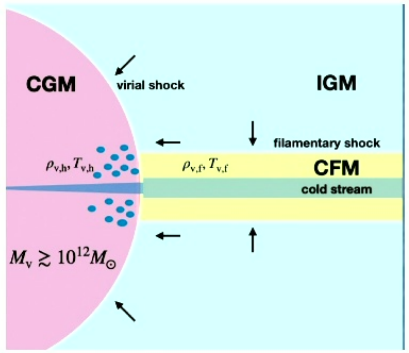

## Next steps: Mothra



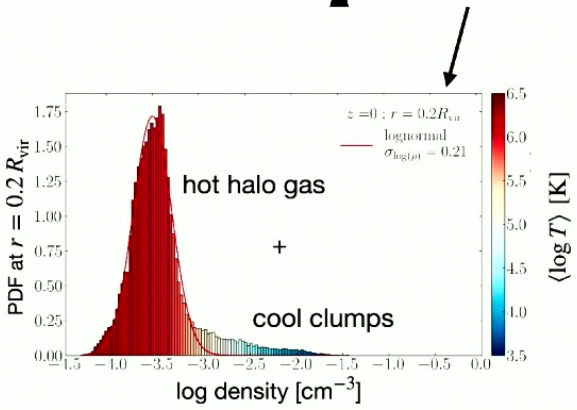

Seeing halo gas in emission

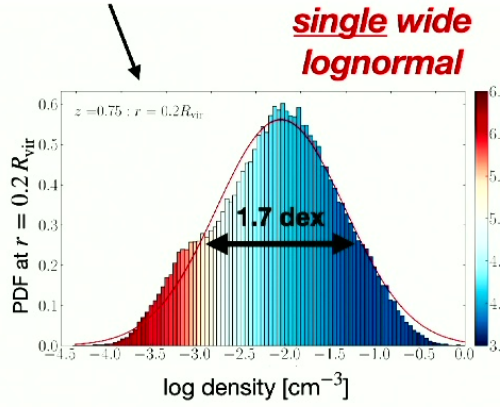
Finally constraining the hot gas component

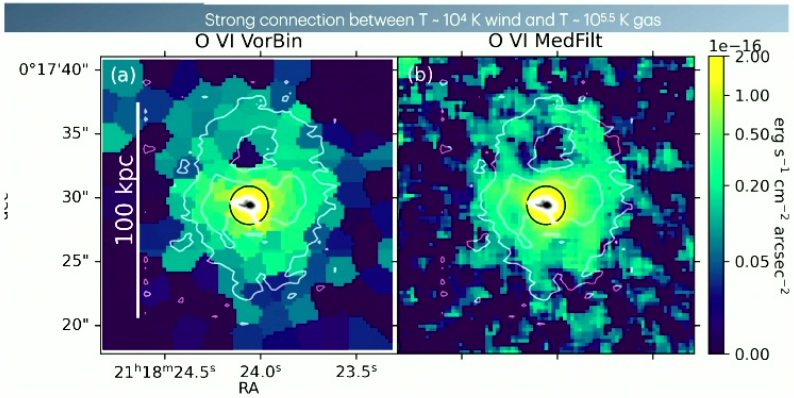
# Still many puzzles in multi-phase interactions




Cold streams must die!!



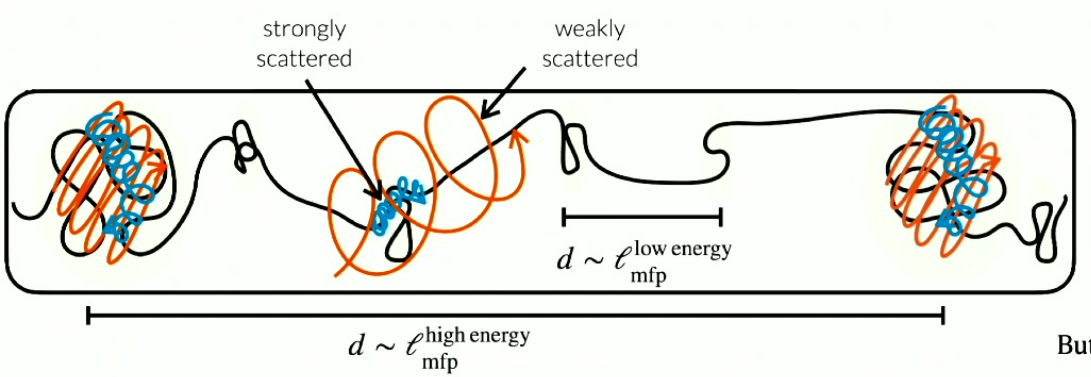

We see OVI emission near cool gas

Maybe it's not always multi-phase

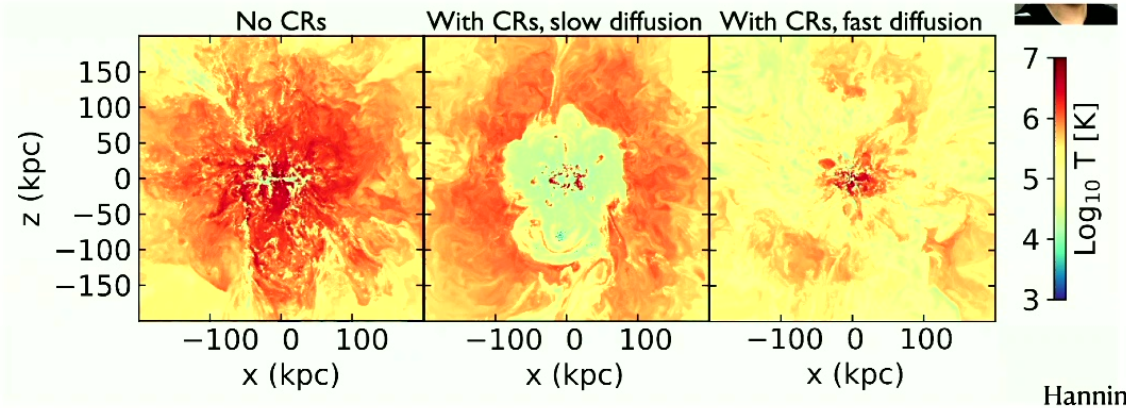
Using metals as nature's tracer particles

# Cosmic Rays are the New Bond Villain

**Much harder than B-fields...like doing radiative transfer without knowing the opacity**




Butsky+23




Hannington+25

...or running structure formation sims when you don't know the background cosmology

# FRB cosmology could be life-changing

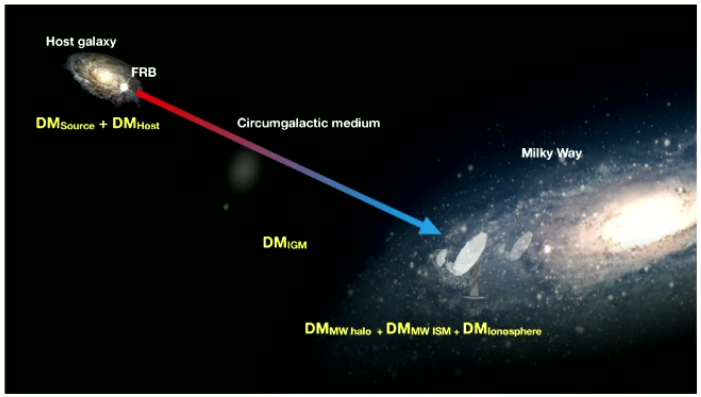
Something for both the chess-players and mud-wrestlers:

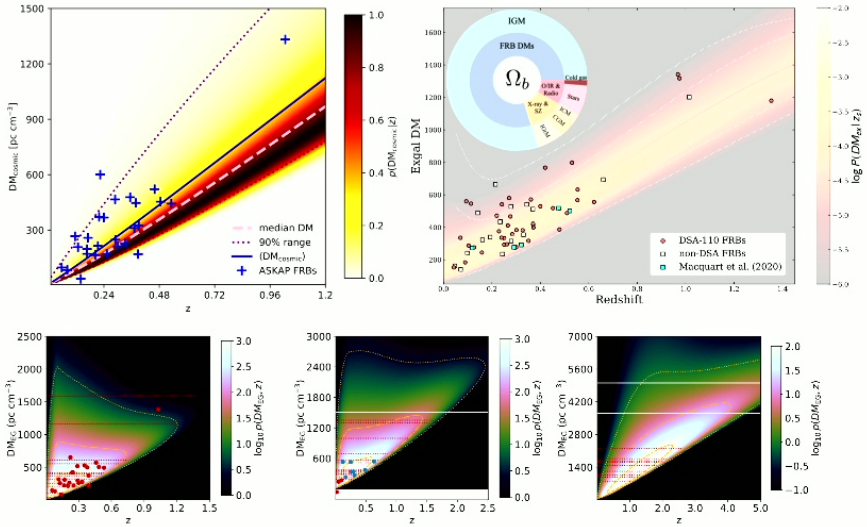
— baryon census

— f_gas, small scale power

— magnetic fields, turbulence

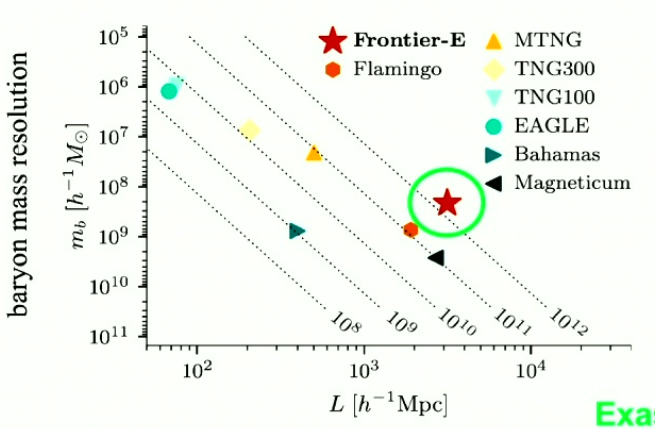
— small scale plasma physics (down to ~ 1000 km scales!)

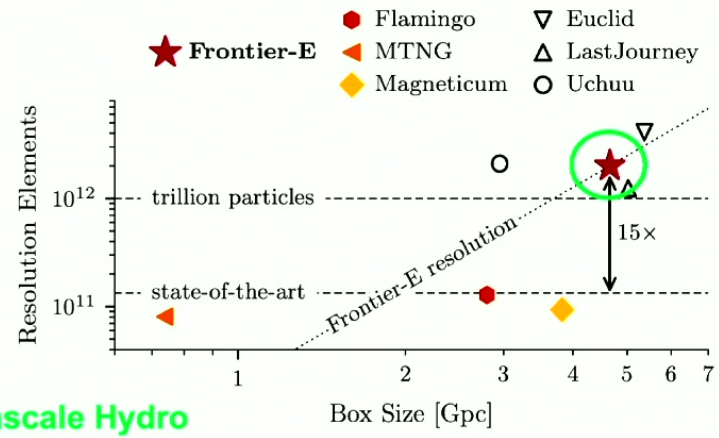


# Moore's Law keeps marching on

## Exascale Class Simulations




**Exascale Hydro**

Exascale unlocks the ability to run previous **state of the art** gravity only simulations now including **hydrodynamics** in a **week** of machine time (~ 1 yr CPU)

Gravity only simulations break into the **10+ trillion** particle class

N. Frontiere (Coolest. Last. Name. Ever.)

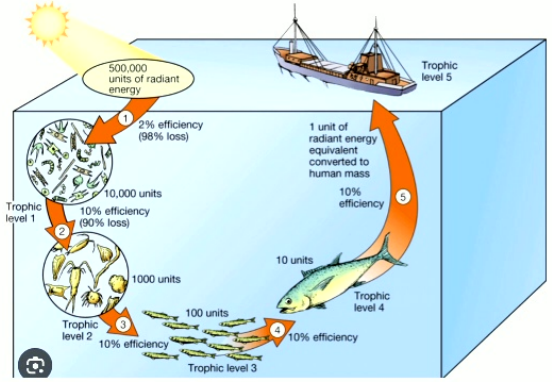
# Battle of Metaphors

**What's a natural twin for halo gas studies?**

Stars? (can we write MESA for halo gas?)

Hydrostatic and thermal equilibrium much stronger for stars

My twins




Eco-systems? Cycles, feedback, many interacting components

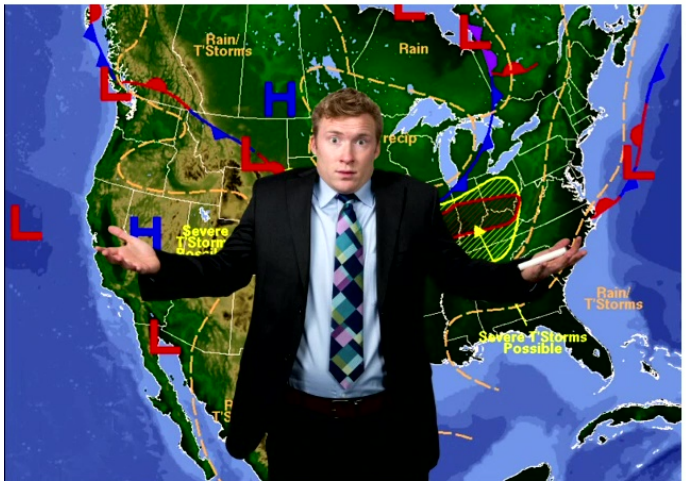
quasi or punctuated equilibria

But energy flows one way (food chain)
CGM does not have self-organization, adaptation,

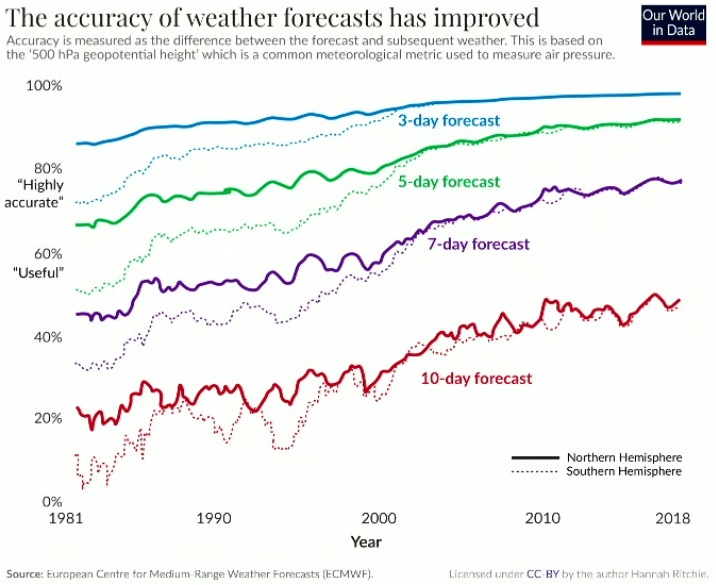
natural selection, biodiversity...

Meteorology?

- Both forcing and feedback mechanisms
- Non-equilibrium, chaotic (probabilistic treatment!)
- Enormous temporal and physical scale separation
- Multi-phase, turbulent, similar fluid processes
- Close interaction between observation ('remote sensing') and theory




- Enormous progress from idealized and global sims, machine learning, sub-grid models...



**After this conference, I'm confident we'll crack this problem.**

**Here's why...**


Secret Passions...
EXPOSED!!
DELTA HOTEL
ON THE STREETS OF WATERLOO AT 1 A.M.