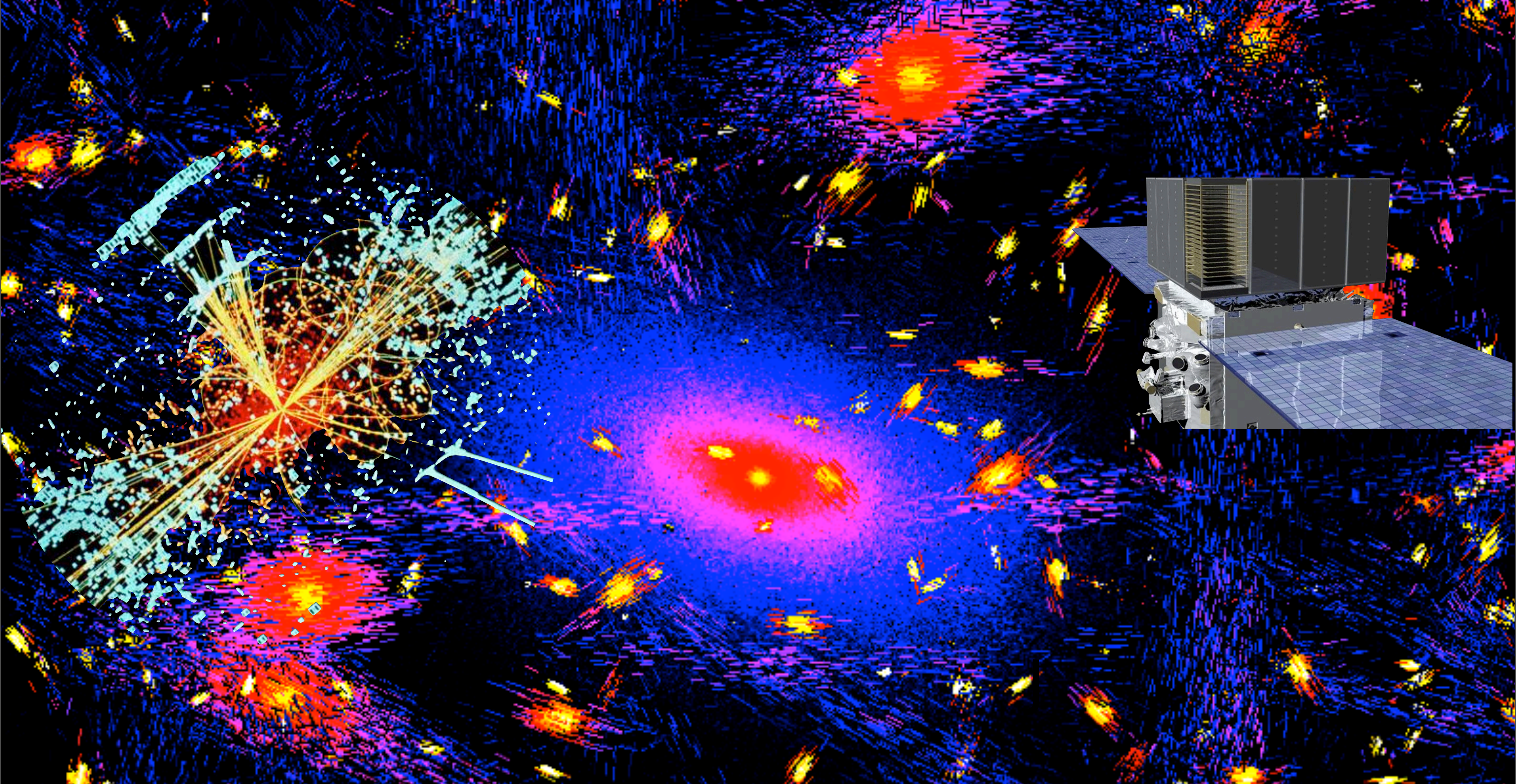
KITP 2012: FIRST LIGHT AND FAINTEST DWARFS



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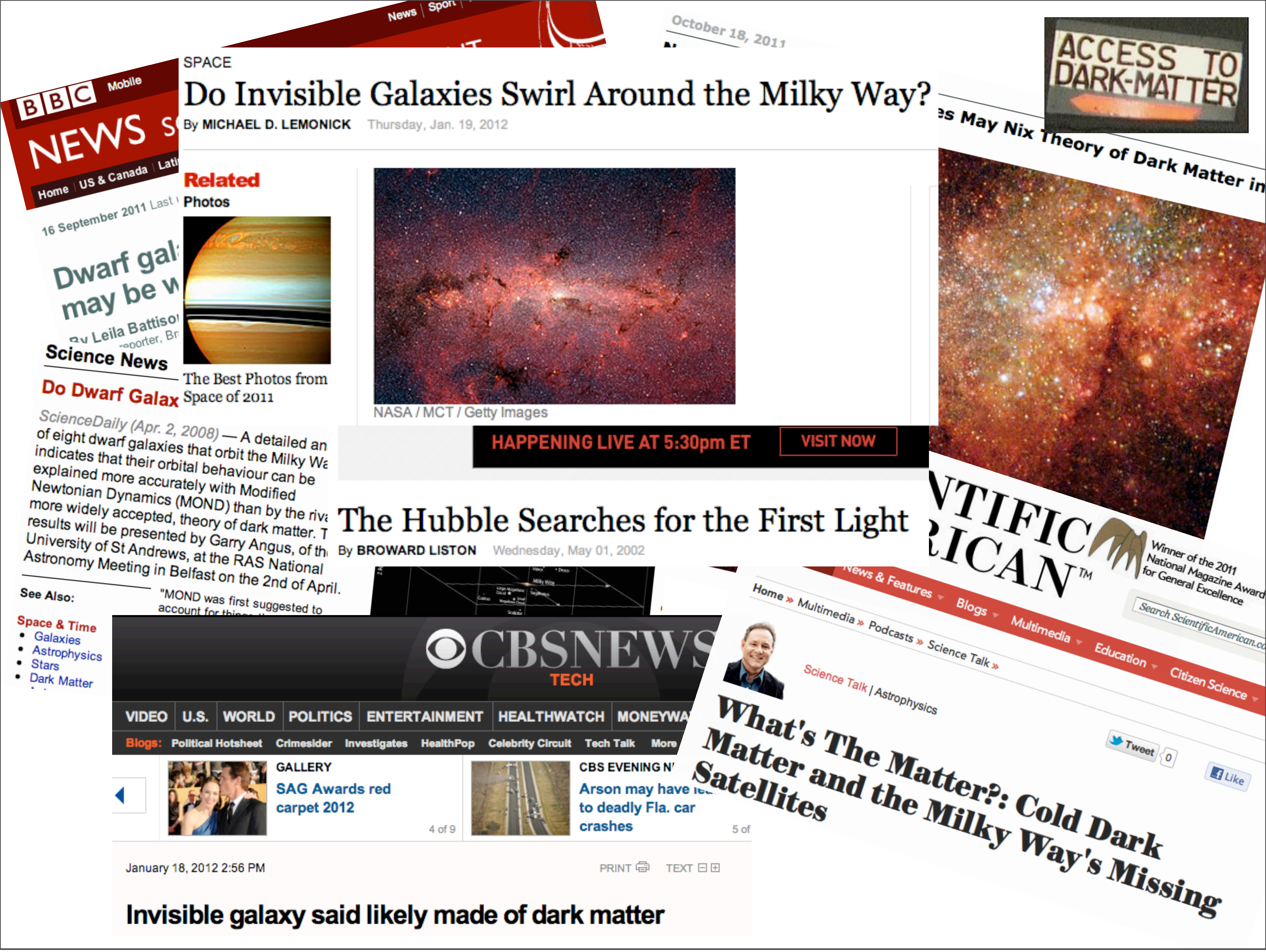
16 September 2011 Last updated at 13:47 ET

Dwarf galaxies suggest dark matter theory may be wrong

By Leila Battison
Science reporter, Bradford



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By MICHAEL D. LEMONICK Thursday, Jan. 19, 2012

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Science News

Do Dwarf Galax

ScienceDaily (Apr. 2, 2008) — A detailed an of eight dwarf galaxies that orbit the Milky Wa indicates that their orbital behaviour can be explained more accurately with Modified Newtonian Dynamics (MOND) than by the riva more widely accepted, theory of dark matter. T results will be presented by Garry Angus, of th University of St Andrews, at the RAS National Astronomy Meeting in Belfast on the 2nd of April.

"MOND was first suggested to account for thin

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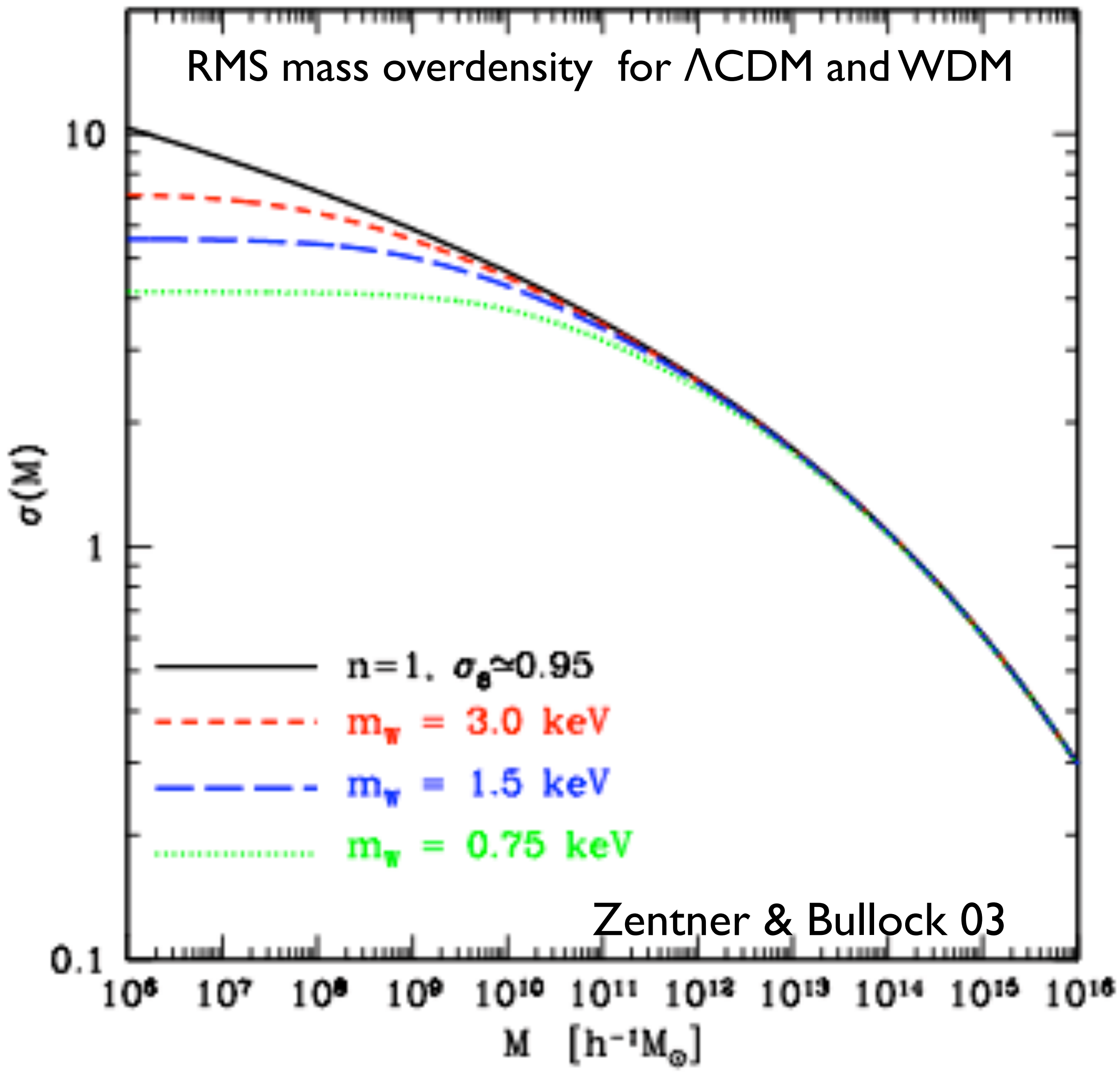
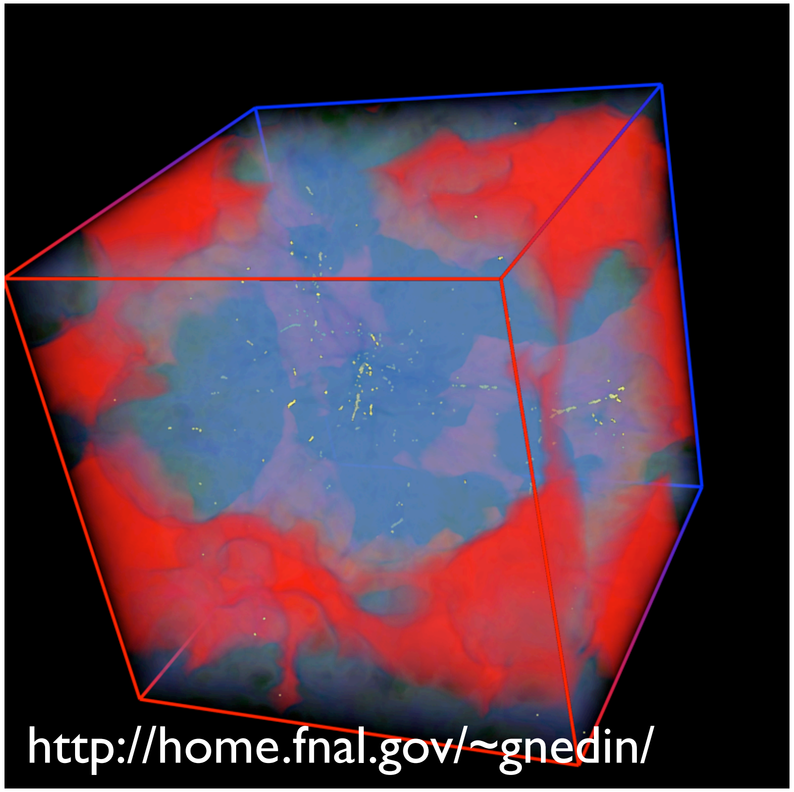
January 18, 2012 2:56 PM PRINT TEXT

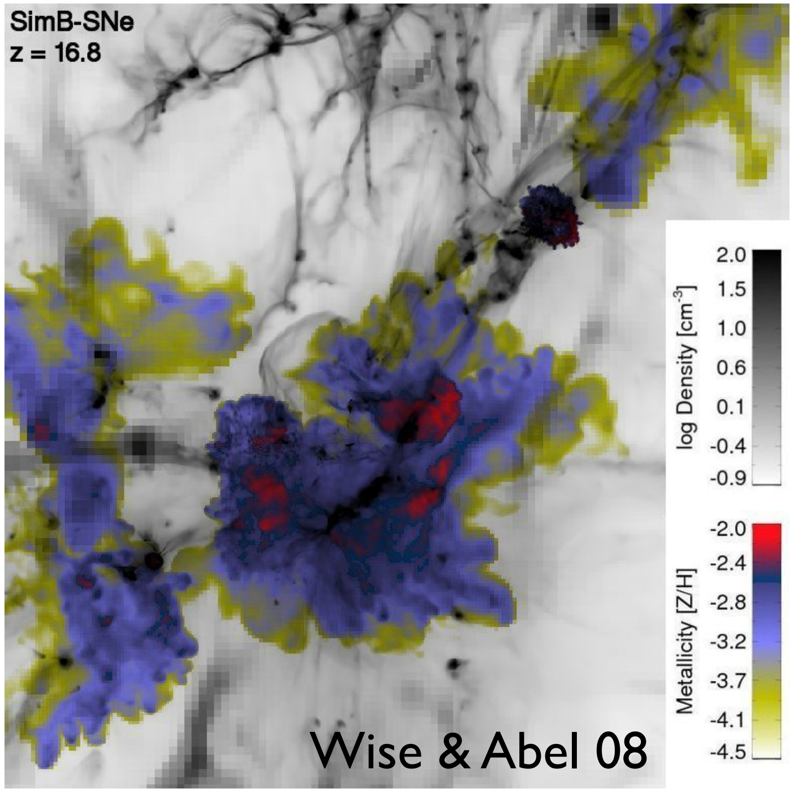
Invisible galaxy said likely made of dark matter

• <u>DGs are DM laboratories</u>: probe the power spectrum on small scales and offer a unique test of the particle nature of dark matter.

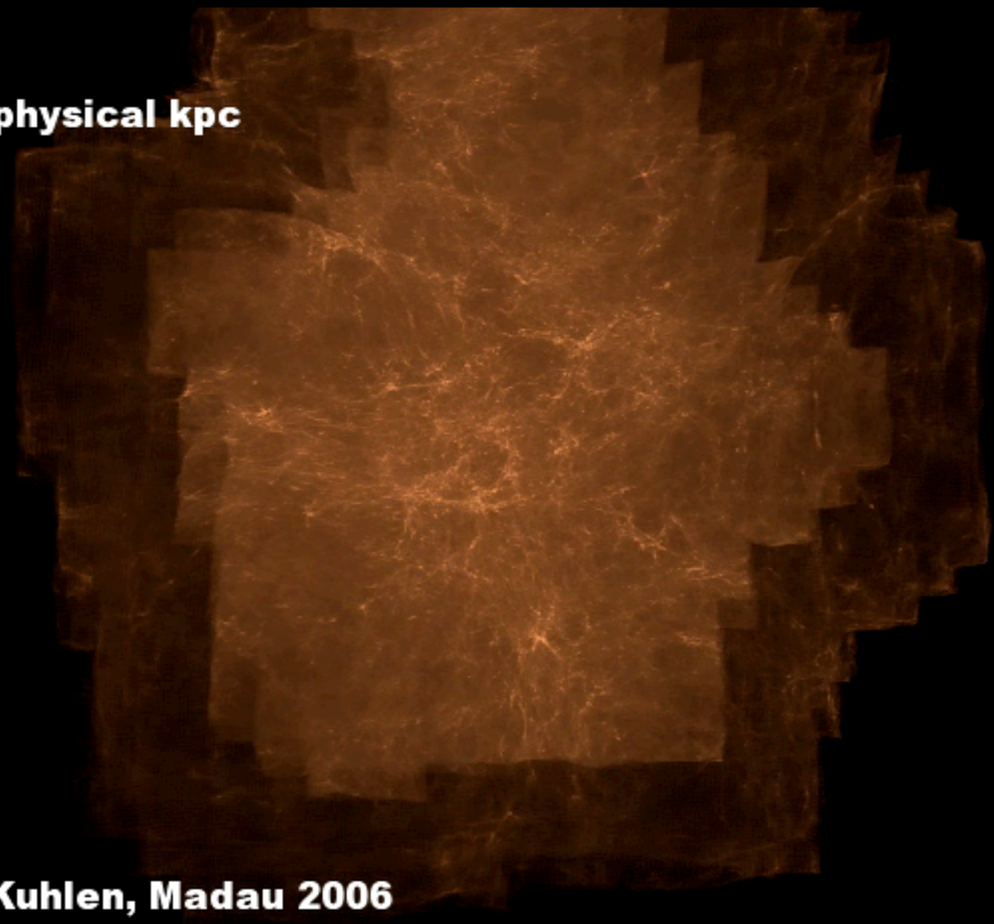


• <u>DGs probe of the epoch of first light</u>: first generation of cosmic structures to go nonlinear ➪ responsible for the reionization and chemical enrichment of the universe.

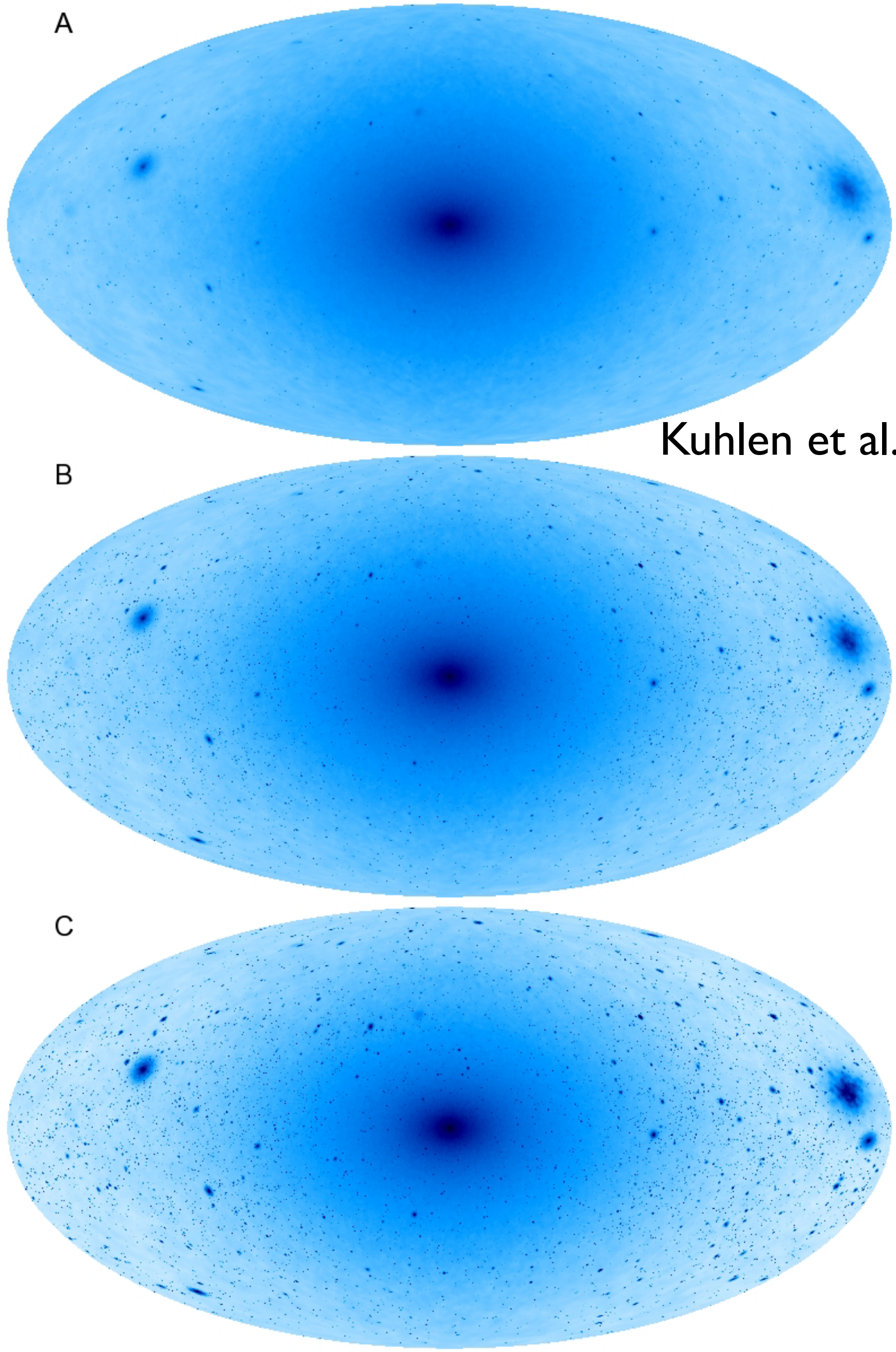




- <u>DGs are the building blocks of more massive galaxies</u>: their remnants provide a powerful test of the hierarchical assembly of cosmic structures.



- Surviving DG satellites in the halo of the MW provide an excellent laboratory for indirect detection of DM.

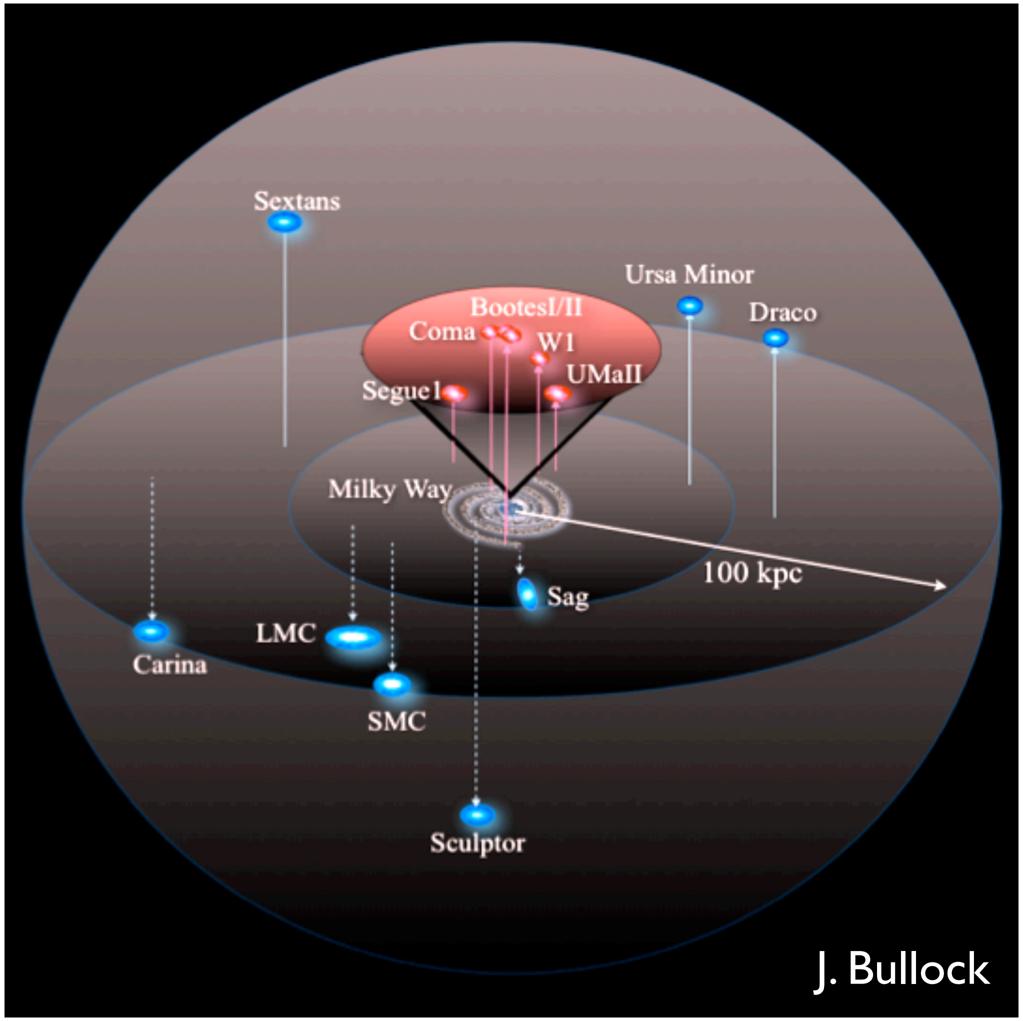


Kuhlen et al. 09

All-sky maps of the *Sommerfeld*-enhanced annihilation surface brightness from all VLII DM particles.

Two main "DG Problems" (which may or may not be related)

1) Missing Satellite Problem: discrepancy between the relatively small number of satellite galaxies known to be orbiting the Milky Way (~20) and the vastly larger number of dark matter subhalos seen in N-body "zoom-in" cosmological simulations (Moore et al. 1999; Klypin et al. 1999; Diemand et al. 2007,2008; Springel et al. 2008).



Like many overachievers, DGs have so far failed to live up to our expectations....

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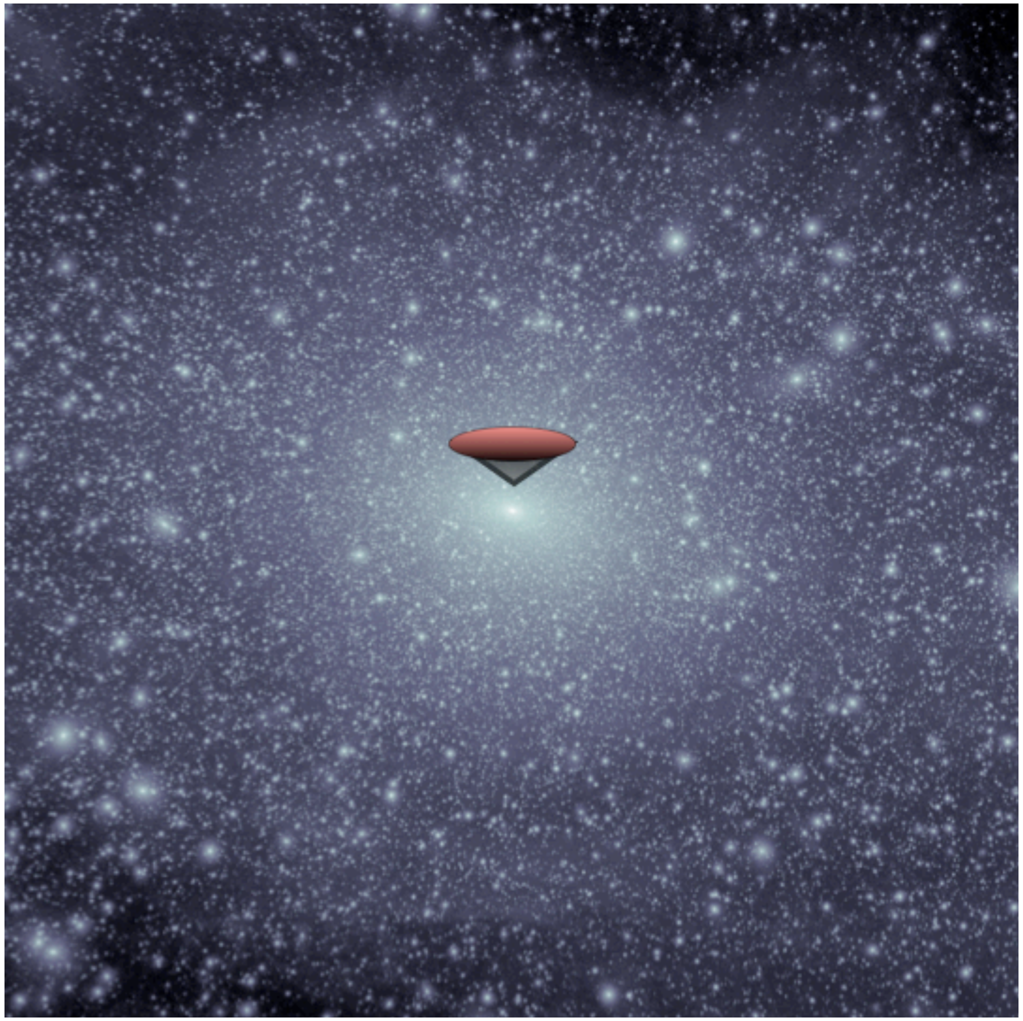
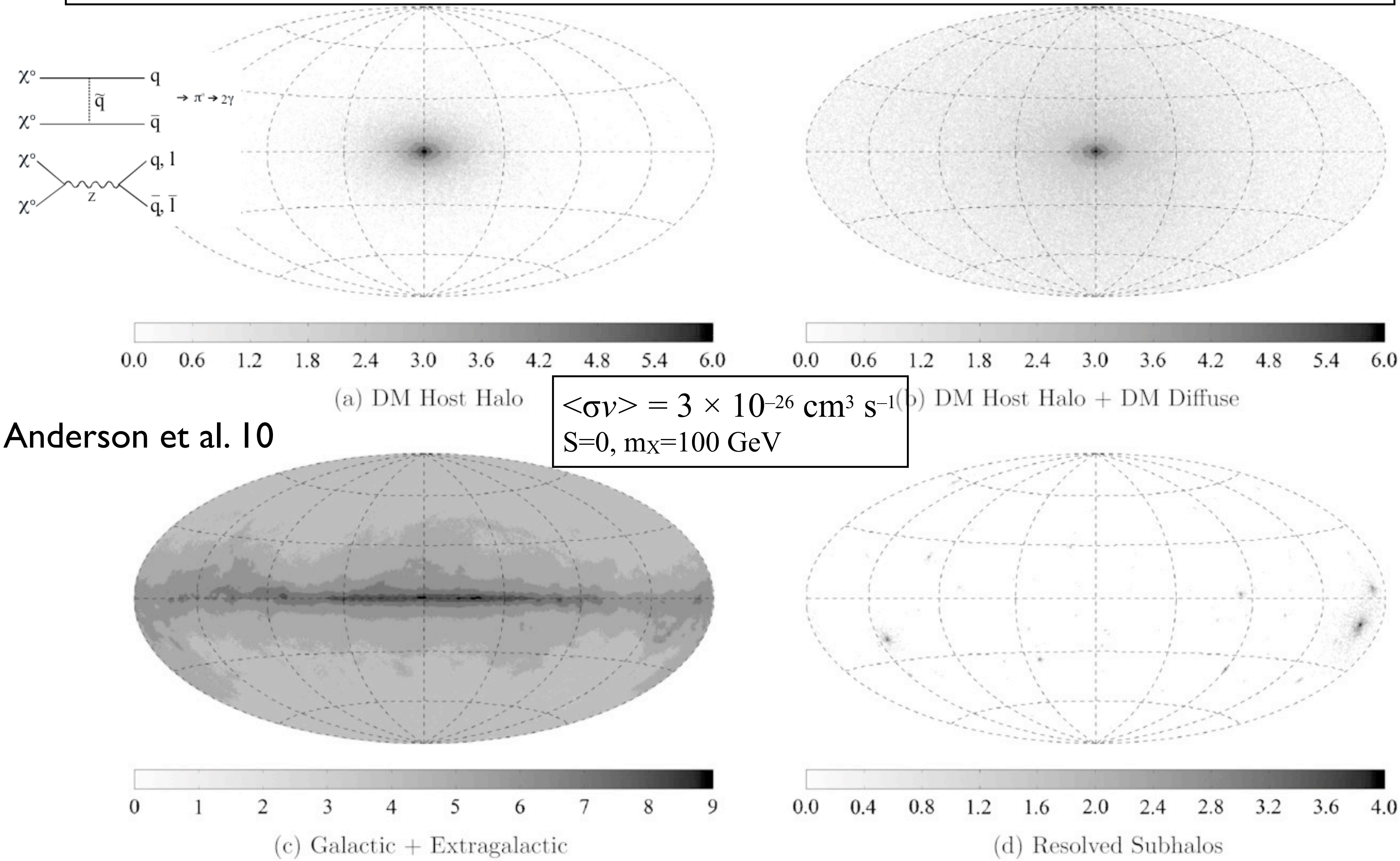


From Fermi-LAT Sensitivity to DM Annihilation in *Via Lactea II* Substructure

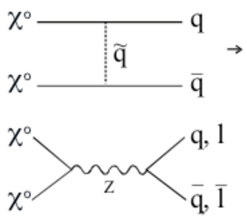


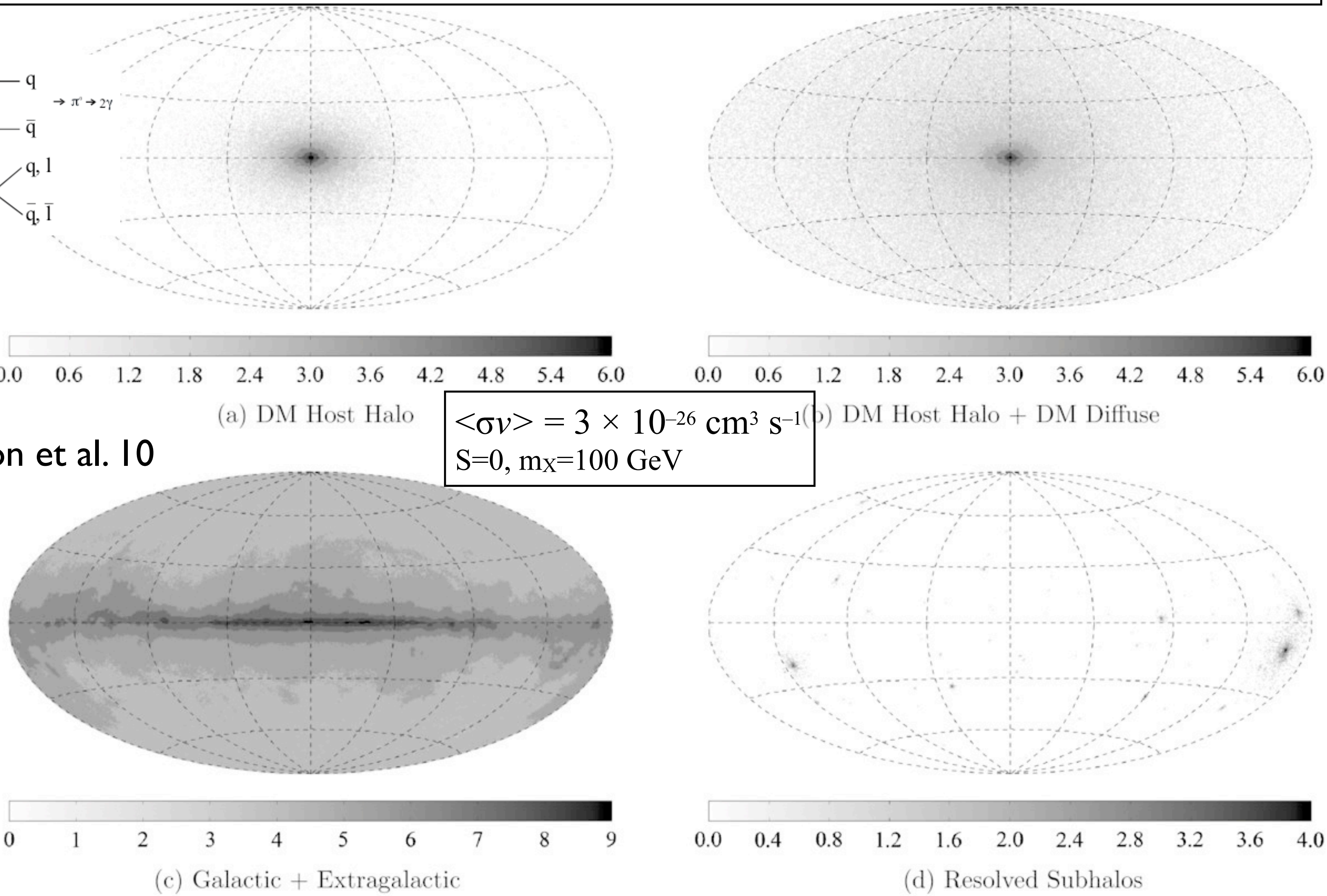
$\langle\sigma v\rangle = 3 \times 10^{-26}$ cm^3 s^{-1}
S=0, m_X=100 GeV

Anderson et al. 10

All-sky log(counts) maps for a WIMP subhalo annihilation signal and the three background sources for 10 years of *Fermi*-LAT orbit. (a) DM host halo, (b) DM host halo + DM diffuse, (c) Galactic + extragalactic, and (d) resolved subhalos.

From Fermi-LAT Sensitivity to DM Annihilation in *Via Lactea II* Substructure





(a) DM Host Halo

(b) DM Host Halo + DM Diffuse

(c) Galactic + Extragalactic

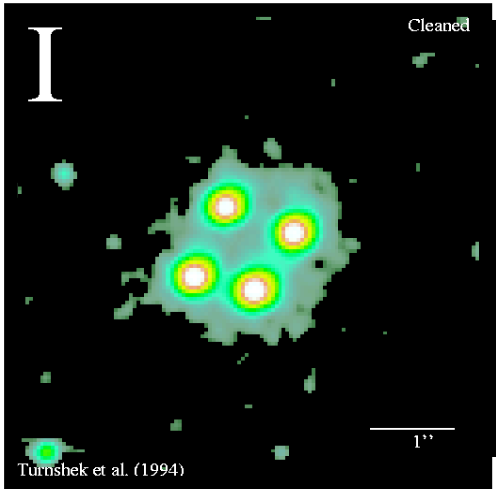
(d) Resolved Subhalos

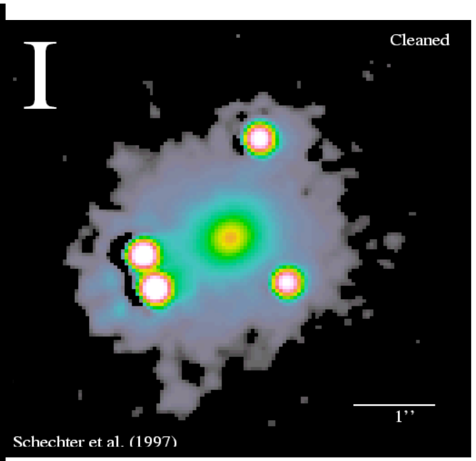
Anderson et al. 10

$\langle\sigma v\rangle = 3 \times 10^{-26}\ \mathrm{cm^3\ s^{-1}}$
S=0, m_X=100 GeV

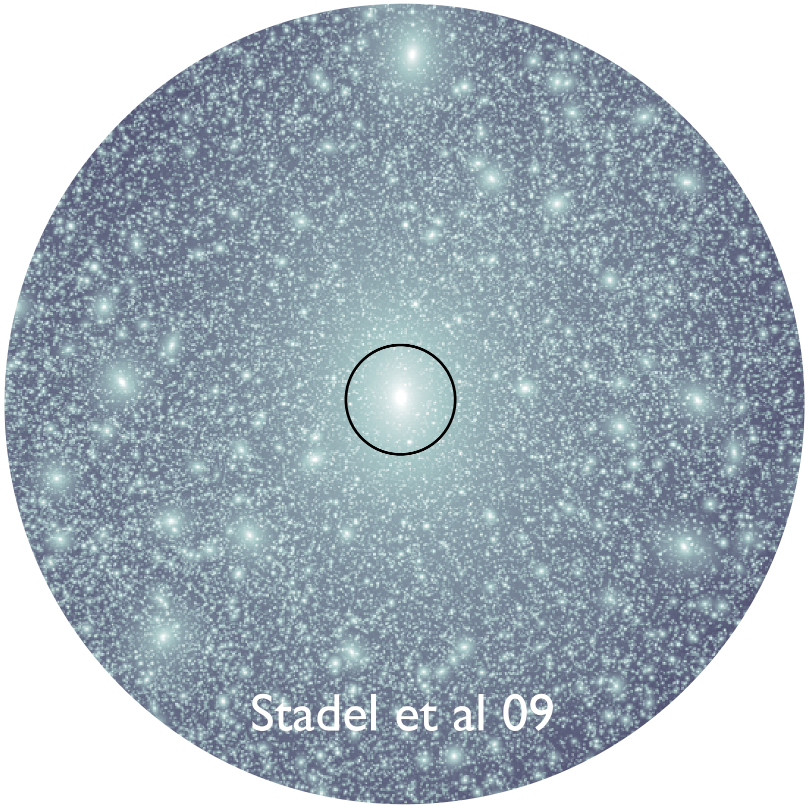
Things I'd like to hear more about: annihilating DM and constraints from Fermi!

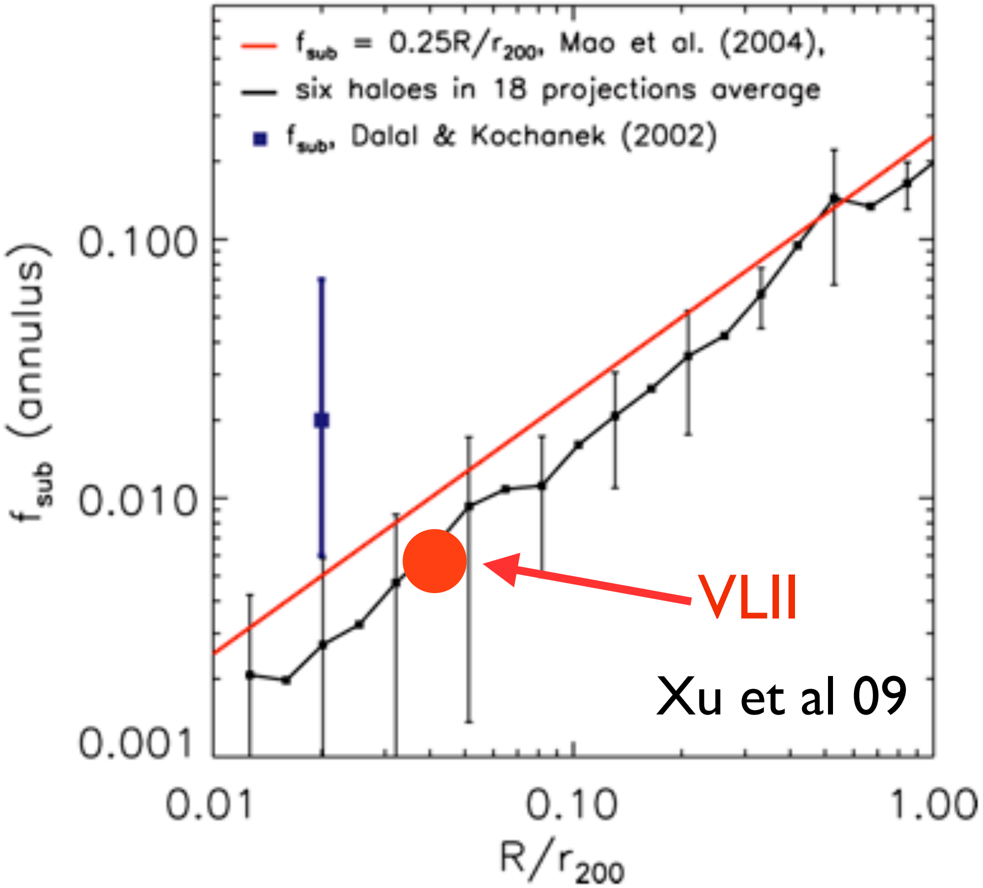
Potential perturbations by DM substructures produce anomalies (compared to a smooth mass distribution) in the relative magnifications of strong gravitational lenses (Metcalf & Madau 01, Chiba 02).





Flux ratio anomalies are observed in multiply-imaged lensed QSOs.





Is there enough substructure in CDM *N*-body simulations to cause the observed flux anomalies?

~YES (e.g. Diemand et al 08; Metcalf & Amara 12)

NO (e.g. Maccio et al 06; Xu et al 09, 11)

Sensitivity to: ellipticity of lens, intergalactic small-scale structure, baryons, small # of lensed QSOs...

<u>New technique</u>: surface brightness anomalies in bright Einstein rings (Vegetti & Koopmans 09)

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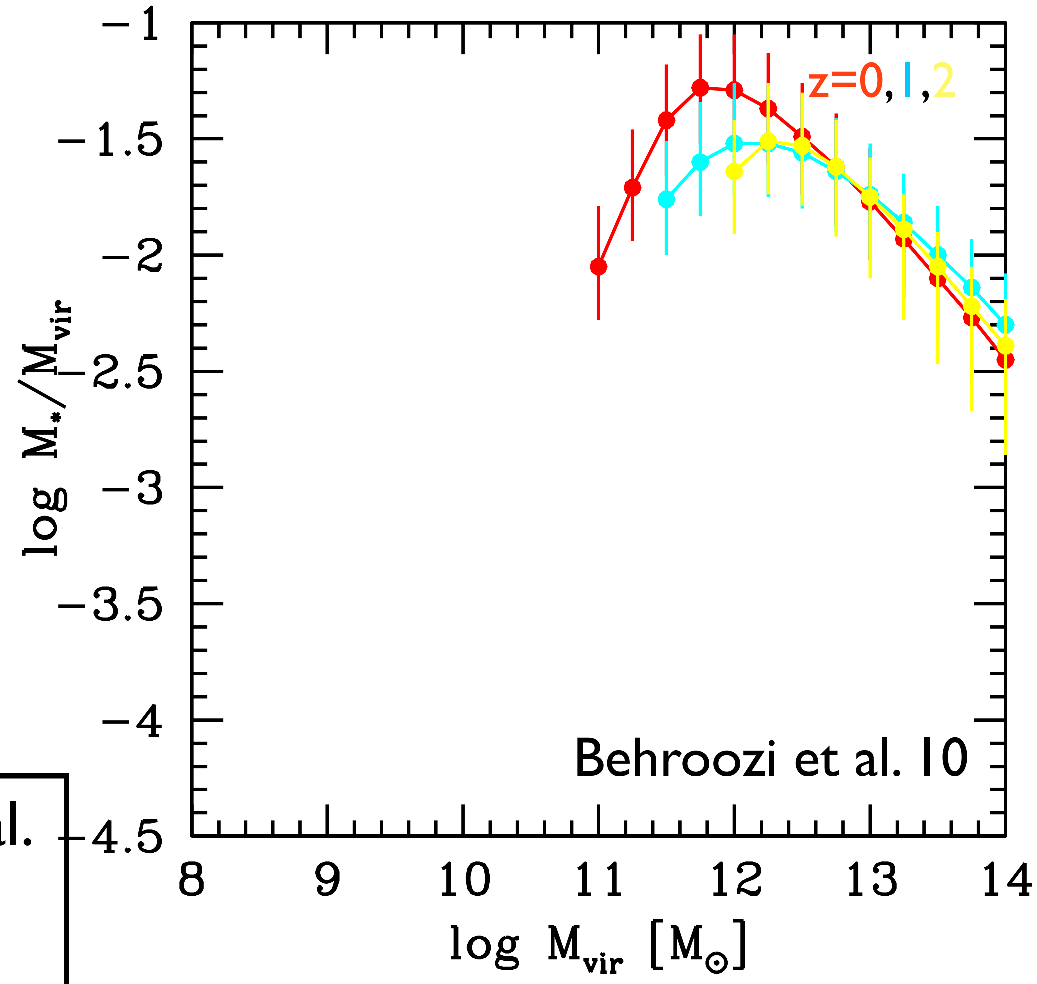
<u>New technique</u>: surface brightness anomalies in bright Einstein rings (Vegetti & Koopmans 09)

Things I'd like to hear more about: flux anomalies in CDM vs. WDM

A solution to the MSP within CDM requires extremely low star formation efficiencies in small dark matter subunits.

<u>Are MW satellites any different than field DGs?</u>



<u>Particle Tagging Technique</u> (Rashkov et al. 12; Cooper et al. 10): subset of VLII DM particles in each of 3,200 progenitor subhalos is tagged as stars at infall, when star particles acquire a stellar mass, an age, and a metallicity. Subsequent evolution is purely photometric and kinematical in character, as the collisionless stellar populations age and are accreted and disrupted in a "live host".

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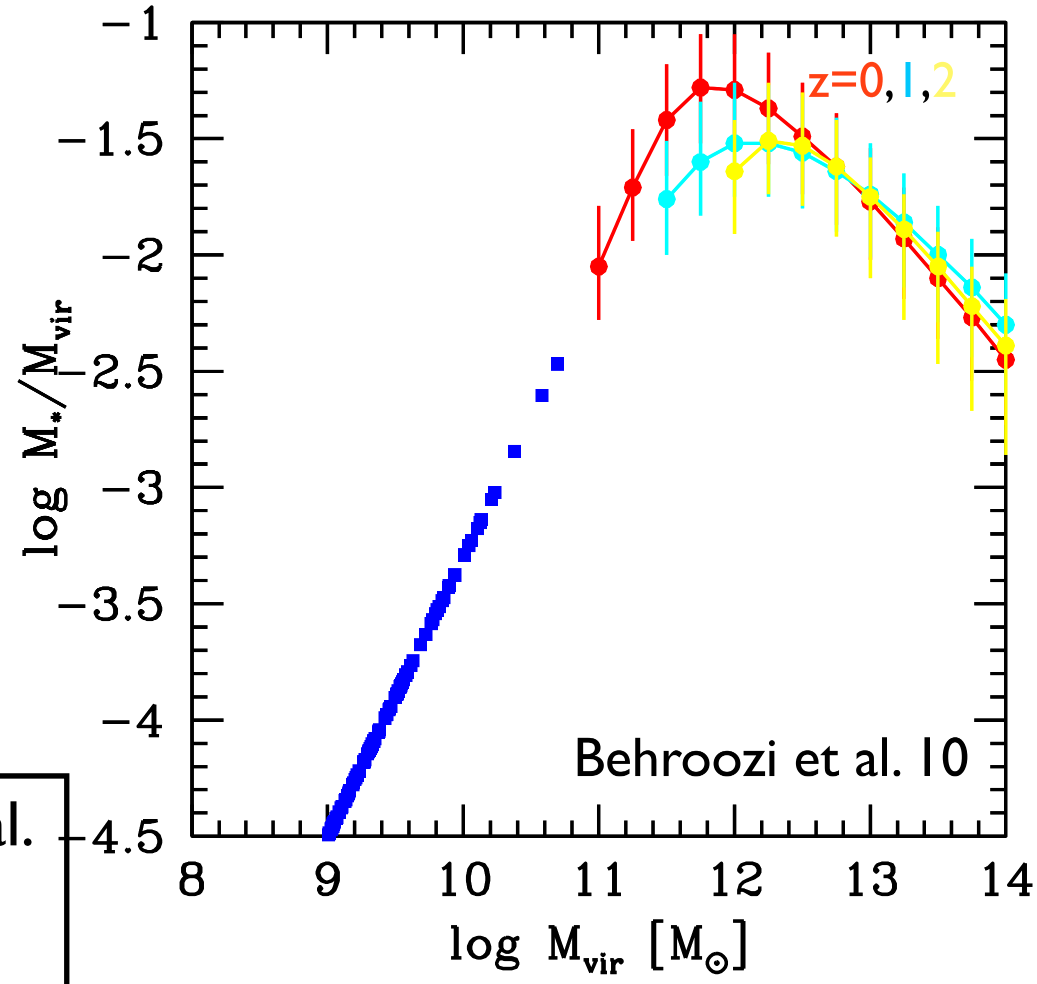
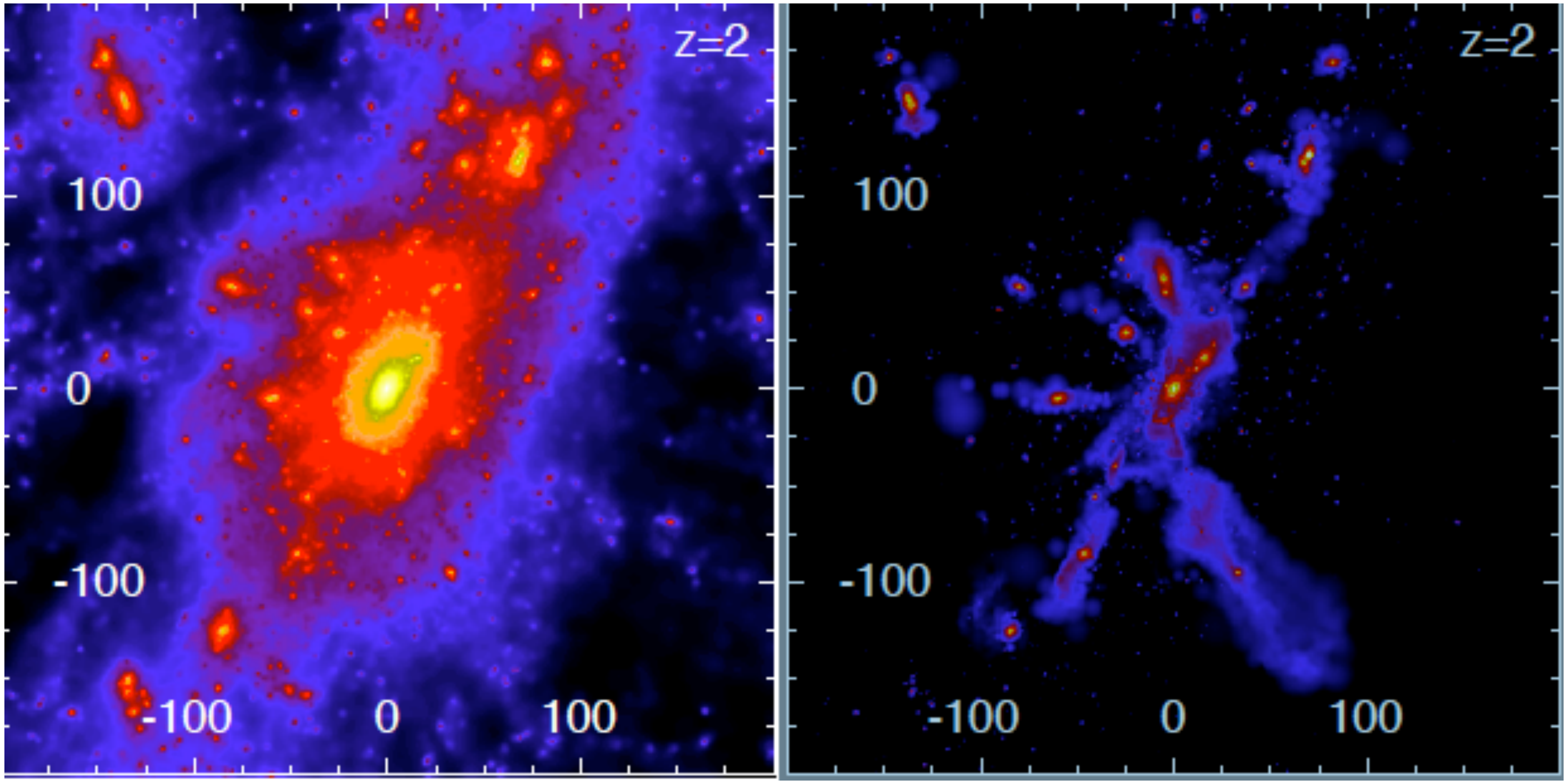
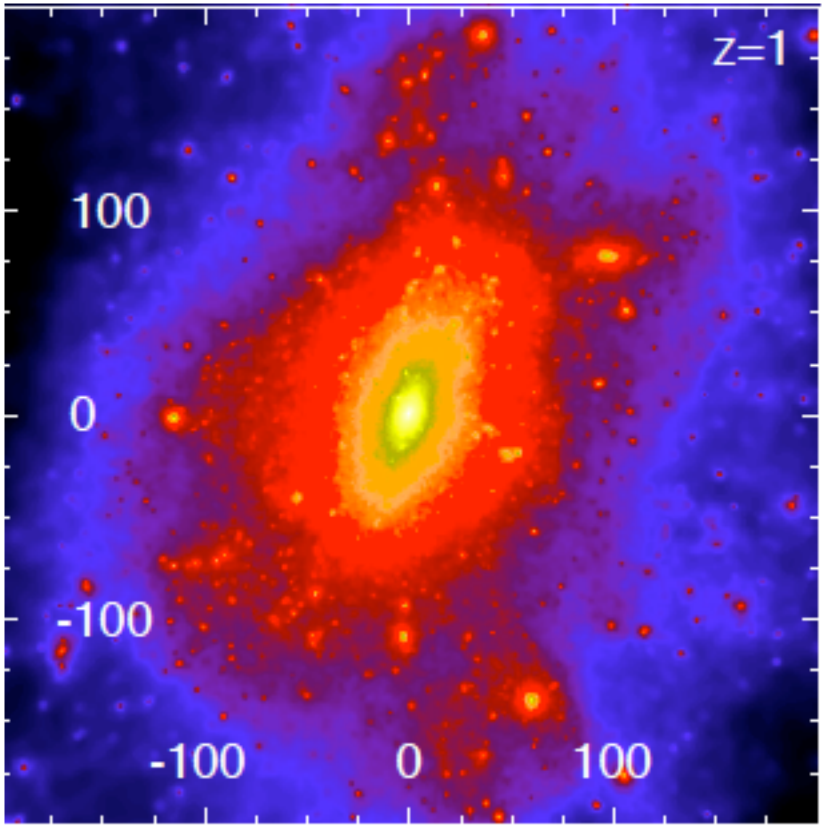


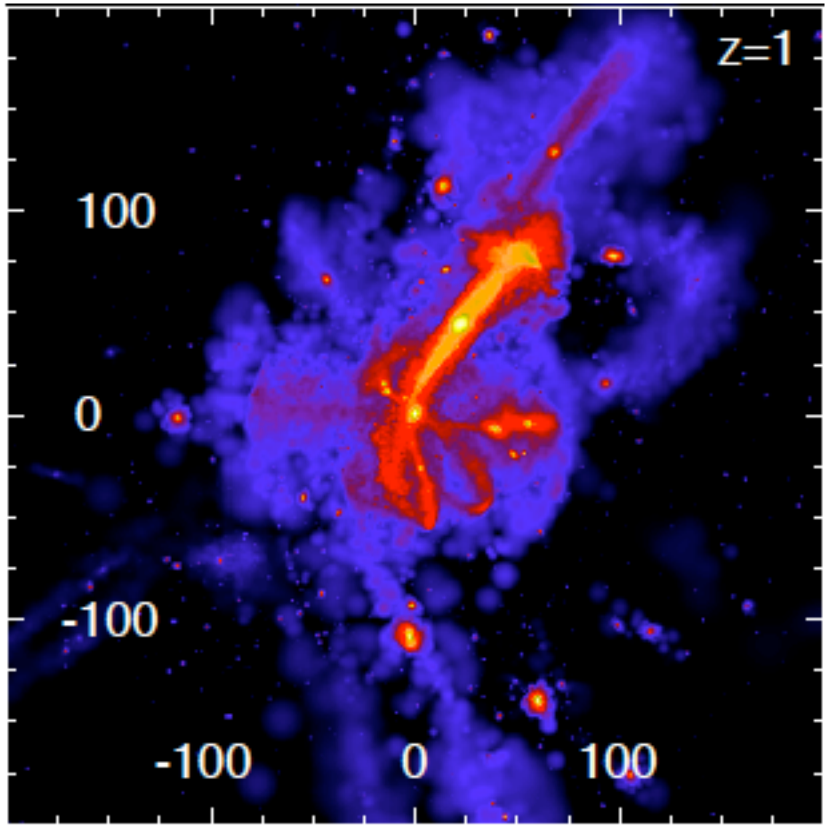
DM STARS



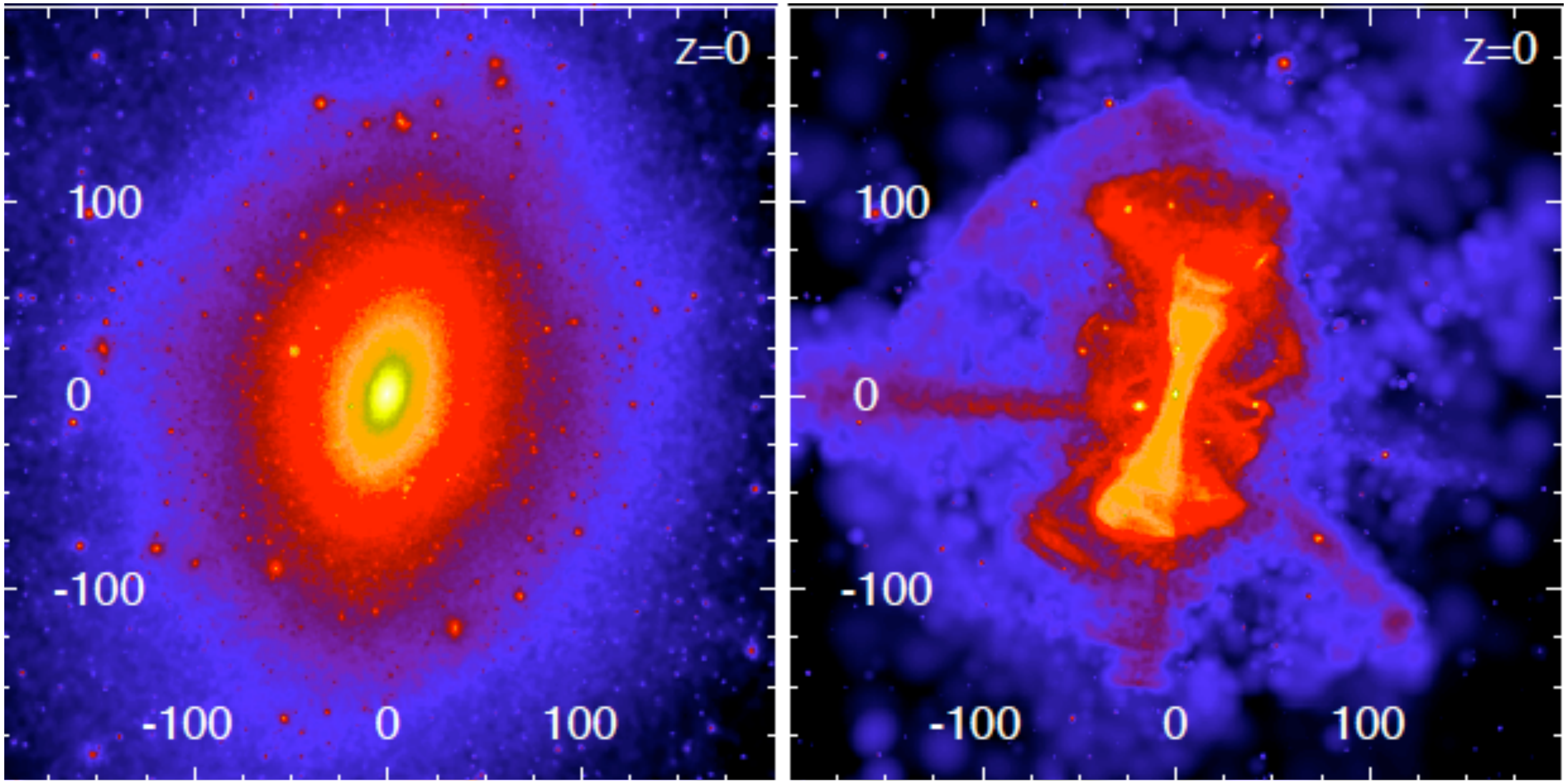
DM

STARS

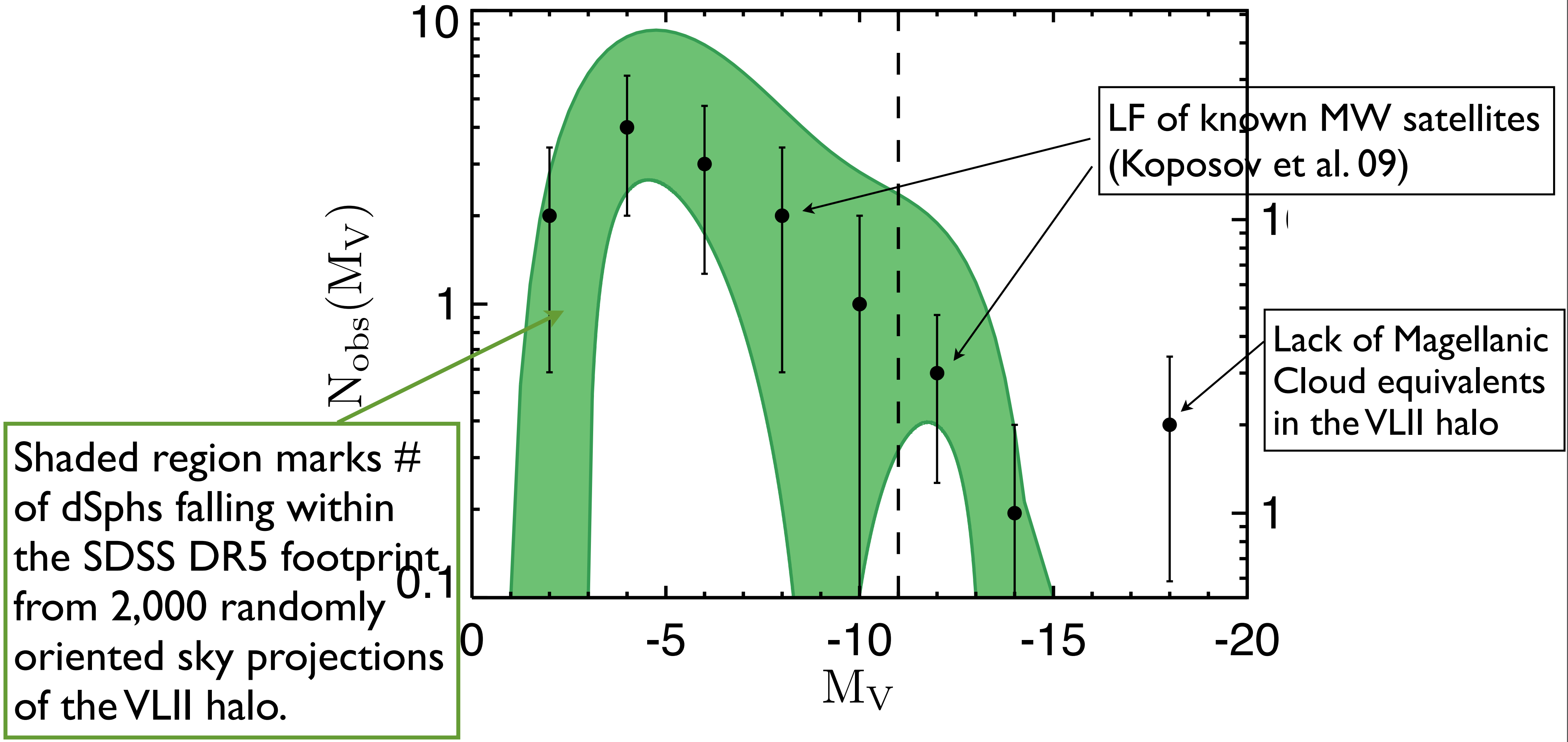




DM STARS



Luminosity function of VLII satellites detectable by the SDSS



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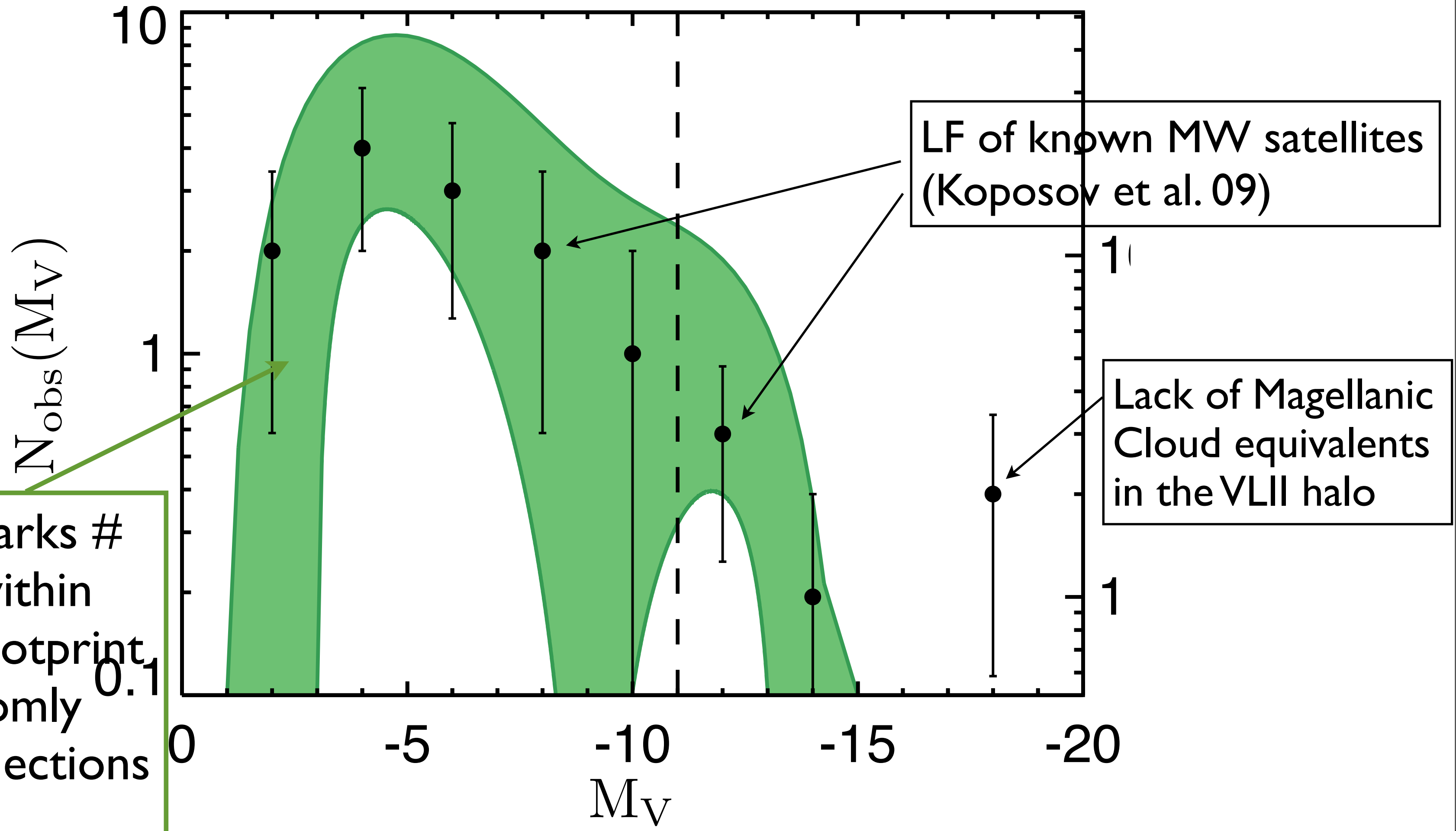


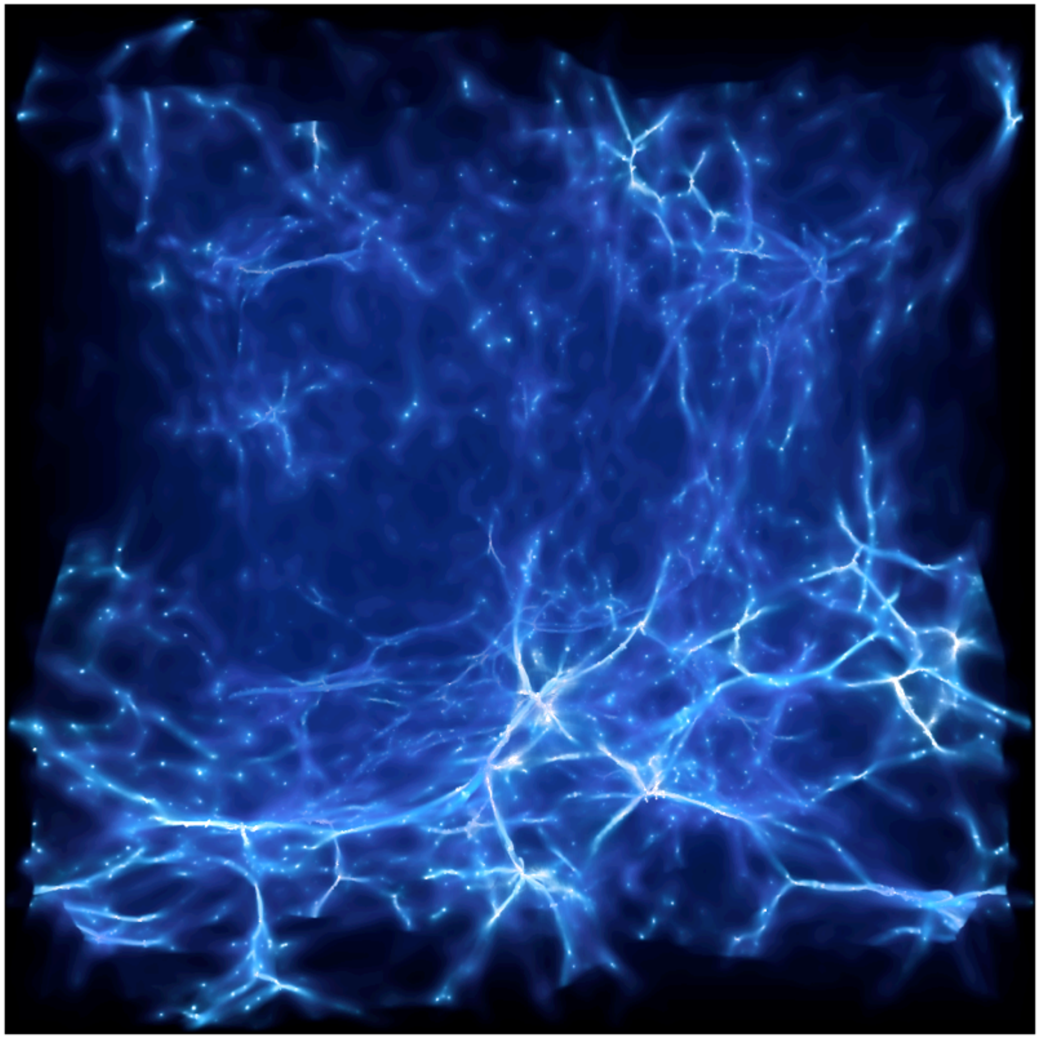
Shaded region marks # of dSphs falling within the SDSS DR5 footprint from 2,000 randomly oriented sky projections of the VLII halo.

TILHMA: SF efficiencies of field DGs vs MW satellites ☞ internal processes determine M_*/M_h

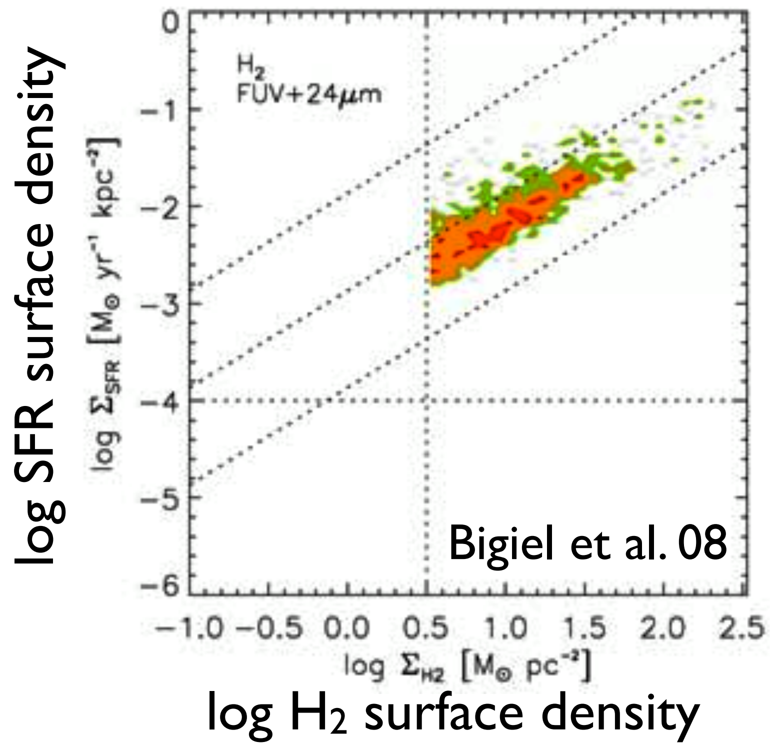
DG Formation with H_2-Regulated SF

$$\dot{\Sigma}_* = \epsilon f_{\mathrm{H}_2} \frac{\Sigma_g}{t_{\mathrm{ff}}}$$
$$f_{\mathrm{H}_2} = f_{\mathrm{H}_2}(\Sigma_g, Z_g, J_{\mathrm{LW}})$$

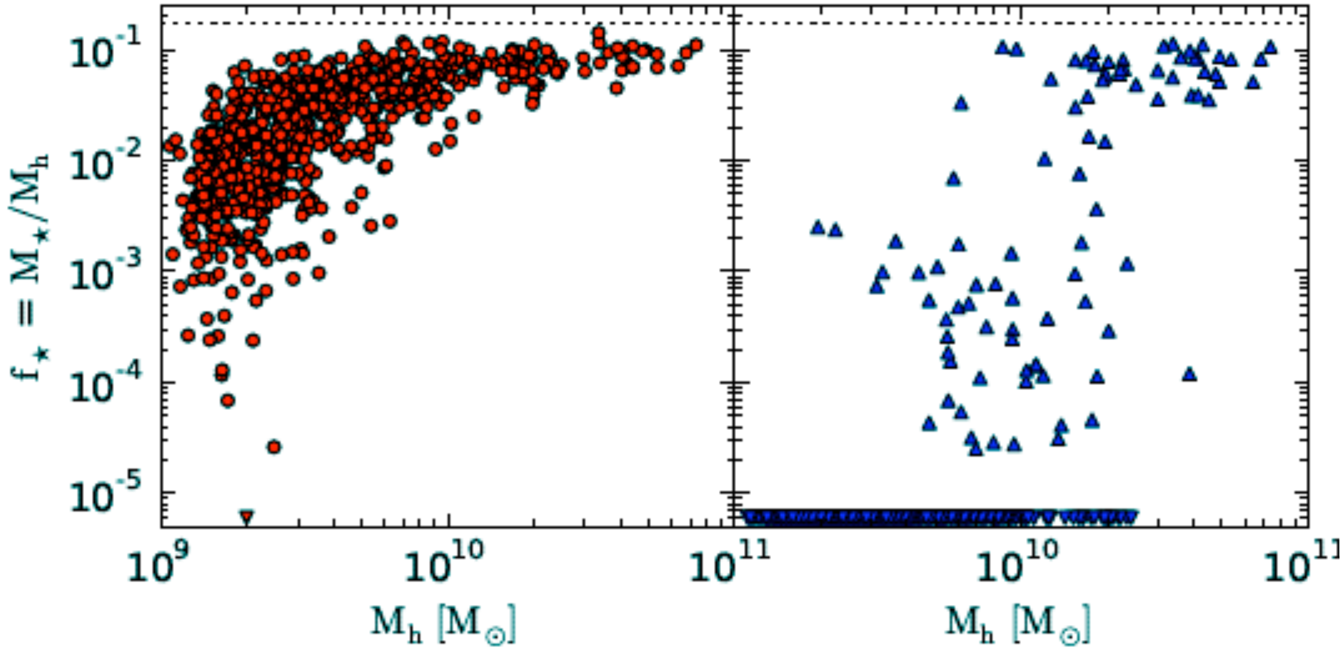
SF inefficient at low Σ_g and Z_g



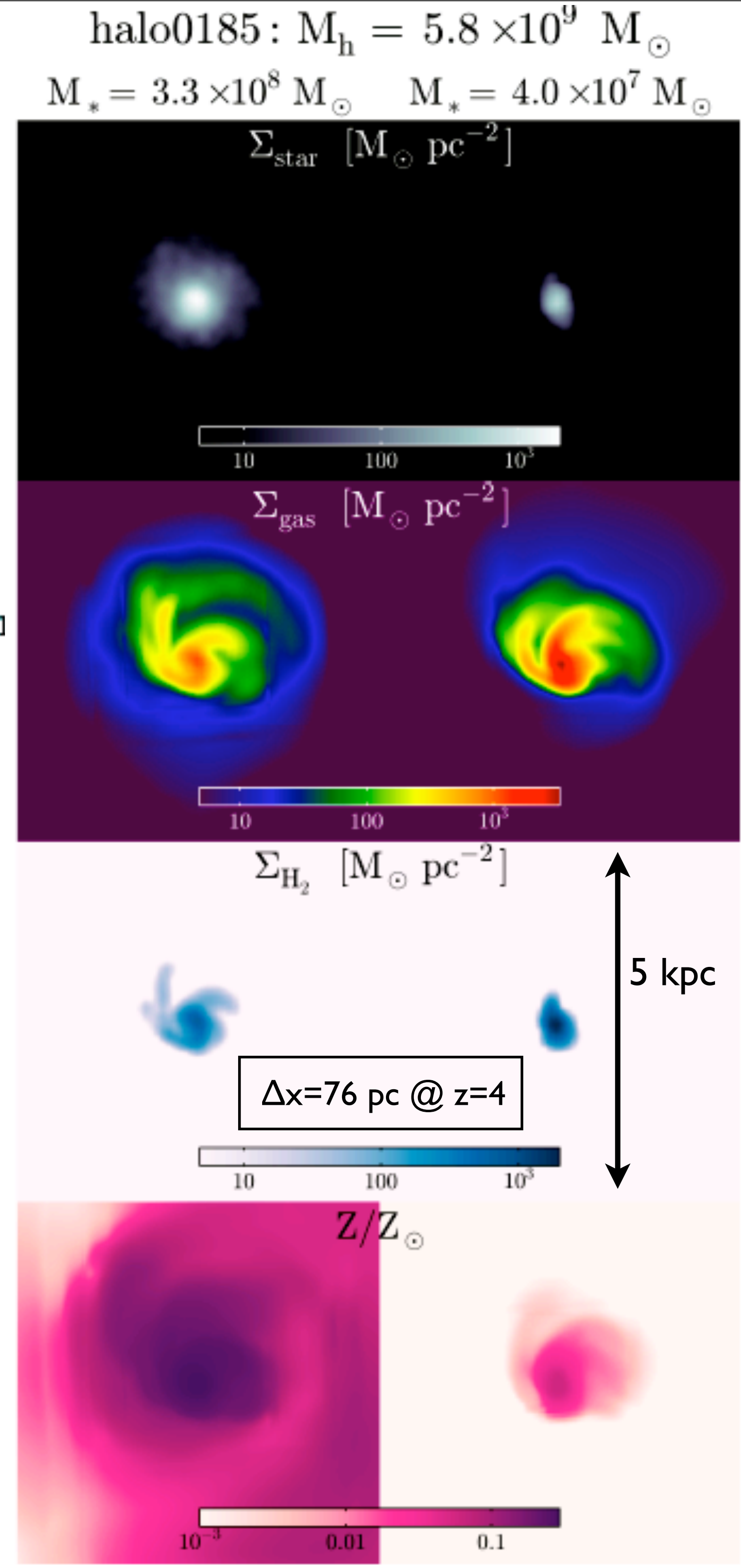
Star formation correlates strongly with the molecular content of a galaxy



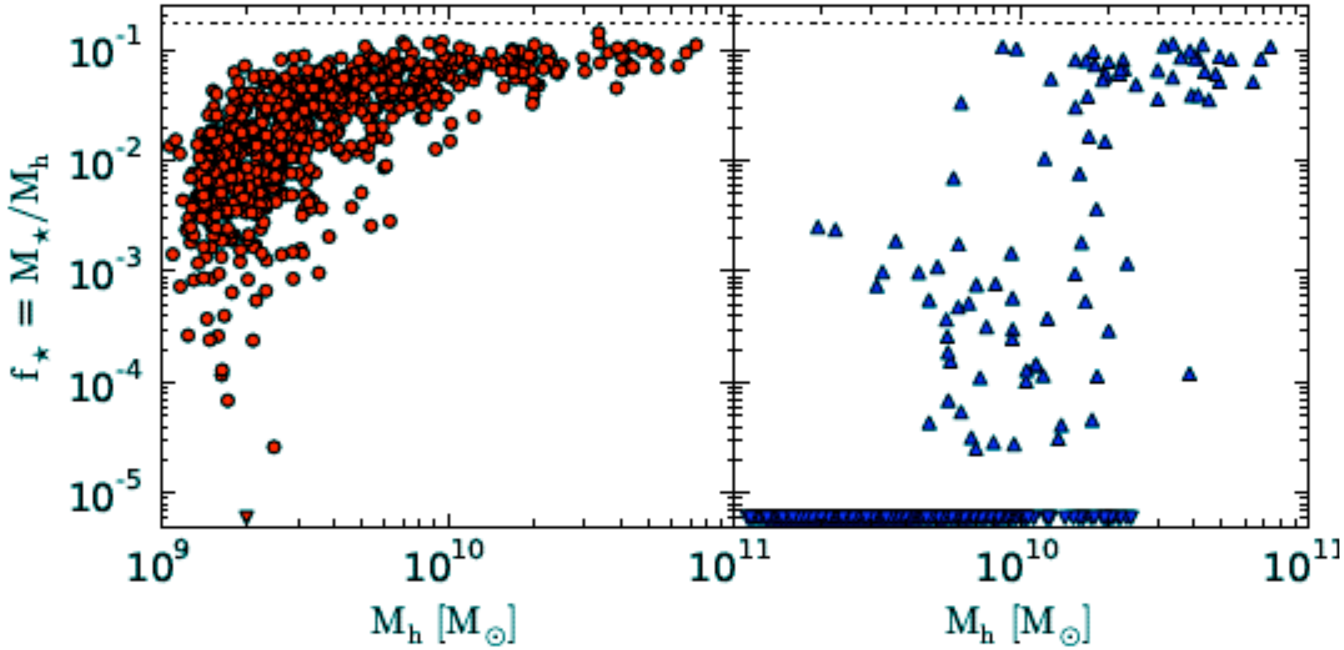
e.g. Robertson & Kravtsov 08; Gnedin et al. 09; Kuhlen et al. 12



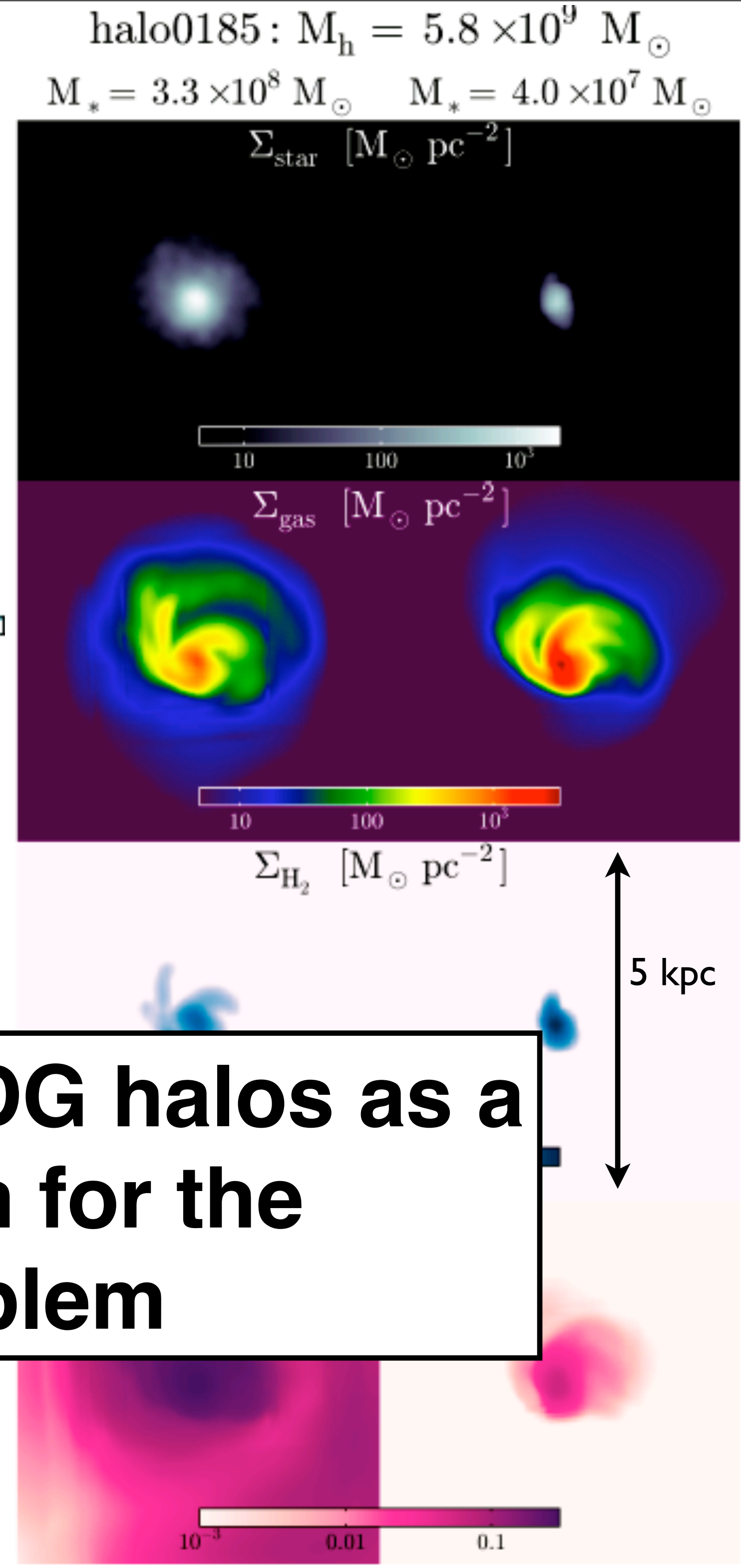
Stellar mass fraction f_* vs. total halo mass in a simulation with standard SF (left) and with H_2-regulated SF (right) at *z* = *4*.



A comparison of the baryonic structure of a DG halo at *z* = *4*. The stellar content in greatly suppressed in the KMT09 low mass halo. (From Kuhlen et al. 2012.)



Stellar mass fraction f_* vs. total halo mass in a simulation with standard SF (left) and with H_2-regulated SF (right) at *z* = *4*.



TILHMA: Inefficient SF in DG halos as a plausible explanation for the substructure problem

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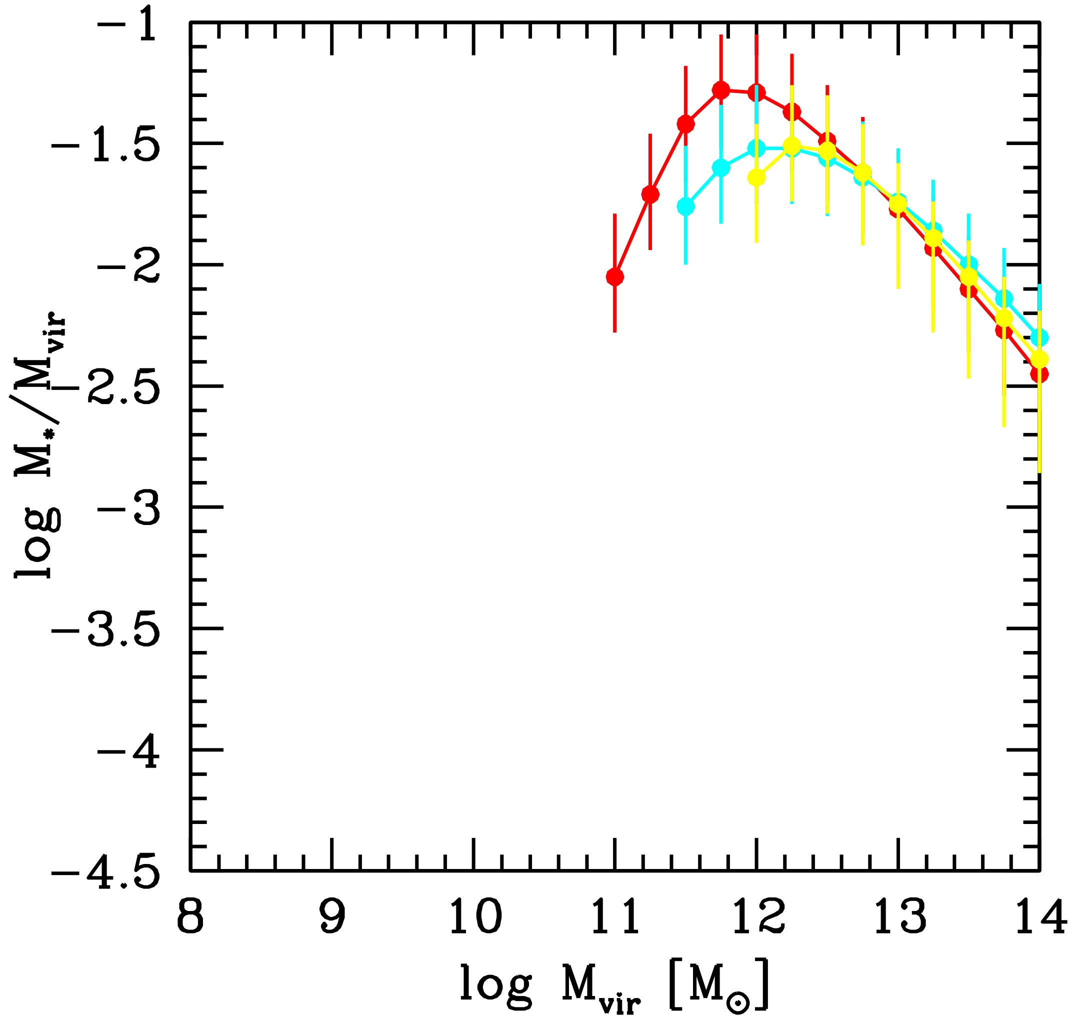

−1
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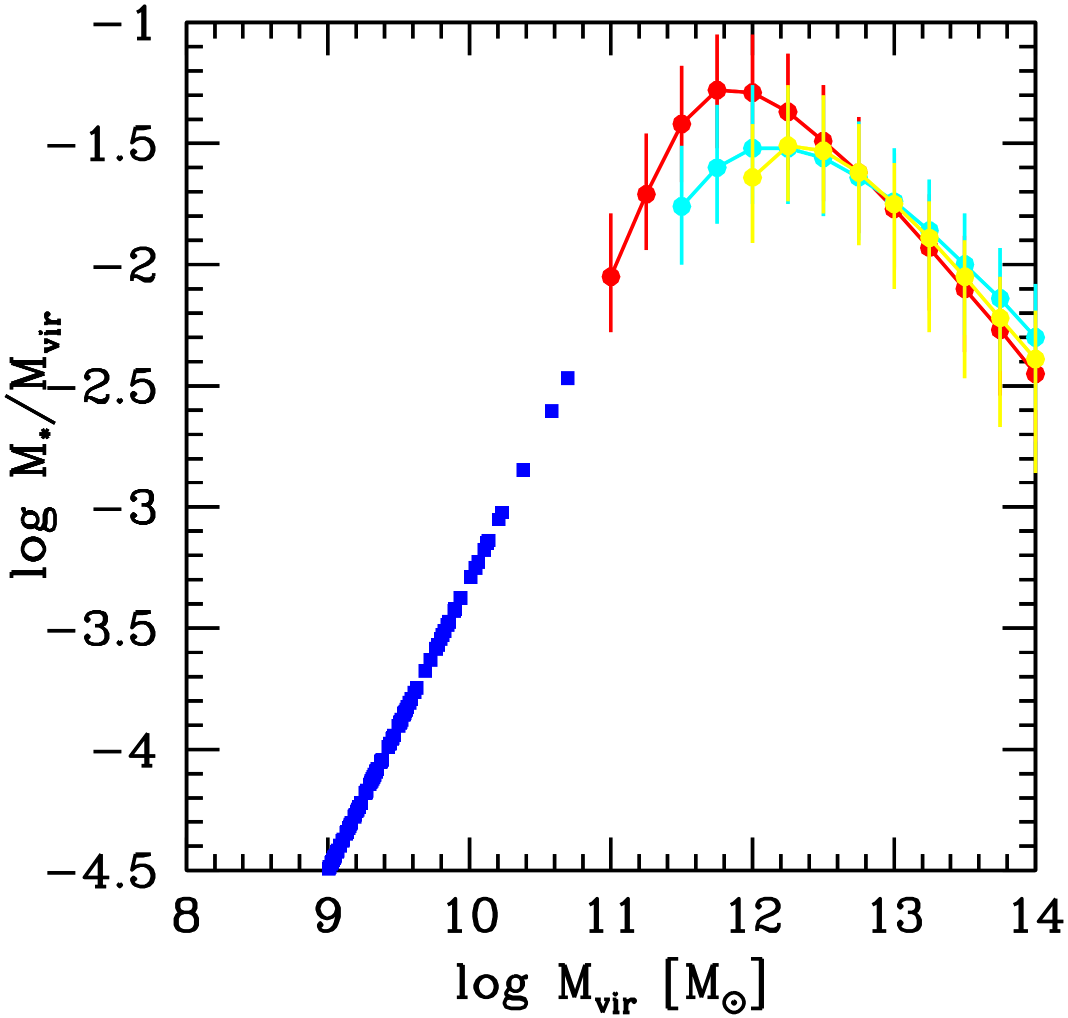
14
log M_*/M_{vir}
log M_{vir} [$M_\odot$]



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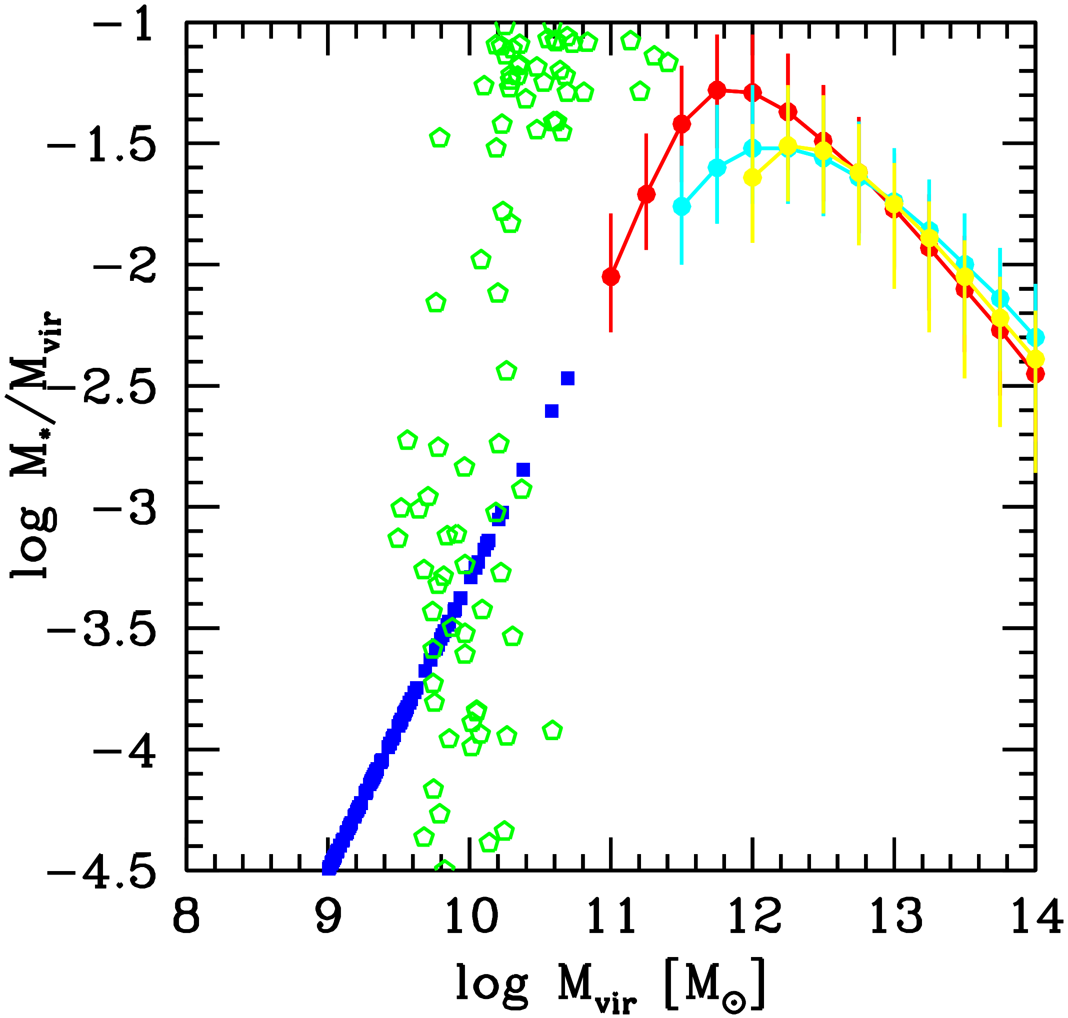

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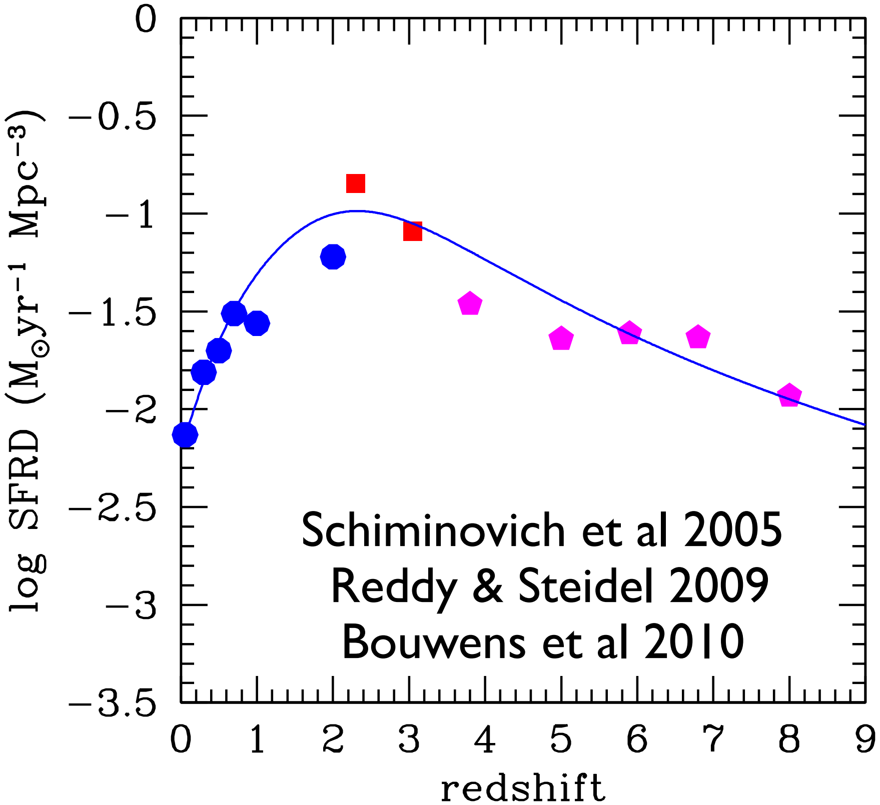
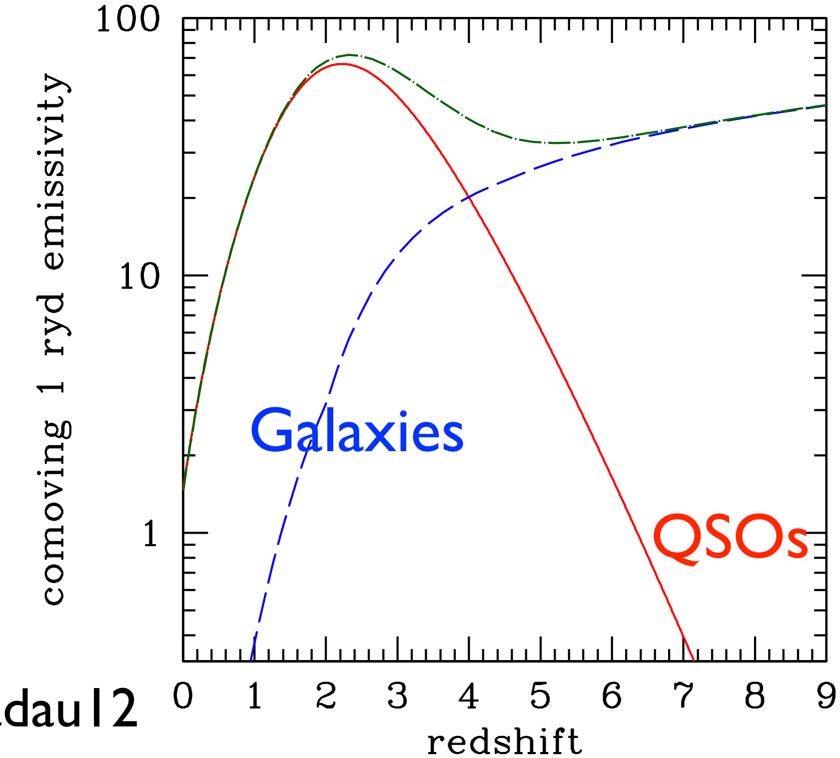
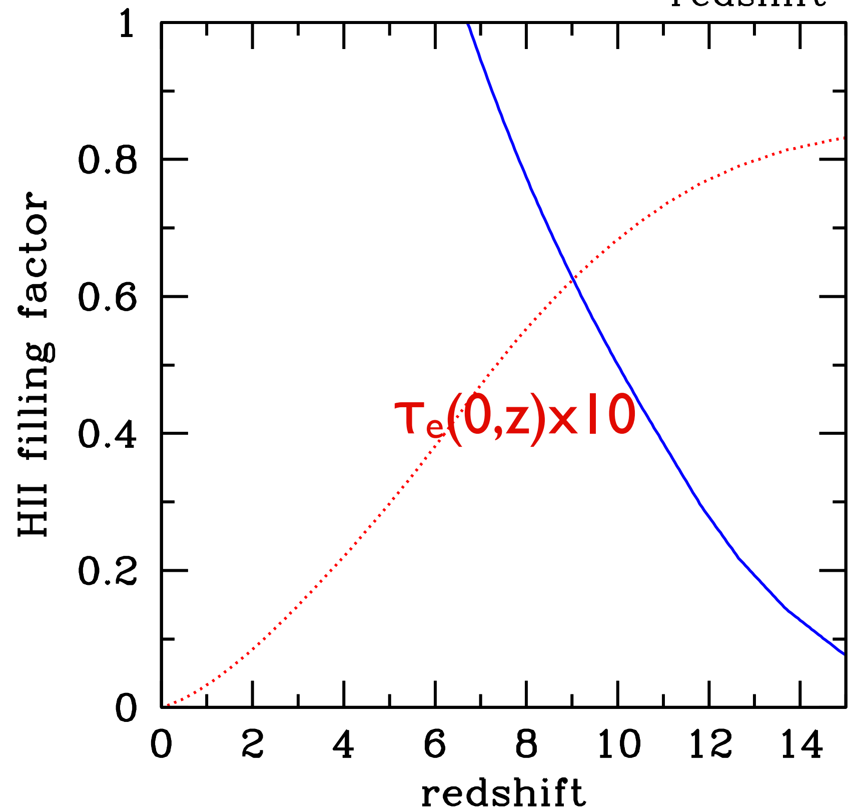
log M_*/M_{vir}
log M_{vir} [$M_\odot$]

Can DGs reionize the universe?



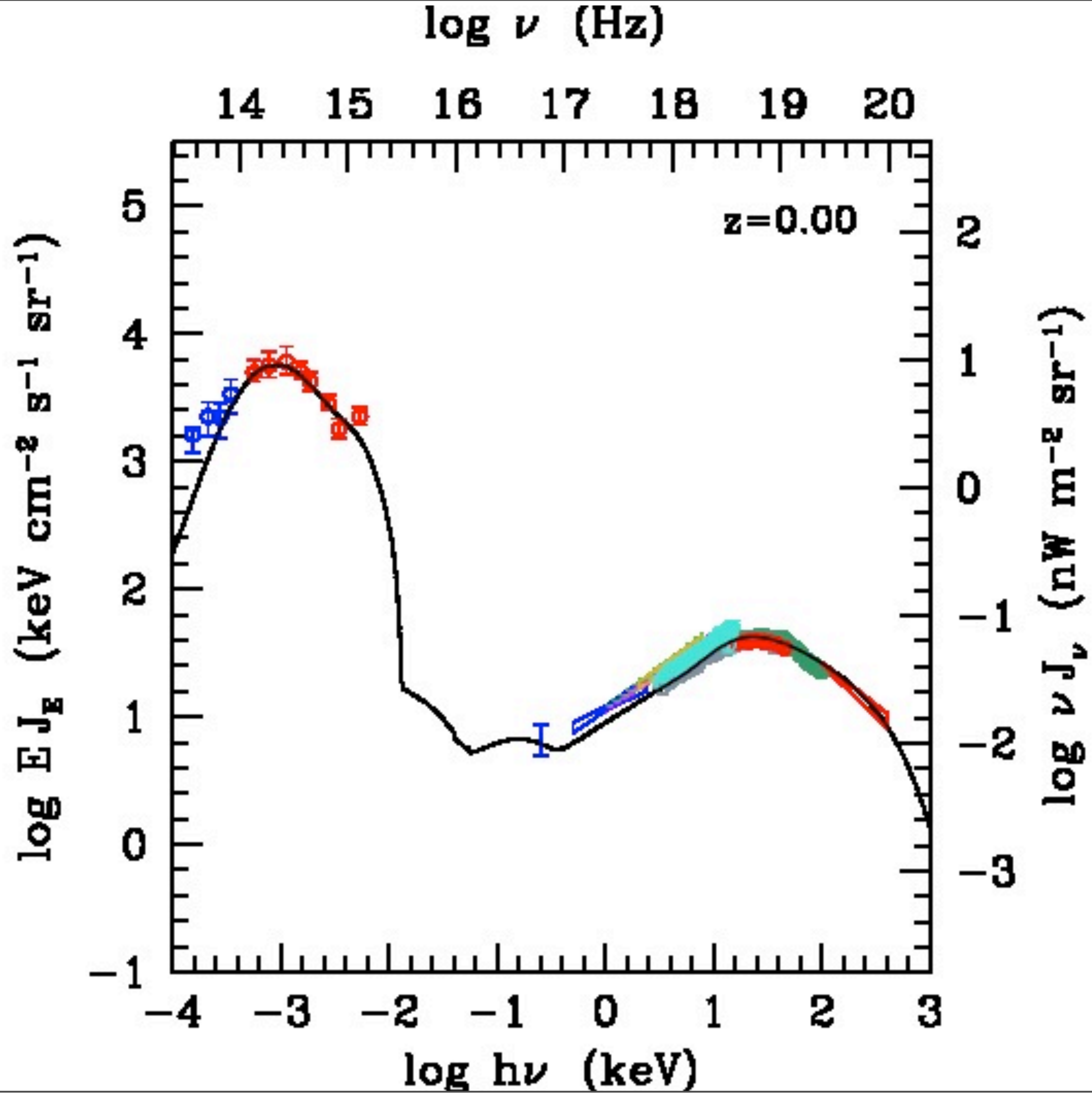


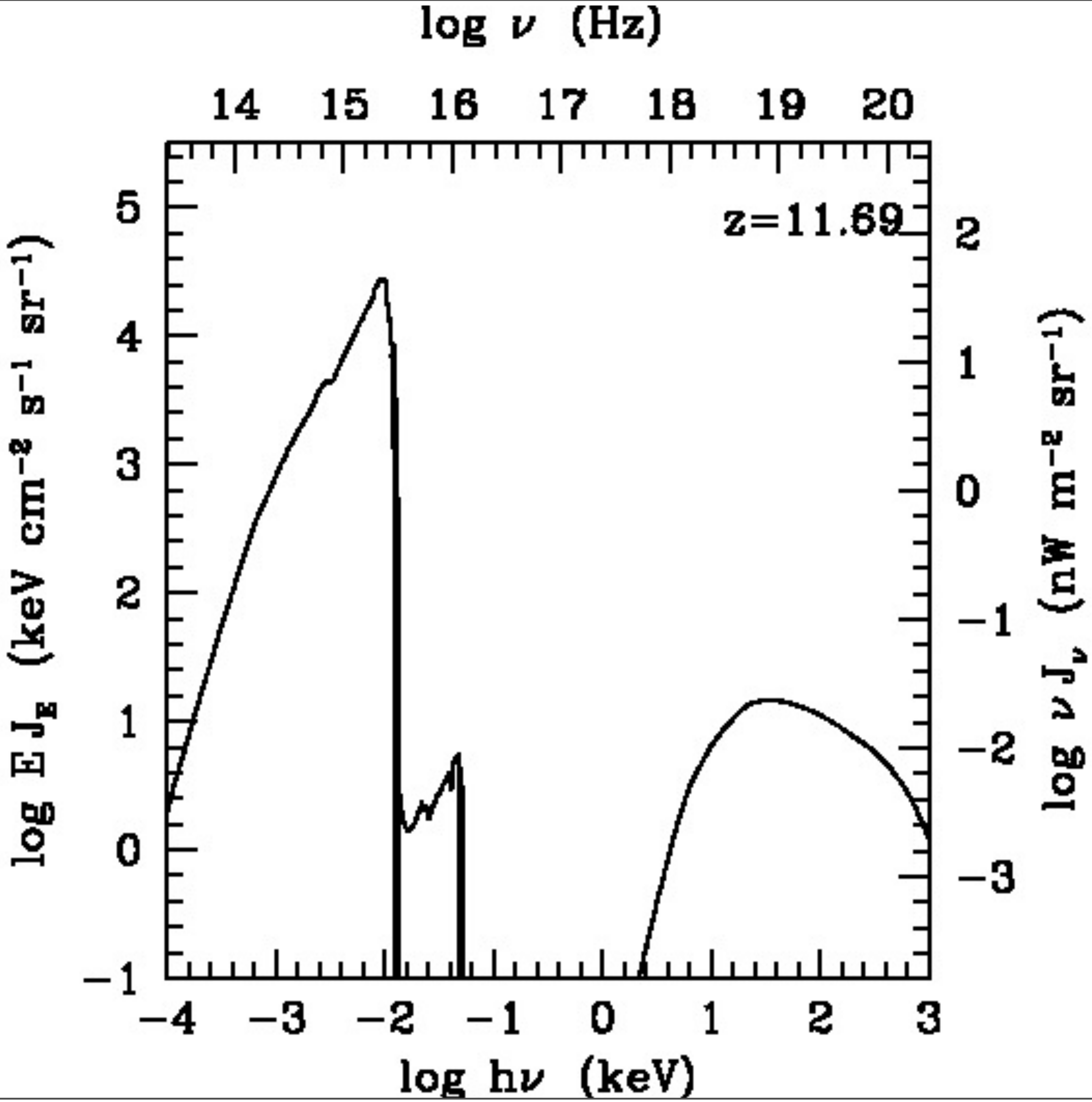
Haardt & Madau12



$$\langle f_{\rm esc} \rangle = 1.8 \times 10^{-4} (1+z)^{3.4}$$

$$\langle f_{\rm esc} \rangle = 2.6\% \qquad @\ z = 3.3$$
$$\langle f_{\rm esc} \rangle = 21\% \qquad @\ z = 7.0$$


log ν (Hz)
14
15
16
17
18
19
20
z=0.00
log E J_E (keV cm^-2 s^-1 sr^-1)
5
4
3
2
1
0
−1
log ν J_ν (nW m^-2 sr^-1)
2
1
0
−1
−2
−3
−4
−3
−2
−1
0
1
2
3
log hν (keV)



log ν (Hz)
14
15
16
17
18
19
20
z=11.69
log E J_E (keV cm^-2 s^-1 sr^-1)
log ν J_ν (nW m^-2 sr^-1)
5
4
3
2
1
0
−1
2
1
0
−1
−2
−3
−4
−3
−2
−1
0
1
2
3
log hν (keV)

http://www.ucolick.org/~pmadau/CUBA/HOME.html

CUBA

Cosmic Ultraviolet BAckground

A cosmological 1D radiative transfer code by
Francesco Haardt and Piero Madau

000422
Contador web

CUBA is a radiative transfer code that follows the propagation of hydrogen and helium Lyman continuum radiation through a partially ionized and clumpy intergalactic medium. The only sources of ionizing radiation included in CUBA are star-forming galaxies and quasars.

http://www.ucolick.org/~pmadau/CUBA/HOME.html

CUBA

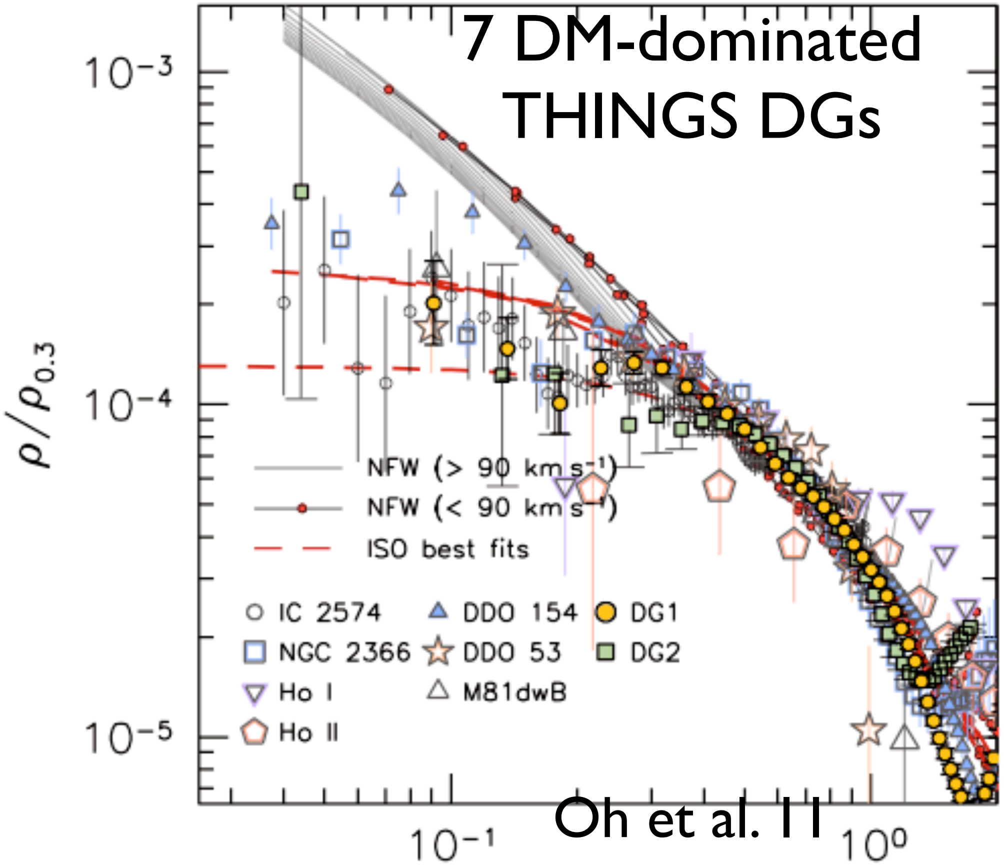
Cosmic Ultraviolet BAckground

A cosmological 1D radiative transfer code by
Francesco Haardt and Piero Madau

TILHMA: SFH, z~6 QSOs, $f_{esc}(z)$, enough UV to ionize the universe if $\langle f_{esc} \rangle \sim 0.5$ at high-z?

2) Core-Cusp Problem:

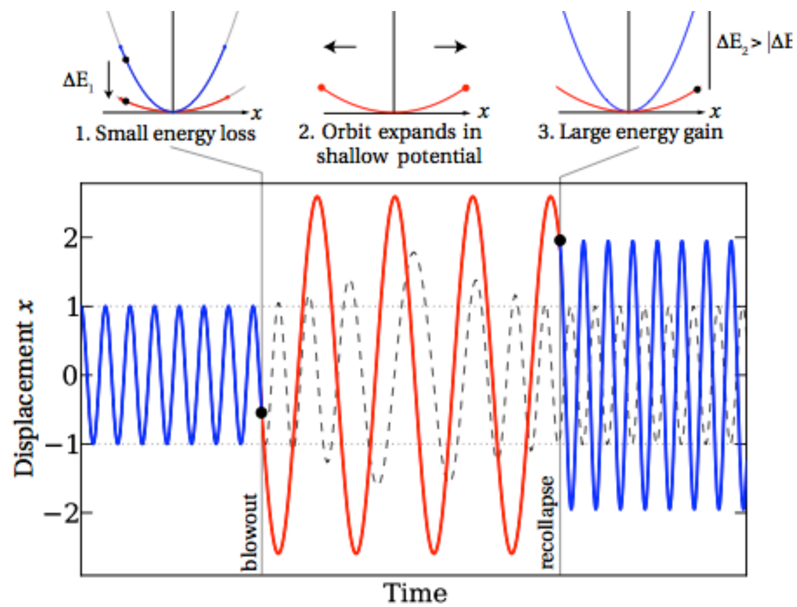
most observed DGs in the field have slowly rising rotation curves implying a near constant-density core (de Block et al 10) rather than the cuspy profiles predicted by CDM.



Oh et al. 11

Governato et al. 10

Pontzen & Governato 12



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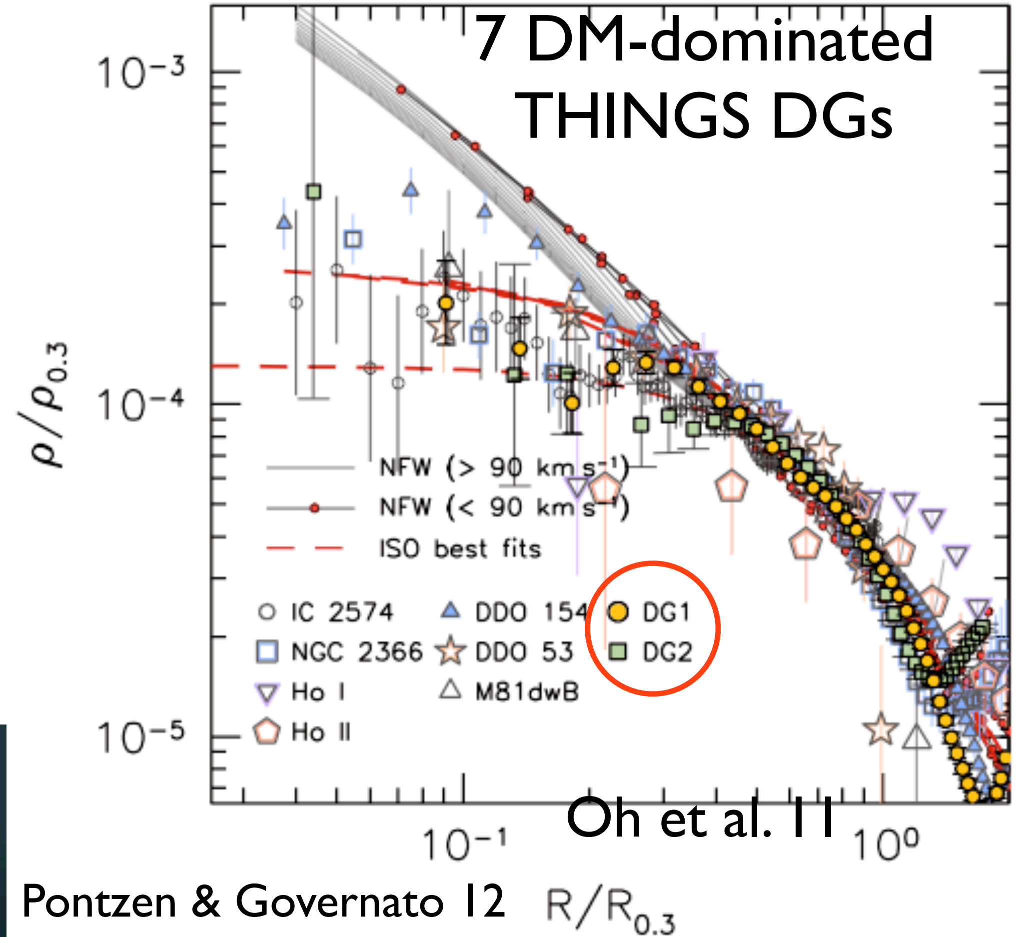

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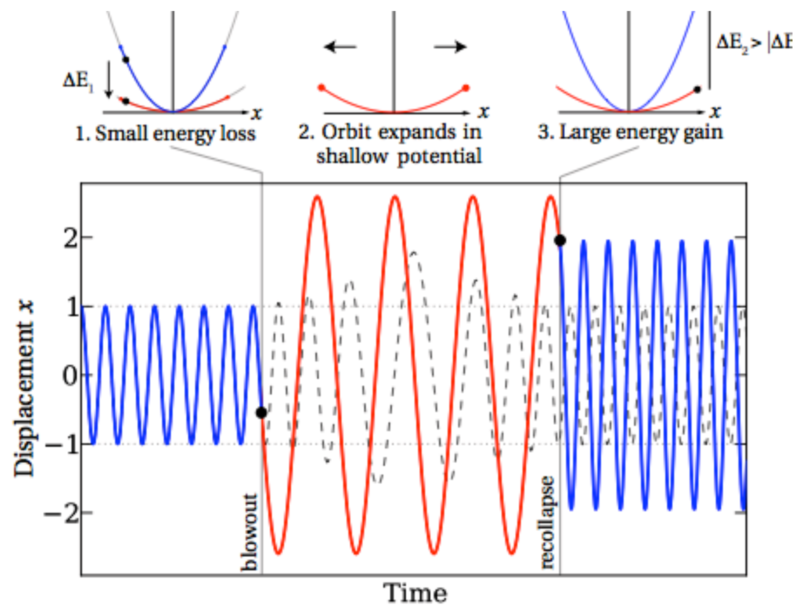
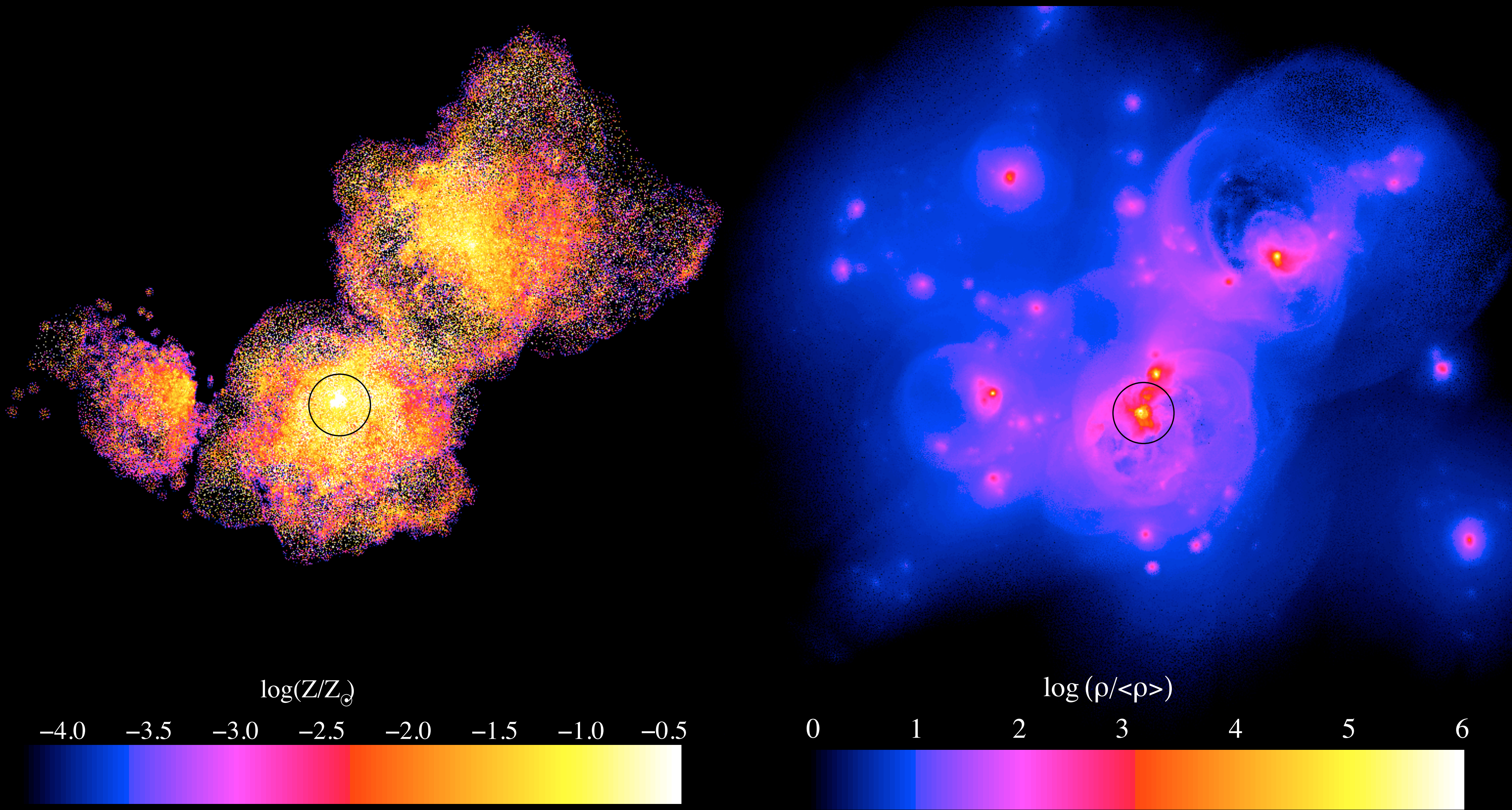
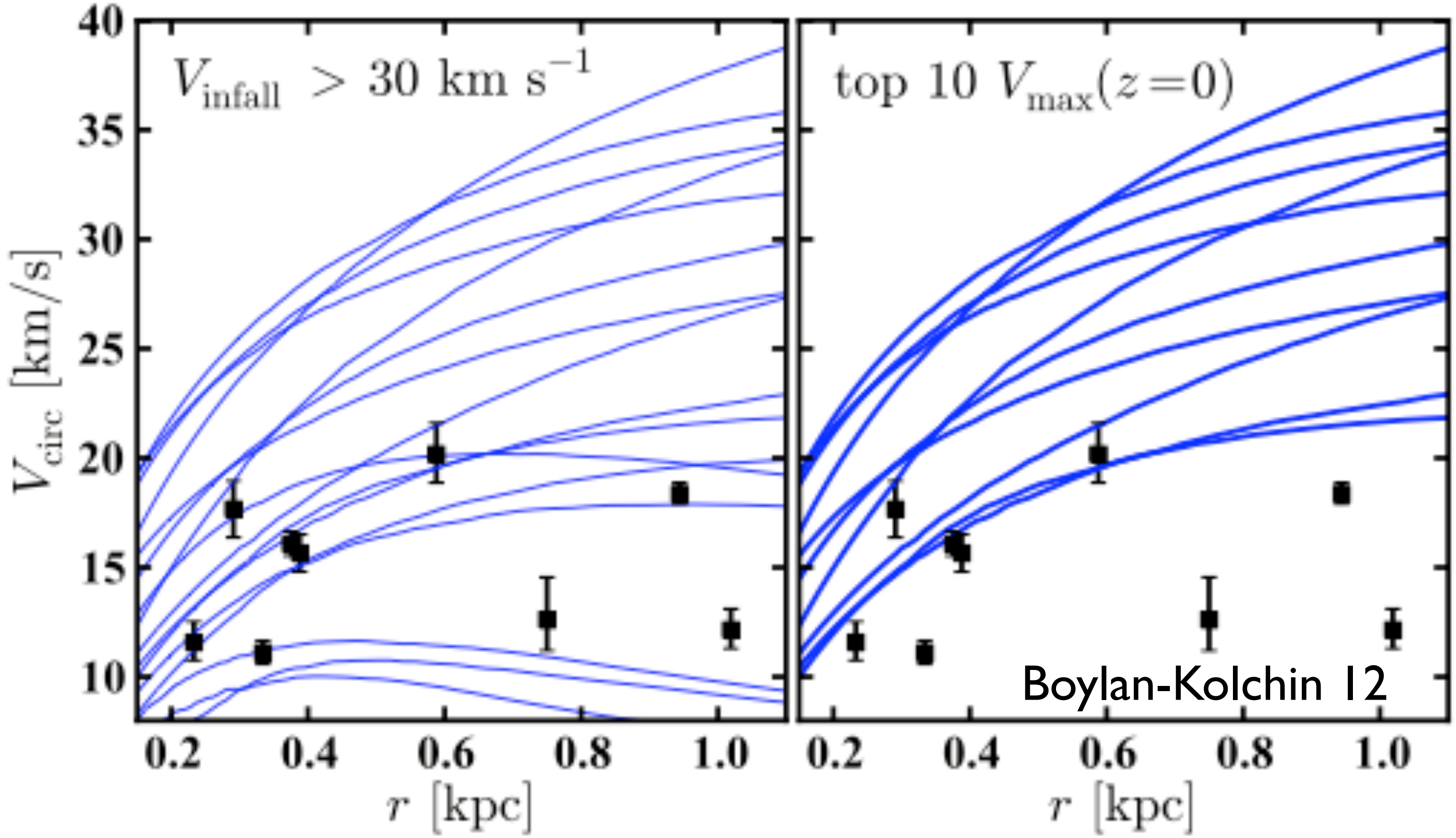


Enrichment of the IGM by DG ouflows at z=3

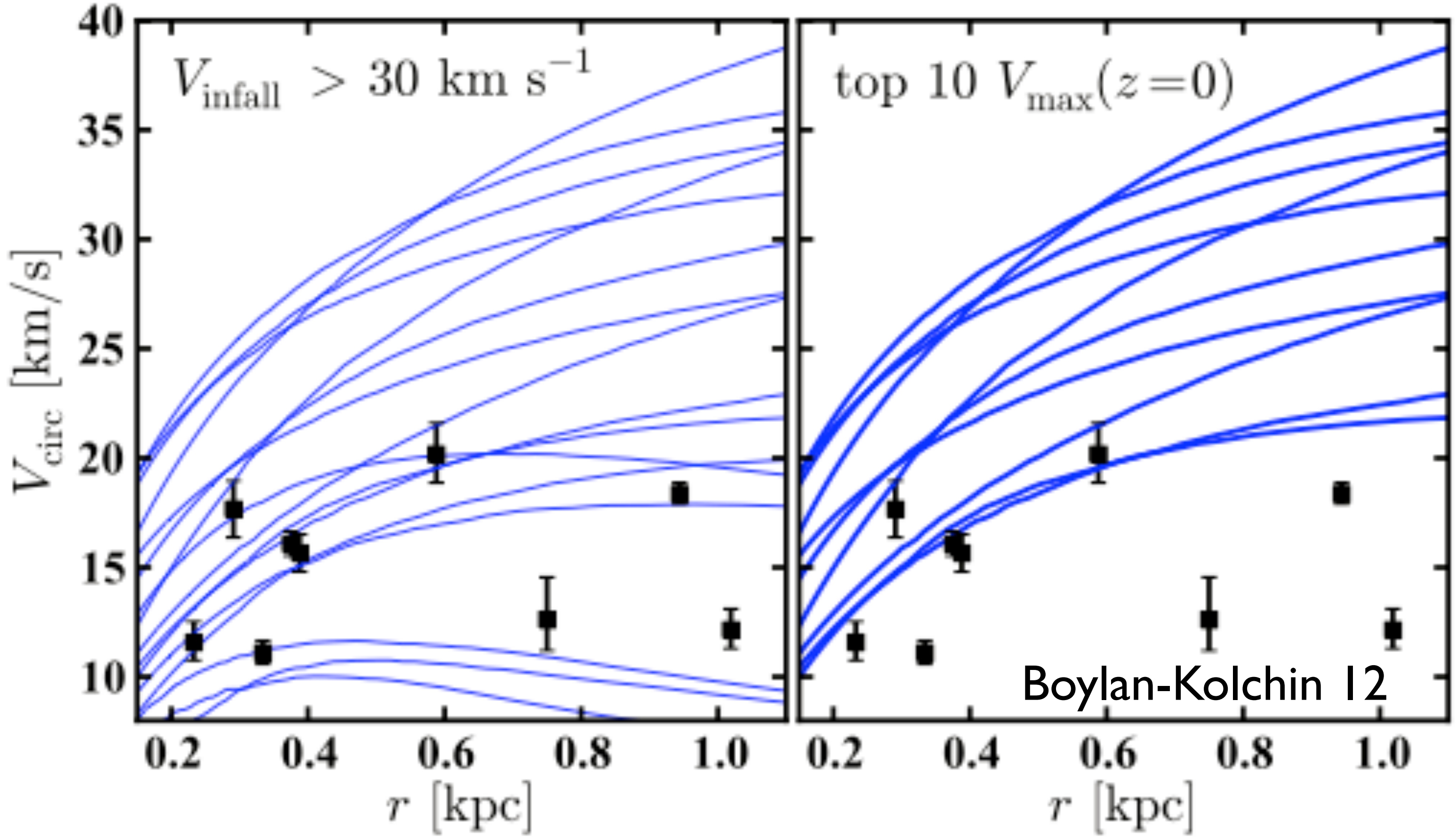


Shen et al. 12

Simulated MW dwarfs too dense compared to observations



Simulated MW dwarfs too dense compared to observations



TILHMA: SN feedback as a plausible explanation for the low inferred densities of MW dwarfs?

THE END