Investigating the Hubble Constant Tension - Two Numbers in the Standard Cosmological Model

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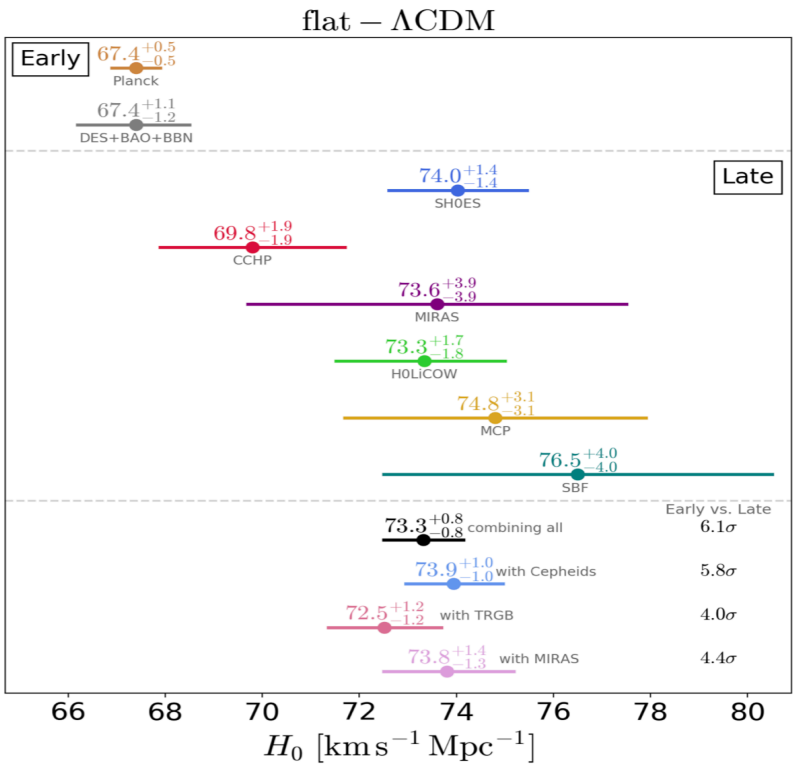
Comparing to other results is important and pressing

Usual presentation of the constraints:



Disadvantages:

1. Many constraints are not strong

2. Combining probes may make results on H0 to be correlated

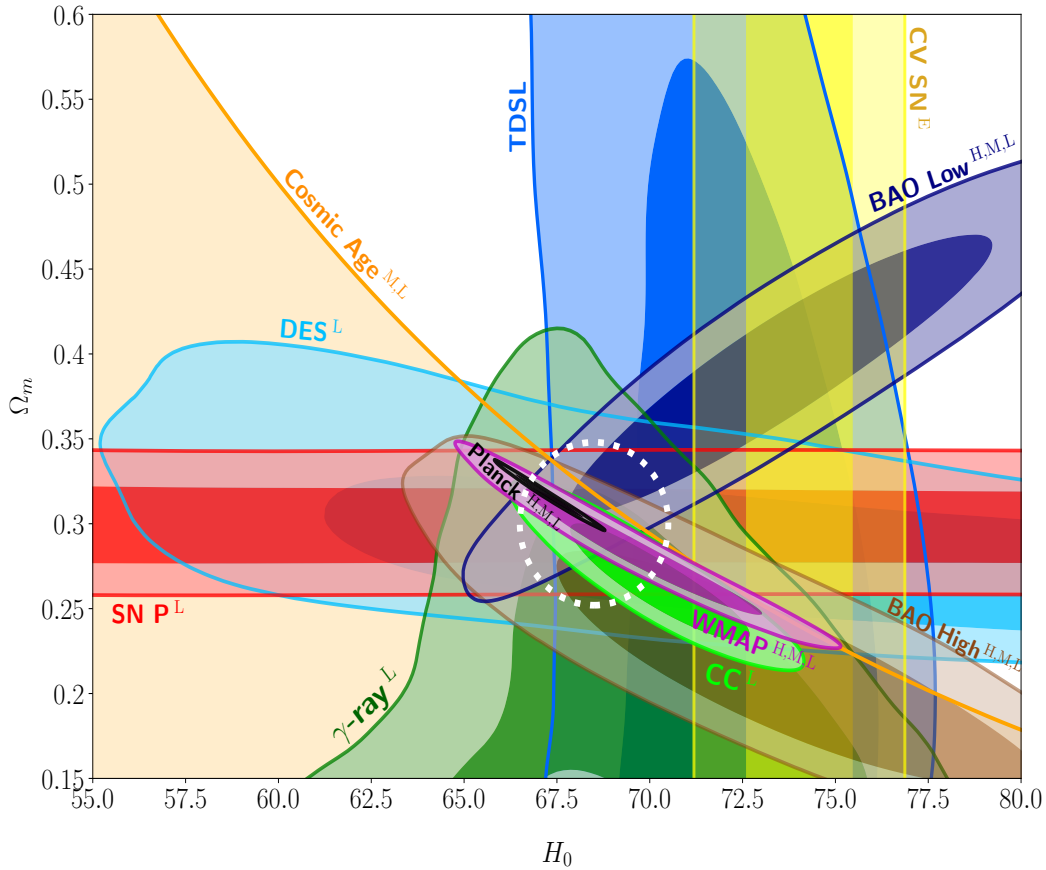
3. Model dependence gets more complicated

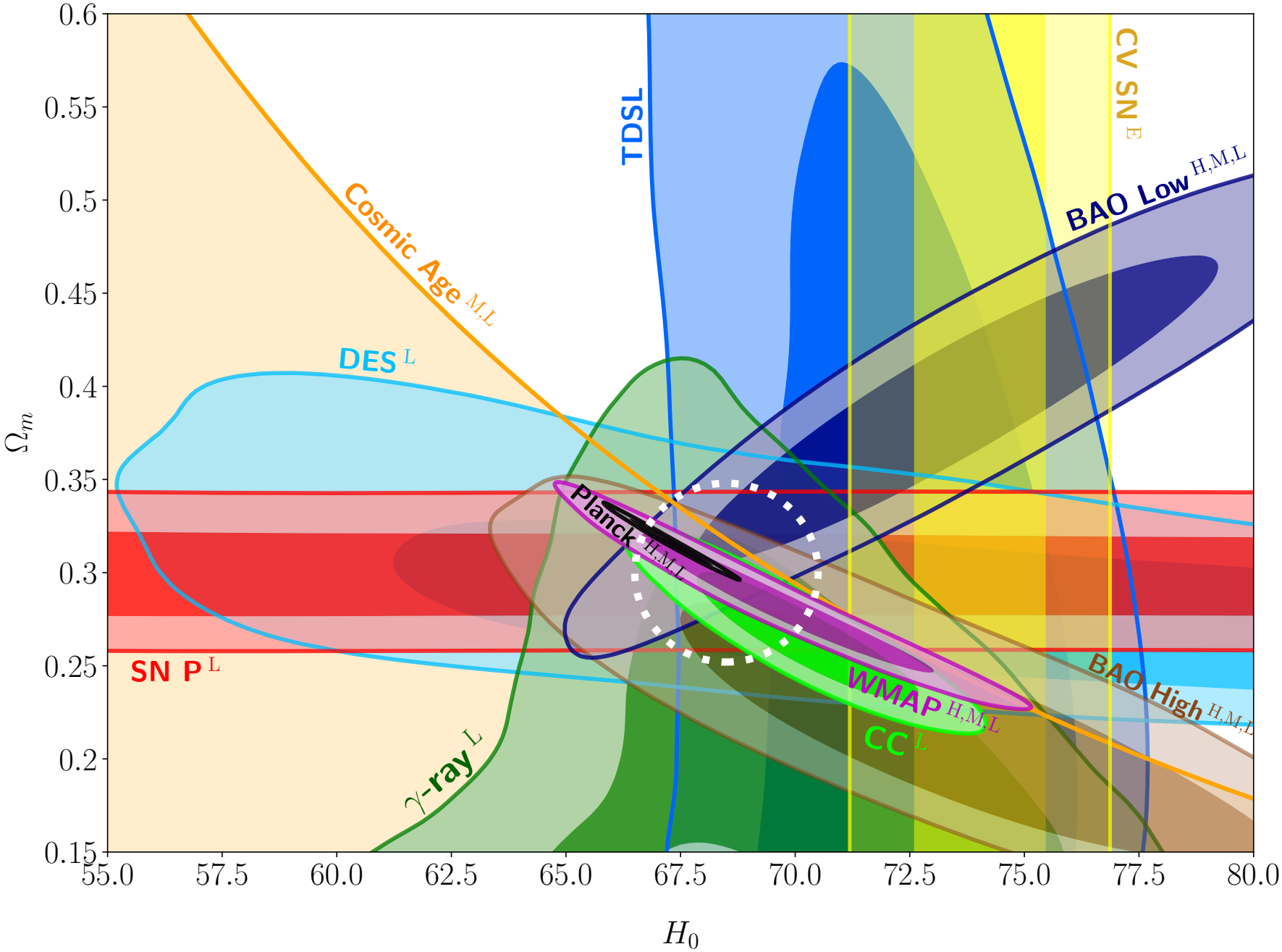
Figure from Verde, Treu and Riess 2019, *Tensions between the Early and the Late Universe,* summary of KITP conference

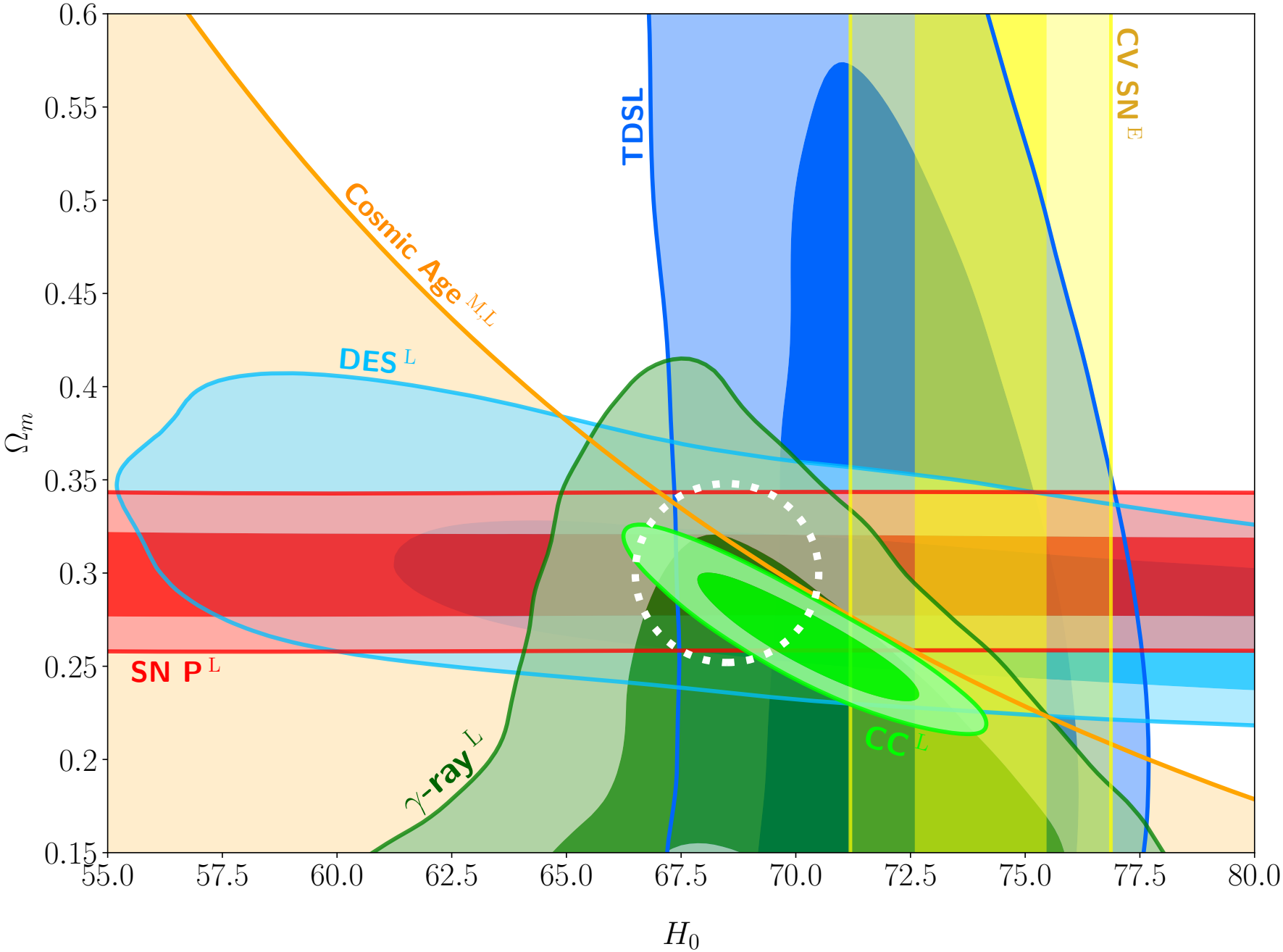
Solution: plot individually in H_0-$\boldsymbol{\Omega}_m$ plane

Advantages:

1. Constraints are presented as independently as possible
2. Constraints not need to be strong on H_0 (e.g., single-sided constraints)
3. Compatibility can be viewed in a more robust way
4. Effectively see whether a nonstandard model can reconcile all




TDSL
CV SN E
Cosmic Age M,L
BAO Low H,M,L
DES L
Planck H,M,L
SN P L
WMAP H,M,L
BAO High H,M,L
CC L
γ-ray L
Ω_m
H_0
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
55.0
57.5
60.0
62.5
65.0
67.5
70.0
72.5
75.0
77.5
80.0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75.0
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80.0

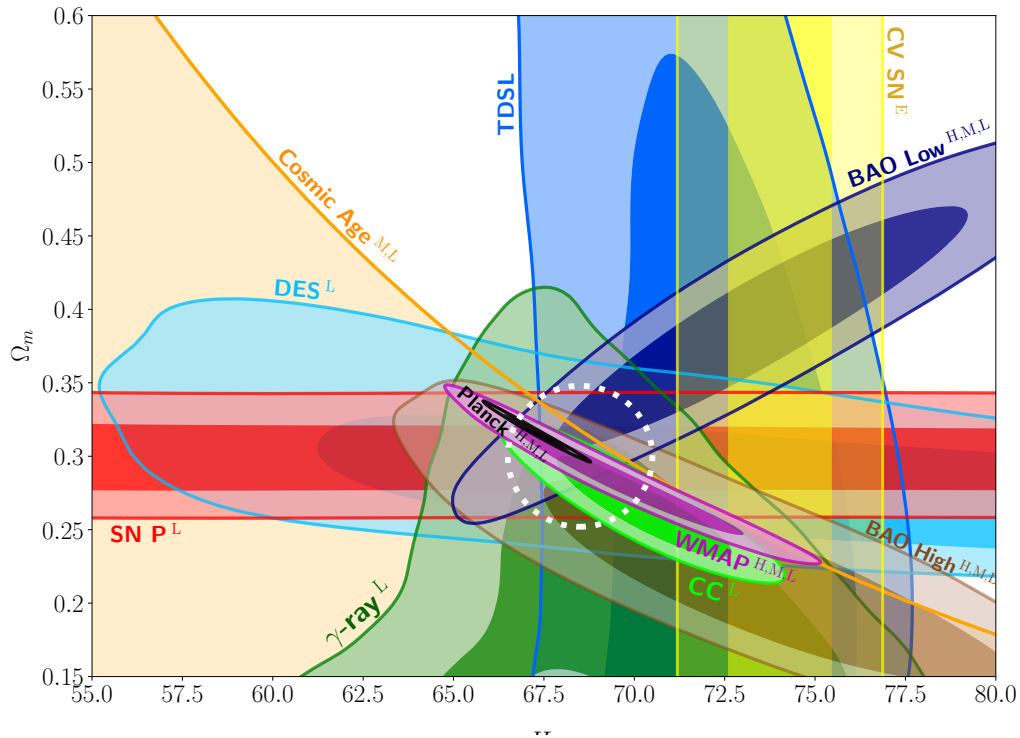
Good to find a numerical way to compare:

Multi-dataset **Index of Inconsistency**:
(Lin & Ishak 2017)

$$\mathrm{IOI}^{(N_\mathrm{d})} = \frac{1}{N_\mathrm{d}}\left(\sum_{i=1}^{N_\mathrm{d}} \boldsymbol{\mu}_i^T \boldsymbol{C}_i^{-1} \boldsymbol{\mu}_i - \boldsymbol{\mu}^T \boldsymbol{C}^{-1} \boldsymbol{\mu}\right),$$

& the associated **Outlier Index**:
(Lin & Ishak 2019)

$$\mathcal{O}_j \equiv \frac{1}{2}\left[N_\mathrm{d}\mathrm{IOI} - (N_\mathrm{d}-1)\mathrm{IOI}^{(j)}\right]$$



(IOI) & $\mathcal{O}_j$	CV SN	Planck	BAO (L)	BAO (H)	others
All (3.21)	7.63	3.91	2.16	1.41	<1.1
~~CV SN~~ (1.87)	N/A	1.97	1.46	1.63	<1.5
~~WMAP~~ (3.54)	7.80	3.80	2.09	1.43	<1.1
TRGB ~~CV SN~~ (1.75)	N/A	2.17	1.54	1.59	<1.4

Conclusions:

- Very beneficial to compare constraints individually in H_0-$\boldsymbol{\Omega}_m$ plane;
- Most constraints consistently overlap in some common region along different degeneracy directions;
- The local measurement(s) is the main driver of the tension;
- Hard for high-, mid- or low-z models to reconcile all constraints as they stand;
- Proposals that shift the local measurement(s) are more likely than a problem with LCDM at large scales.

This work is based on Lin, Mack & Hou (2019): arXiv **tomorrow morning**.

For more on IOI:
Lin & Ishak (2019), submitted to JCAP, arXiv:1909.10991;
Lin & Ishak (2017), PRD, 96, 023532, arXiv:1707.01072.