# Are Dark Matter Interactions Favoured by Cosmological Data?


Deanna C. Hooper


*Based on DH, Murgia, Archidiacono, Lesgourgues (1807.XXXX)*


*Dark Side of the Universe,*

*LAPTh, Annecy*

Institute for Theoretical Particle Physics and Cosmology

RWTH AACHEN UNIVERSITY

# Overview

1. **LCDM tensions**
   - Small scale
   - Large scale
2. **Possible solutions**
   - Models
   - Problems
3. **DM-DR (ETHOS)**
   - Model
   - Effects on observables
4. **Does this solve our problem?**
5. **Outlook**

# LCDM Cosmology - Small Scale Crisis

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- Possible solutions: baryon feedback, WDM, DM interactions

*talk by Laura Lopez Honorez*

# LCDM Cosmology - $H_0$

$H_0$ from Planck (68% CL):

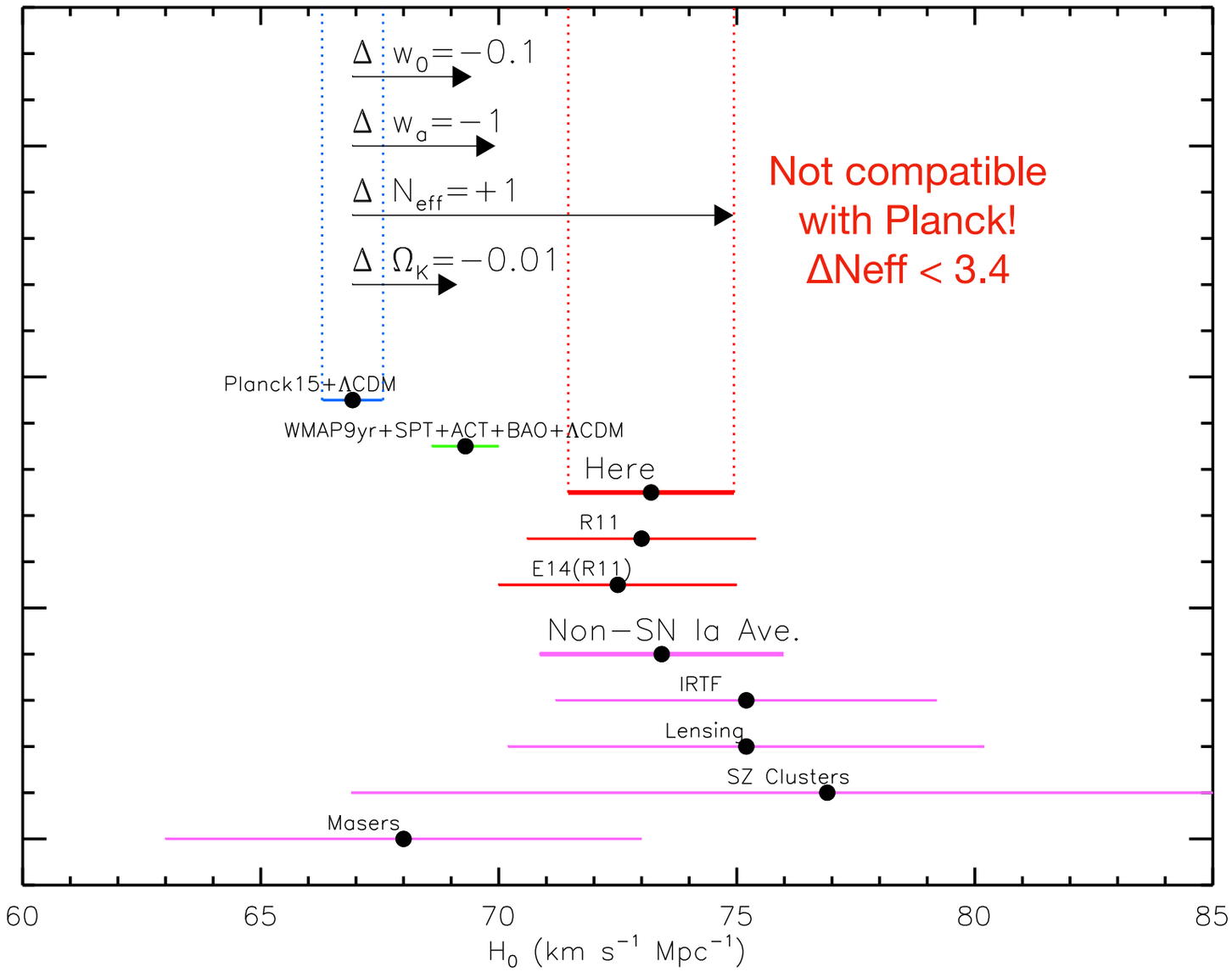
$$H_0 = 67.74 \pm 0.46$$

(*Planck Collaboration 1502.01589*)

$H_0$ from Supernova:

$$H_0 = 73.52 \pm 1.62$$

*(Riess et al. 1804.10655)*




*Riess et al. 1604.01424*

# LCDM Cosmology - $\sigma_8$

$\sigma_8 =$ measurement of the amplitude of the power spectrum on the scale of 8 Mpc/h $S_8 \equiv \sigma_8\sqrt{(\Omega_m/0.3)}$

S8 from Planck (68% CL)

$$S_8 = 0.852 \pm 0.018$$

(*Planck Collaboration 1502.01589*)

S8 from DES:

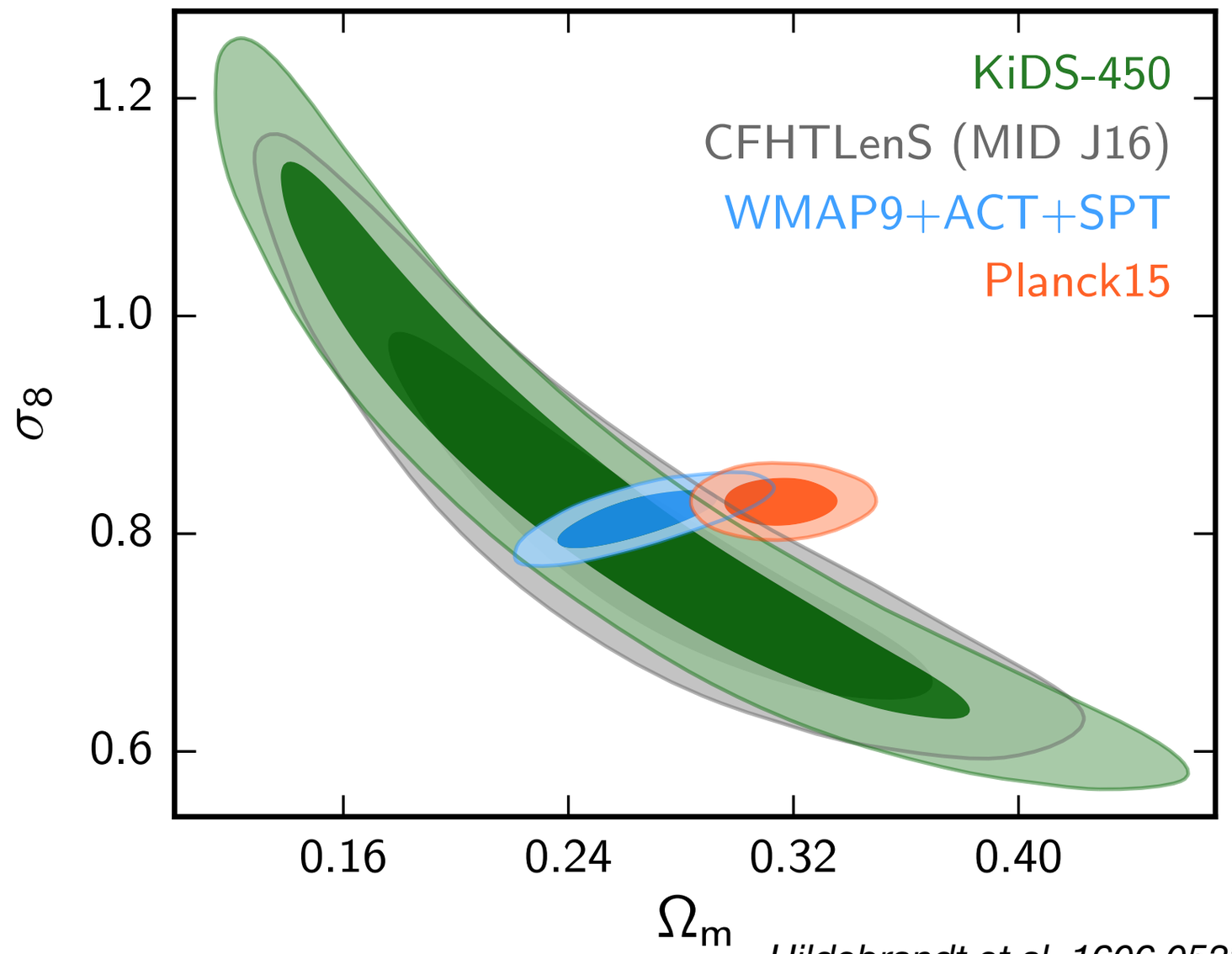
$$S_8 = 0.783 \pm 0.023$$

(*DES Collaboration 1708.01530*)

S8 from KiDS:

$$S_8 = 0.651 \pm 0.058$$

(*Köhlinger et al. 1706.02892*)




*Hildebrandt et al. 1606.05338*

# Possible Simple Solutions?

- Lower $S_8$: massive neutrinos *talk by Yvonne Wong*
  - Free streaming, small scale matter power suppression, lower $S_8$
  - Less lensing, not compatible with CMB
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$$LCDM + \{a_{dm-dr},\ \xi,\ m_{\rm dm},\ f_{idm}\}$$

$a_{dm-dr}$ → amplitude of the scattering rate

$\xi = T_{\rm dr}/T_\gamma$ → amount of dark radiation (~$N_{eff}$)

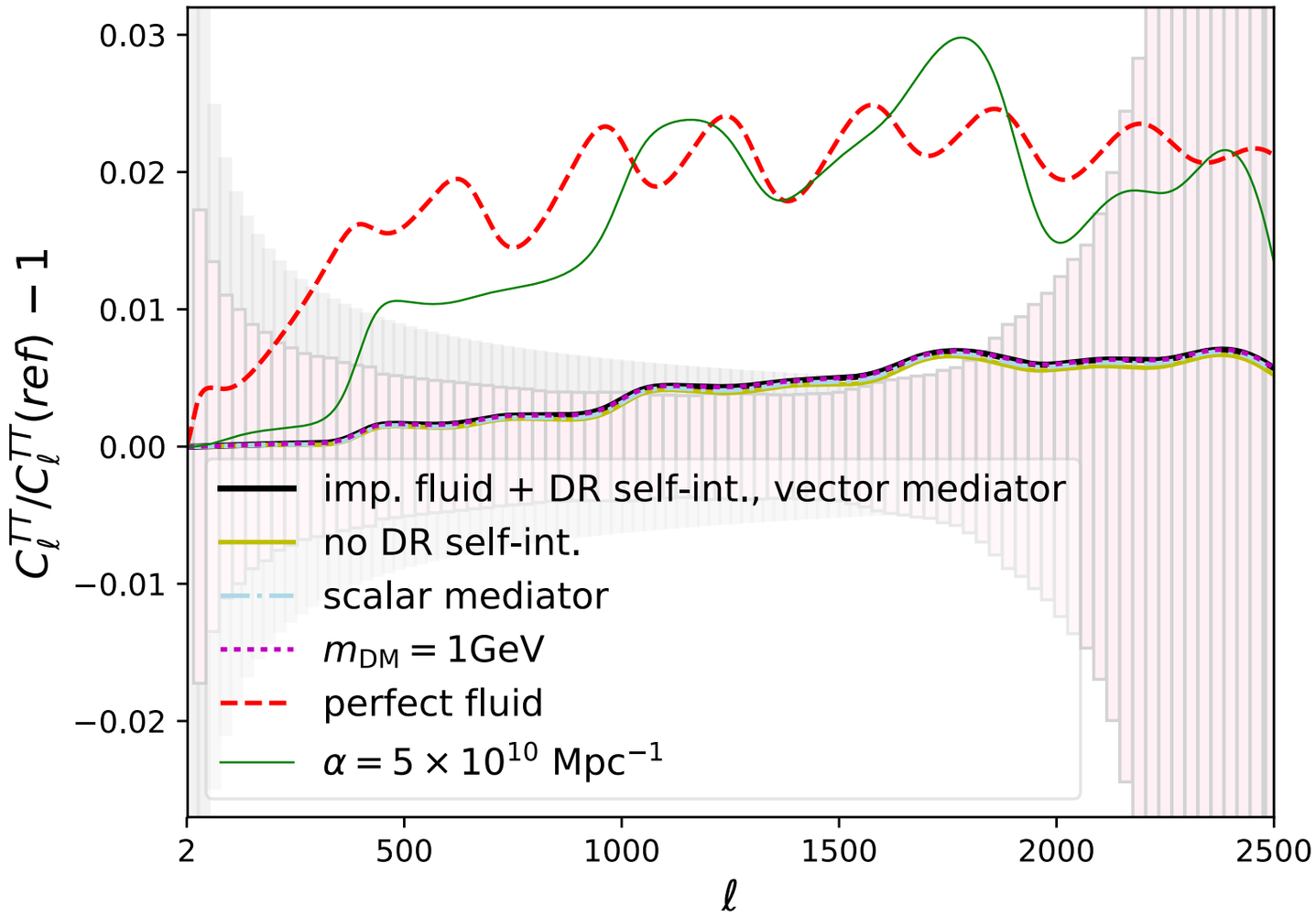
$m_{\rm dm}$ → dark matter mass (in eV)

*talk by Francis-Yan Cyr-Racine*

$f_{idm}$ → fraction of interacting dark matter

# Effects on Observables

- Matter power spectrum like lcdm up to some step-like feature in *k*
- No change to the background history relative to LCDM + $N_{eff}$, DR always relativistic
- DR self interactions preserve CMB peak scale
- DM-DR behaves as coupled fluid at early time, enhances peaks on small scales, compensates damping




*Bohr et al. 1706.06870*

**Also applicable to other DM-DR interactions, like NADM** *(Buen-Abad et al. 1708.09406)*

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**interacting with dm**

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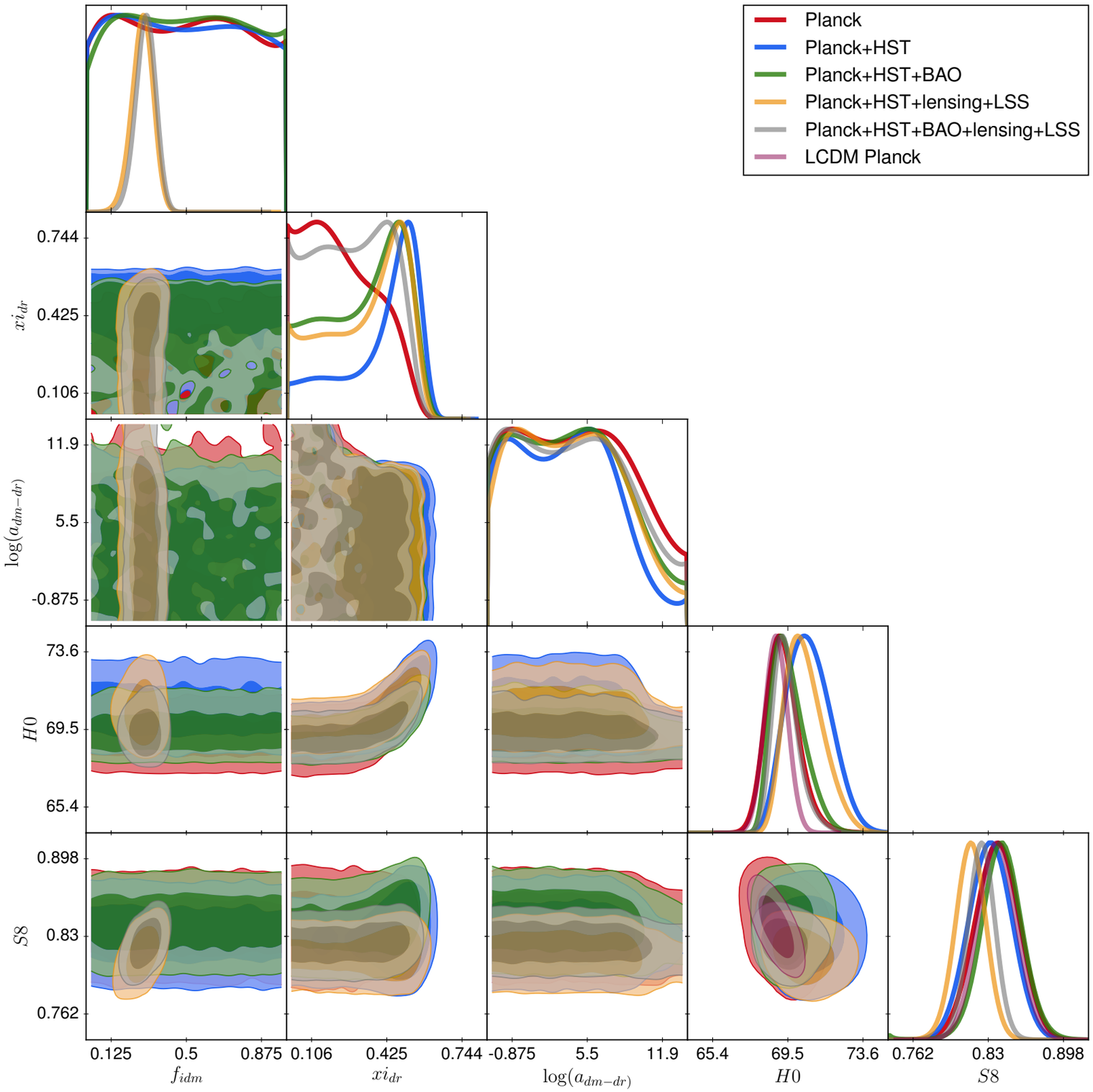
# DM-DR Constraints



# DM-DR Constraints

| | **LCDM** | **DM-DR (+3 d.o.f.)** | $\Delta\chi^2$ | $\sigma$ |
|---|---|---|---|---|
| Planck | 6759.62 | 6758.80 | -0.36 | 0.065 |
| Planck + HST | 6763.25 | 6761.67 | -3.16 | 0.90 |
| Planck + HST + BAO | 6766.94 | 6766.00 | -1.88 | 0.53 |
| Planck + HST + lensing + LSS | 6780.24 | 6768.05 | -24.38 | 4.3 |
| Planck + HST + BAO + lensing + LSS | 6787.01 | 6773.00 | -28.02 | 4.6 |

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Not over yet: Ly-alpha data could exclude a lot of the parameter space that solves $S_8$ tension, but $f_{idm}$ could mitigate this effect. Stay tuned!

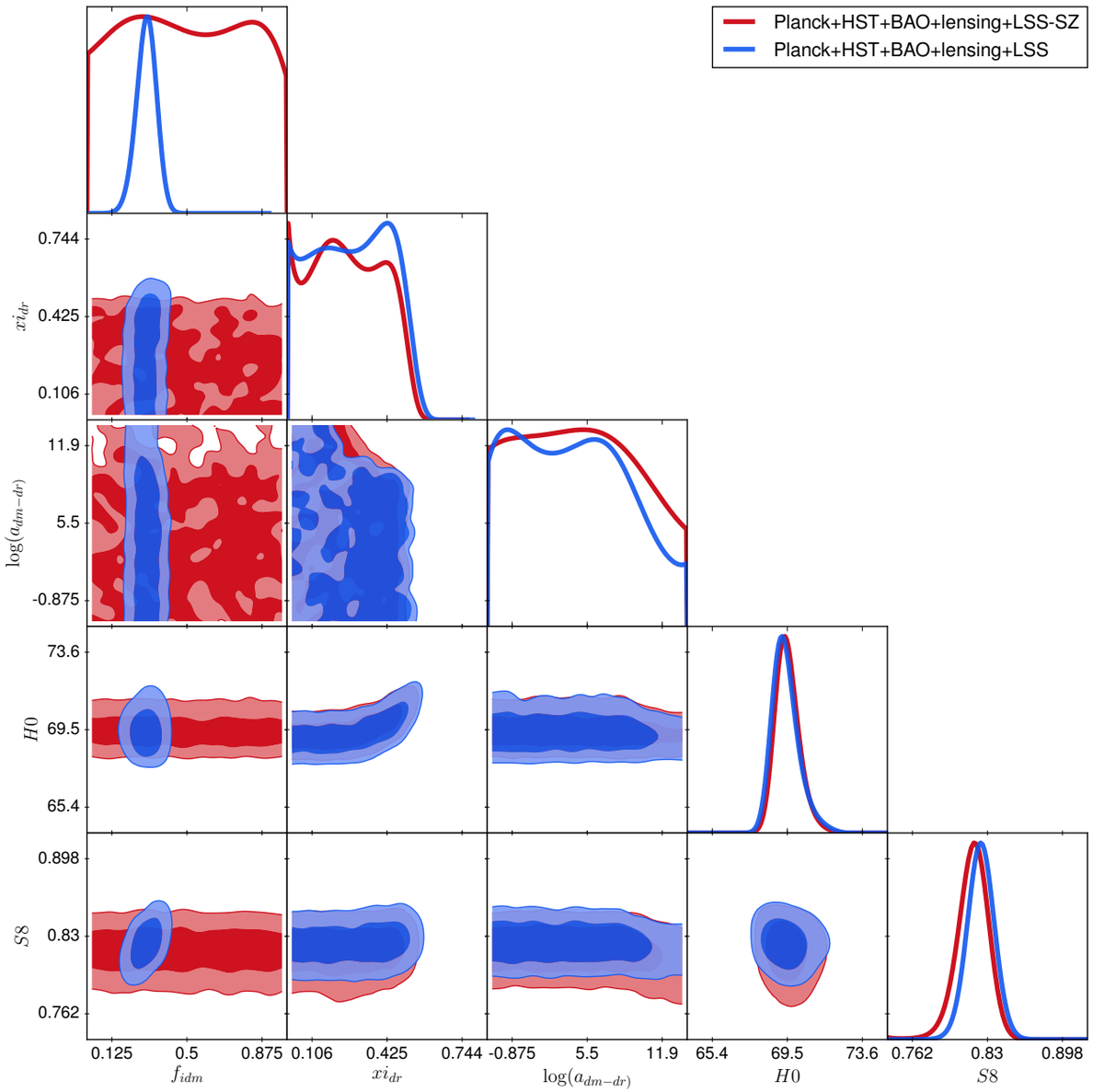
# Summary

- Some unresolved tensions in LCDM still remain
- Interacting Dark Matter - Dark Radiation models offer many possibilities to alleviate cosmological tensions
- Can also alleviate small scale crisis *(Bohr et al. 1706.06870)*
- Lyman-alpha data crucial to constrain these models
- Hints of Dark Matter interactions in cosmological data?

# Thank you for your attention

# Problem with SZ?

The validity of the Planck Sunyaev-Zeldovich (SZ) cluster counts likelihood has been questioned *(Pan et al. 1801.07348)*




$$\Delta\chi^2 = -0.52$$

$$\sigma \sim 1.1$$