Cosmological constraints on multi-interacting dark matter

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*Based on Becker, **DCH**, Kahlhoefer, Lesgourgues, Schöneberg (2010.04074)*

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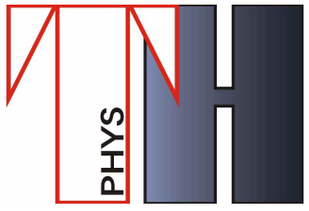


Why interacting DM?

- The standard cosmological paradigm has several issues: small scale crisis, H_0 and S_8 tensions, EDGES anomaly

- Many alternatives to cold dark matter have been proposed to solve these, such as interacting dark matter

- Each type of interaction can provide different benefits

- We want to see if we can combine these effects

- We have implemented dark matter with multiple possible interaction channels in `CLASS`

DM - baryon interactions

- We have implemented DM - baryon interactions with a power-law dependence on the relative bulk velocity *(Dvorkin et al. 1311.2937, Muñoz et al. 1509.00029, Slatyer et al. 1803.09734)*

- DM and baryons are assumed to be non-relativistic ($m_{\rm DM} \geq 1$ MeV), and following a Maxwell velocity distribution

- We consider a momentum transfer cross section of the form

$$\sigma = \sigma_{\rm DM-b} v^{n_b}$$

- We consider $n_b = \{-4,4\}$. Well-motivated cases include $n_b = 0$ (contact interactions) and $n_b = -4$ (milicharged, may explain EDGES)

DM - photon interactions

- We consider DM - photon interactions similar to the standard Thomson scattering *(Wilkinson et al. 1309.7588, Stadler et al. 1803.10229)*

- We assume the interactions are independent of temperature

- We parametrise the scattering cross section relative to the Thompson cross section as

$$u_{\mathrm{DM}-\gamma} = \frac{\sigma_{\mathrm{DM}-\gamma}}{\sigma_{\mathrm{Th}}} \left(\frac{m_{\mathrm{DM}}}{100\mathrm{GeV}} \right)^{-1}$$

- Suppress the matter power spectrum, may solve the S_8 tension

DM - dark radiation interactions

- DM - DR interactions were implemented in CLASS v2.9 *(Archidiacono, **DCH**, et al. 1907.01496)*

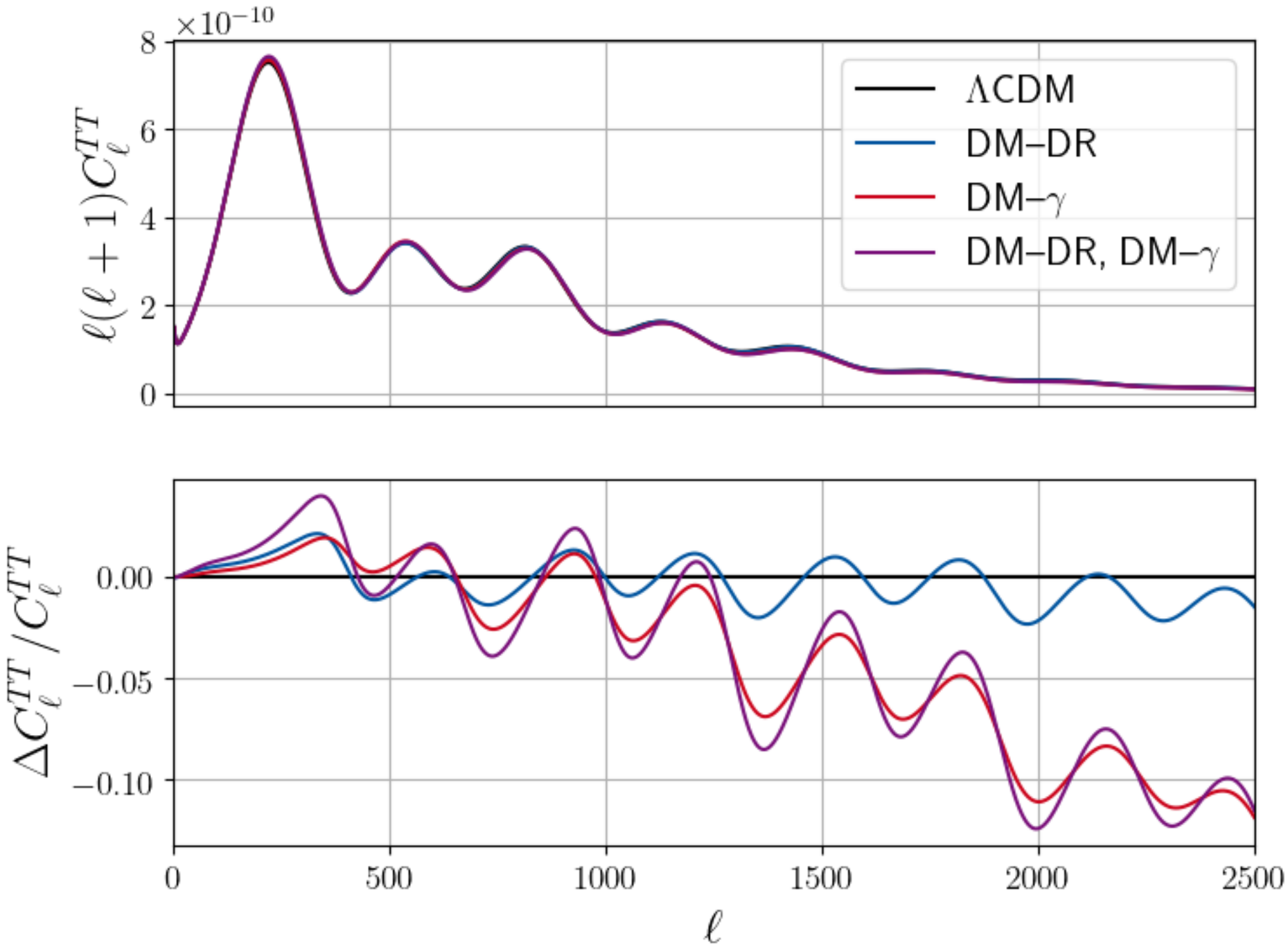
- For general interactions, implementation based on the ETHOS formalism *(Cyr-Racine et al. 1512.05344)*

- DR is assumed to be massless and not interacting with SM particles. Can be either free-streaming or fluid-like

- Parameters: current momentum exchange rate $\Gamma^0_{\rm DM-DR}$, amount of dark radiation $N_{\rm DR}$, temperature dependence of scattering rate $n_{\rm DR}$

- Case of $n_{\rm DR} = 0$ may solve H_0 and S_8 tensions *(Buen-Abad et al. 1505.03542)*

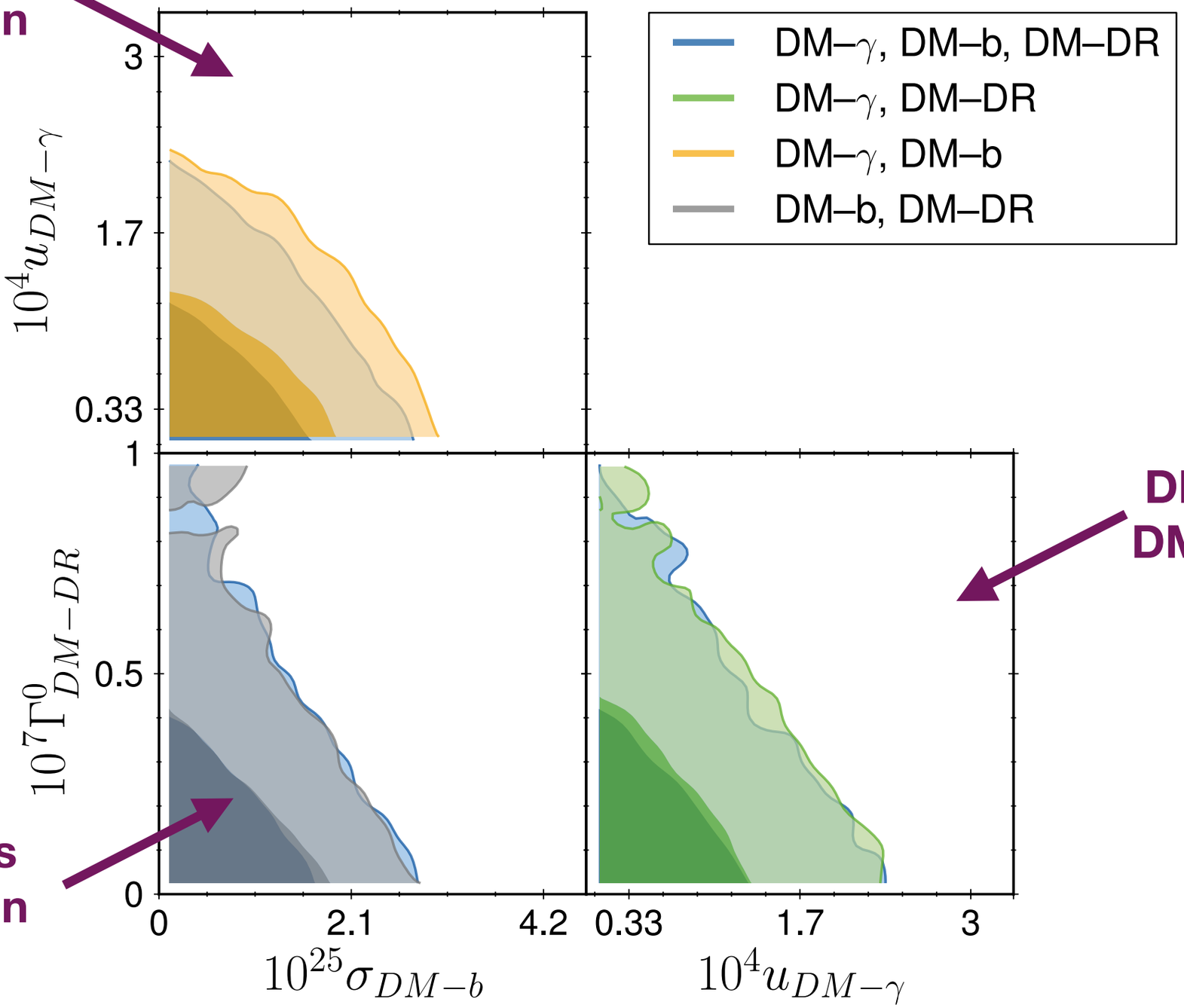
Effects on the observables



IDM cross sections

*Becker, **DCH**, et al. 2010.04074*

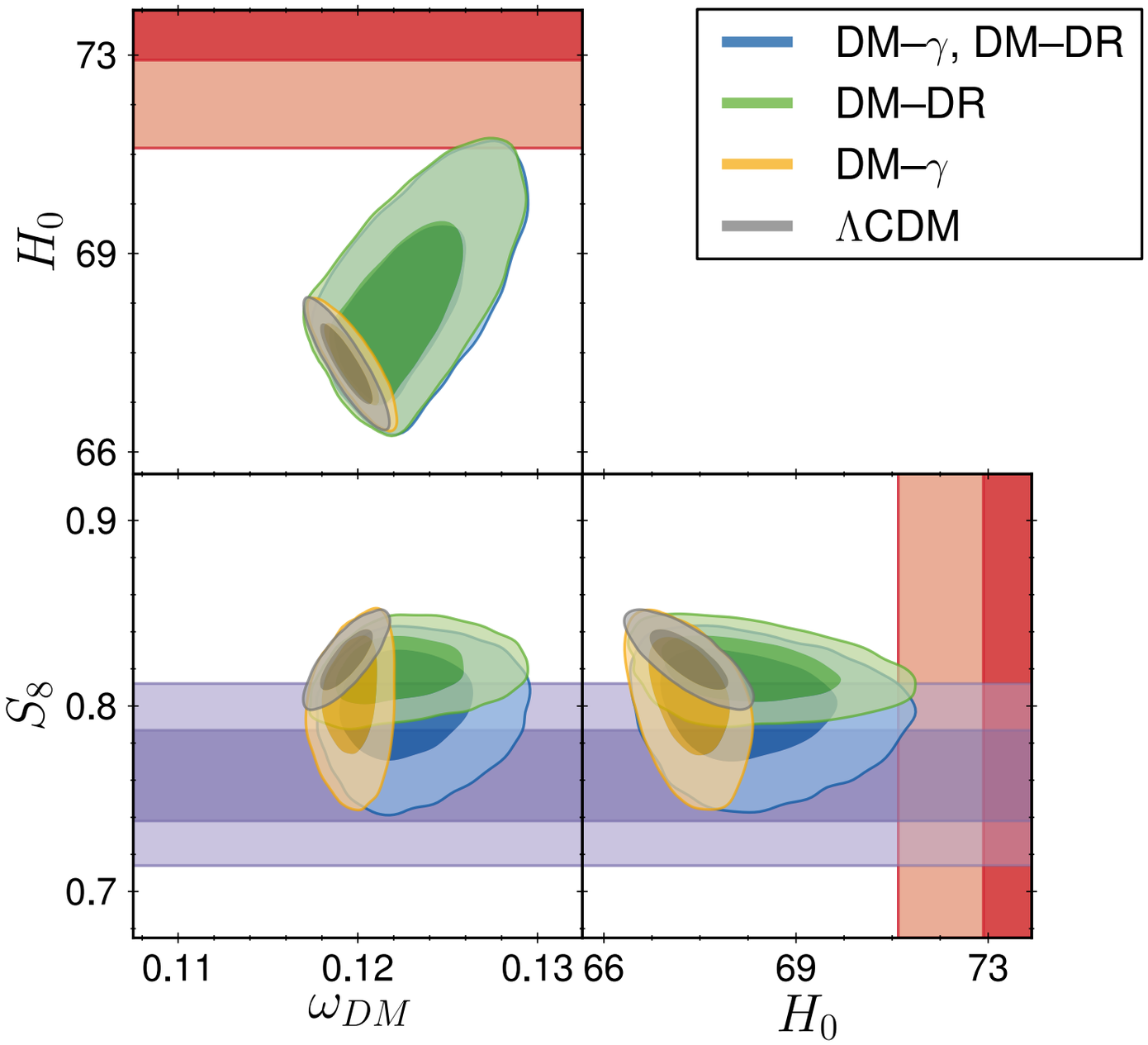
DM - photon vs DM - baryon



DM - DR vs DM - photon

DM - DR vs DM - baryon

Cosmological tensions



*Becker, **DCH**, et al. 2010.04074*

- DM - photon interactions push to a lower S_8 than ΛCDM
- DM - DR interactions push to higher H_0 than ΛCDM
- Together they allow for both higher H_0 and lower S_8 values
- Comes at the expense of three new parameters

Summary

- We have developed a new version of `CLASS`: one dark matter species can have simultaneous interactions with baryons, photons, and dark radiation
- We have shown that the effects of different interactions on the cosmological observables are additive
- The existing bounds on the different interaction strengths are robust to the underlying model
- Such interacting models can solve both the H_0 and S_8 tensions, but at the expense of adding three new parameters
- Lyman-α data is expected to severley constrain these models
- The public release of our code as `CLASS v3.1` paves the way for the study of various rich dark sectors

Thank you for your attention