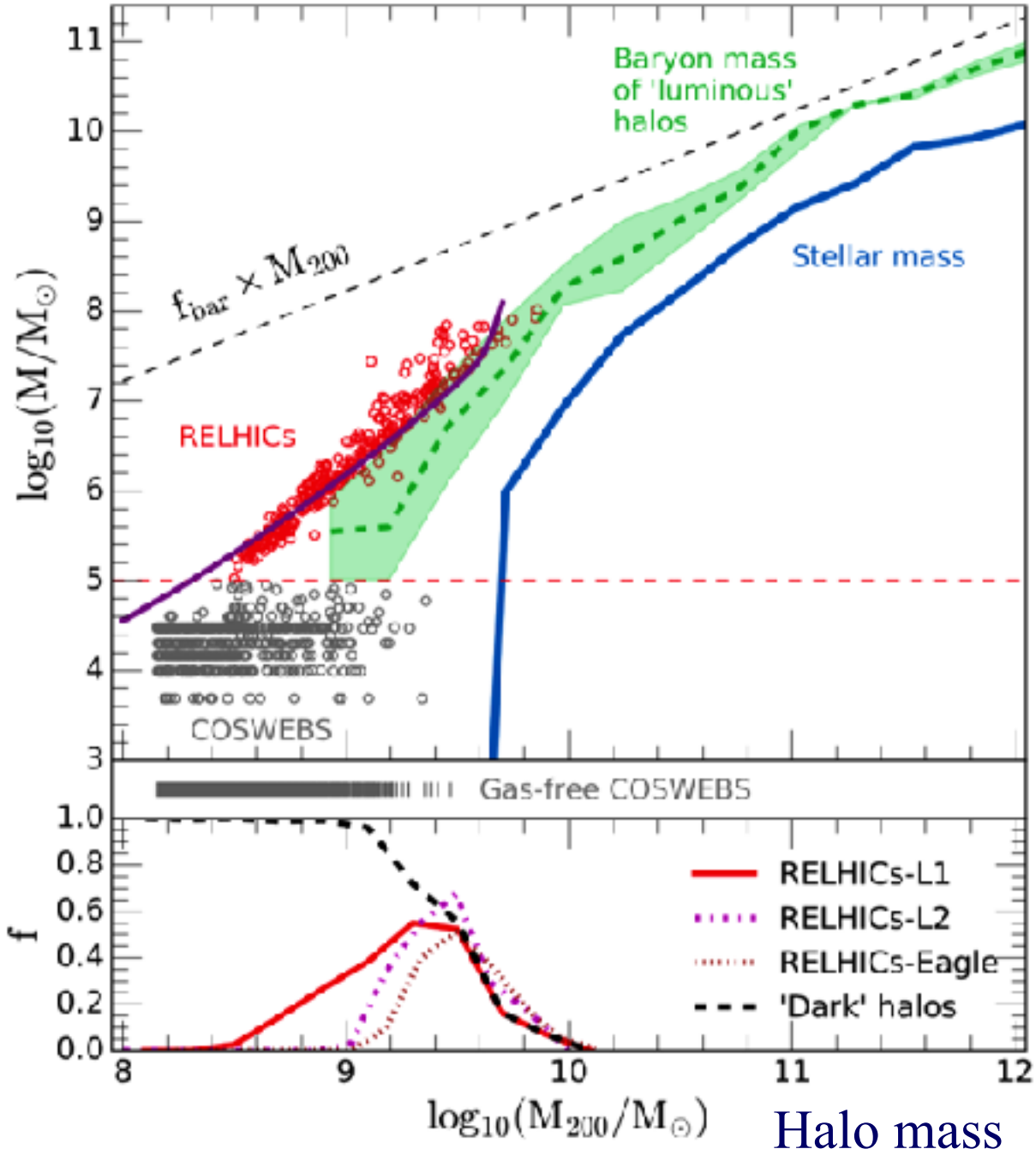
Dark matter clues from the faintest galaxies

Julio F. Navarro

"Dark" halos in a Cold Dark Matter Universe



CDM halos below ~$10^{9.5}$ M_{sun} fail to form luminous galaxies: yet many of them are filled with gas

This is a very important prediction of the LCDM paradigm

Two kinds of systems appear at low masses: those that retain bound gas and those that don't

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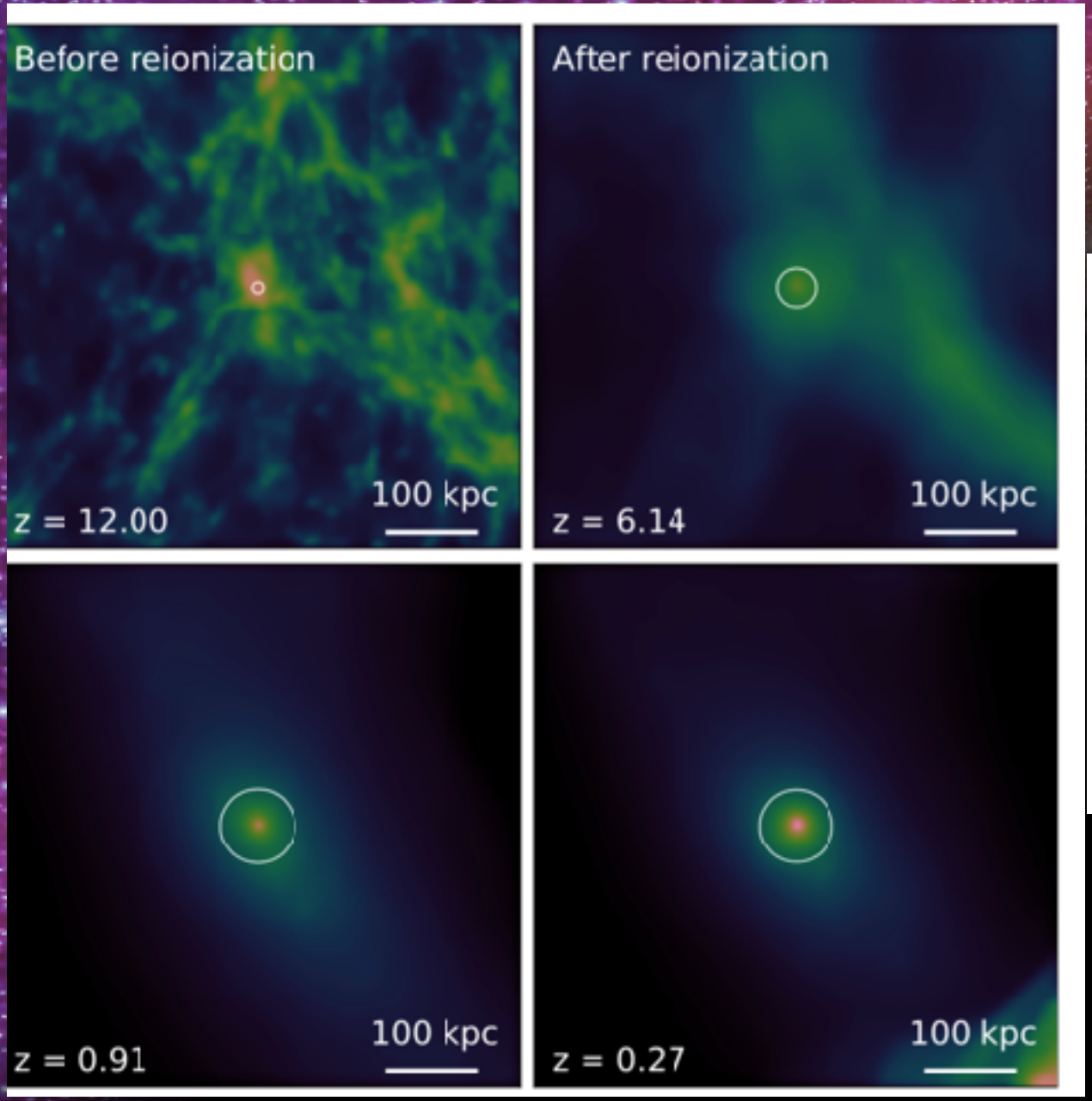

RELHICS

"Reionization-Limited HI Clouds"

- Gas in hydrostatic equilibrium
- Nearly round
- Mostly ionized except for the core
- Metal-free
- Avoid dense environments

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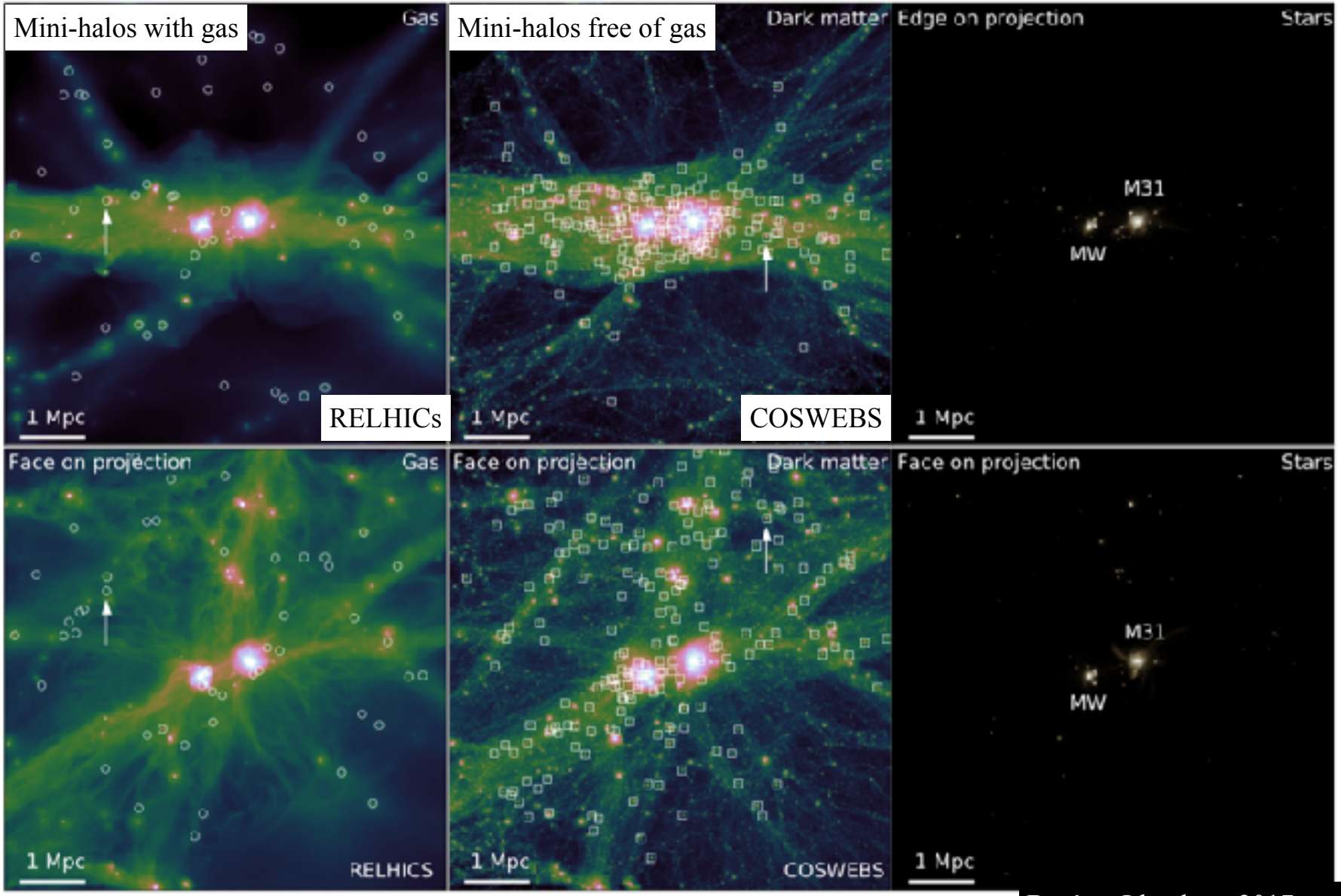
Star-free halos in the Local Group



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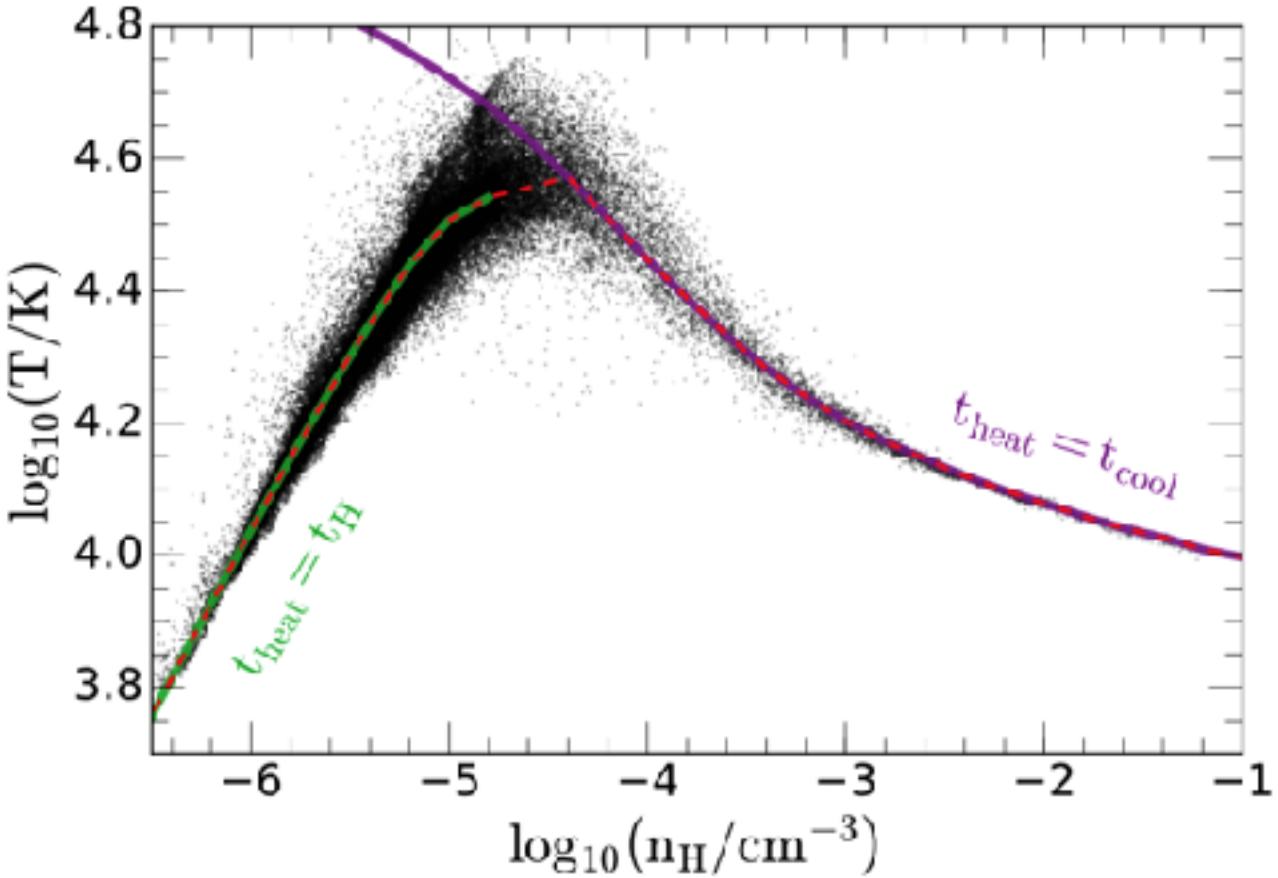
The "Equation of State" of Gas in RELHICs



Gas bound to RELHICS is in ionization equilibrium with the cosmic ionizing UV background

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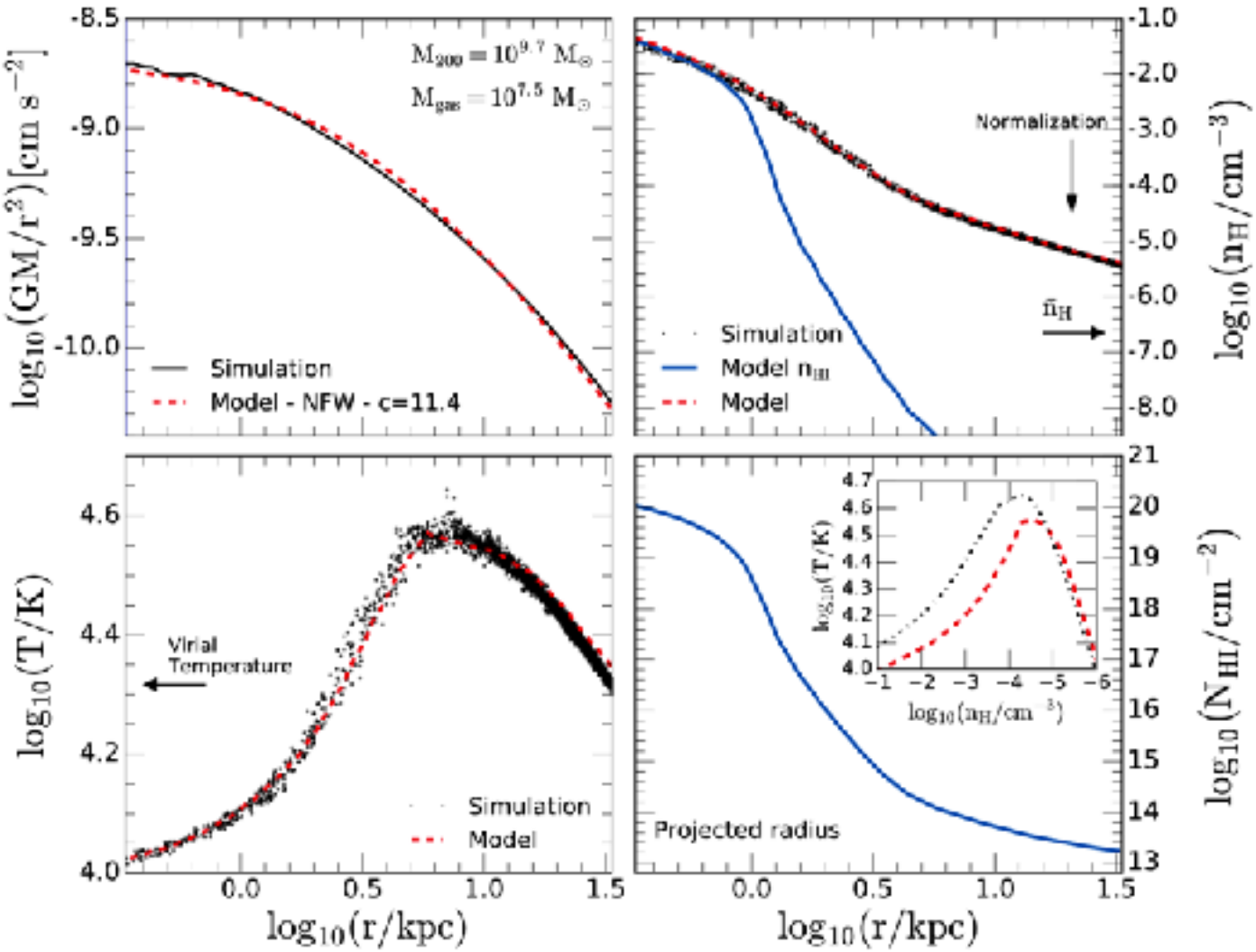
Gas in RELHICs



Gas in RELHICs is in hydrostatic equilibrium in the gravitational potential of their cold dark matter halos

Total gas mass of a RELHIC may be predicted

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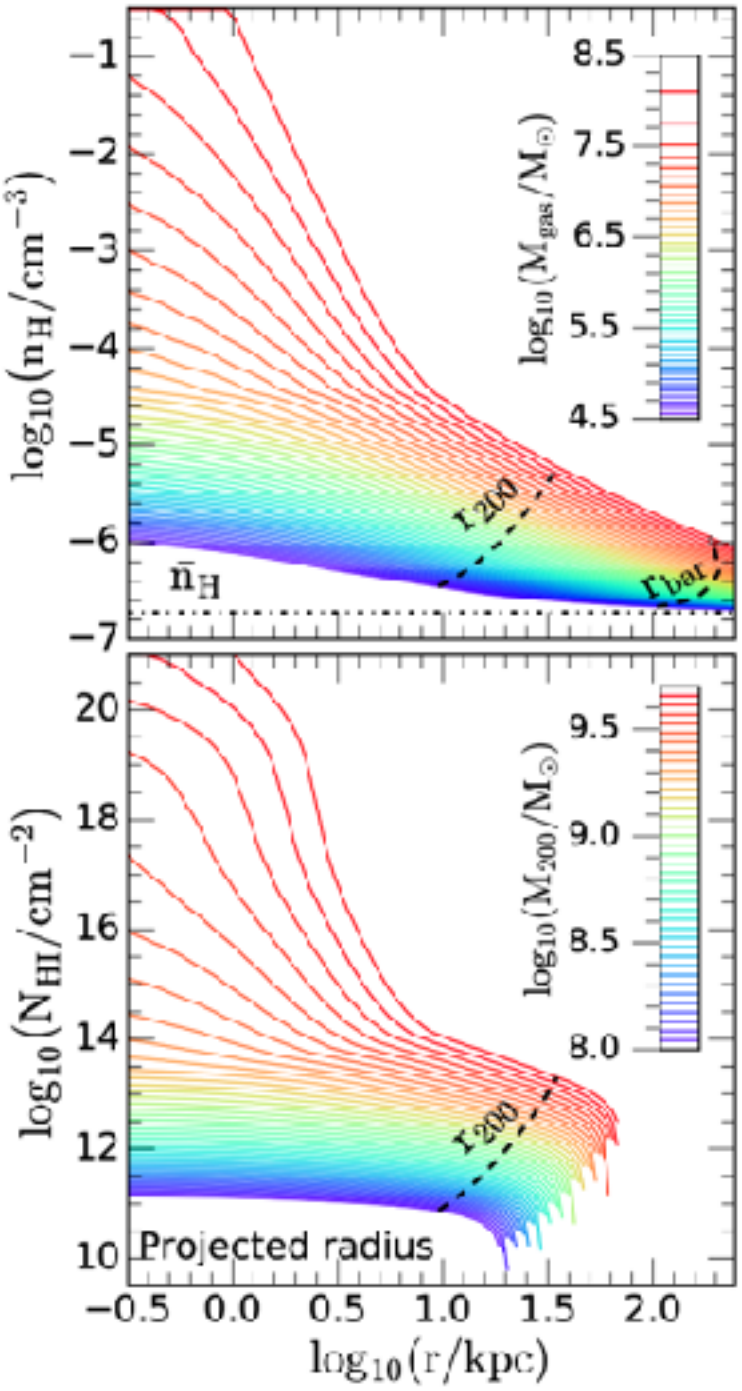
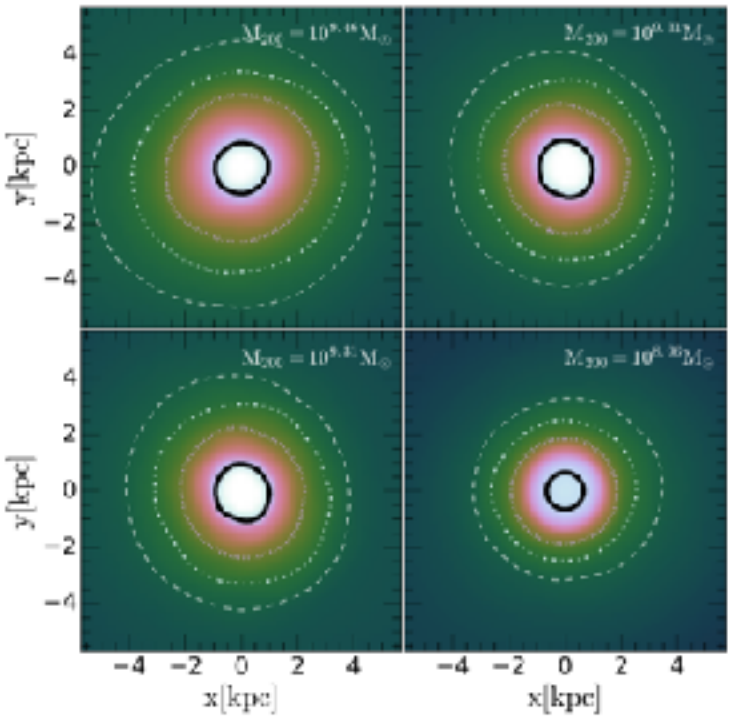
HI in RELHICs





- Gas properties in RELHICs may be computed analytically
- Only the very central regions of massive RELHICs achieve HI column densities high enough to be detected in emission.
- Halo mass “threshold” for galaxy formation is ~5e9 Msun

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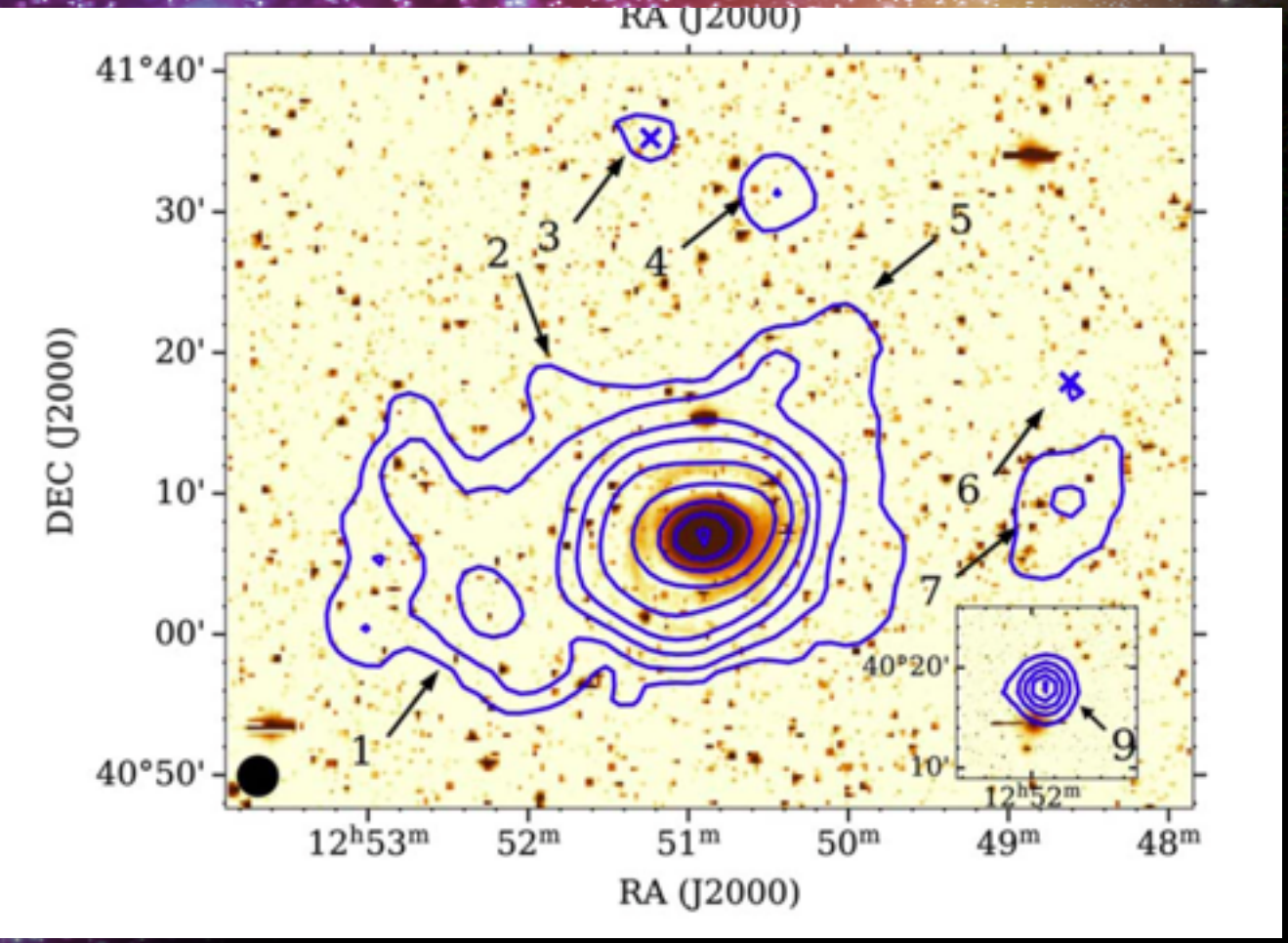
The Astrophysical Journal, 952:130 (11pp), 2023 August 1
https://doi.org/10.3847/1538-4357/acdef5

FAST Reveals New Evidence for M94 as a Merger

Ruilei Zhou[1,2,3], Ming Zhu[1,2,3,4], Yanbin Yang[5], Haiyang Yu[1,2,3], Lixia Yuan[6], Peng Jiang[1,3,4], and Wenzhe Xi[2,7]
[1] National Astronomical Observatories, Chinese Academy of Sciences, A20 Datun Road, Beijing 100101, People's Republic of China; mz@nao.cas.cn
[2] University of Chinese Academy of Sciences, Beijing 100049, People's Republic of China



A new HI survey of the surroundings of the spiral galaxy M94 reveals the presence of a "starless" HI cloud with properties reminiscent of RELHICs

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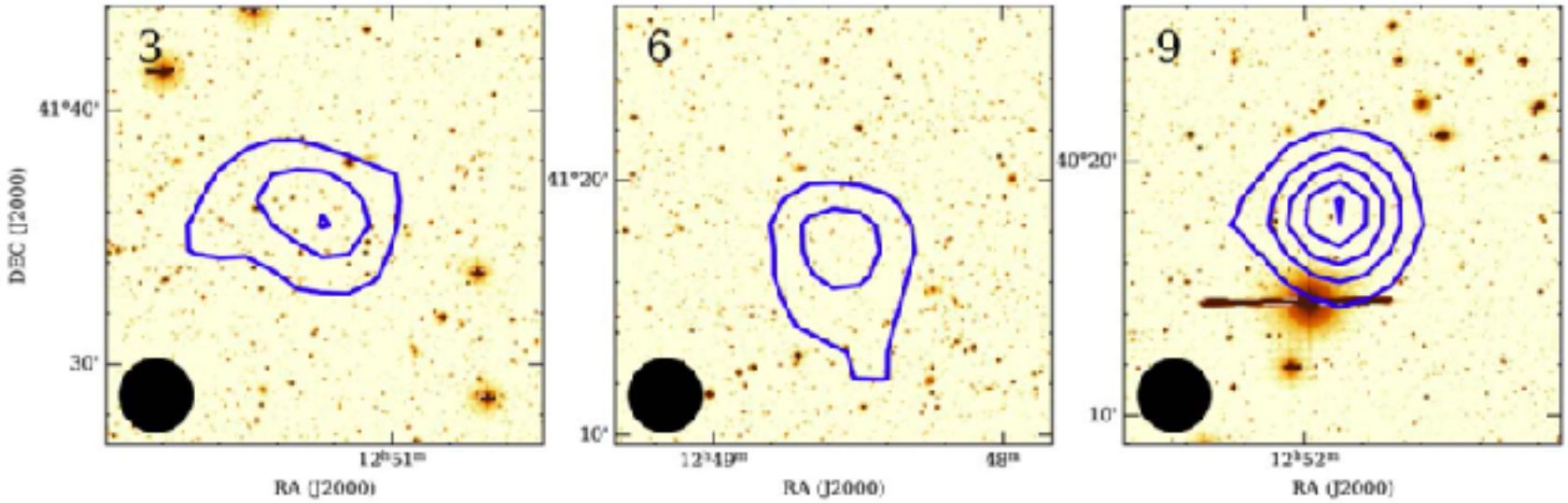
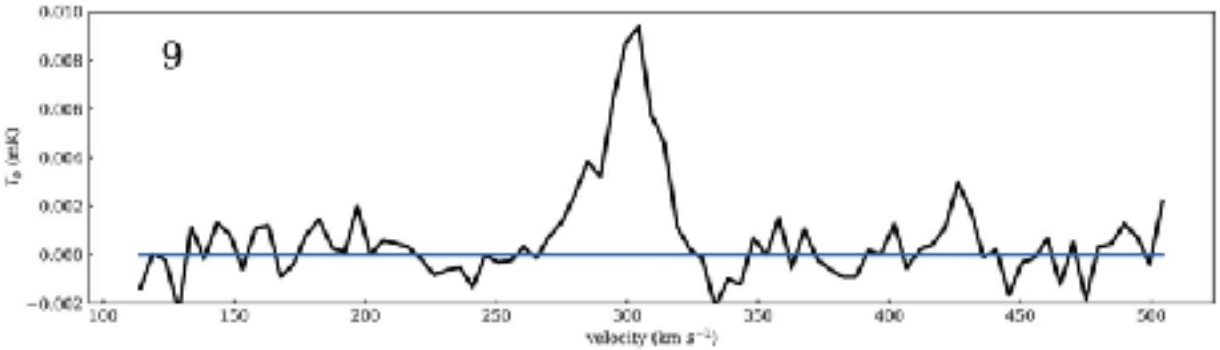
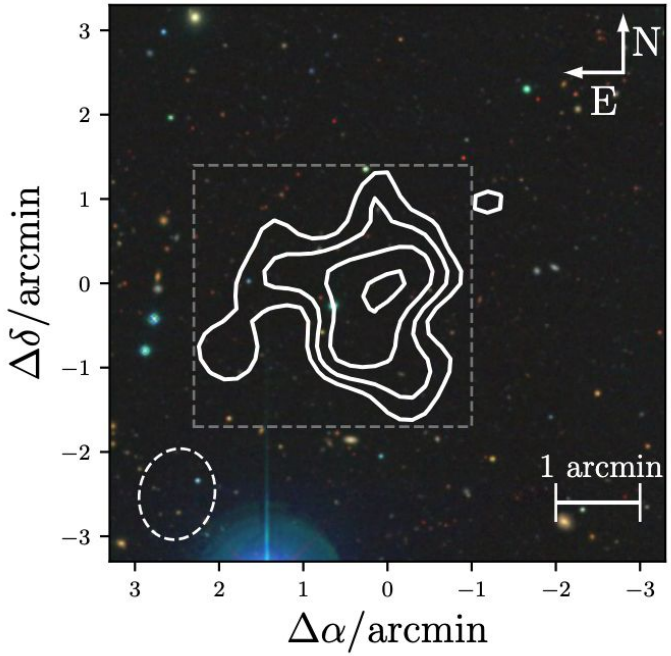
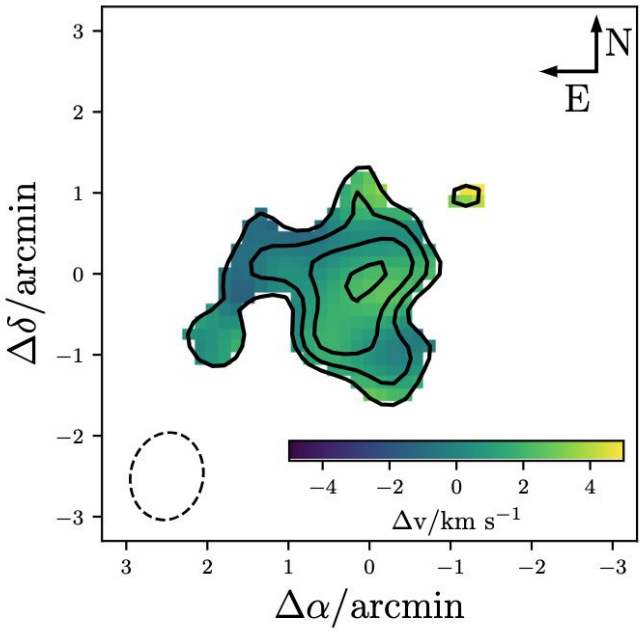




Cloud 9 is round, and has a virial mass >>M_{HI}. Gas is close to hydrostatic equilibrium

Cloud-9 as seen with the Very Large Array





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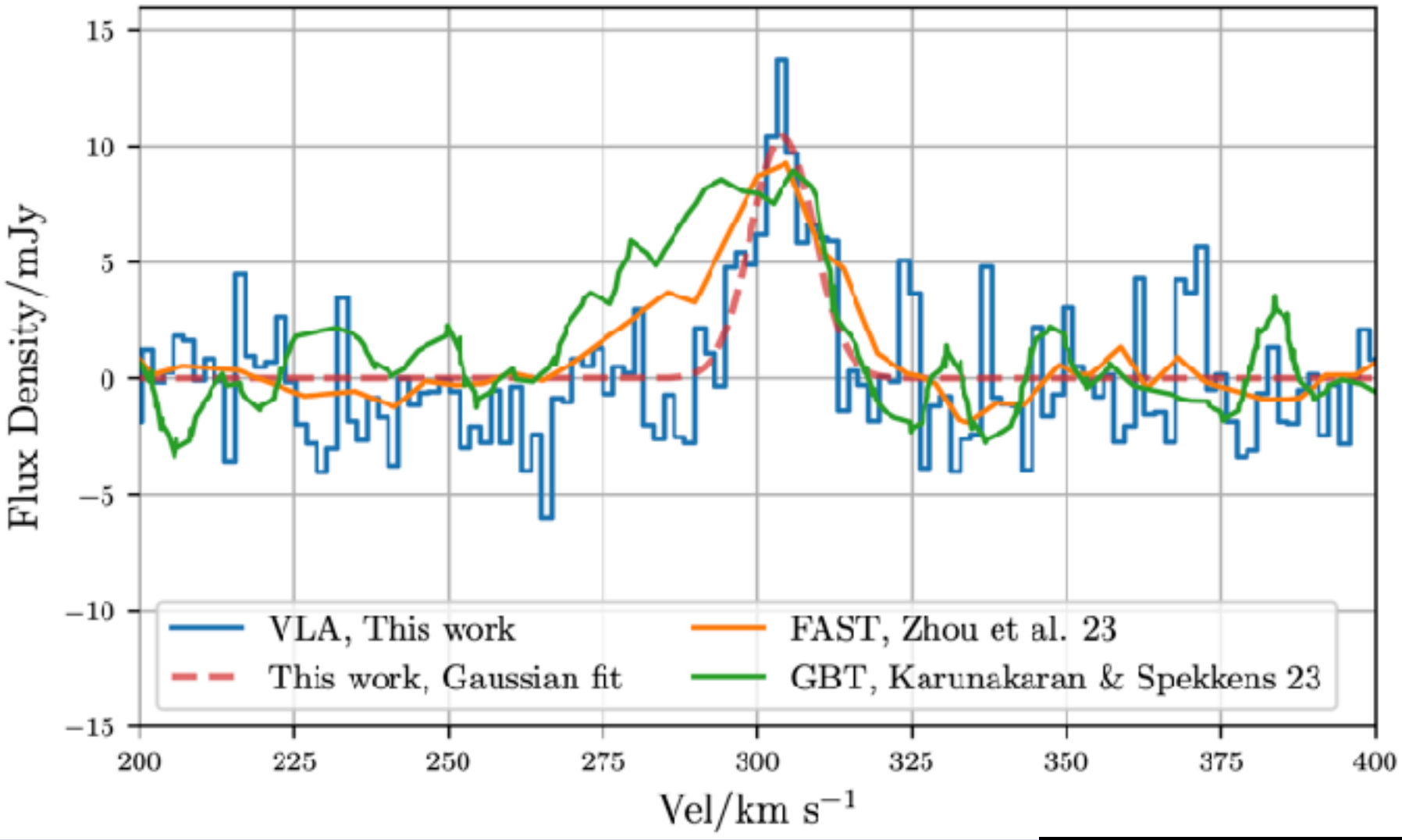
Cloud-9 line profile



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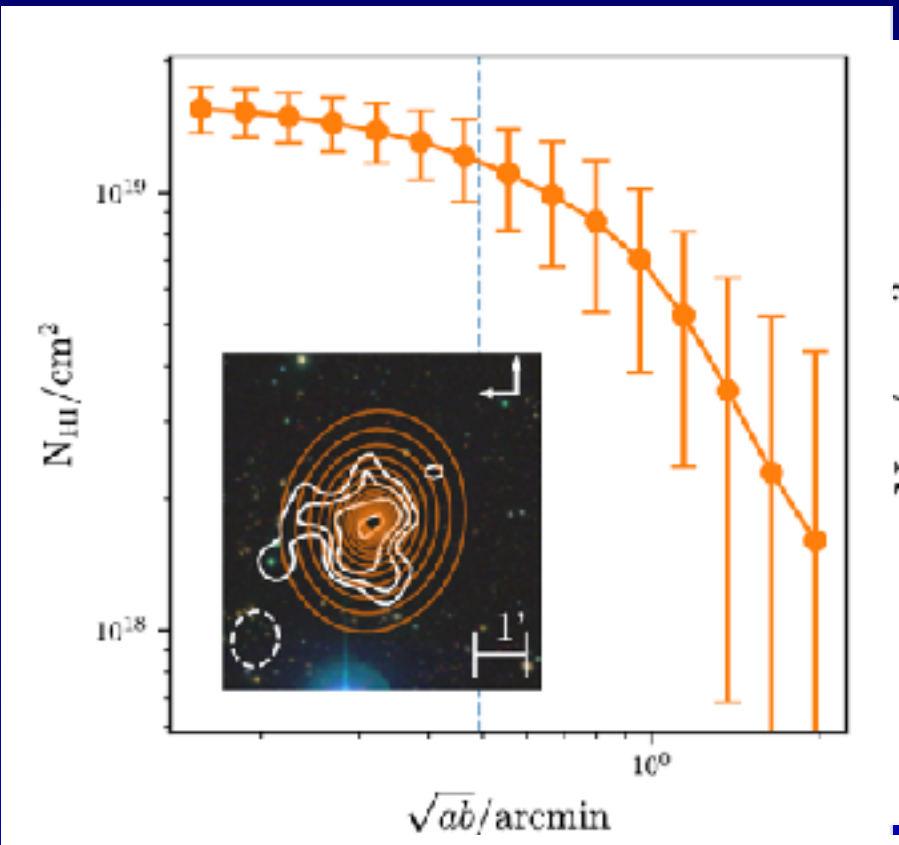
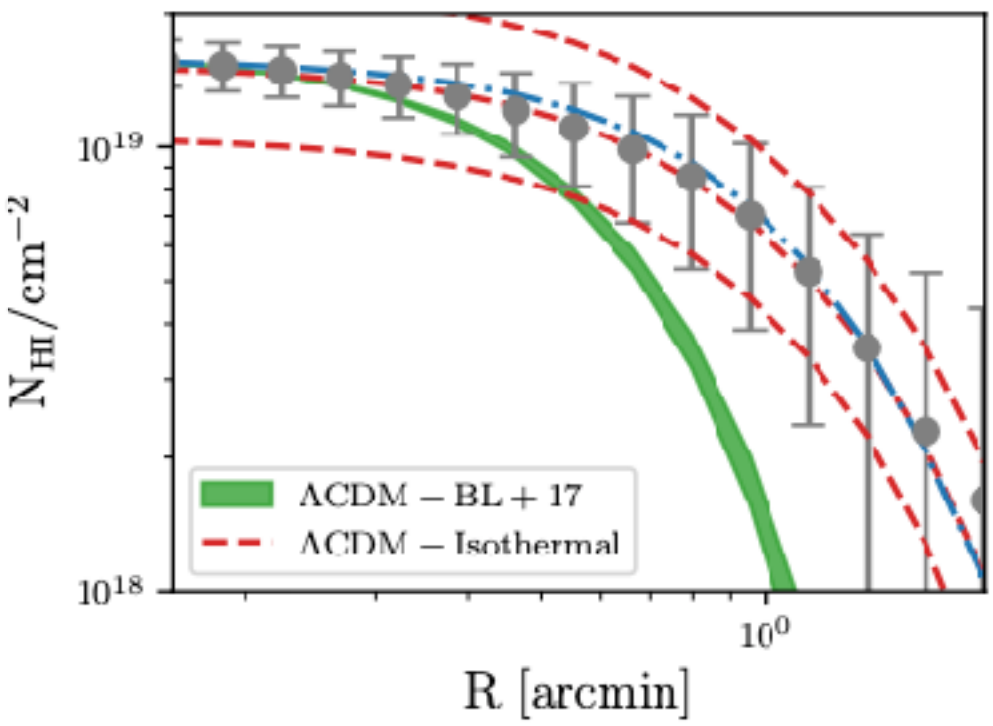
Cloud-9 HI profile





Cloud-9 appears more extended than expected if it was a LCDM RELHIC (T~10^4 K)

However, a slightly higher gas temperature (2 10^4 K) seems to fit well

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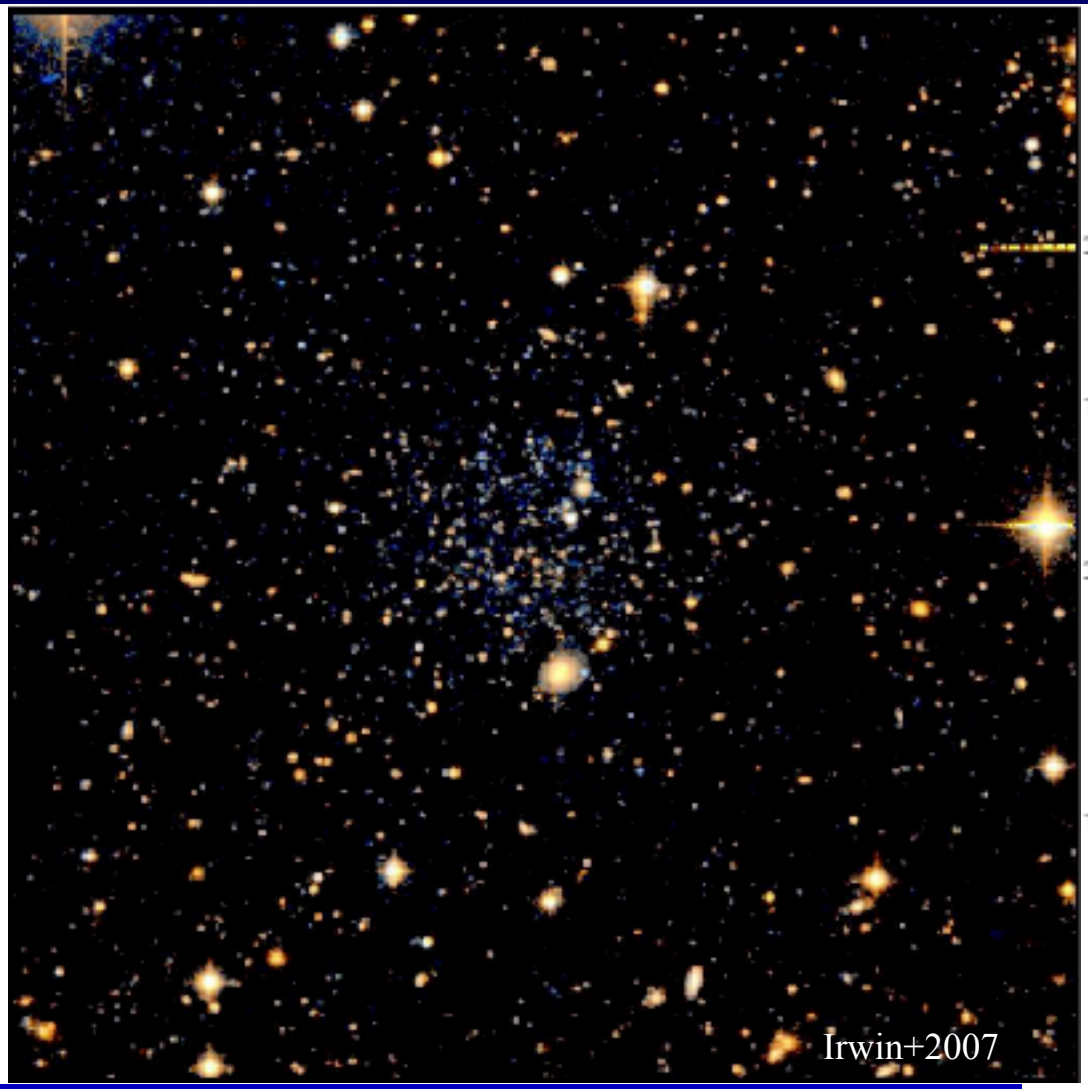
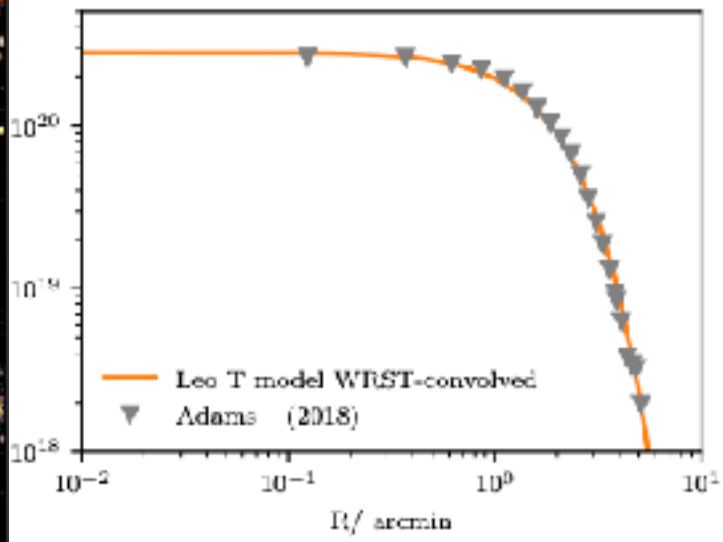
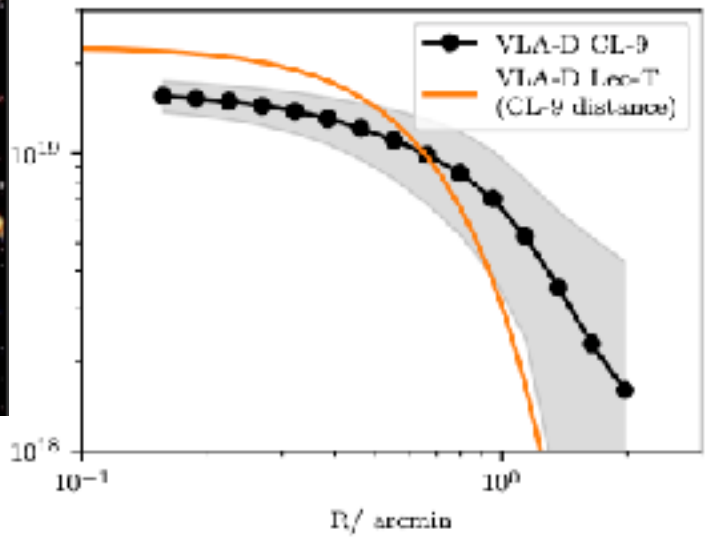






Leo T: the faintest galaxy known to contain HI

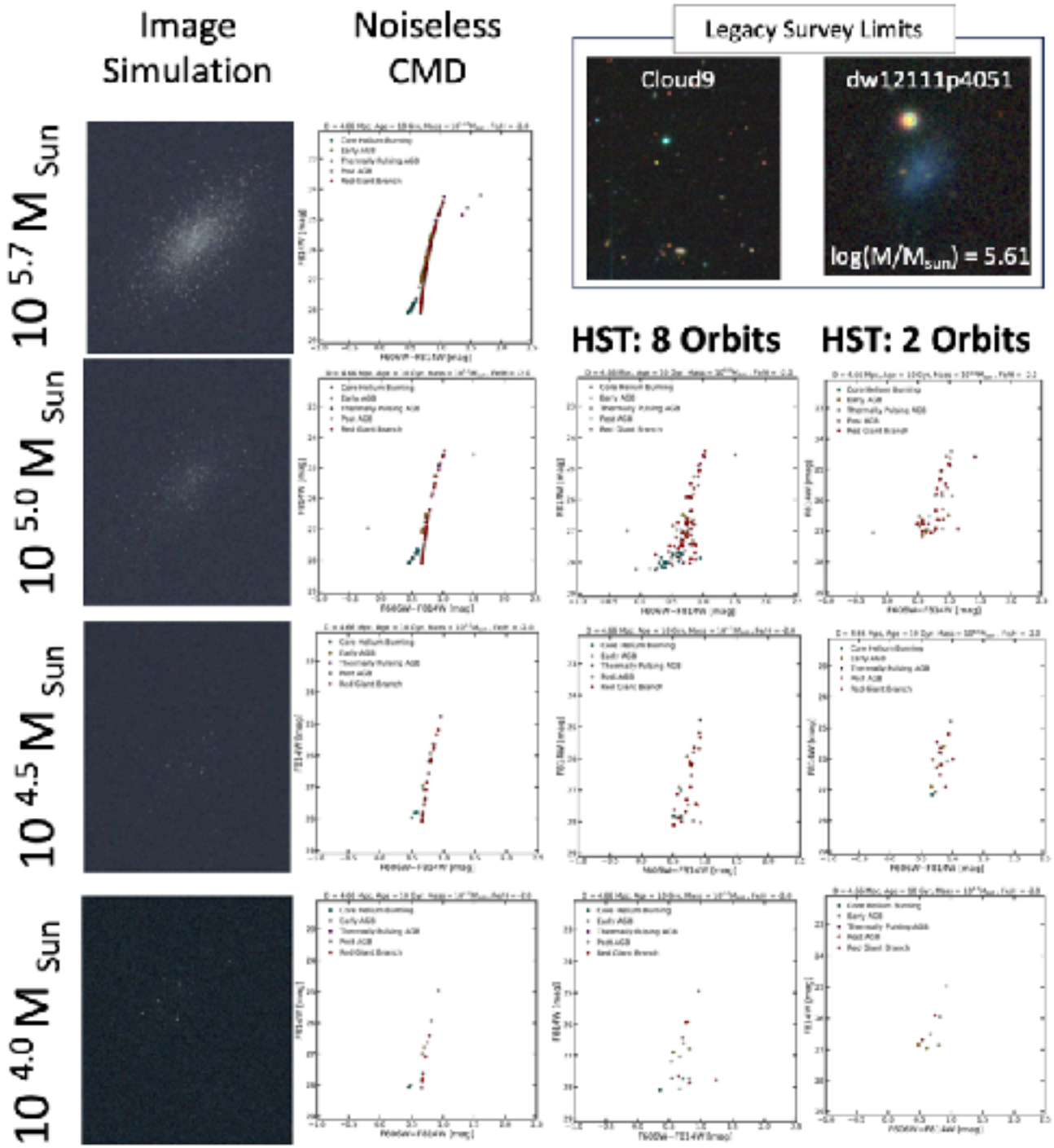
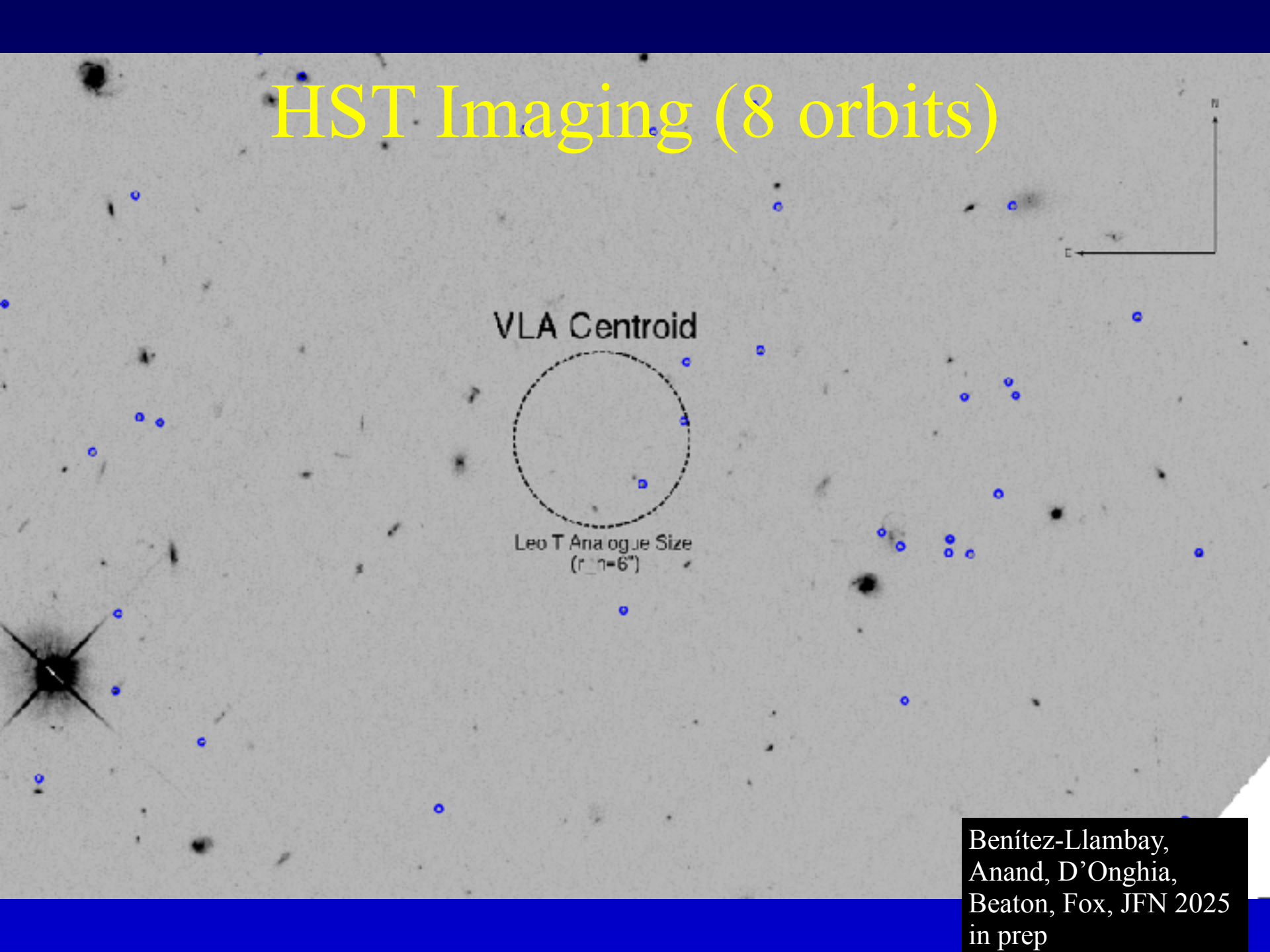


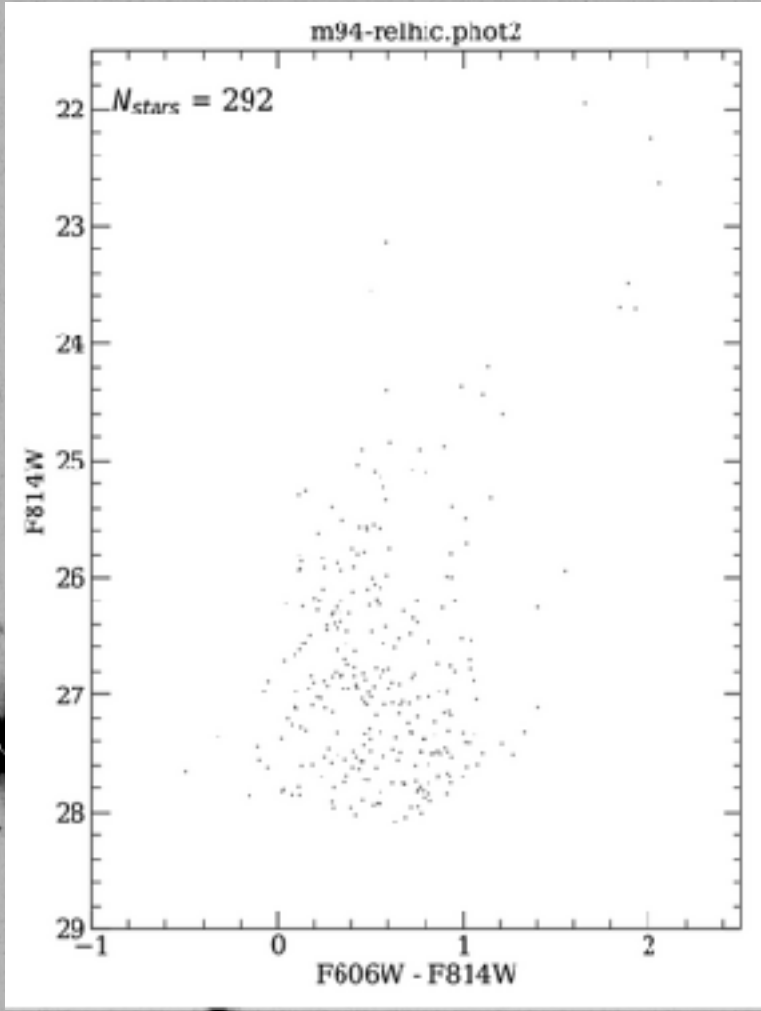
Image Simulation
Noiseless CMD
Legacy Survey Limits
Cloud9
dw12111p4051
log(M/M_sun) = 5.61
HST: 8 Orbits
HST: 2 Orbits
10 5.7 M Sun
10 5.0 M Sun
10 4.5 M Sun
10 4.0 M Sun

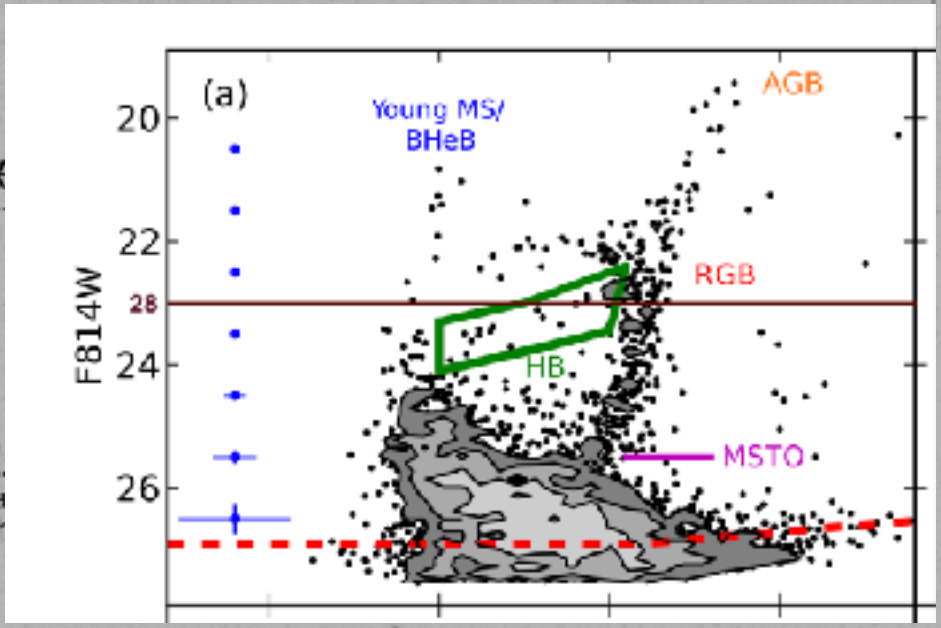
HST Imaging (8 orbits)



Benítez-Llambay, Anand, D'Onghia, Beaton, Fox, JFN 2025 in prep

HST Imaging (8 orbits)





Leo T seen by HST

Benítez-Llambay, Anand, D'Onghia, Beaton, Fox, JFN 2025 in prep

Summary

- The dependence between satellite galaxy size and mean density is in good agreement with LCDM expectations and is not easily reproduced in alternative DM models.
  - This is also inconsistent with simple predictions of "fuzzy" or self-interacting dark matter models
- The discovery of faint, compact satellites with small pericentric radii suggests that the DM halos of the faintest galaxies are cuspy, as predicted by LCDM. More discoveries like this would strengthen this conclusion.
- The discovery of RELHICs would be the first confirmation of a basic tenet of LCDM: the existence of dark matter clumps on sub-galactic scales.
  - M94-Cloud 9 is a candidate worth following up closely