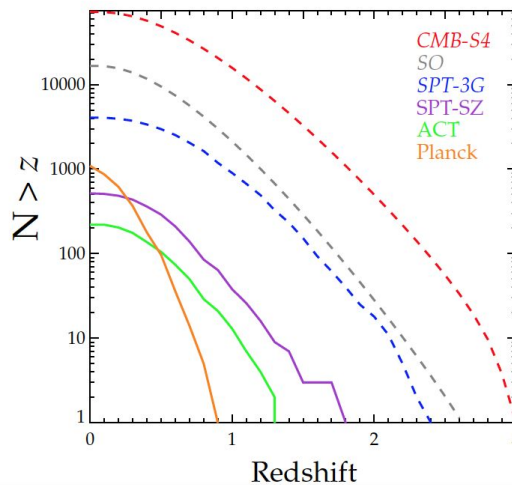




Cosmology and Astrophysics with Galaxy Clusters from CMB-S4

Clusters (formerly Sources) Analysis Working Group

Session organisers: Hao-Yi (Heidi) Wu and Srinivasan Raghunathan



CMB-S4 DSR, arXiv:[1907.04473](https://arxiv.org/abs/1907.04473)

CMB-S4 summer collaboration meeting
12 August 2021

New clusters analysis working group



Jim Bartlett
(APC - U. of Paris)

- Co-coordinating along with Prof. Jim Bartlett.
- Goals: Clusters along with all possible SZ science including cross-correlations.
- Please sign-up, if not done so already.
 - <https://cmb-s4.org/> → <https://cmb-s4.org/team-page/> → Your membership record.

Working Groups:	
LowElBB	<input checked="" type="checkbox"/>
Maps2Cell	<input checked="" type="checkbox"/>
Maps2Stats	<input checked="" type="checkbox"/>
Clusters	<input checked="" type="checkbox"/>
Sources	<input checked="" type="checkbox"/>

Details about cluster parallel session

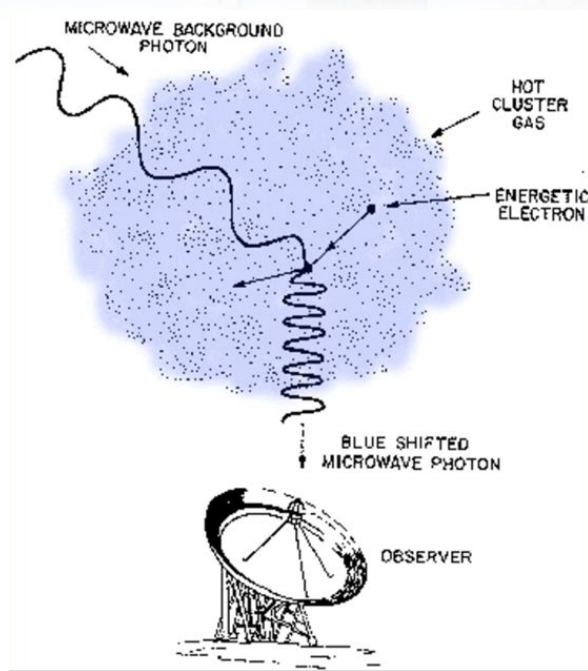
- Status of eROSITA - **Vittorio Ghirardini**.
- SPT/DES Cluster Cosmology - **Sebastian Bocquet**.
- Understanding the mass and galaxy distribution in Clusters: A perspective from the edge of DM halos - **Susmita Adhikari**.
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 - Discussion/Close.

Secondary CMB anisotropies and their correlations with LSS:

ISW, lensing, kSZ, moving-lens (Birkinshaw-Gull), tSZ.

- Synergies of Large Scale Structure Surveys with CMB-S4 (Tuesday).
 - Andrina Nicola and Emmanuel (Manu) Schaan.
- Backlighting the Baryons with CMB-S4 (Wednesday).
 - Alexie Leauthaud and Simone Ferraro.

Thermal Sunyaev-Zeldovich (SZ) effect



- Galaxy clusters contain hot gas (free electrons).
- CMB photons, that pass through clusters of galaxies, are inverse Compton scattered by free electrons in the intracluster medium (ICM).
- Used for blind detections of clusters in CMB surveys.
- *SZ effect is redshift independent and hence allows us detect distant clusters.*

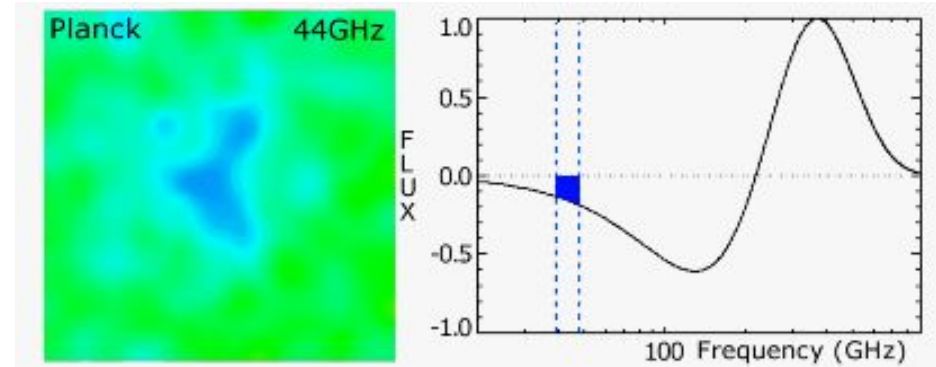


Image: L. Van Speybroeck

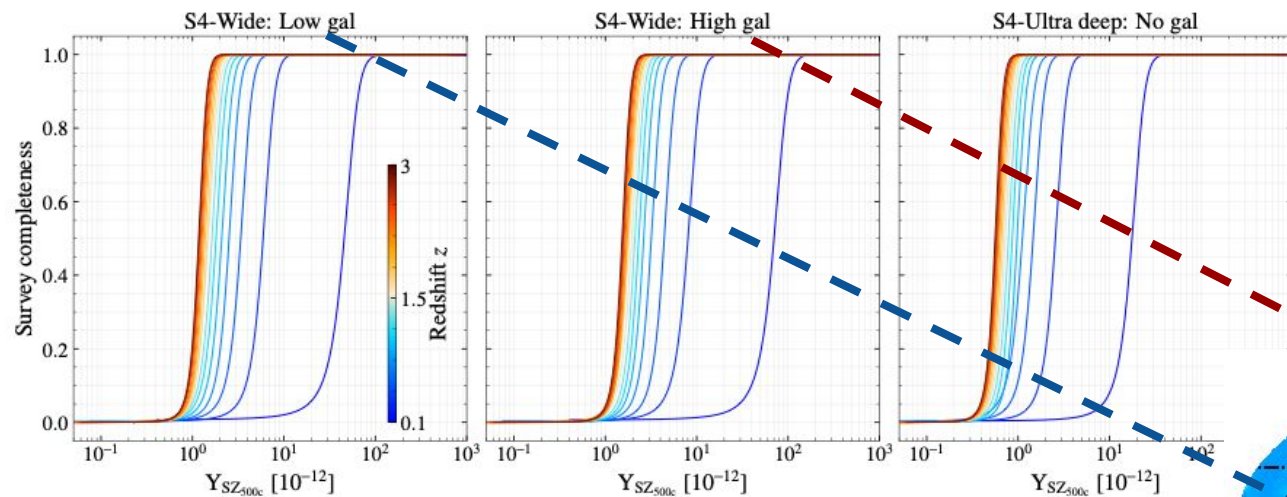
Frequency dependence of thermal SZ (Image: ESA)

CMB-S4 cluster forecasts

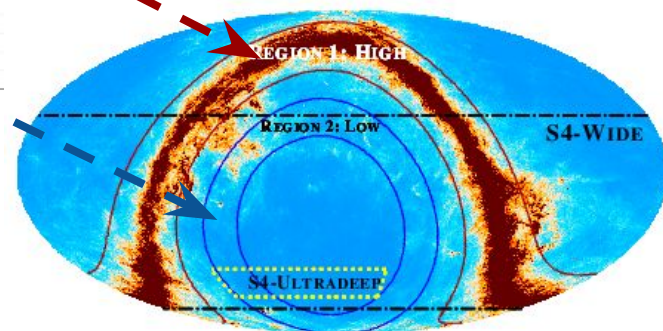
- **CMB-S4 cluster surveys:**
 - 6-metre telescopes → 1.4 arcmin beam at 145 GHz.
 - CMB-S4 Wide: Chilean survey: $f_{\text{sky}} = 67\%$.
 - CMB-S4 Ultra-deep: South Pole survey: $f_{\text{sky}} = 3\%$.
- **Signal-to-noise threshold: 5σ .**
- **Observable:**

CMB-S4 shall detect (at 5σ) all galaxy clusters with an integrated Compton $Y_{\text{SZ}} \geq XX$ at $z \geq 1.5$ over the large area survey footprint ($f_{\text{sky}} = 67\%$). Furthermore, it shall detect (at 5 sigma) all galaxy clusters with an integrated Compton $Y_{\text{SZ}} \geq YY$ at $z \geq 1.5$ over the de-lensing survey footprint ($f_{\text{sky}} = 3\%$).

CMB-S4 cluster survey completeness



CMB-S4 PBDR (in prep.)

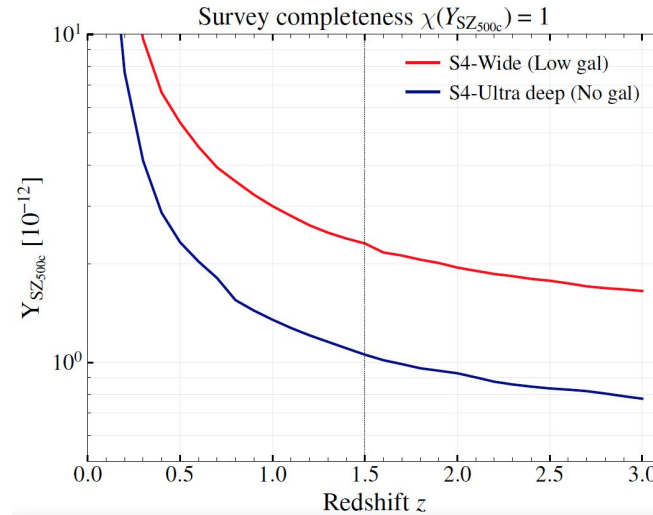


$$\int_{q\sigma_{Y_{SZ}}}^{\infty} dY_{SZ} P(Y_{SZ} | Y_{SZ}^{\text{true}}) = 0.5 \left(1 + \text{erf} \left[\frac{Y_{SZ}^{\text{true}} - q\sigma_{Y_{SZ}}}{\sqrt{2}\sigma_{Y_{SZ}}} \right] \right)$$

Planck collaboration 2014 XX, arXiv: [1303.5080](https://arxiv.org/abs/1303.5080)
 Alonso, Louis, Bull et al. 2016, arXiv: [1604.01382](https://arxiv.org/abs/1604.01382)

CMB-S4 cluster survey completeness

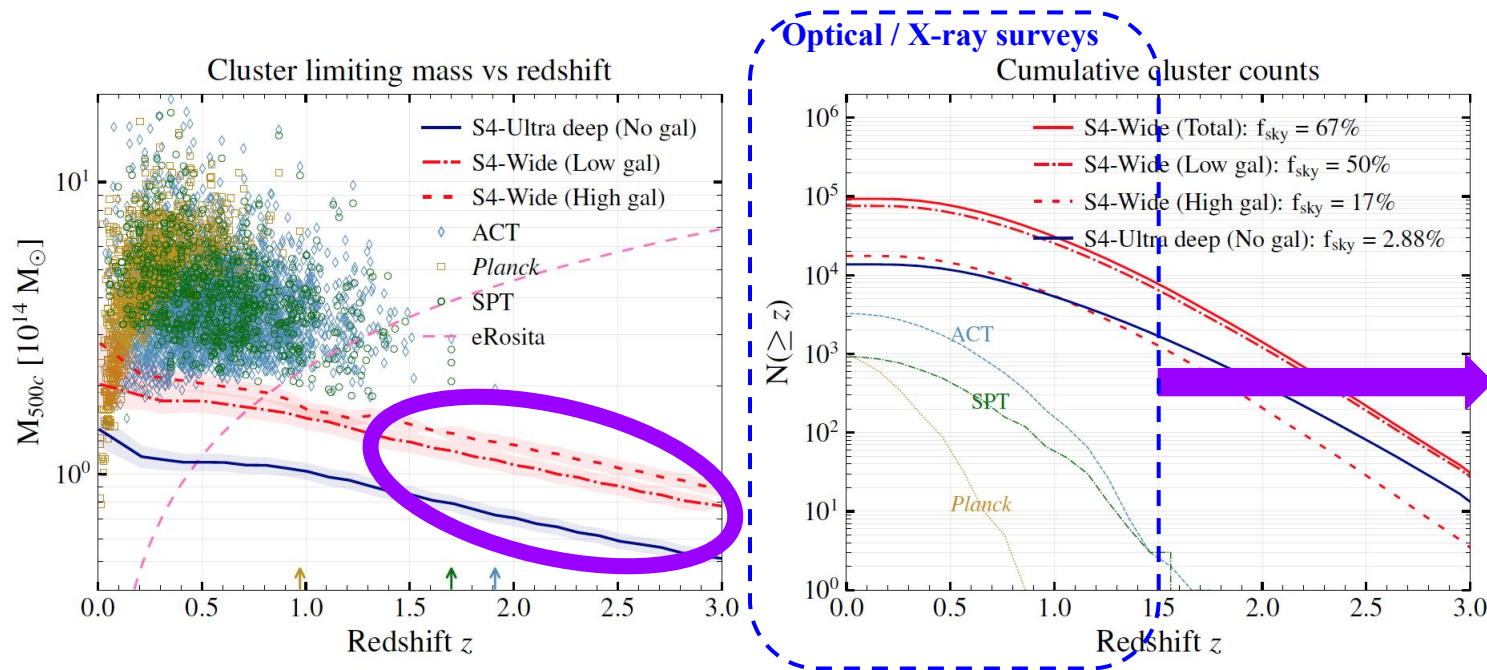
CMB-S4 PBDR (in prep.)



CMB-S4 shall detect (at 5σ) all galaxy clusters with an integrated Compton $Y_{SZ} \geq 2 \times 10^{-12}$ sr at $z \geq 1.5$ over the large area survey footprint ($f_{sky} = 65\%$ 50%). Furthermore, it shall detect (at 5σ) all galaxy clusters with an integrated Compton $Y_{SZ} \geq 10^{-12}$ sr at $z \geq 1.5$ over the de-lensing survey footprint ($f_{sky} = 3\%$).

CMB-S4 cluster sensitivity / counts

- **S4-Wide:** Contains clusters from low ($f_{\text{sky}} = 0.5$) + high ($f_{\text{sky}} = 0.15$) galactic emission regions. Removing high galactic emission region reduces $\sim 20\%$ objects.
- **High- z ($z \geq 2$) clusters:** S4-Wide $\rightarrow \sim 1000$ clusters; S4-Ultra deep $\rightarrow \sim 350$ clusters.

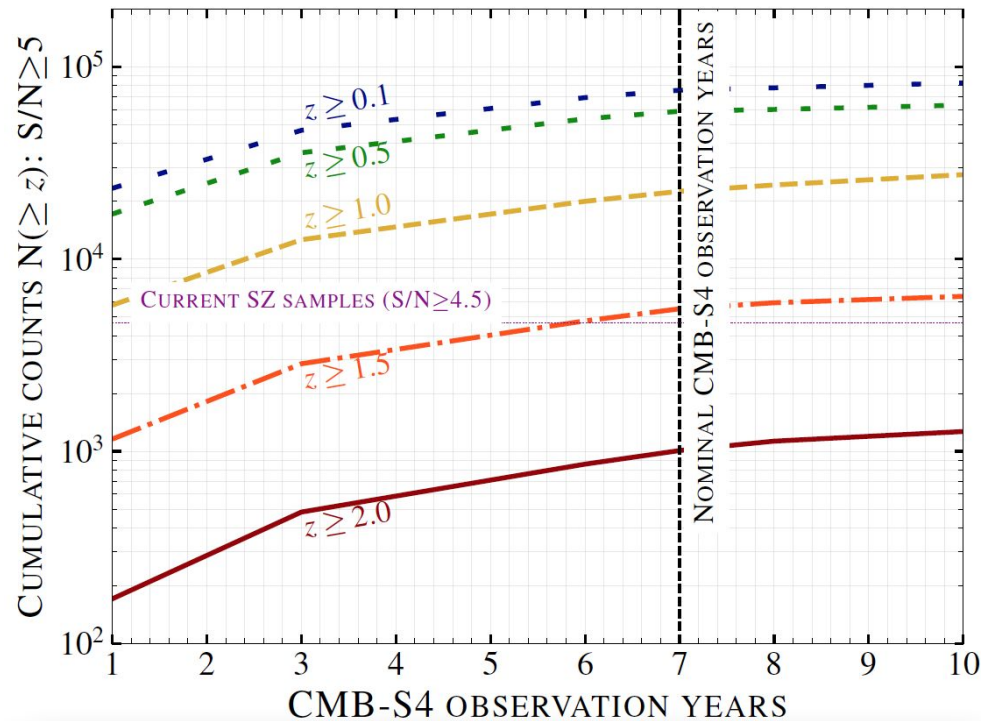


Talks in the parallel session:

Vittorio Ghirardini, Tesla Jeltema, and Grant Tremblay.

CMB-S4 PBDR (in prep.)

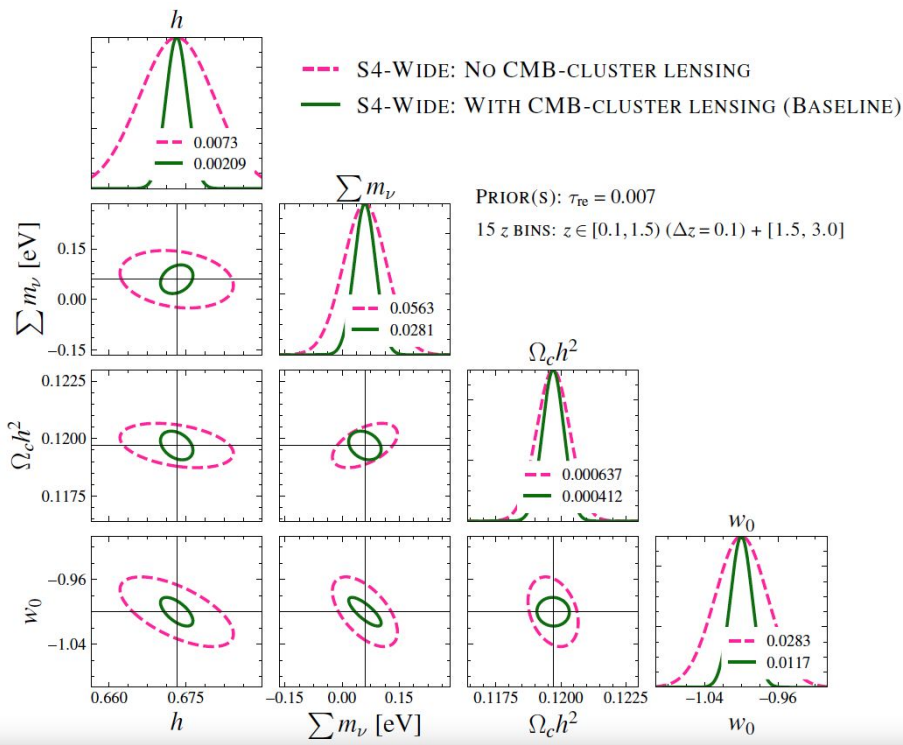
CMB-S4 cluster forecasts: Expected counts



Work done with *Marcelo Alvarez*, *Han Aung*, *Nick Battaglia*, *Gil Holder*, *Daisuke Nagai*, *Elena Pierpaoli* and *Nathan Whitehorn*.
Look into arXiv:[2107.10250](https://arxiv.org/abs/2107.10250) for more details.

Cosmological constraints

CMB-S4 Wide: CMB (TT/EE/TE) with Cluster counts using CMB-cluster lensing mass calibration.



Including information from galaxy weak lensing will further strengthen the constraints and also offer an important systematic check.

Data:

To et al. 2021, arXiv: [2010.01138](https://arxiv.org/abs/2010.01138)

DES collaboration 2020, arXiv: [2002.11124](https://arxiv.org/abs/2002.11124)

Bocquet et al. 2019, arXiv: [1812.01679](https://arxiv.org/abs/1812.01679)

Zubeldia & Challinor 2019, arXiv: [1904.07887](https://arxiv.org/abs/1904.07887)

*Talks in the parallel session:
Sebastian Bocquet and Tesla Jeltema.*

Look into arXiv: [2107.10250](https://arxiv.org/abs/2107.10250) for more details.

Also see Louis & Alonso 2017, arXiv: [1609.03997](https://arxiv.org/abs/1609.03997); Madhavacheril, Battaglia & Miyatake 2017, arXiv: [1708.07502](https://arxiv.org/abs/1708.07502).



What about cluster astrophysics?

Talks in the parallel session:

*Susmita Adhikari, Eric Baxter, Han Aung/Daisuke Nagai/Erwin Lau
and Grant Tremblay.*

Virialisation mechanism of distant clusters

What about the virialisation process of high- z clusters?

- **Observations:** Only one cluster at $z \sim 2$. Mantz et al. 2014, 2018 (arXiv: [1401.2087](#), [1703.08221](#)) find the properties of this cluster to be consistent with low- z clusters.
- CMB-S4 will make a giant leap in the field of cluster science.

$$Y_{\text{SZ}_{500c}} = v(z) Y_* \left[\frac{h}{0.7} \right]^{-2+\alpha} \left[\frac{M_{500c}}{M_*} \right]^\alpha \left[\frac{D_A(z)}{100\text{Mpc}} \right]^{-2} E^{2/3}(z)$$

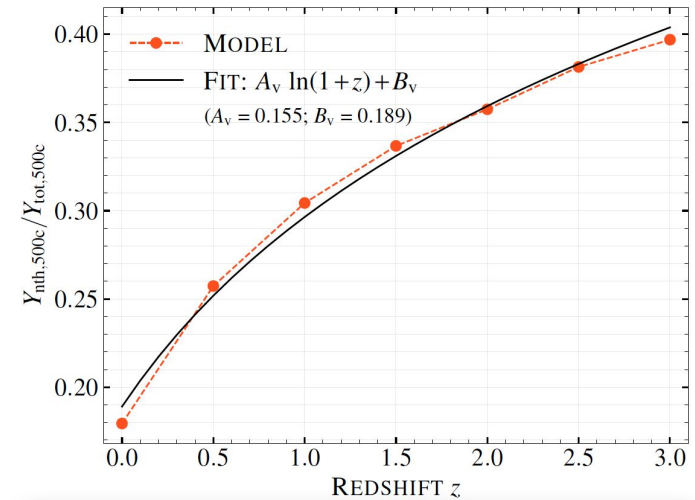
Planck Y_{SZ} -M scaling relation with a constant HSE bias.

Model 1: $v(z) = \eta_v(z) (1 - b_{\text{HSE}})^\alpha$

Simple linear scaling.

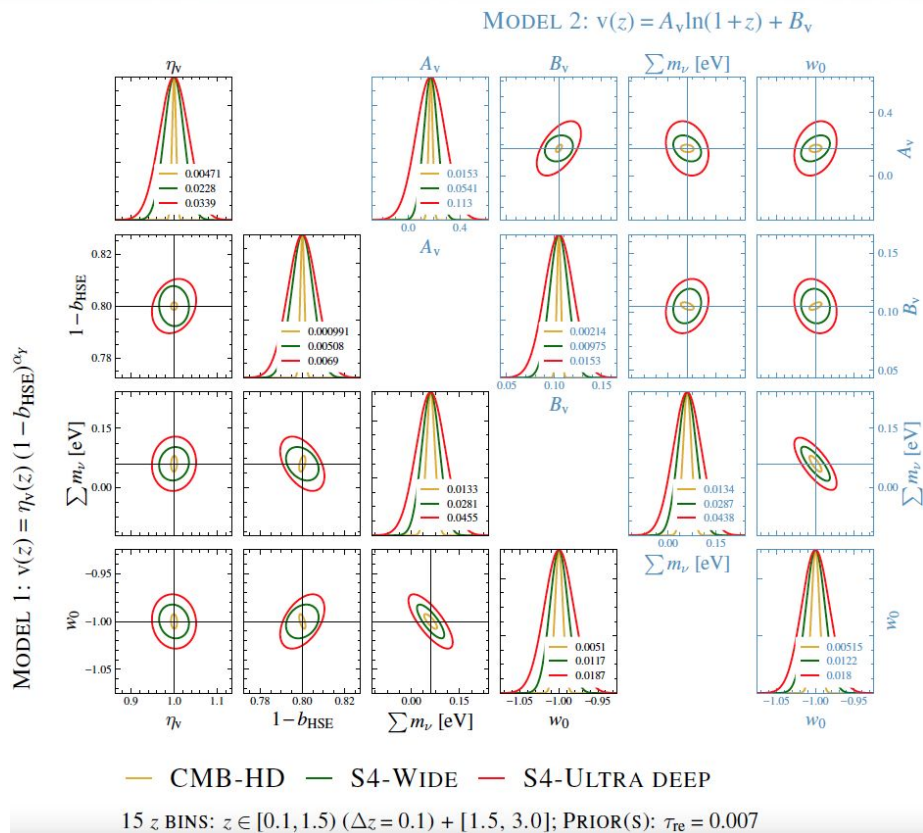
Model 2: $v(z) = A_v \ln(1 + z) + B_v$

Analytic model tested using simulations.



Talks in the parallel session: Han Aung/Daisuke Nagai/Erwin Lau.

Constraining astrophysics and cosmology with clusters



Look into arXiv:[2107.10250](https://arxiv.org/abs/2107.10250) for more details.

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