Panel Discussion: Time-Delay Cosmography

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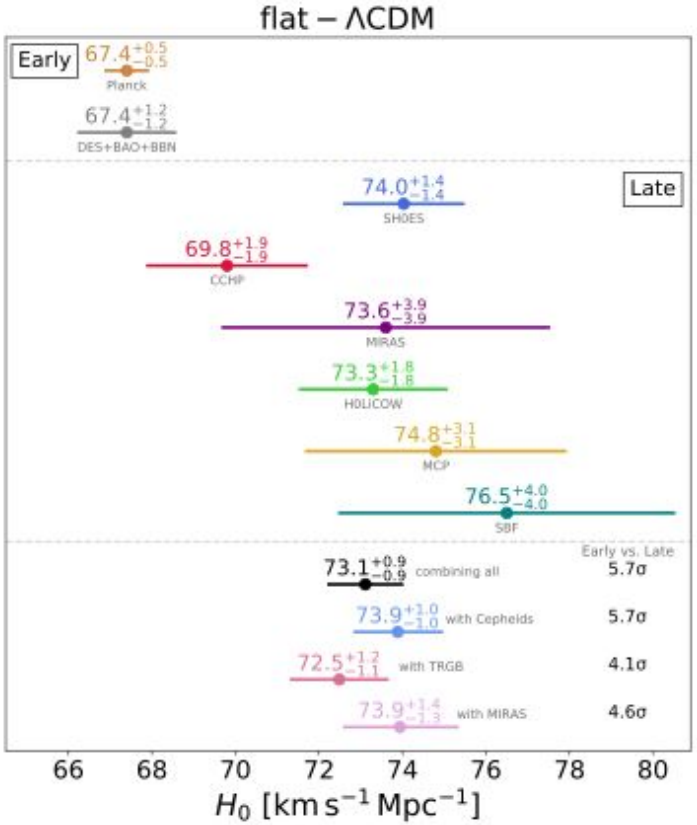
Topics

1. Competitive Landscape. Is time domain cosmology with strong lensing going to be competitive with other probes and what's the added value.
    a. Is it worth pursuing (one should always ask this question!)
2. If the answer to 1 is yes, what are the challenges? What the obstacles to overcome?
    a. Discovery
    b. Follow-up
    c. Modeling
3. How do we organize ourselves?
    a. Lens database (on the wish list for 20+ years) to avoid duplications/etc. How do we maintain it?
    b. Dedicated monitoring telescope
4. How do we communicate with the outside world?
    a. Lensing is still seen as "black magic" by some

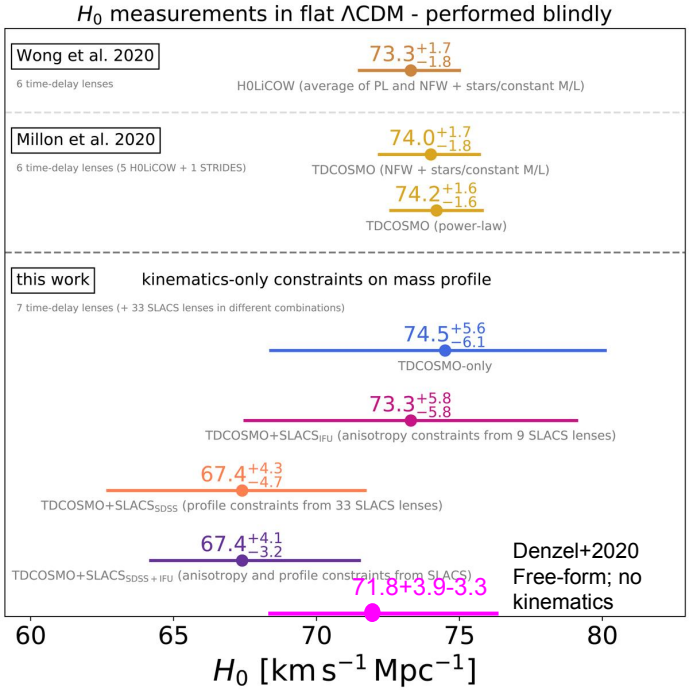
Competitive landscape. H0



Verde, Treu & Riess 2019, already out of date..

- Precision is getting to 1% (Riess et al. 2021)
- Accuracy of course is a different story. Multiple methods are needed (e.g. Denzel et al. 2000)

Competitive landscape. H0 from time delays



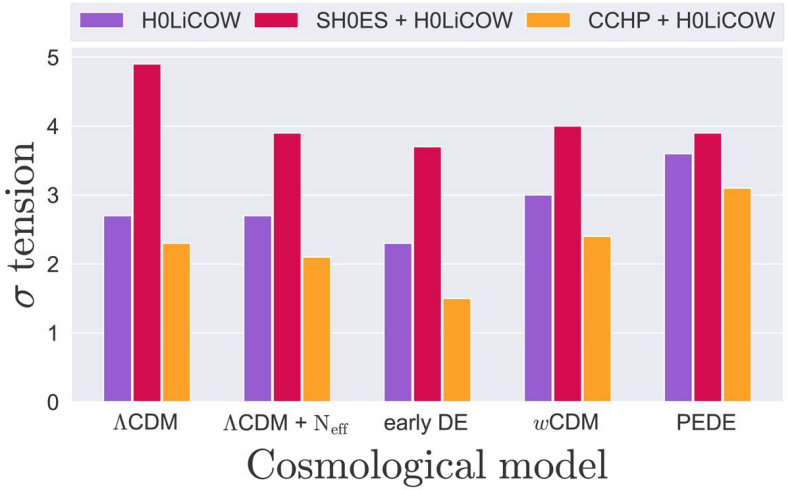
Birrer et al. 2020

Current scenario	resolution	$\delta\sigma_*/\sigma_*$	FWHM	R_{spec}/R_{eff}	N_{bin}	δH_0	+50 δH_0	+50IFU δH_0
7 TDCOSMO-5%	unresolved	5%	0.″8	-	1	8.5%	7.0%	2.7%
7 TDCOSMO+O-IFU	resolved	5%	0.″8	2	3	4.7%	2.9%	2.6%
7 TDCOSMO+AO-IFU	resolved	5%	0.″1	1	10	4.7%	3.0%	2.5%
7 TDCOSMO+JWST-IFU	resolved	3%	0.″1	2	10	3.5%	2.6%	2.6%
Future scenario							+200 δH_0	+200IFU δH_0
40 TDCOSMO-5%	unresolved	5%	0.″8	-	1	7.3%	7.1%	1.2%
40 TDCOSMO+O-IFU	resolved	5%	0.″8	2	3	2.0%	1.3%	1.2%
40 TDCOSMO+AO-IFU	resolved	5%	0.″1	1	10	2.0%	1.4%	1.2%
40 TDCOSMO+ELT-IFU	resolved	3%	0.″02	3	30	1.5%	1.2%	1.2%

Birrer & Treu 2021

- Without assumptions to break MST TDC is not competitive at the moment
- What assumptions are justified to break MST?
- If not, can we get spatially resolved kinematics fast enough?
- What about other (shape) degeneracies?

Competitive landscape. Other cosmological parameters



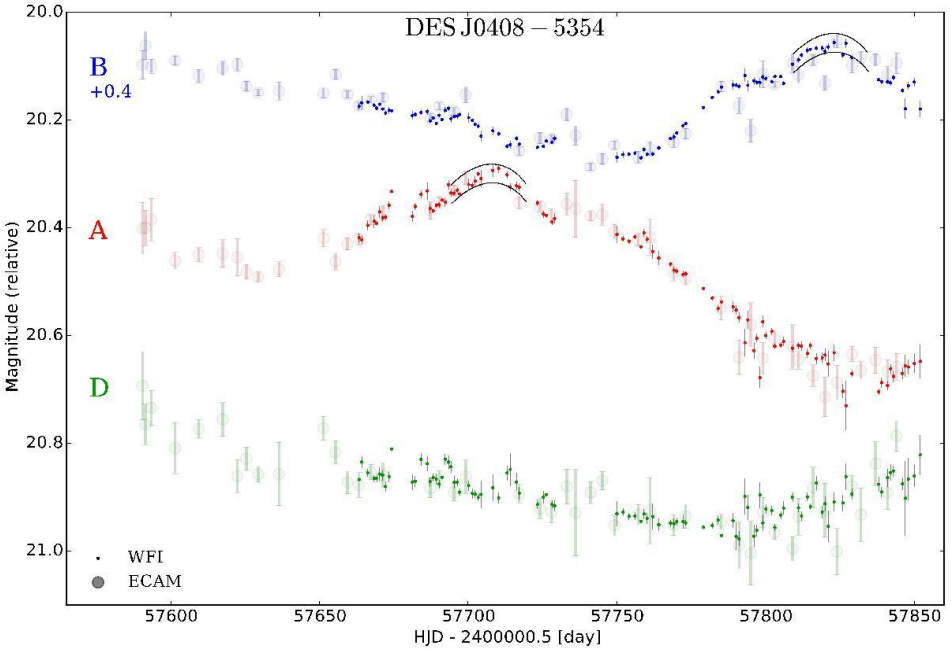
Arendse et al. 2020

- TDC gives information that is substantially different from other probes (z, etc)
- The key is to achieve sufficient precision on absolute distances (1-2%) in a timely manner

Assuming yes to Q1, what are the challenges?

1. To reach precision one needs more time variable lenses (either QSO or SN) with excellent ancillary data
    a. Monitoring (dedicated 3/4m telescope)
    b. High resolution imaging (HST/AO/JWST)
    c. High angular resolution spectroscopy (too hard for OSIRIS on Keck; needs LIGER on Keck and JWST)
2. Modeling/investigator time
    a. Still too slow to do the models. Shajib et al. (2019), Schmidt et al. (2021) and others are making progress. But we need FAST cosmography grade models

How do we organize ourselves? Dedicated monitoring telescope



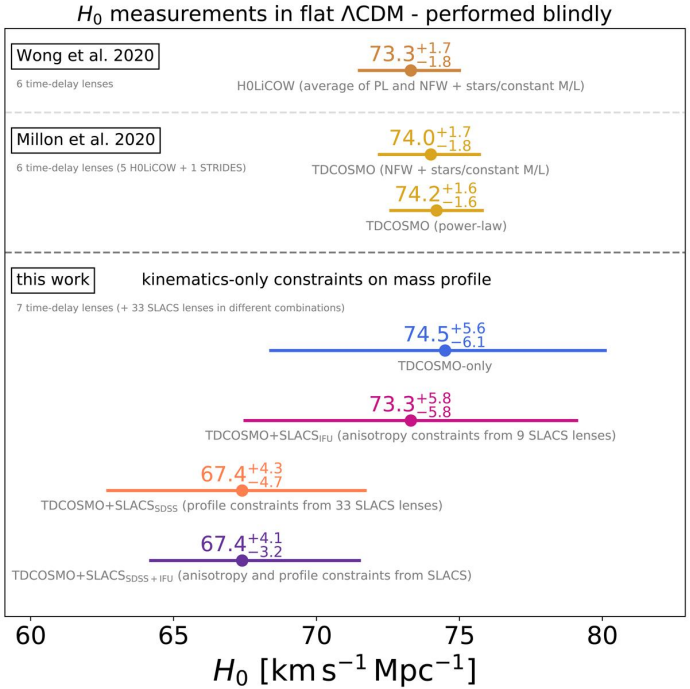
Courbin et al. 2018

- COSMOGRAIL really demonstrated the power of having control over telescopes for optimal scheduling and stability
- Several 2m class telescopes are being used (2.2m 2.6m..)
- If we want to increase samples of both QSO and SN we need a 4m or 2x3m (N+S)

How do we organize ourselves? Database

- Master Lens Database [Brownstein, Moustakas et al.] was a great initiative
- Community effort needed to keep the database up to date, but few updates to the Master Lens Database in recent years
- Thousands of lens candidates scattered in various databases, publications
  - It's not easy to check whether a lens system has been previously found/observed by others
- Dream: one database containing all the lens candidates with follow-up info
- Lemon, Vernardos et al. setting up such a new database
- How to organize ourselves to ensure this database will be up-to-date and easy to use, as we enter the era with $>10^5$ lenses?
  - Set up common standard for lens grades
  - Define minimum information required for each candidate
  - Find ways to fund and reward the effort!

How do we communicate with the outside world? Example



We spent A LOT of time writing that paper to try and be clear

Birrer et al. 2020

Typical reaction to TDCOSMO IV by non experts

How do we communicate to non experts?

The community is at best confused, at worst has given up on time delay cosmography

It’s our job to explain ourselves and convince them that what we are doing is worth understanding

How do we achieve this goal?