

# Large scale structure and new physics at the eV scale

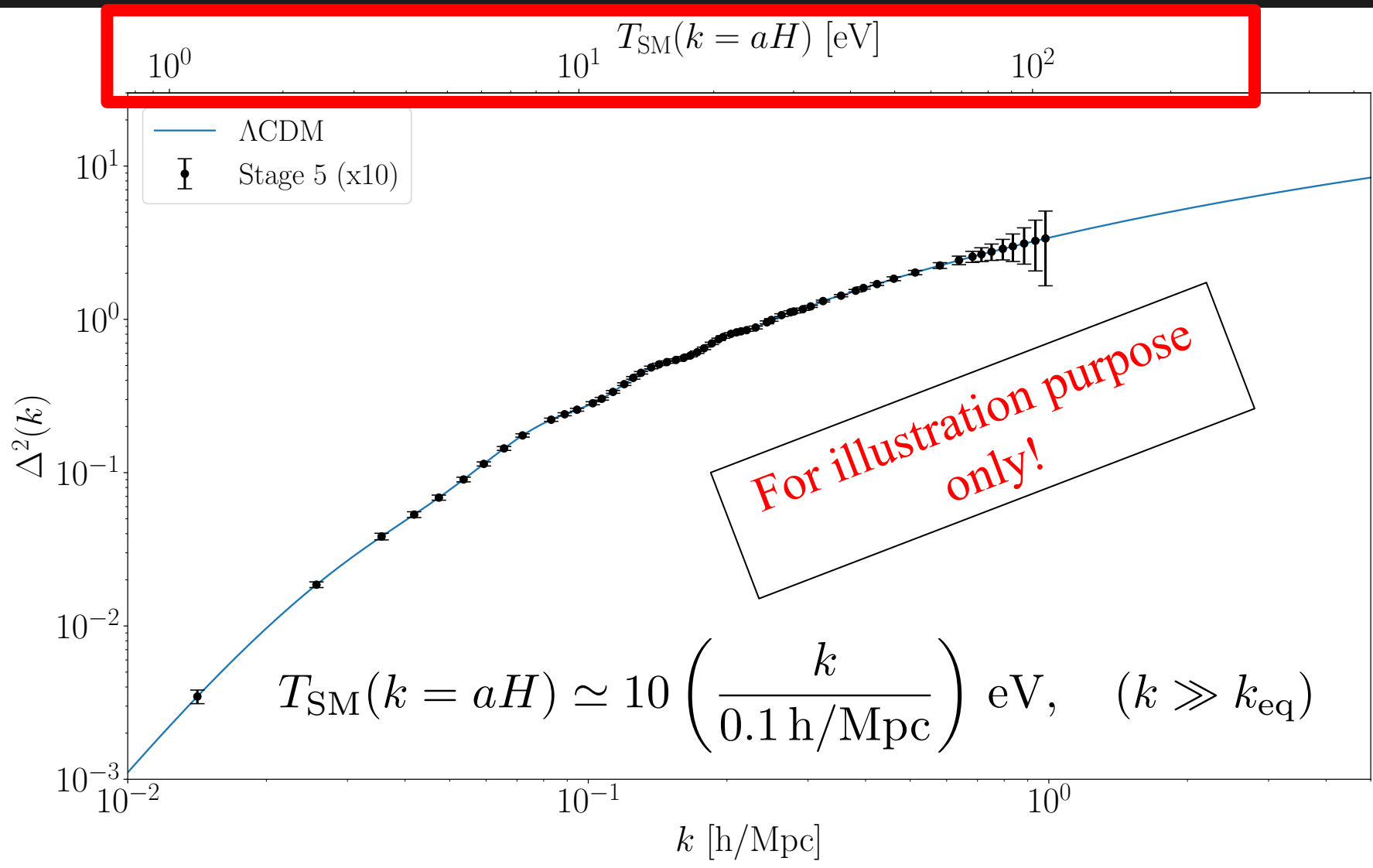
Fundamental Physics from Future Spectroscopic Surveys  
May 6-8, 2024

Francis-Yan Cyr-Racine

Department of Physics and Astronomy, University of New Mexico

**...and some random thoughts about Spec-S5  
and new physics**

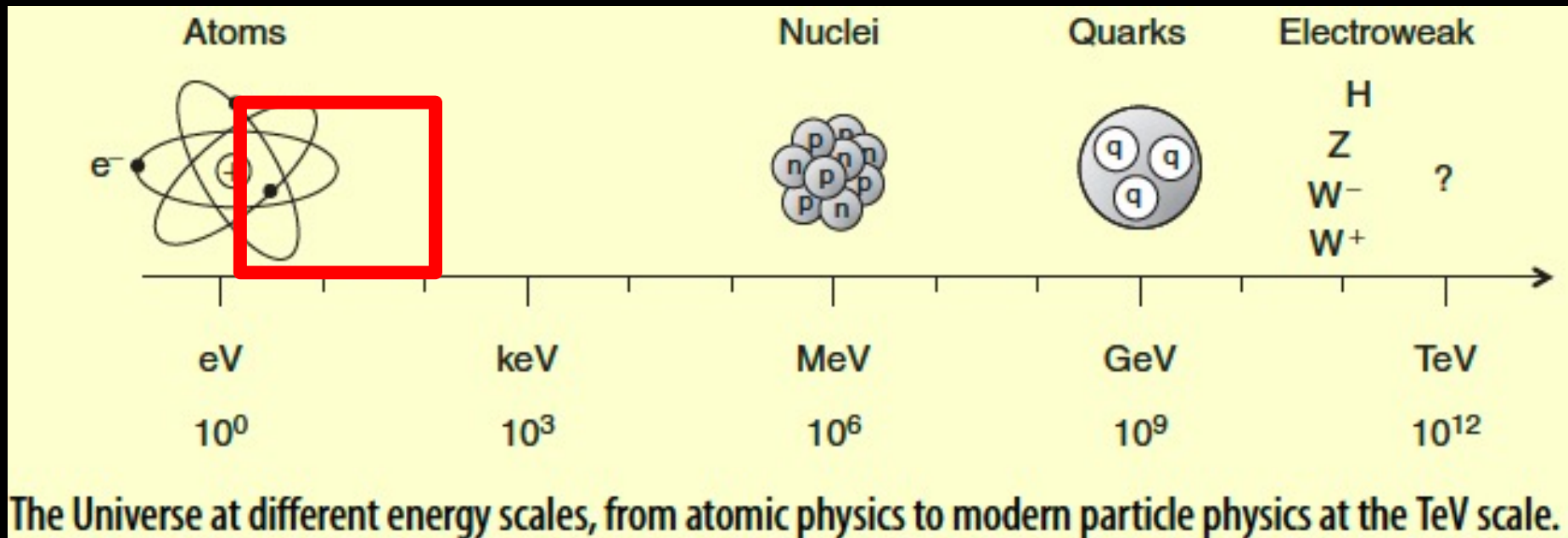
# LSS and Physics at 1-100 eV



# No Standard Model physics known in this regime



See e.g. Aloni et al. (2022), Joseph et al. (2023), Aloni et al. (2023), Buen-Abad (2023ab), Giovanetti et al. (2024), Allali et al. (2024)

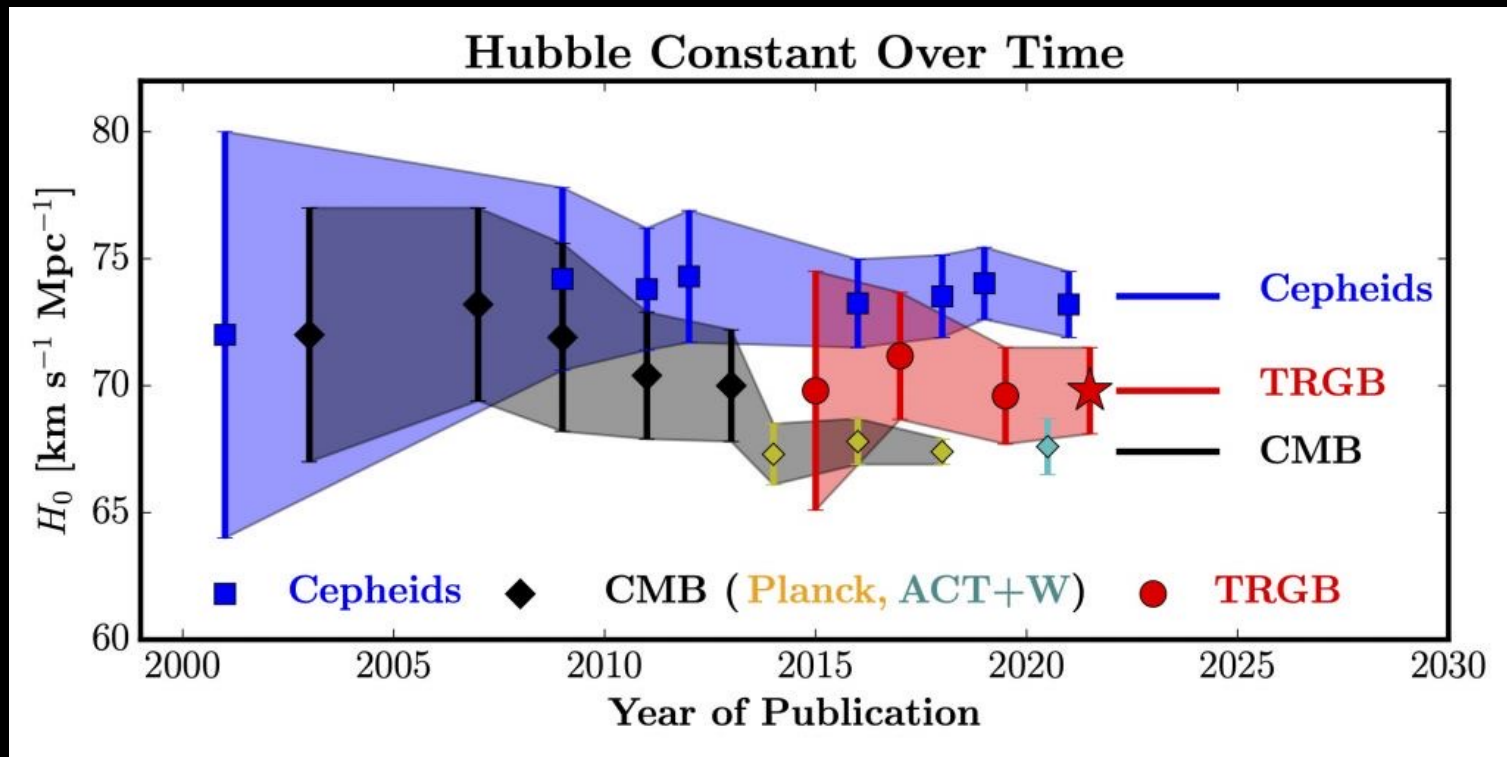


The Universe at different energy scales, from atomic physics to modern particle physics at the TeV scale.

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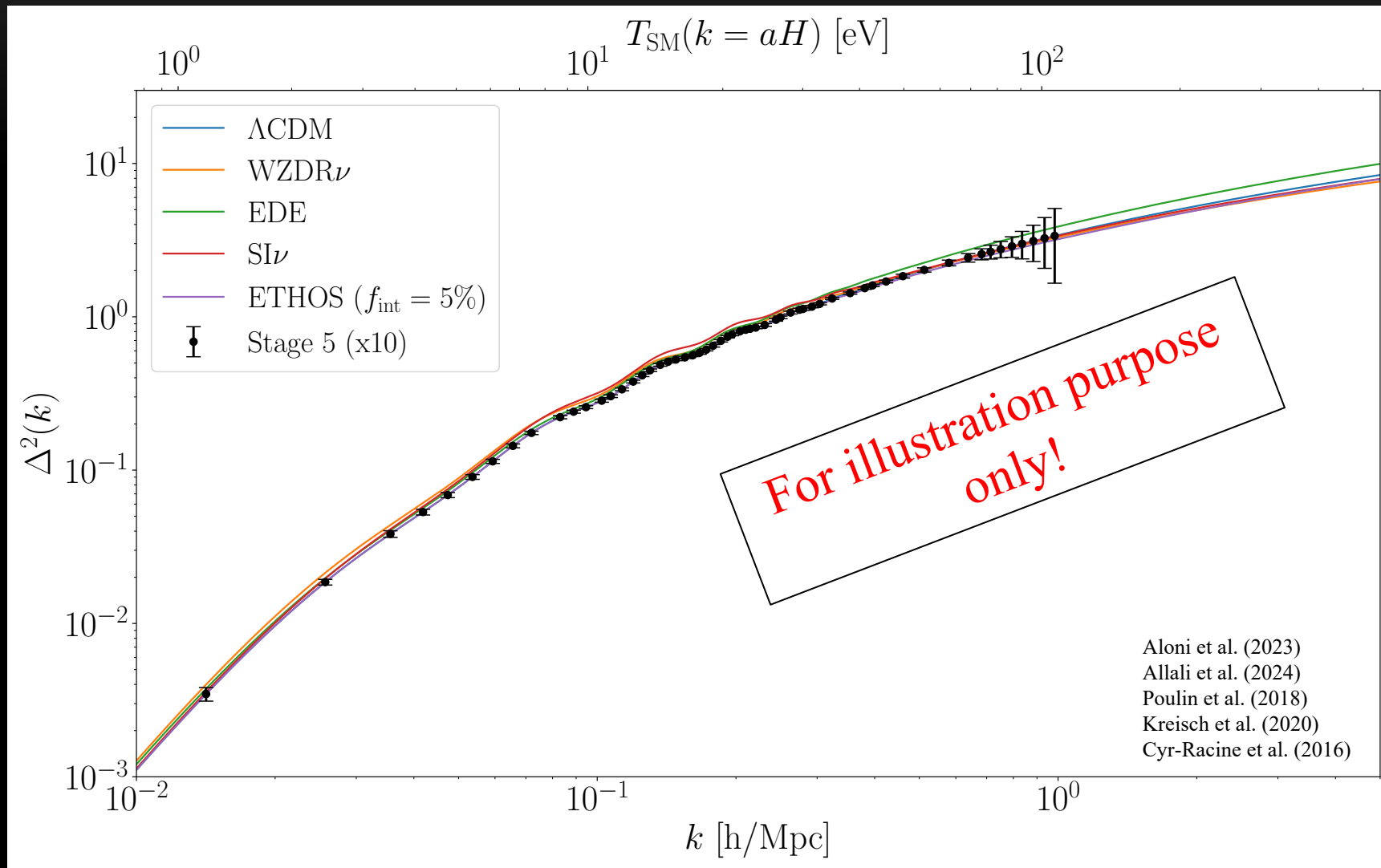
# The Hubble tension (?)

- Ongoing discrepancy between CMB-based and distance ladder measurements of the Hubble constant.

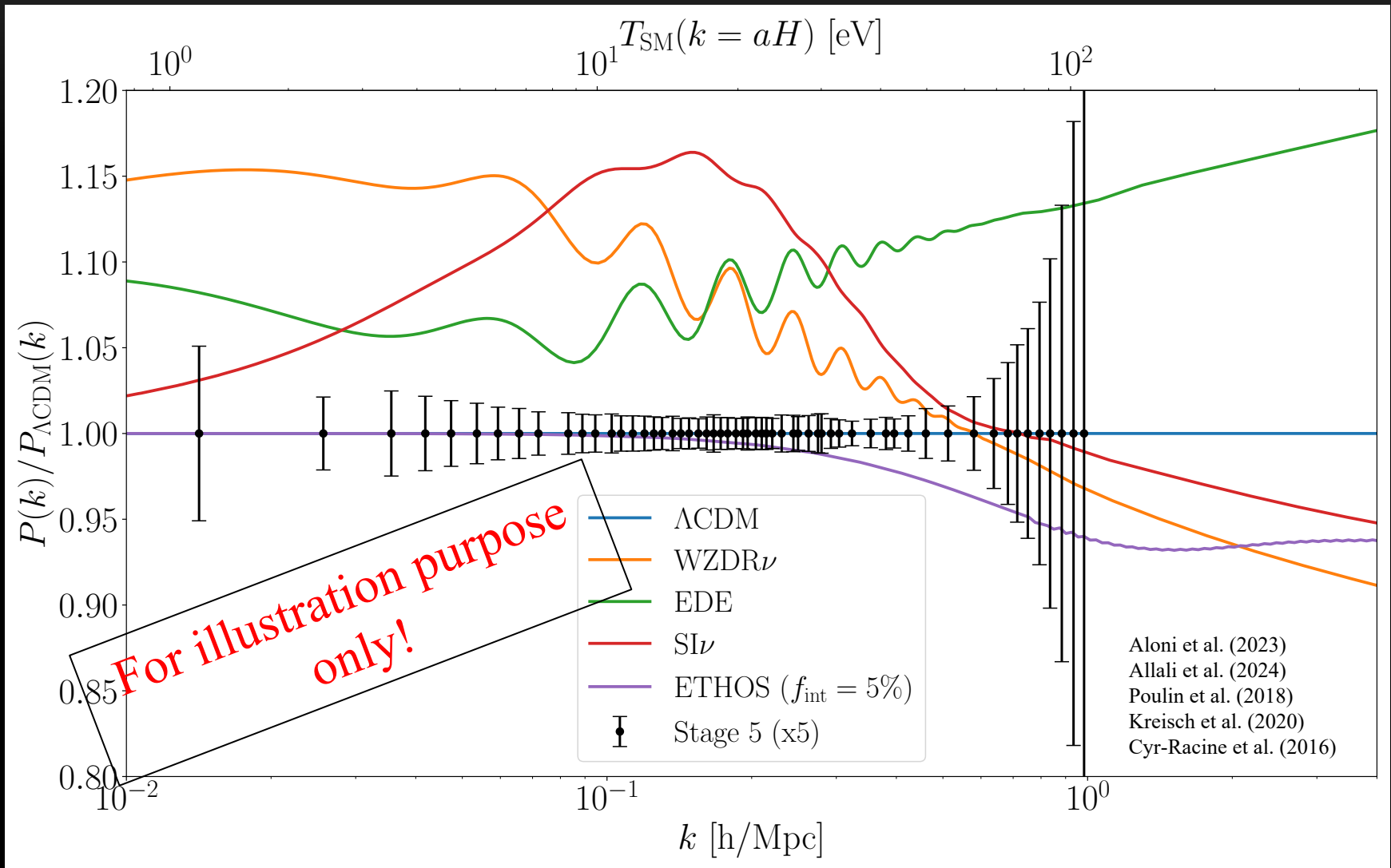


Wendy Freedman

# Spec-S5 and cosmic evolution at the eV scale



# Spec-S5 and cosmic evolution at the eV scale



# Spec-S5 and cosmic evolution at the eV scale

- “Intermediate scale” physics (i.e. not primordial nor late times) can imprint 10-15% deviations on matter clustering.
  - => Discovery space for Spec-S5!
- Such effects are often folded under the “light relics” science case, but diversity of matter power spectrum shapes much greater.
- For those models leaving the late Universe largely unchanged, EFT techniques developed for  $\Lambda$ CDM should be applicable.
  - => Tractable analyses!
- Can yet unknown cosmic evolution at the  $\sim 1-100$  eV scale sow confusion on our inference of inflationary physics (e.g. search for primordial features, etc.)??

# Spec-S5 and dark matter

2023 P5 report

- While not a design driver, there are **important opportunities for dark matter** with Spec-S5.
- However, we need to better **flesh out** the dark matter science cases to make sure these are not missed!

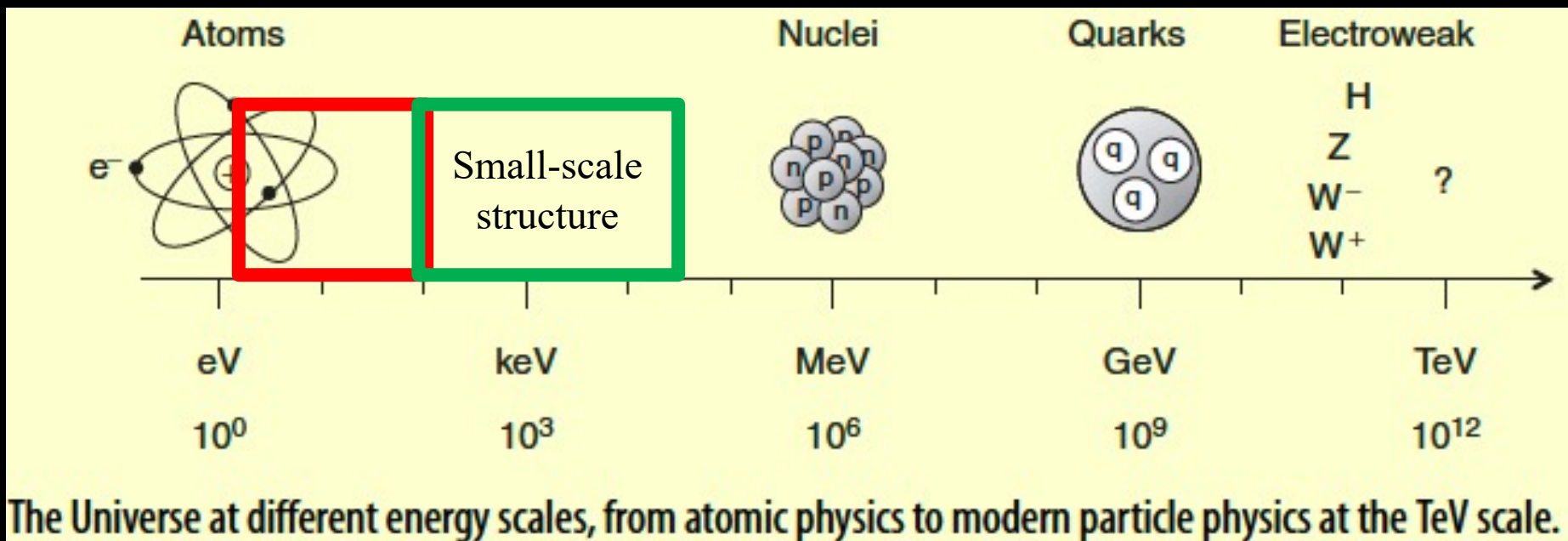
Figure 1 – Program and Timeline in Baseline Scenario

**Index:** ■ Operation ■ Construction ■ R&D, Research P: Primary S: Secondary  
 § Possible acceleration/expansion in more favorable budget situations

Science Experiments	Timeline	2024	2034	Science Drivers						
				Neutrinos	Higgs Boson	Dark Matter	Cosmic Evolution	Direct Evidence	Quantum Imprints	Astronomy & Astrophysics
LHC					P	P		P	P	
LZ, XENONnT						P				
NOvA/T2K				P				S		
SBN				P				S		
DESI/DESI-II				S		S	P			P
Belle II						S		S	P	
IceCube				P		S				P
SuperCDMS						P				
Rubin/LSST & DESC				S		S	P			P
Mu2e									P	
DarkSide-20k						P				
HL-LHC					P	P		P	P	
DUNE Phase I				P				S	S	S
CMB-S4				S		S	P			P
CTA						S				P
G3 Dark Matter §				S		P				
IceCube-Gen2				P		S				P
DUNE FD3				P				S	S	S
DUNE MCND				P				S	S	
Higgs factory §					P	S		P	P	
DUNE FD4 §				P				S	S	S
Spec-S5 §				S		S	P			P
Mu2e-II									P	
Multi-TeV §					P	P		P	S	
LIM				S		P	P			P



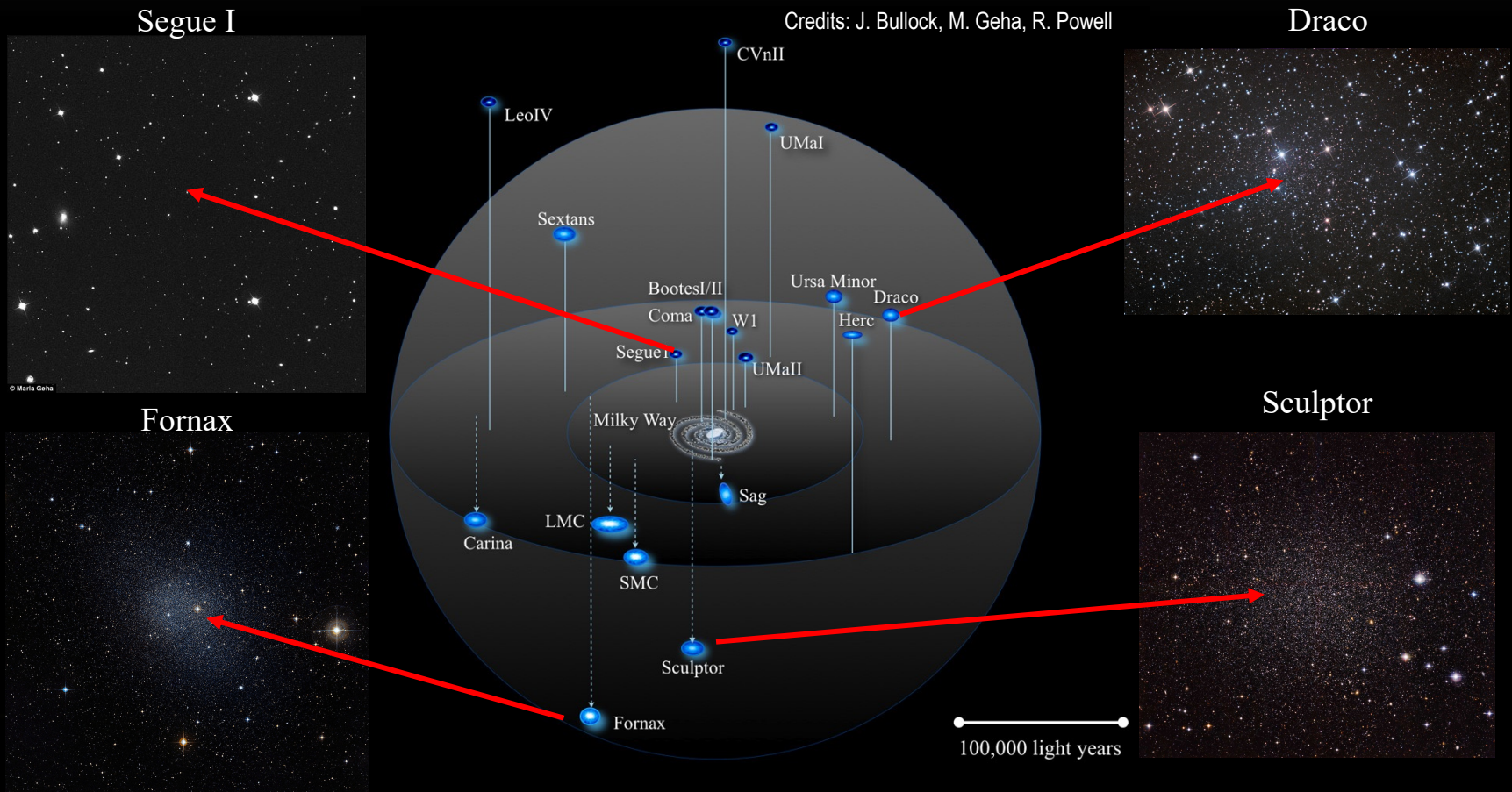
# Small-scale structure probes deeper in the desert



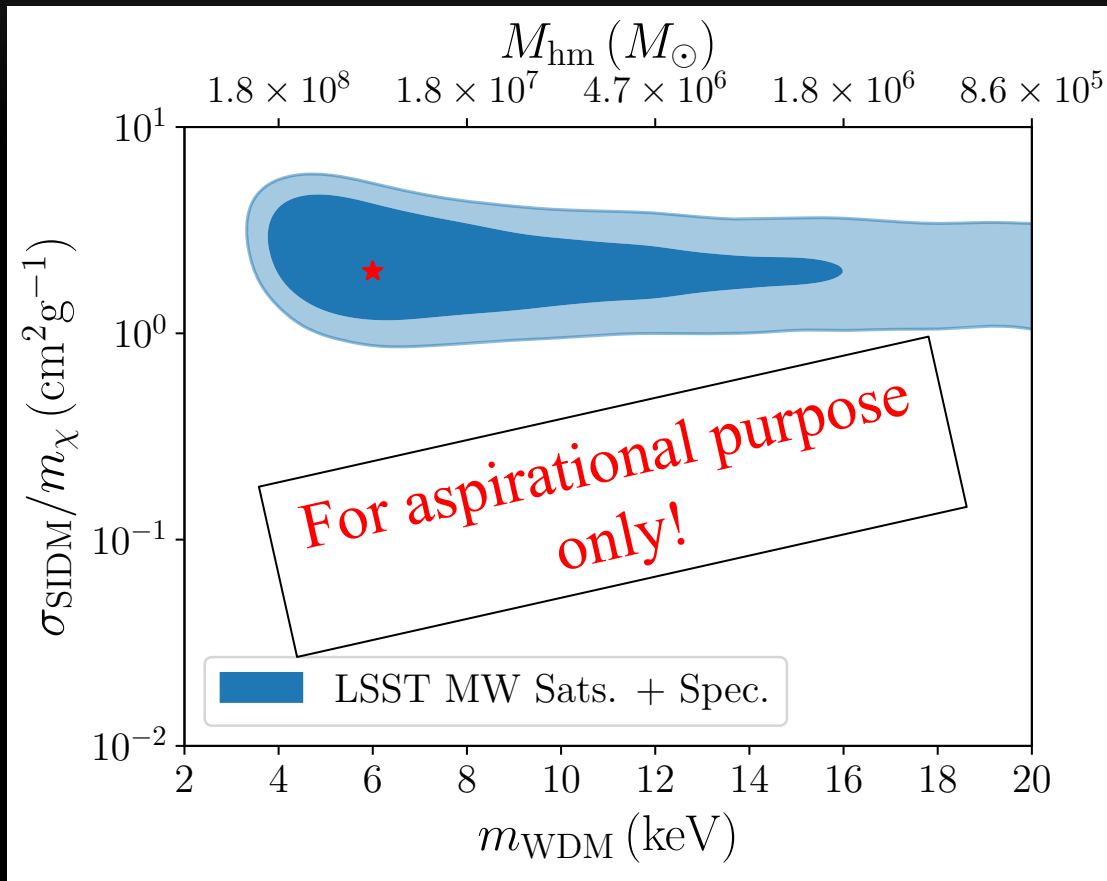
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# Small-scale structure: Milky Way

- Each of these satellites is hosted by a small dark matter subhalo



# While challenging to model, spectroscopic data are key to extract DM constraints from local structure



Much work remains to be done to fully capture the complexity of the data. **This work needs to happen now.**

See Ethan's talk this afternoon.

Drlica-Wagner et al. (2019)

# Important Take-Home Messages

- Beyond inflationary and late-time physics, Spec-S5 has **great potential to probe cosmic evolution in the  $\sim 1\text{-}100\text{ eV}$  regime with LSS, and in the  $\sim 0.1\text{-}50\text{ keV}$  regime with the distribution of dark matter on small scales.**
- LSS analyses of such models can (for the most part) **leverage all the work done in the  $\Lambda\text{CDM}$  context.**
- While challenging, there is an **urgent need to better flesh out the dark matter science case** for Spec-S5, in the context of early science results from DESI and Rubin.