

# Black hole dark matter, inflation and the Higgs

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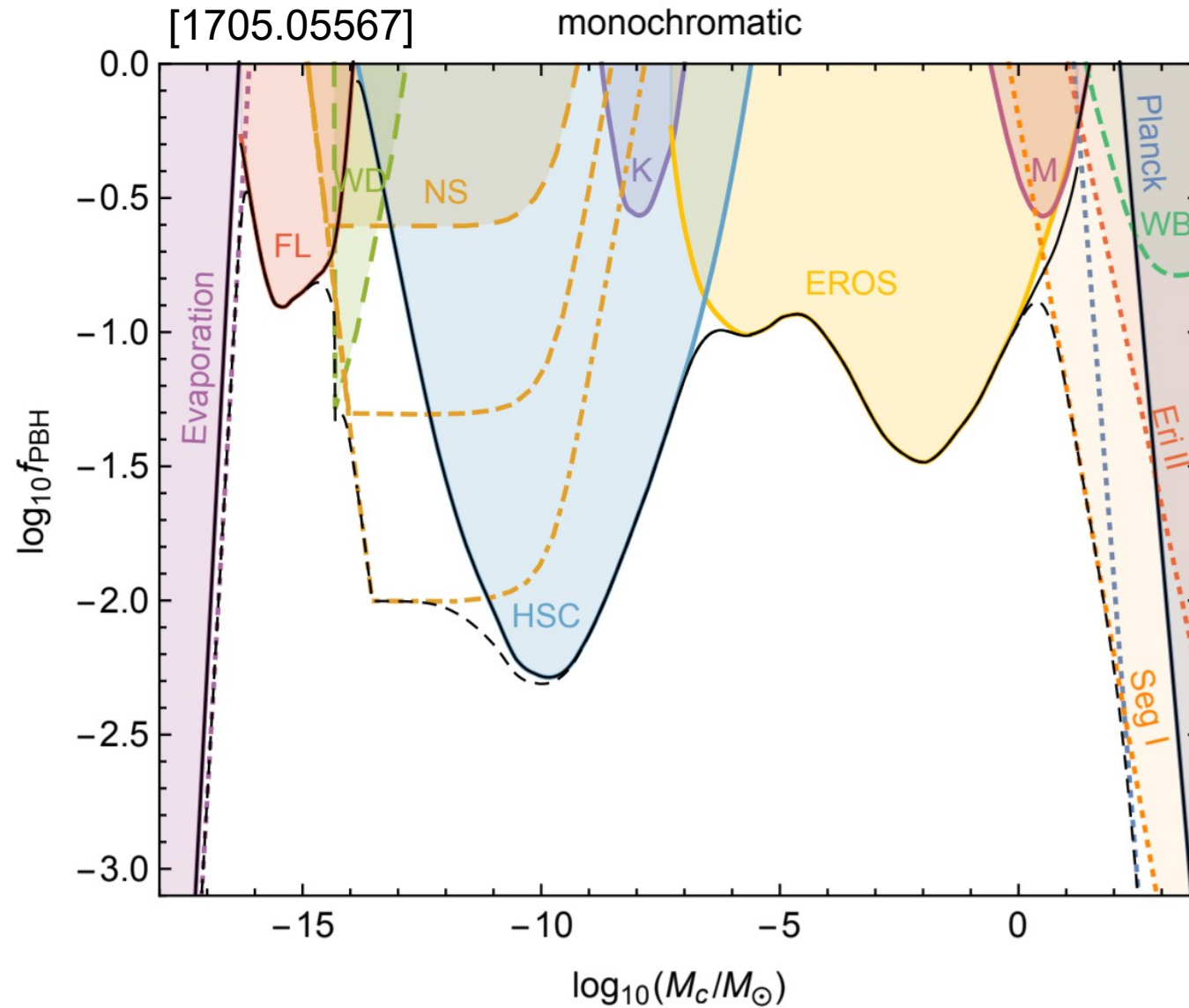
# Primordial Black Holes

- Formed in early universe
  - Phase transitions
  - Perturbations from cosmic inflation
  - Cosmic strings
  - Etc.
- Masses: from tiny to solar mass and beyond

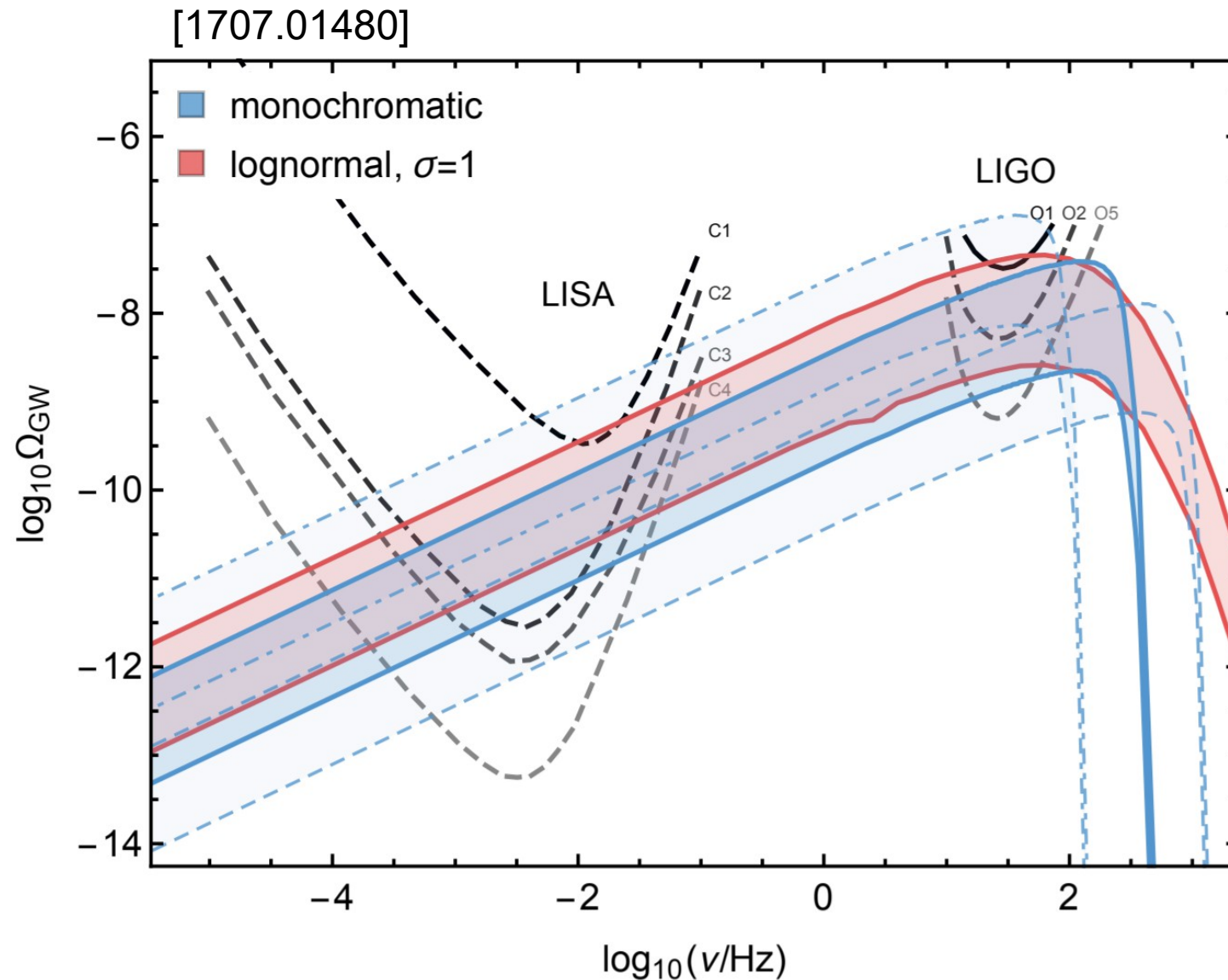
# Primordial Black Holes

- Why interesting?
  - Signal of new physics
  - Could be **dark matter**
  - Could be detected in gravitational wave experiments (LIGO, Virgo, LISA...)

# PBHs as dark matter



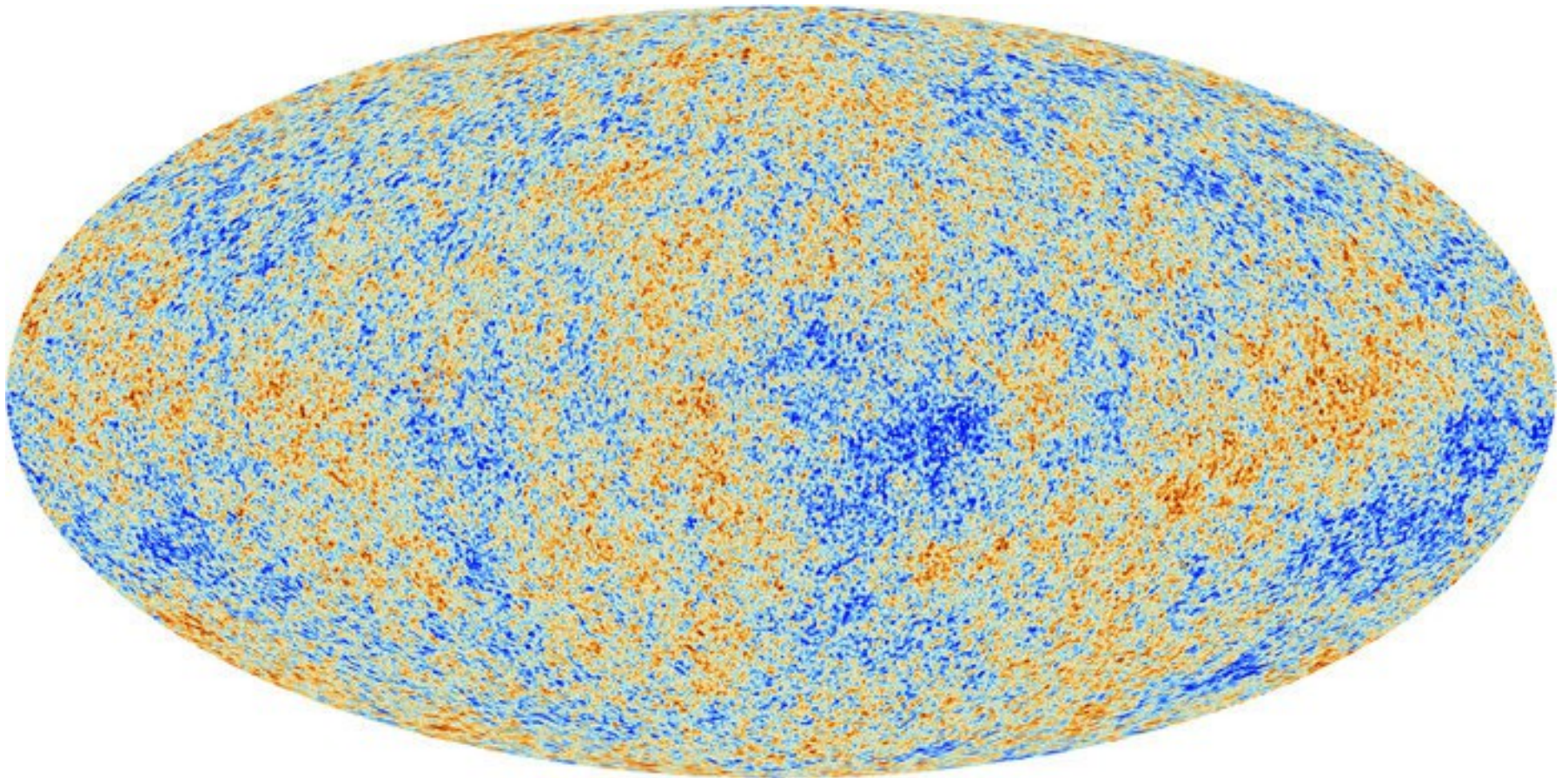
# PBHs and GW experiments





# PBHs from cosmic inflation

- Quantum fluctuations = seeds of cosmic structure



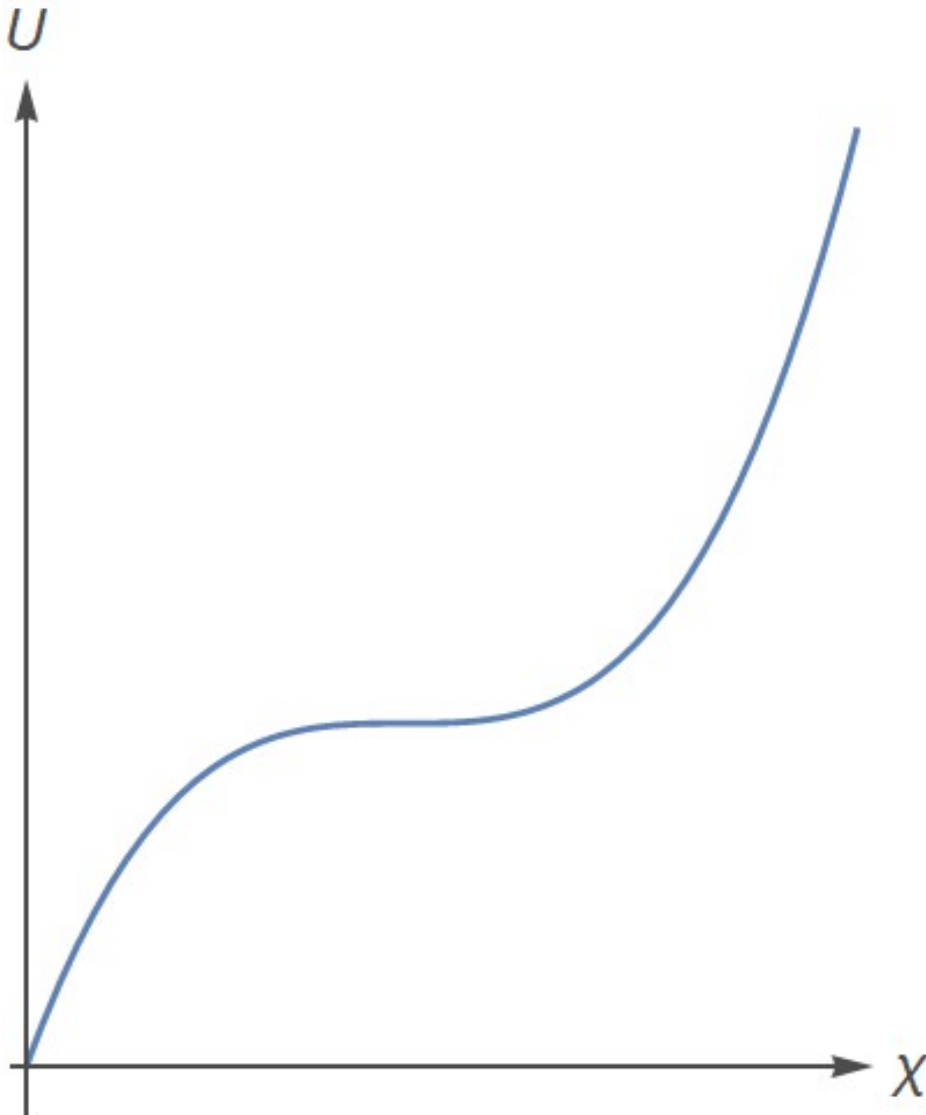
[Planck collaboration 2013]

# PBHs from cosmic inflation

- Strong perturbation at smaller scales: PBHs?
- Depends on dynamics during inflation, inflaton potential
  - Perturbations at a scale sensitive to background evolution at time of Hubble exit



# PBHs from cosmic inflation



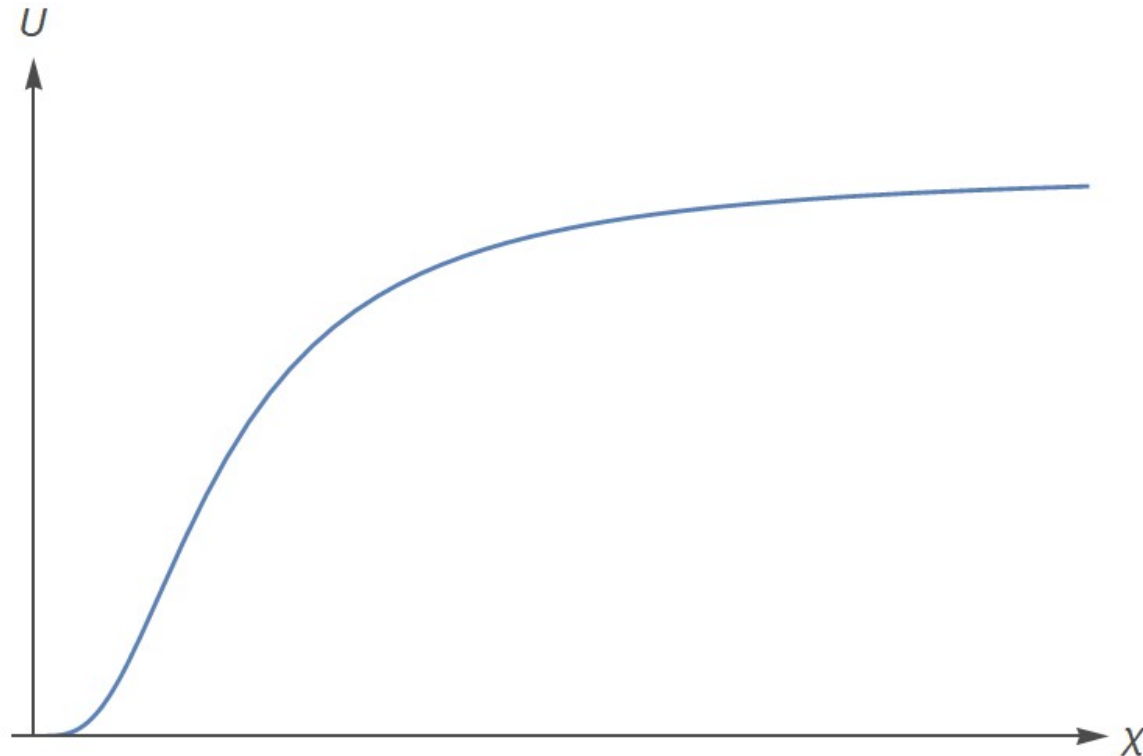
- Strong perturbations from **critical point** potential

# PBHs from cosmic inflation

- After Hubble exit: expansion prevents collapse
- After Hubble re-entry: **collapse** into PBH
  - Typically during radiation domination
- Afterwards: merger events, gravitational waves

# Higgs inflation

- **Standard model Higgs field**, coupled non-minimally to gravity, is inflaton
- Asymptotically flat potential, consistent with CMB

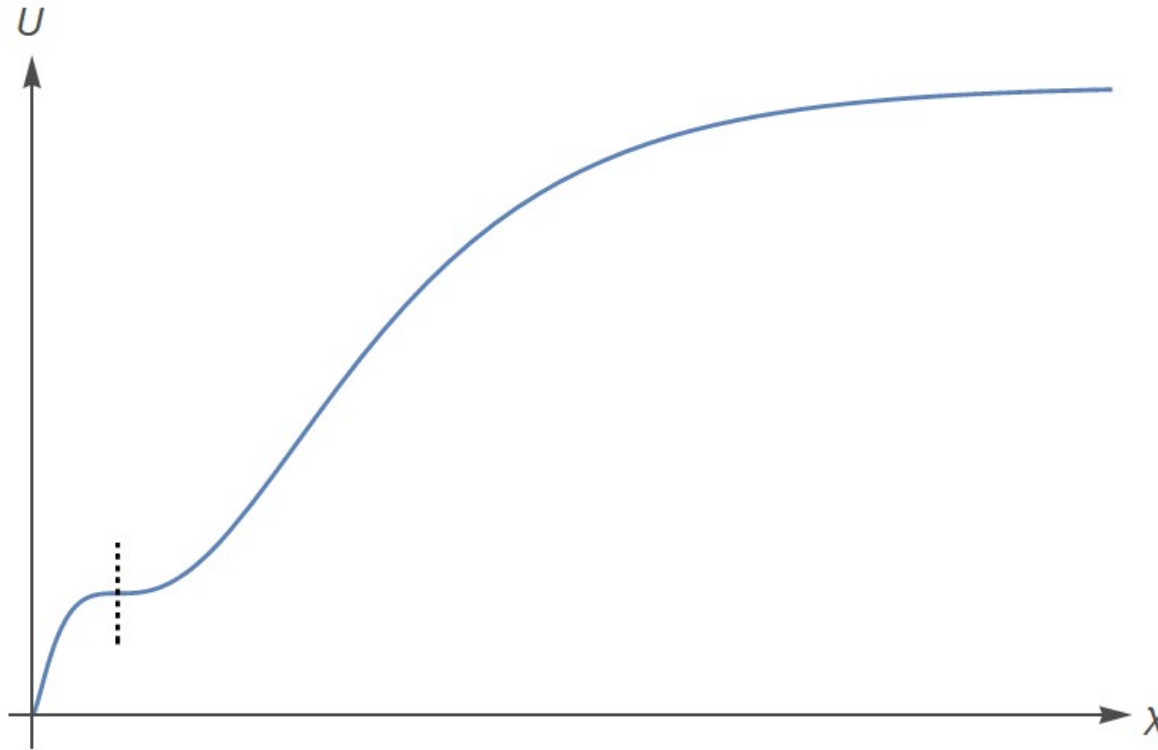


# Higgs inflation

- Many recent studies with different variations, also in Helsinki
  - [1603.07572], [1709.07853], [1802.09299], [1810.05536], [1811.09514], [1812.08754]
- **PBH** dark matter from Higgs inflation?

# PBHs from Higgs inflation

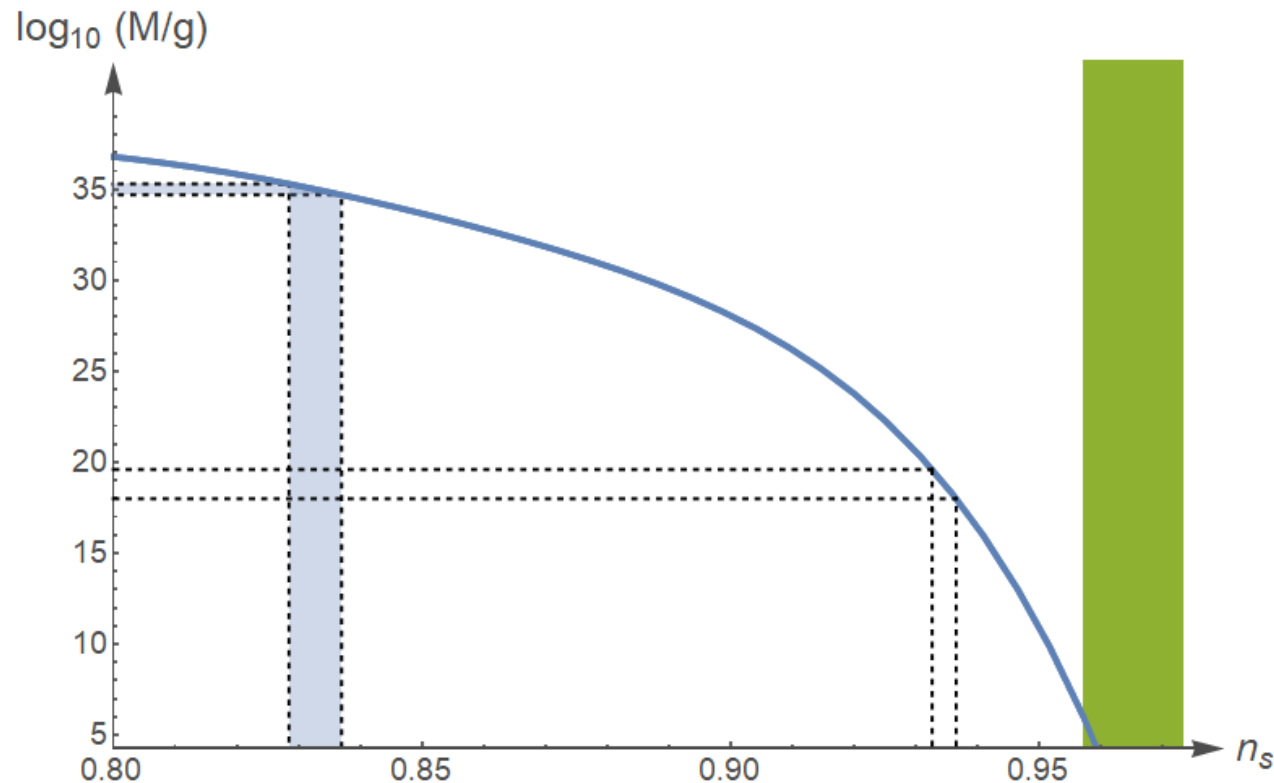
- We added quantum corrections to Higgs potential to produce a (near-)critical point



- Scan over all such potentials

# PBHs from Higgs inflation

- Fine-tuning: lots of PBHs CAN be produced...



- ...but their mass and CMB spectral index **aren't compatible!**

# Planck mass relics

- Only very light PBHs allowed by CMB
  - These evaporate by Hawking radiation
  - BUT if they leave behind Planck mass relics: these could constitute (all) dark matter



# Summary

- **Primordial black holes** could constitute all or part of dark matter
- PBHs can be formed from perturbations produced in **cosmic inflation**
- Higgs inflation: enough PBH dark matter only in the form of **Planck mass relics**