Constraining the primordial power spectrum using minihalos

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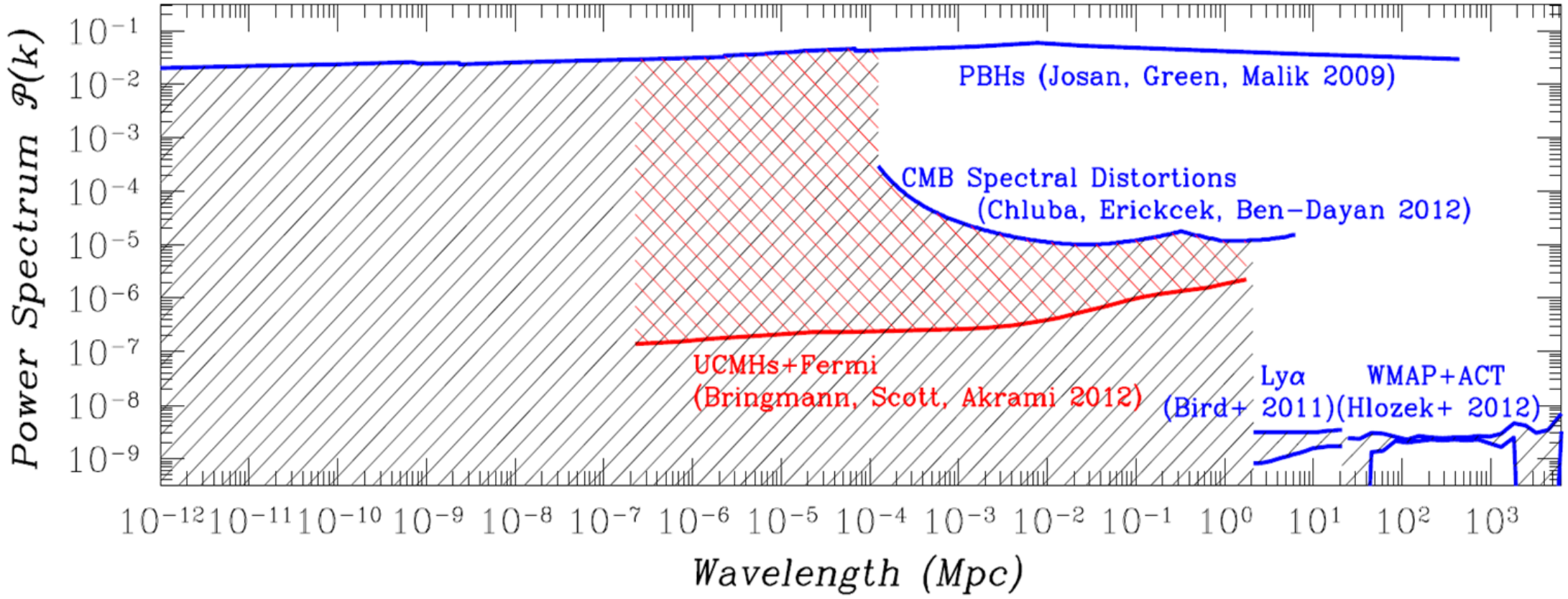
The primordial power spectrum

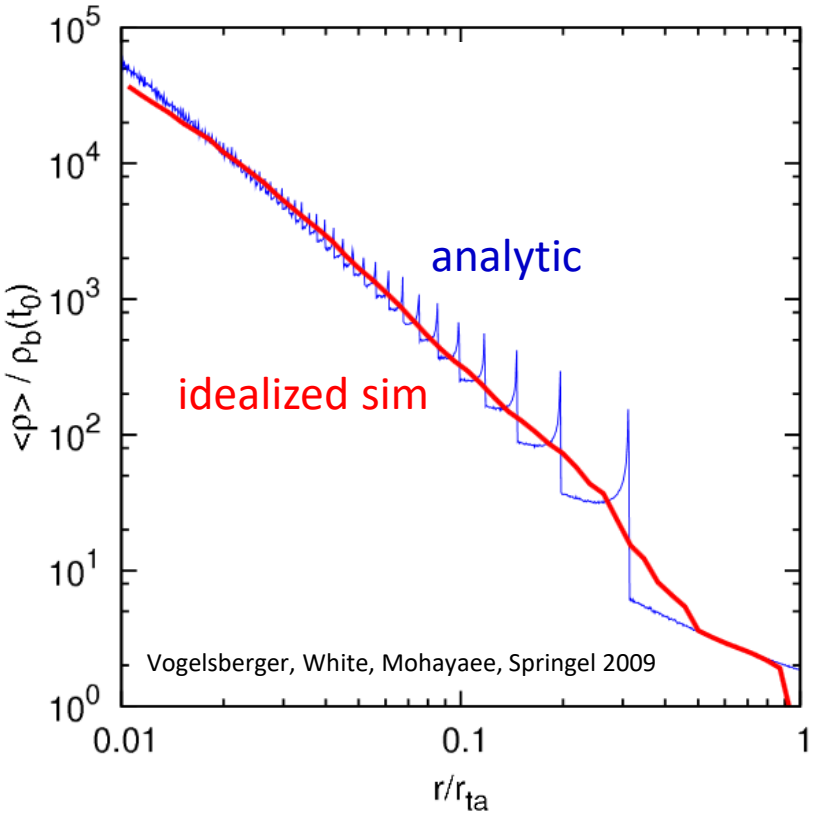


Ultracompact minihalos

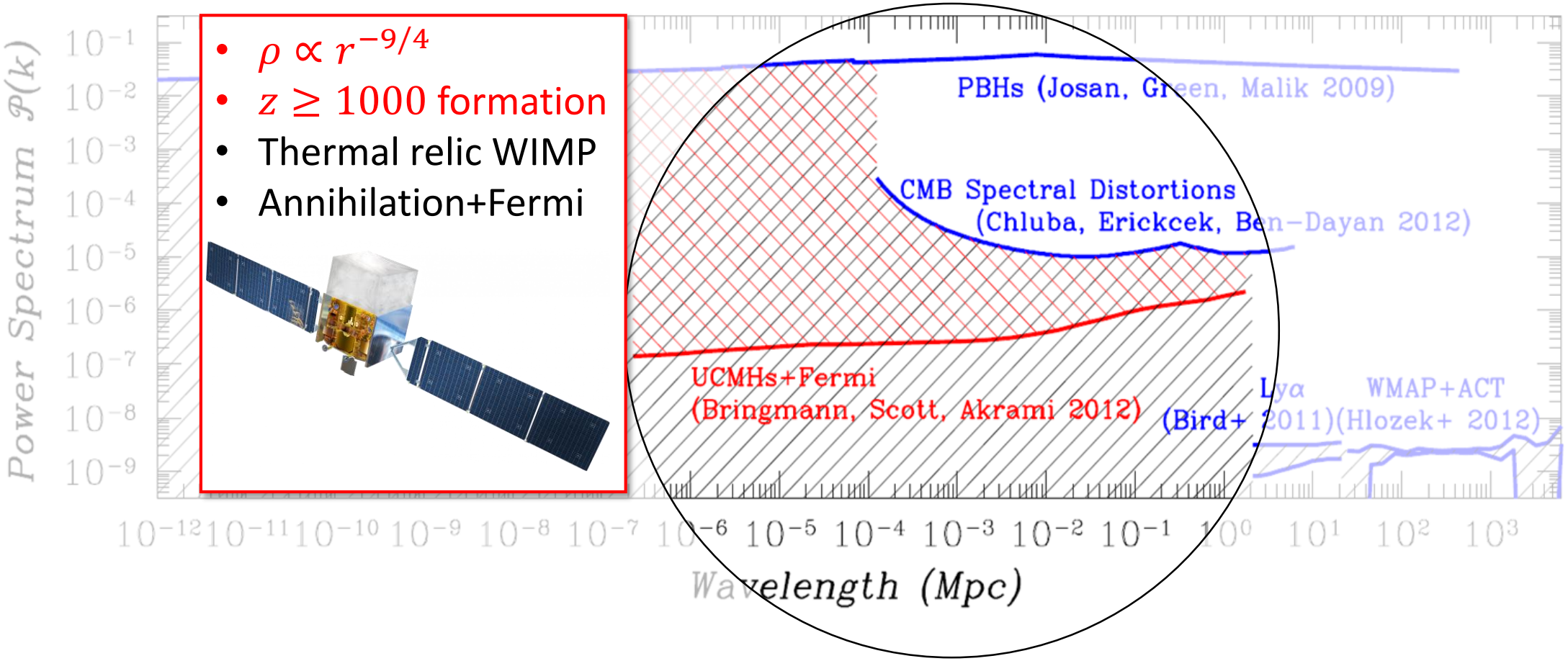
- Large density contrasts ($\delta_{\rm hor} \gtrsim 10^{-3}$) form halos early
- Halo density ∝ background density at formation
- Nondetection → constraints on primordial power

- $z{\sim}1000$ formation → small velocity dispersion
  → radial infall
- $\rho(r) \propto r^{-9/4}$ from analytic theory*
- Steep, "ultracompact" profile enhances signals

*Fillmore & Goldreich 1984, Bertschinger 1985



The primordial power spectrum



Ultracompact minihalos

- Large density co
- Halo density ∝ b
- Nondetection →
- $z\sim1000$ formatio
- $\rho(r) \propto r^{-9/4}$ from
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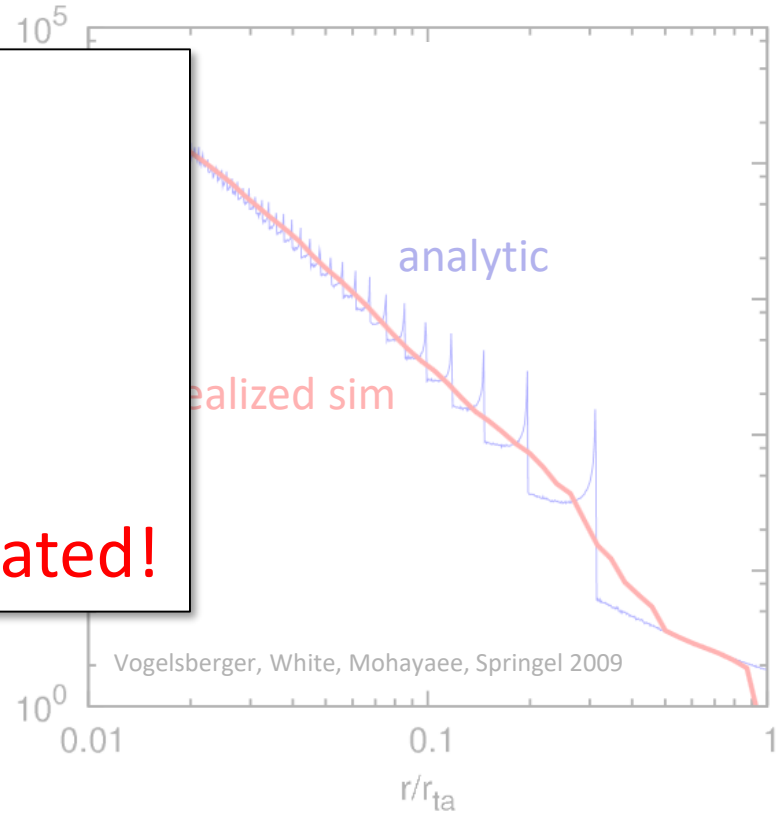
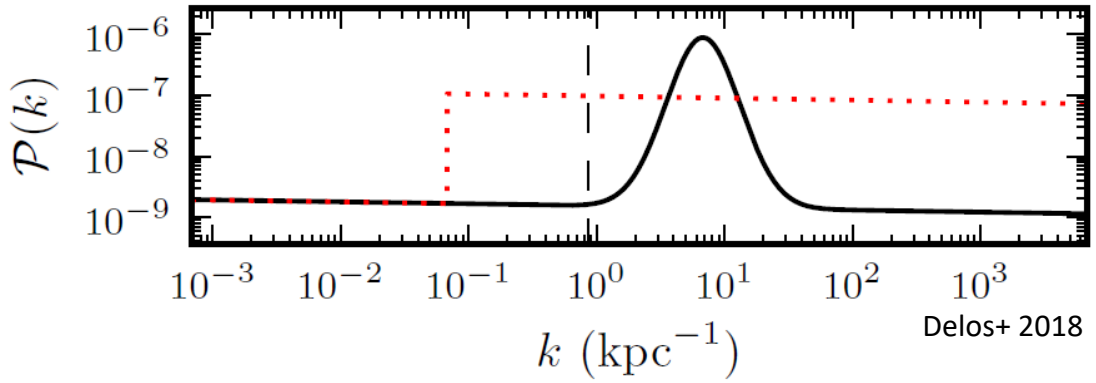
Analytic theory assumes
- Spherical symmetry
- Radial motion
- Self-similarity

Realistic infall is more complicated!



*Fillmore & Goldreich 1984, Bertschinger 1985

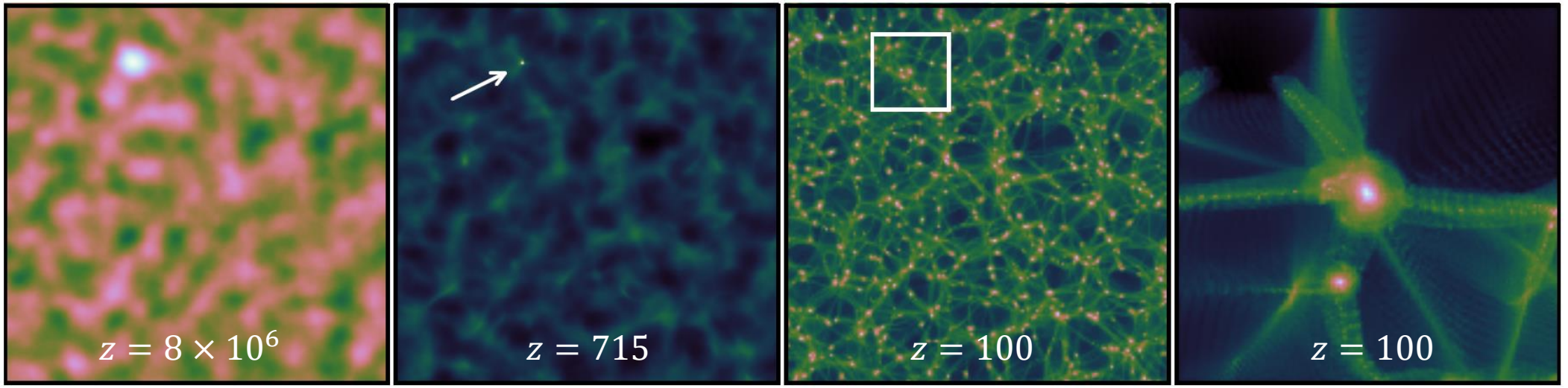
Simulating a natural formation scenario



Delos+ 2018

- Study extreme halos ($\delta \simeq 7\sigma$) forming at $z \simeq 1000$ in spiked power spectrum
- Study similar halo in flat spectrum

(spiked power spectrum)



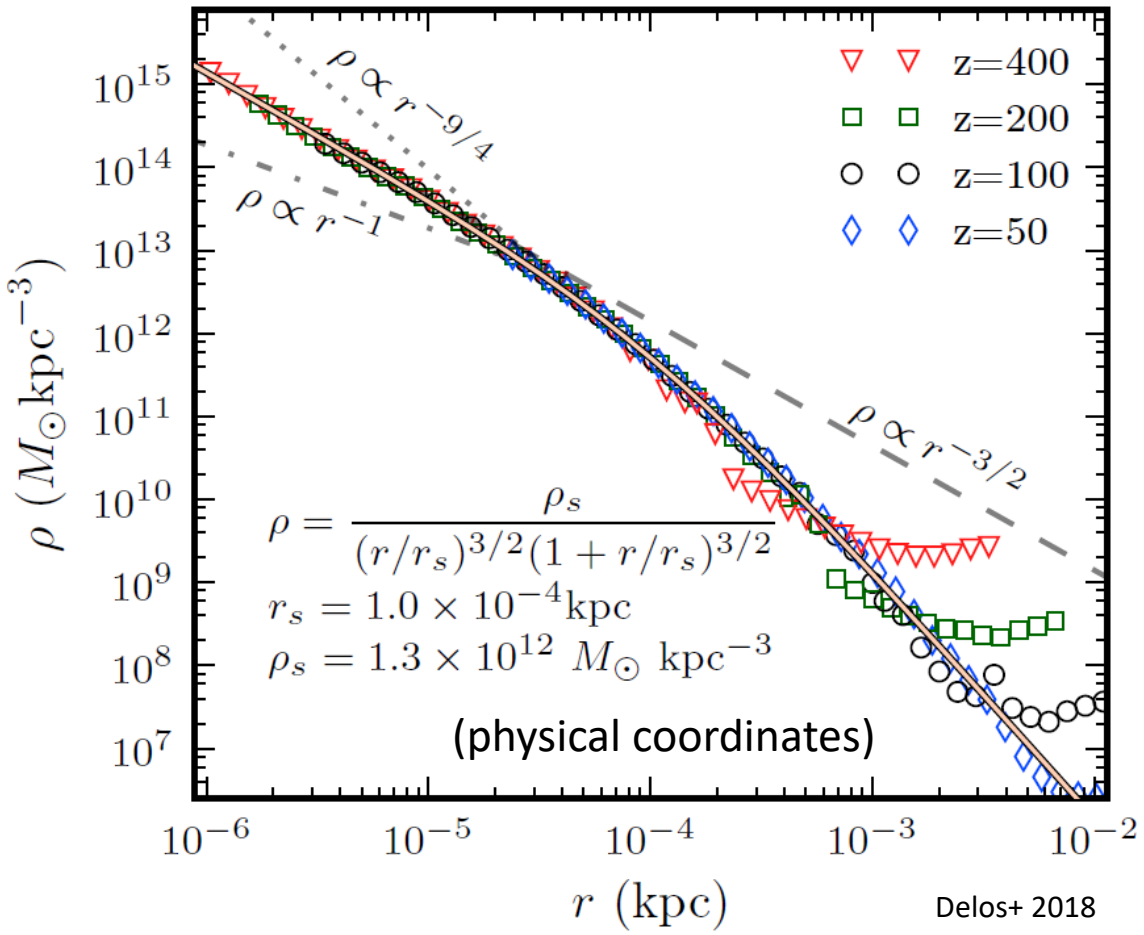
Delos+ 2018

Density profile

- **Spiked power spectrum** → Moore* profile ($\rho \propto r^{-3/2}$ for small r)
  - Density profile stable in time
  - Scaling relations:

$\rho_s \simeq 30 \times$ (cosmological density at formation)
$r_s \simeq 0.7 \times$ (physical scale of spike at formation)
Use to calculate observational signature!

- **Scale-invariant spectrum** → NFW profile ($\rho \propto r^{-1}$ for small r)

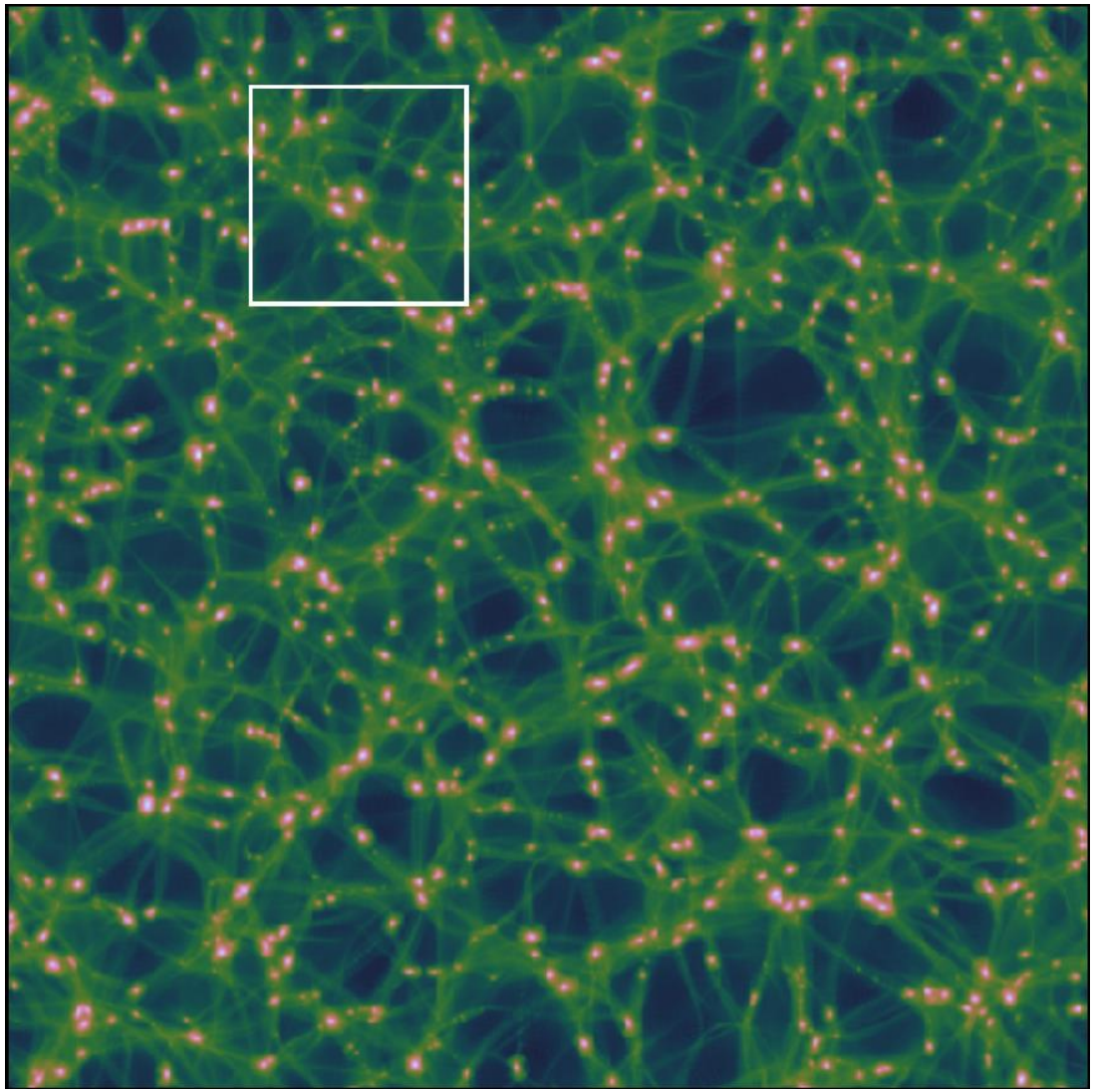


Delos+ 2018

*Similar to the form in Moore, Quinn, Governato, Stadel, Lake 1999

Consequences

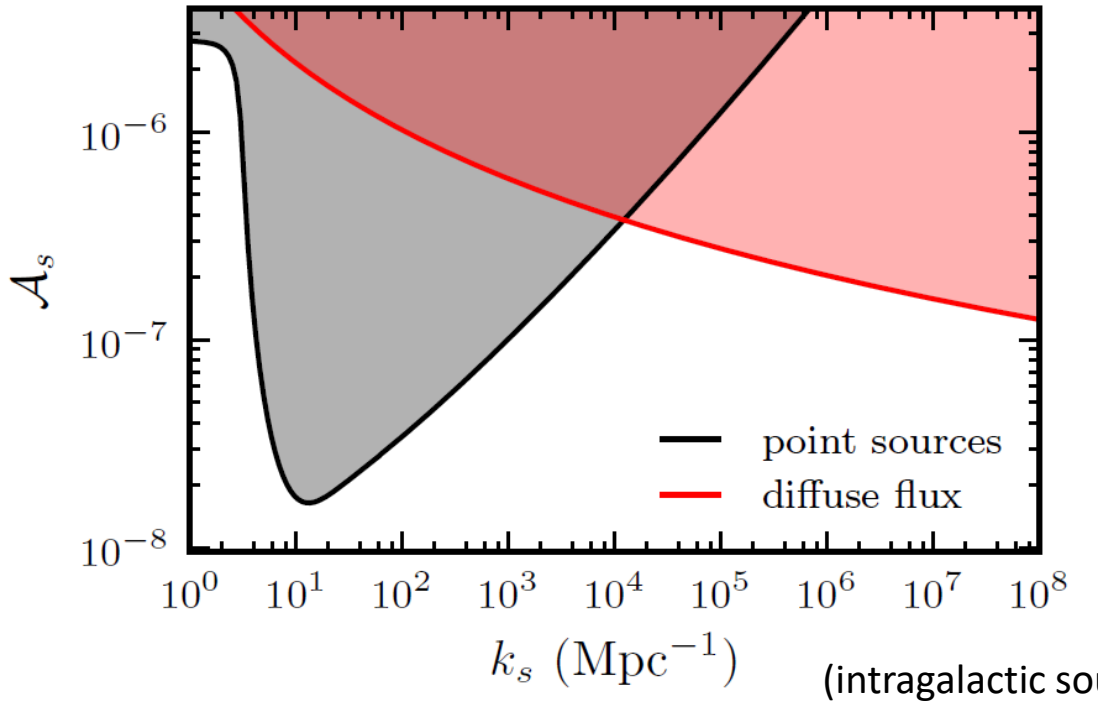
- UCMHs have Moore or NFW profiles
  - Pure power law requires special initial conditions
- Weaker observational signals
- Many more halos

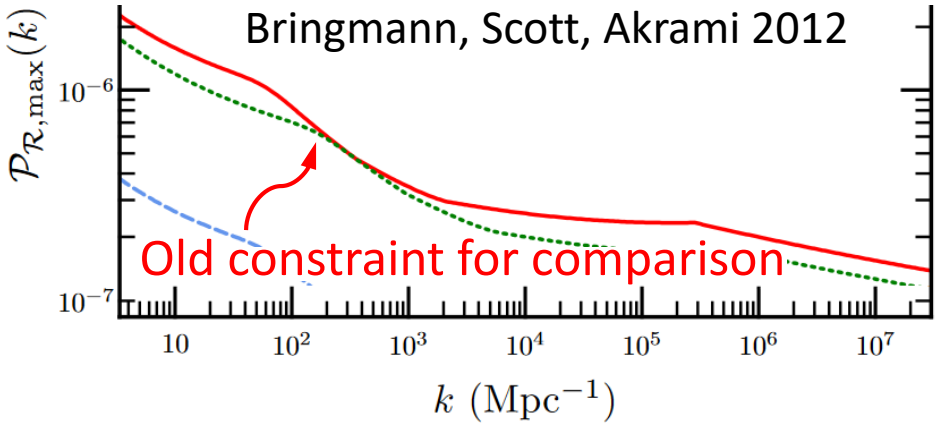


Delos+ 2018

Constraining a δ-spike $\mathcal{P}(k) = \mathcal{A}_s k_s \delta(k - k_s)$

- Calculate UCMH gamma-ray signal from DM annihilation
  - Function of formation time and k_s
- Signal nondetection (Fermi) → abundance constraint → power spectrum constraint



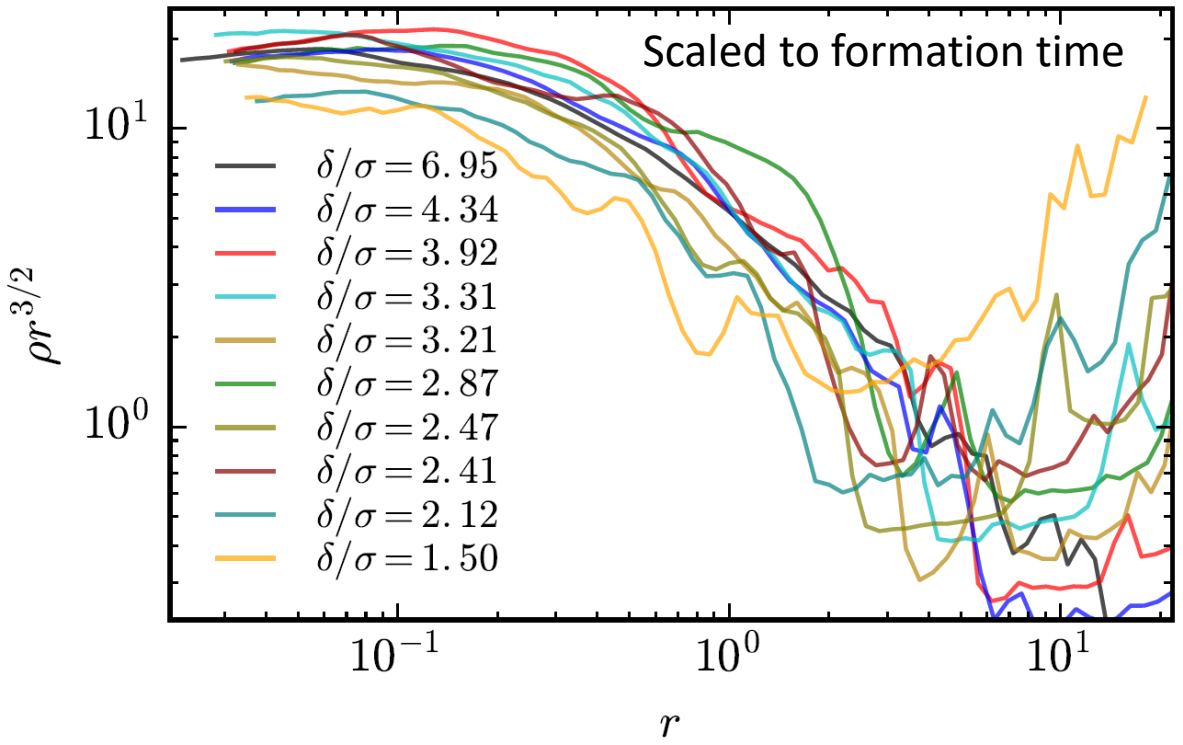


New constraint is generally stronger for narrow spikes!

(intragalactic sources only, same DM model)

Complications

- Spread in halo properties
  - Need more than formation time
- Halo mergers
  - Reduce halo count
  - Can boost central density*
  - Push toward NFW profiles* (~10× weaker signal)
  - Only matter for wider spike
- Halo survival
  - Disruption inside galactic halos



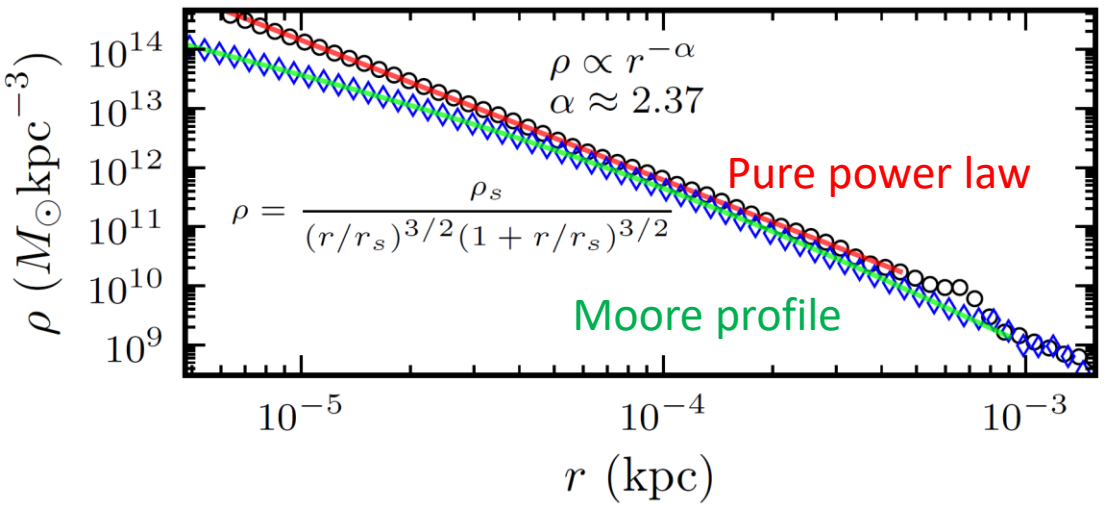
*Ogiya, Nagai, Ishiyama 2016

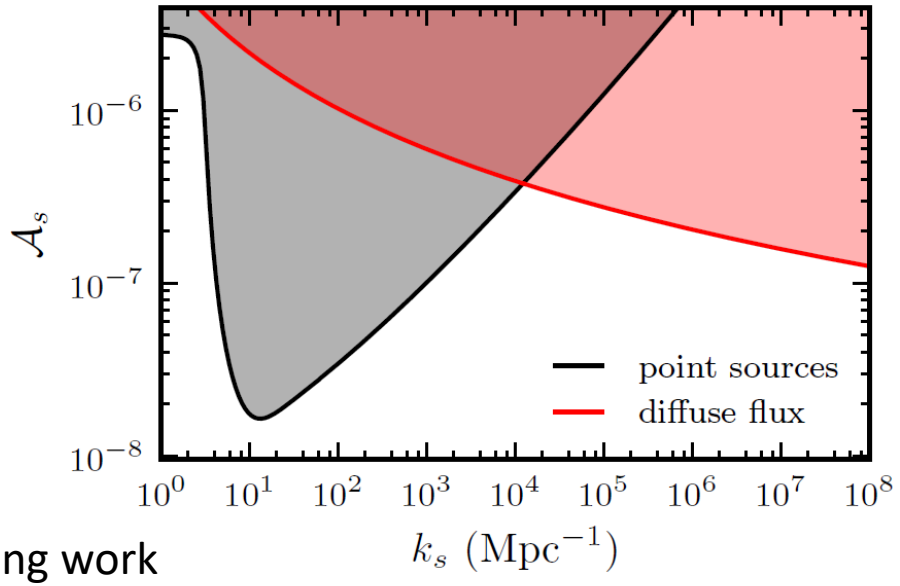
Summary

- UCMH density profiles are shallower than previously assumed

  $\rho \propto r^{-3/2}$ or $\rho \propto r^{-1}$ at small r

- New theory can account for all halos instead of just the rarest
- Crude calculations suggest corrected UCMHs may possess more constraining power
- Work is still needed to fully account for halo statistics and evolution





Further detail:
Phys. Rev. D 97, 041303(R) [arXiv:1712.05421] and forthcoming work

Supplemental

Flat power spectrum results