Curiosity, Community, and Cosmology

A PhD Story

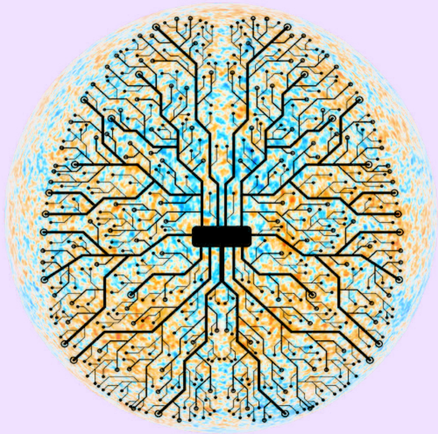
Sinah Legner, July 29th

Who am I ?

Sinah Legner

- Third year PhD student
- Astrophysics group, Cavendish Laboratory
- Supervisors: Will Handley, Will Barker

Handley lab



handley-lab.co.uk

- Exploring the Universe using tools from **Bayesian statistics**, **AI**, and **Machine Learning.**
- **Research Area:**
  - Early Universe & Inflation
  - Dark Energy & Dark Matter
  - 21-cm Cosmology & the Epoch of Reionisation
  - Gravitational Wave Astrophysics
- **Softwares:** PolyChord, anesthetic, margarine, GLOBALEMU, maxsmooth, fgivenx, and nestcheck

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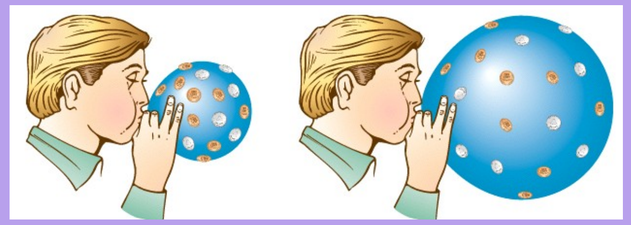
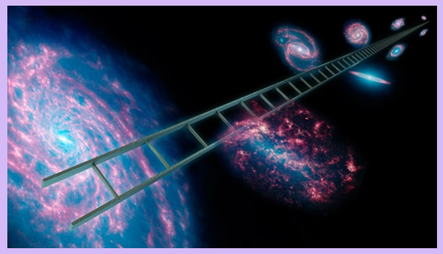
July 29th 2025

My research - an overview

Cosmological Tensions: H_0



H_0 - Rate of expansion of the Universe today

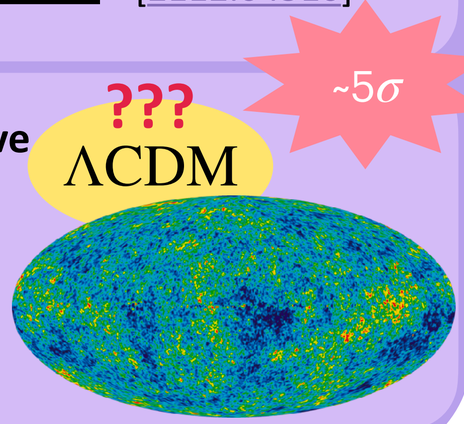


Supernovae observations

$H_0 = 73.2 \pm 1.3$ km/s/Mpc. [2112.04510]

Cosmic microwave background

$H_0 = 67.4 \pm 0.5$ km/s/Mpc. [1807.06209]



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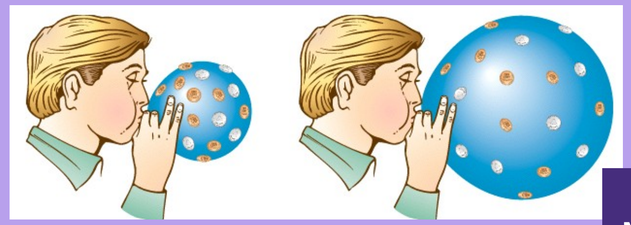

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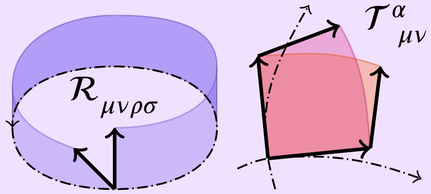
Motivates

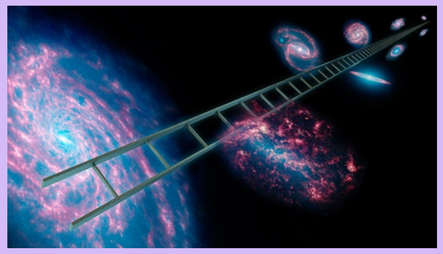
Exploration of different theories of gravity

Poincaré gauge theory

Torsion Condensation (TorC)

$$\mathscr{L} \propto R^2 + T^2$$





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~5σ

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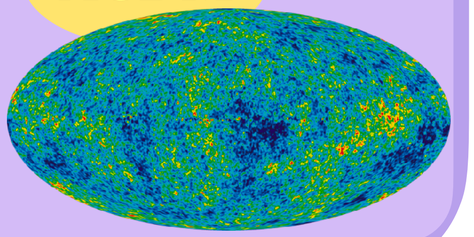
ΛCDM



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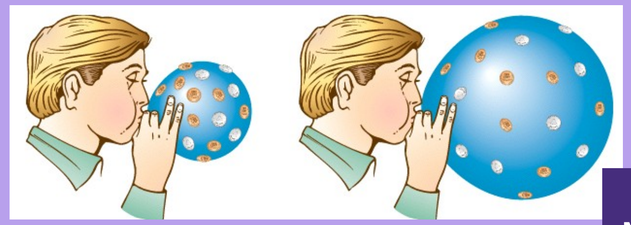

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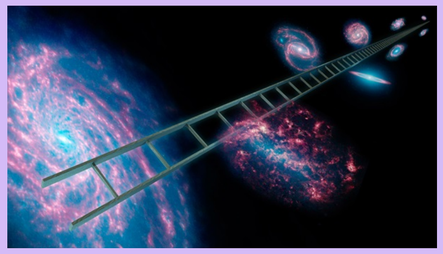

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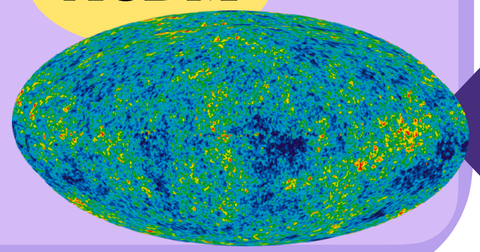

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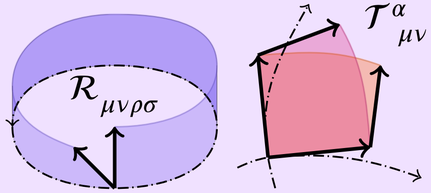
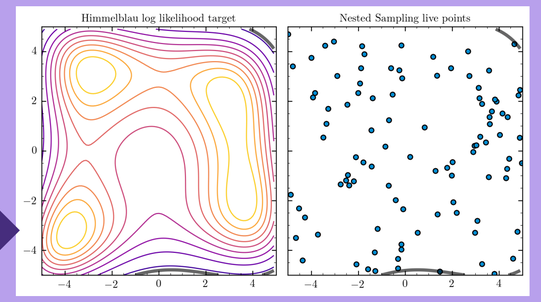
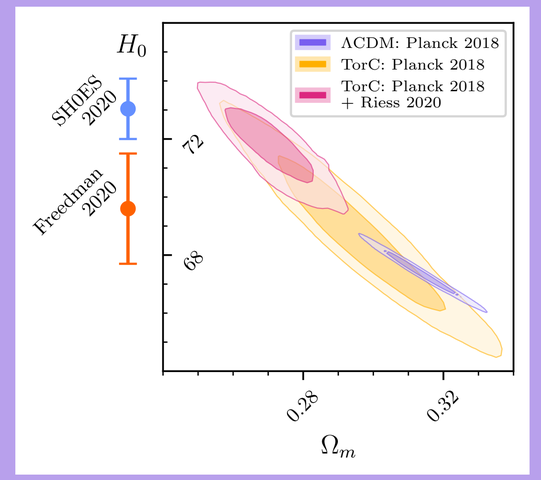


Analysis

Constraining TorC parameters





Using Bayesian inference and model comparison with ΛCDM

Alleviates Tension?

ArXiv: 2507.09228

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Life at the department - CUWPS

CAMBRIDGE UNIVERSITY WOMEN IN PHYSICS SOCIETY

Fostering a community for minorities within the physics department

www.cuwps.com

Instagram: cu_wps

^ International Women's Day 2025

^ CUWPS 10-year anniversary dinner at Churchill College

< Coffee hour every Monday

< Start of semester Pizza Social

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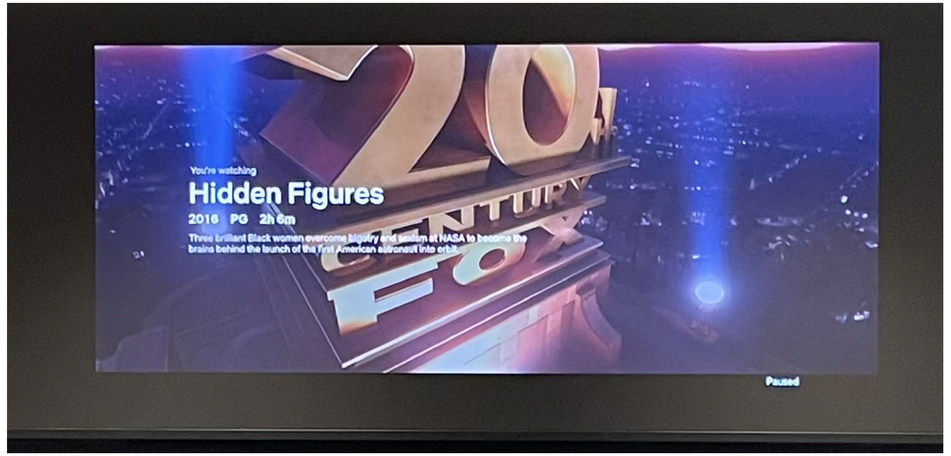
Life at the department - Social

- Different research groups have different ways of social
- Going out for drinks and dinner
- Going to lunch together as a group
- Battcock: Christmas pub quizzes organised by first year PhDs

^ Christmas tree decoration DIY event (CUWPS)

^ Battcock Centre Halloween coffee



Movie screening of *Hidden Figures* > part of International Women's Day celebrations (GSCC + CUWPS)

Life at the department - Academic

- There are often talks/ colloquia/seminars going on
- Usually followed with drinks, coffee or snacks
- Some talks will come with free lunch or dinner
- Undergraduate supervisions
- You can get involved with talks!

^ PhD application panel discussion, given by PhD students

^ IWD talk series

Snacks after talk events! >

A day in my life

Home

Gym

(Not everyday…)

In department

- Work/learning
- Go to talks (free food)
- Lunch with friends
- Debugging
- Meeting with supervisor
- Group meeting
- Coffee break/talk to friends
- Giving a talk/report/ supervision

Outside department

- Do more work
- Food with friends
- Playing dnd
- Formal dinner (term time)
- Watching a movie
- Society
- Marking supervision work (term time)

Thank you!

PGT Lagrangian

PGT Lagrangian is obtained via enforcing local Poincare transformation.

$$\mathcal{L}_{\mathrm{PGT}} = h^{-1}\left[L_{\mathcal{R}^2} + \kappa^{-1}\left(L_{\mathcal{R}} + L_{\mathcal{T}^2} + L_{\Lambda}\right) + L_m(\Phi, \Psi; h, A)\right]$$

$$\begin{aligned}
L_{\mathcal{R}} &= -\frac{1}{2}\alpha_0 \mathcal{R}, \\
L_{\Lambda} &= -\Lambda, \\
L_{\mathcal{R}^2} &= \alpha_1 \mathcal{R}^2 + \alpha_2 \mathcal{R}_{ab}\mathcal{R}^{ab} + \alpha_3 \mathcal{R}_{ab}\mathcal{R}^{ba} + \alpha_4 \mathcal{R}_{abcd}\mathcal{R}^{abcd} + \alpha_5 \mathcal{R}_{abcd}\mathcal{R}^{acbd} \\
&\quad + \alpha_6 \mathcal{R}_{abcd}\mathcal{R}^{cdab}, \\
L_{\mathcal{T}^2} &= \beta_1 \mathcal{T}_{abc}\mathcal{T}^{abc} + \beta_2 \mathcal{T}_{abc}\mathcal{T}^{bac} + \beta_3 \mathcal{T}_a \mathcal{T}^a.
\end{aligned}$$

Gauge Fields:

h_a^{μ} Translational

A_{μ}^{ab} Lorentz

Field Strength Tensors:

$$\mathcal{R}^{ab}{}_{cd} = 2h_c{}^{\mu} h_d{}^{\nu}\left(\partial_{[\mu} A^{ab}{}_{\nu]} + A^{a}{}_{e[\mu} A^{ae}{}_{\nu]}\right),$$

$$\mathcal{T}^{a}{}_{bc} = -2b^{a}{}_{\mu} D_{[b} h_{c]}{}^{\mu}.$$

Bayesian Inference and Nested Sampling

Parameter Estimation:

- What does data tell us about parameters?
- $P(\theta \mid D, M) = \dfrac{P(D \mid \theta, M)P(\theta \mid M)}{P(D \mid M)}$

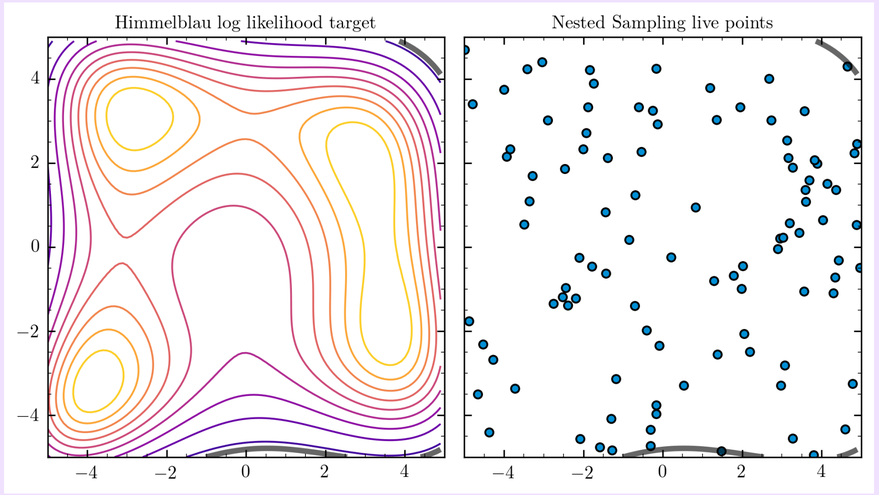
P - posterior
L - likelihood
π - prior
Z - evidence

Model Comparison:

- How much does data support the model?
- $P(M \mid D) = \dfrac{P(D \mid M)P(M)}{P(D)}$
- Higher evidence favours a model
- Penalises complexity

Nested Sampling:

- Computes evidence directly
- Handles multimodal posteriors



Gif from David Yallup

- **Polychord**: nested sampling algorithm tailored for high-dimensional parameter spaces. [1506.00171]

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