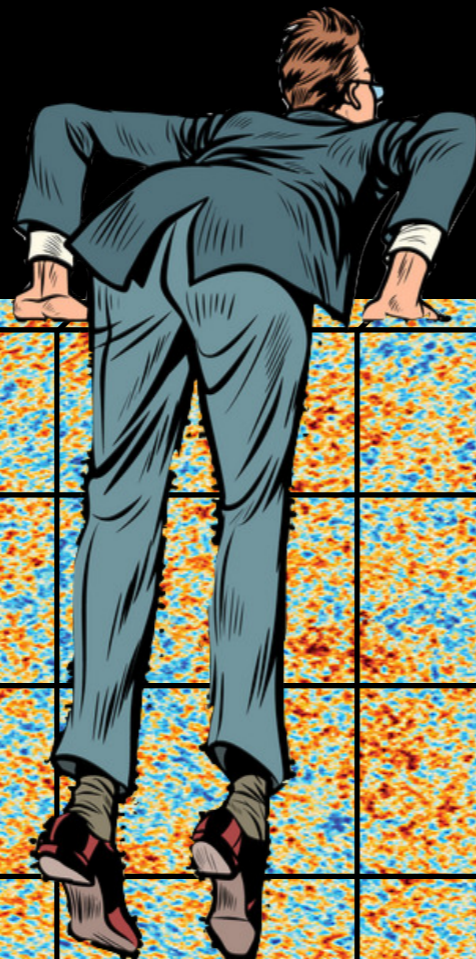
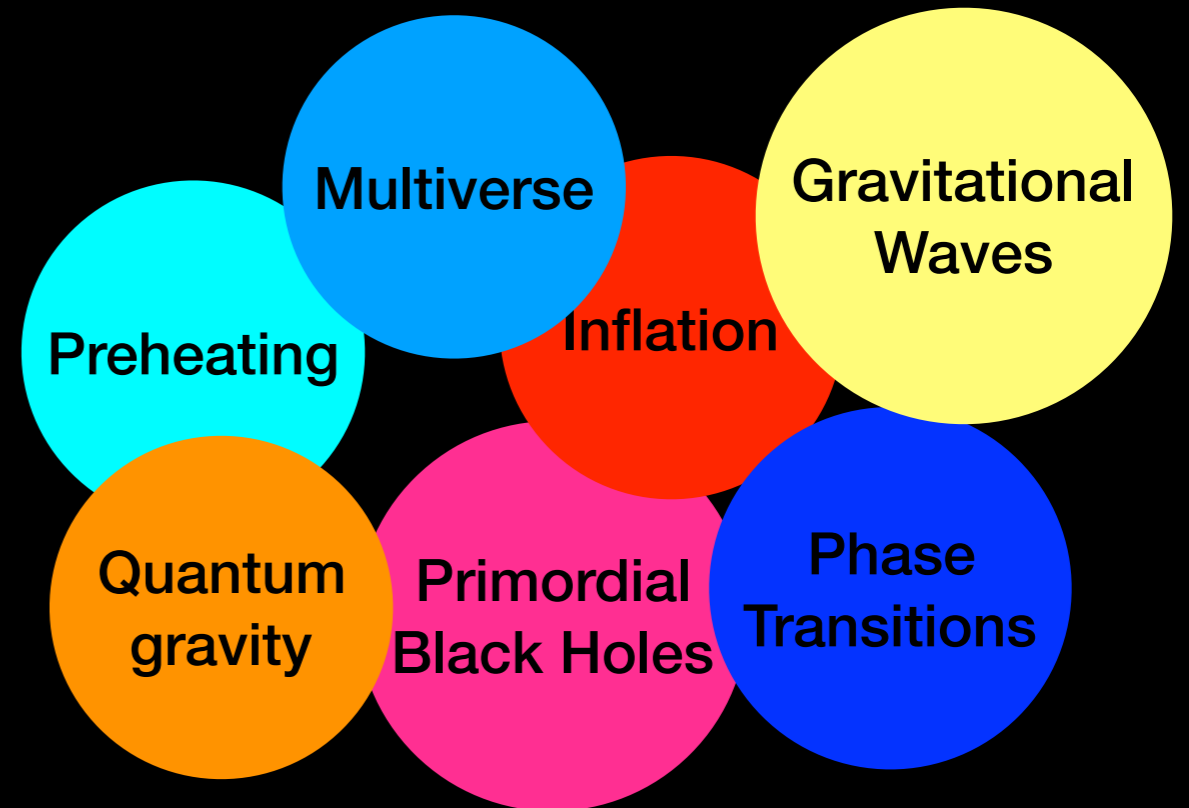


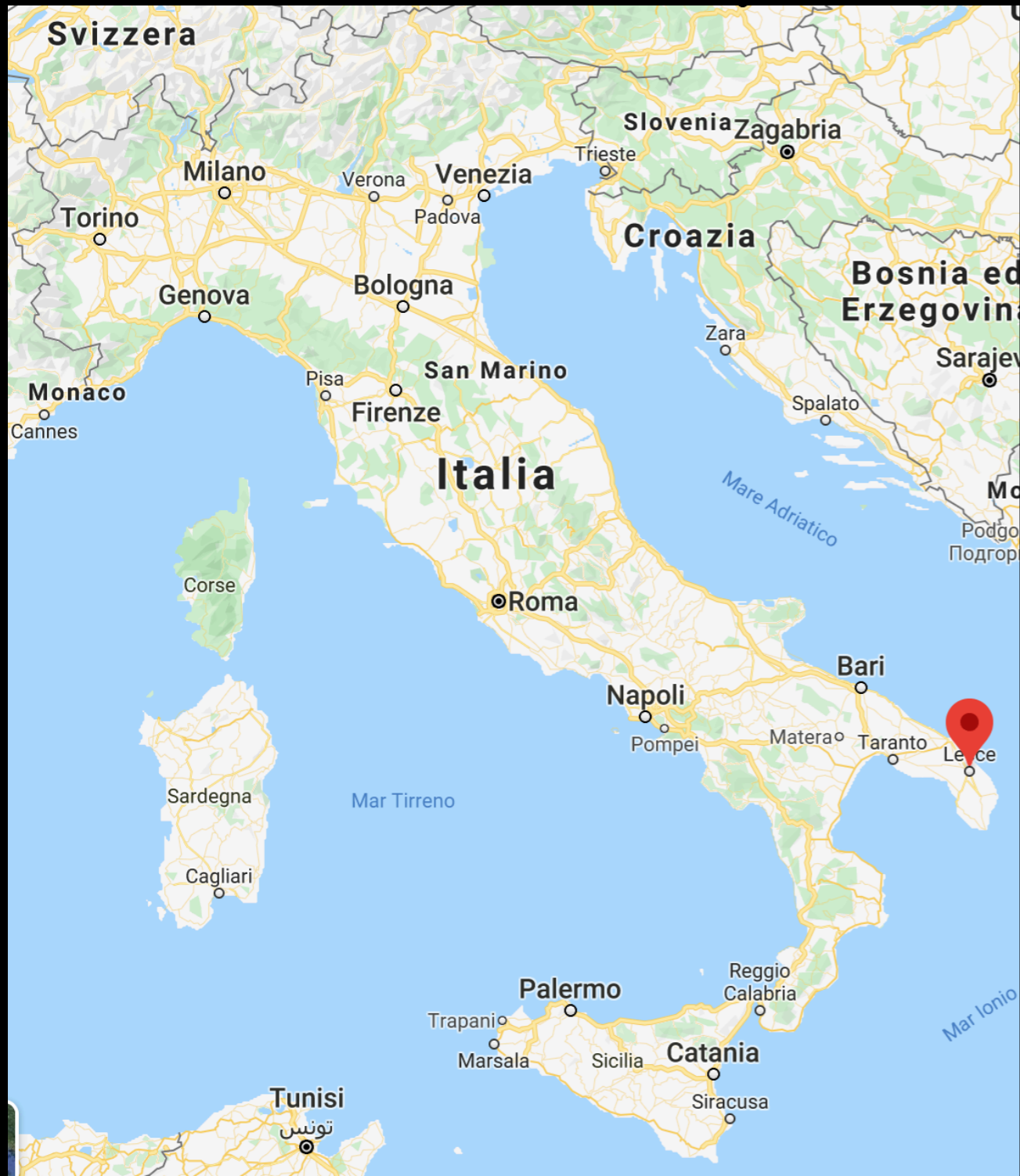
Before and After Inflation

CLUSTER OF EXCELLENCE

QUANTUM UNIVERSE

Francesco Muia





Lecce



Pisa (2006-2012)



Pisa (2006-2012)



Bologna (2013-2016)



Pisa (2006-2012)



Bologna (2013-2016)

Michele Cicoli



Pisa (2006-2012)



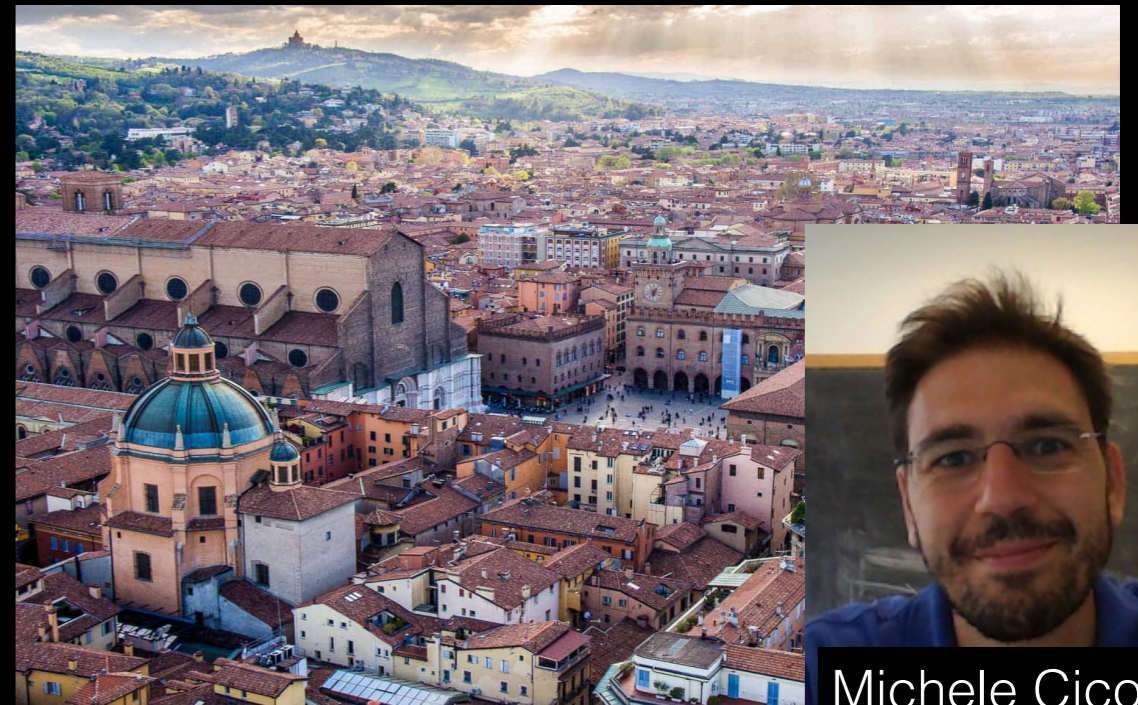
Bologna (2013-2016)



Oxford (2016-2017)



Pisa (2006-2012)



Bologna (2013-2016)



Oxford (2016-2017)

Joe Conlon



Pisa (2006-2012)



Bologna (2013-2016)



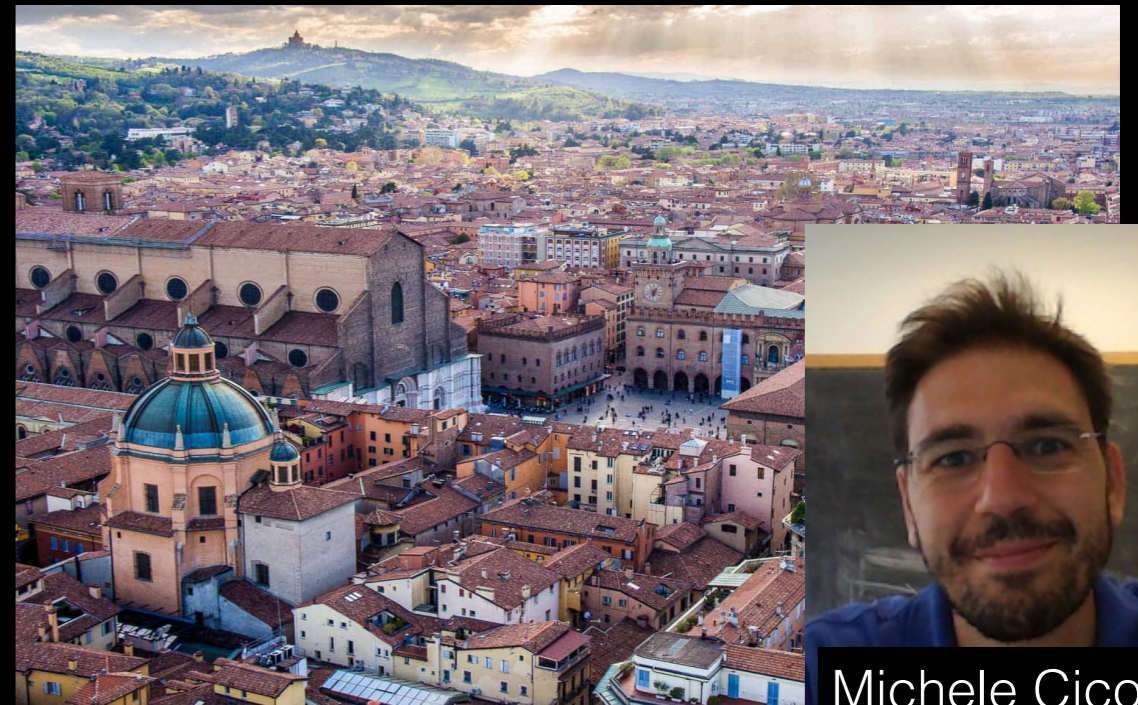
Oxford (2016-2017)



Trieste (2017-2019)



Pisa (2006-2012)



Bologna (2013-2016)



Oxford (2016-2017)



Trieste (2017-2019)

Before Inflation

Before Inflation

$$\frac{\rho_{\text{vac}}(\text{theory})}{\rho_{\text{vac}}(\text{observed})} \approx \left(\frac{10^{19} \text{ GeV}}{10^{-3} \text{ eV}} \right)^4 \approx 10^{122}$$

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Anthropic selection

1. Microscopic theory provides a huge number of vacua, i.e. a Landscape.
2. Different regions of the universe sit in different vacua, and they are all populated.
3. Observers can only exist for a small range of vacuum energies.

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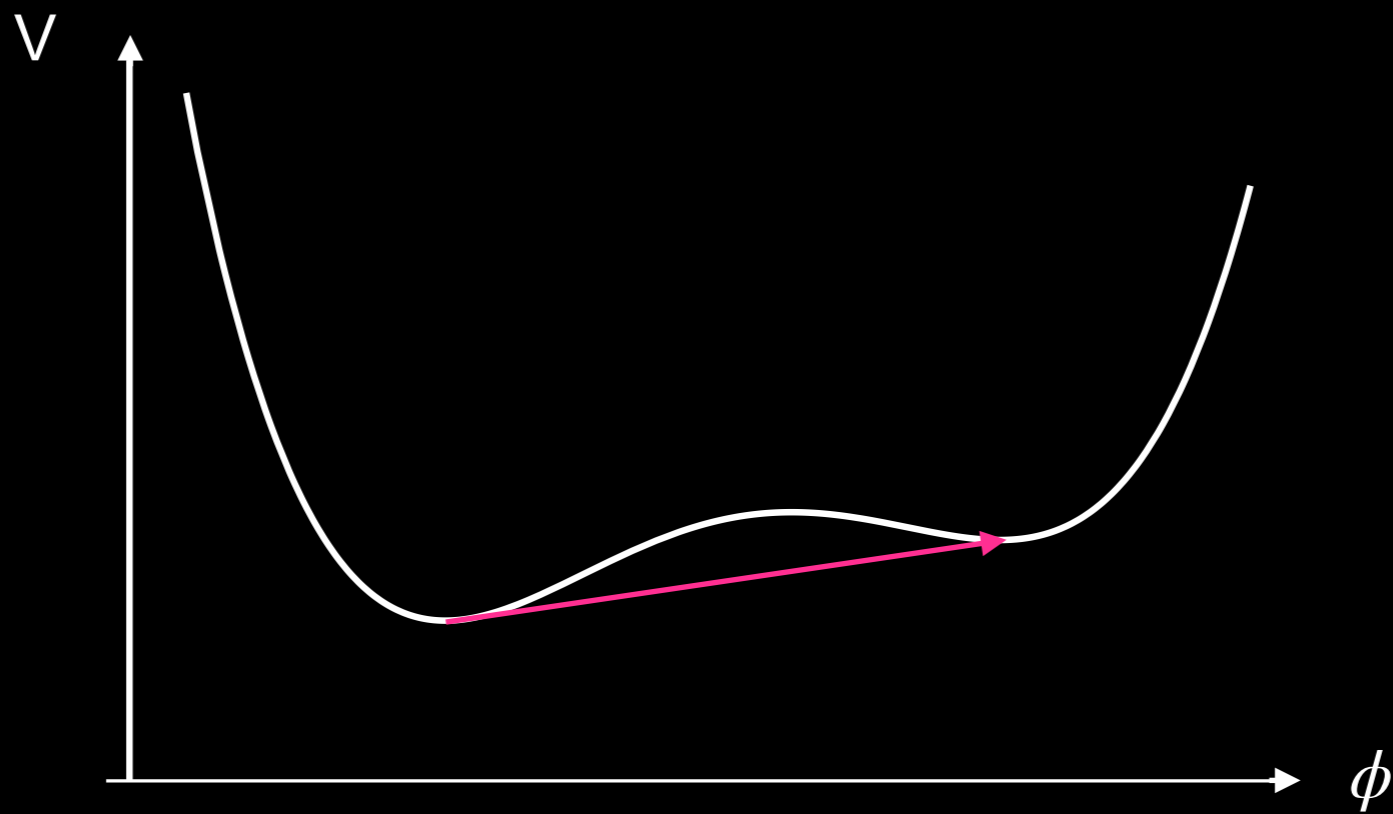
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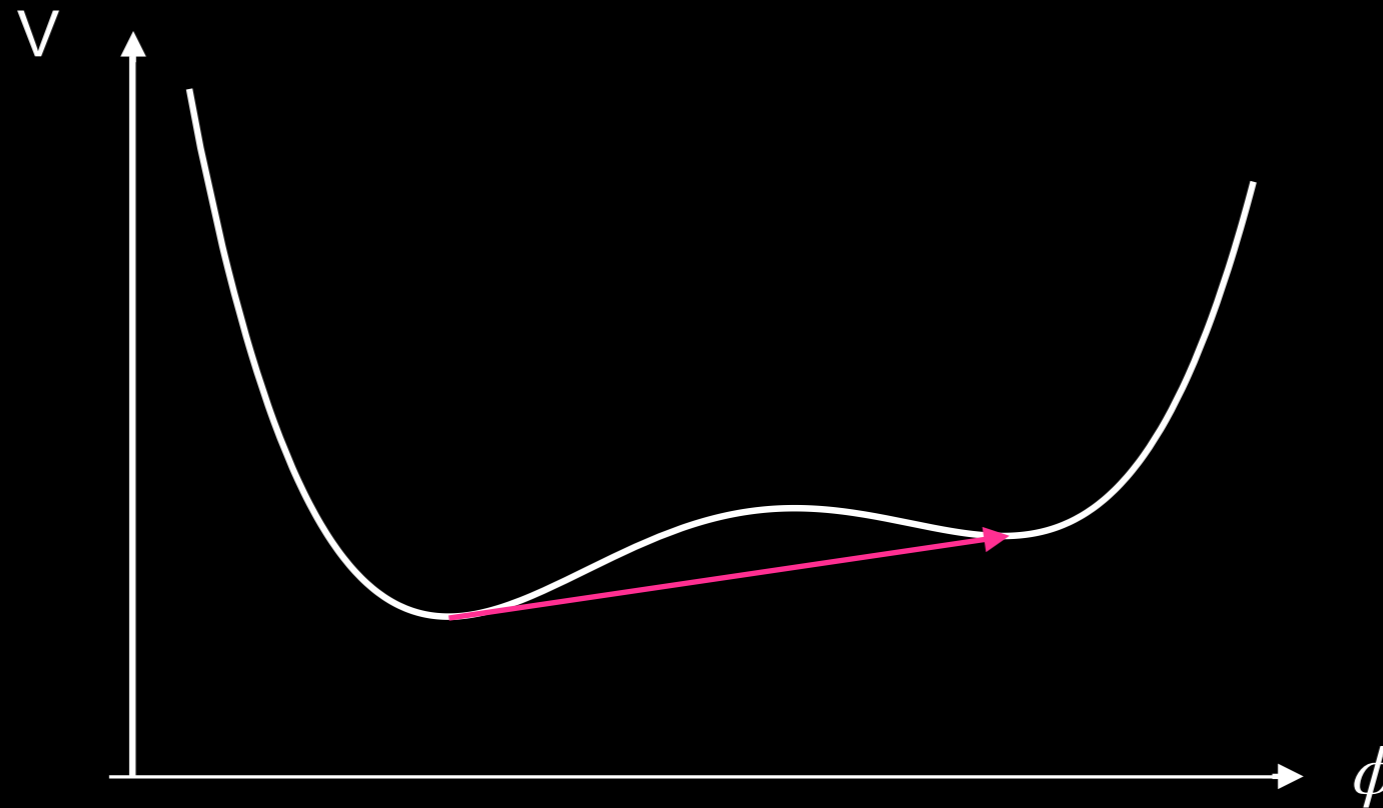
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Populating the String Landscape



Populating the String Landscape



PHYSICAL REVIEW D

VOLUME 21, NUMBER 12

15 JUNE 1980

Gravitational effects on and of vacuum decay

Sidney Coleman*

Stanford Linear Accelerator Center, Stanford University, Stanford, California 94305

Frank De Luccia

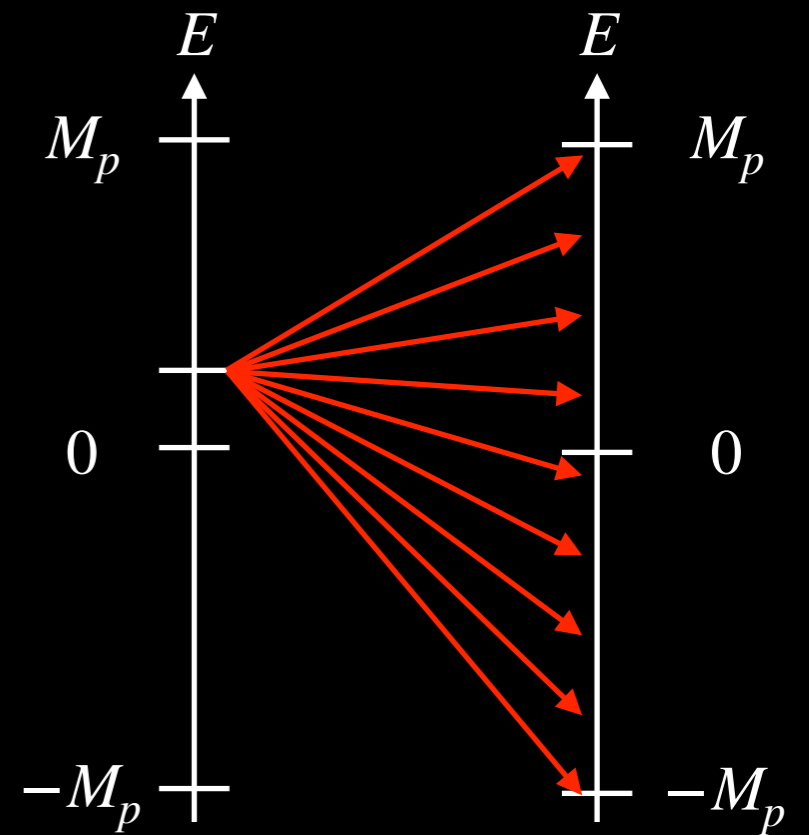
Institute for Advanced Study, Princeton, New Jersey 88548

(Received 4 March 1980)

It is possible for a classical field theory to have two stable homogeneous ground states, only one of which is an absolute energy minimum. In the quantum version of the theory, the ground state of higher energy is a false vacuum, rendered unstable by barrier penetration. There exists a well-established semiclassical theory of the decay of such false vacuums. In this paper, we extend this theory to include the effects of gravitation. Contrary to naive expectation, these are not always negligible, and may sometimes be of critical importance, especially in the late stages of the decay process.

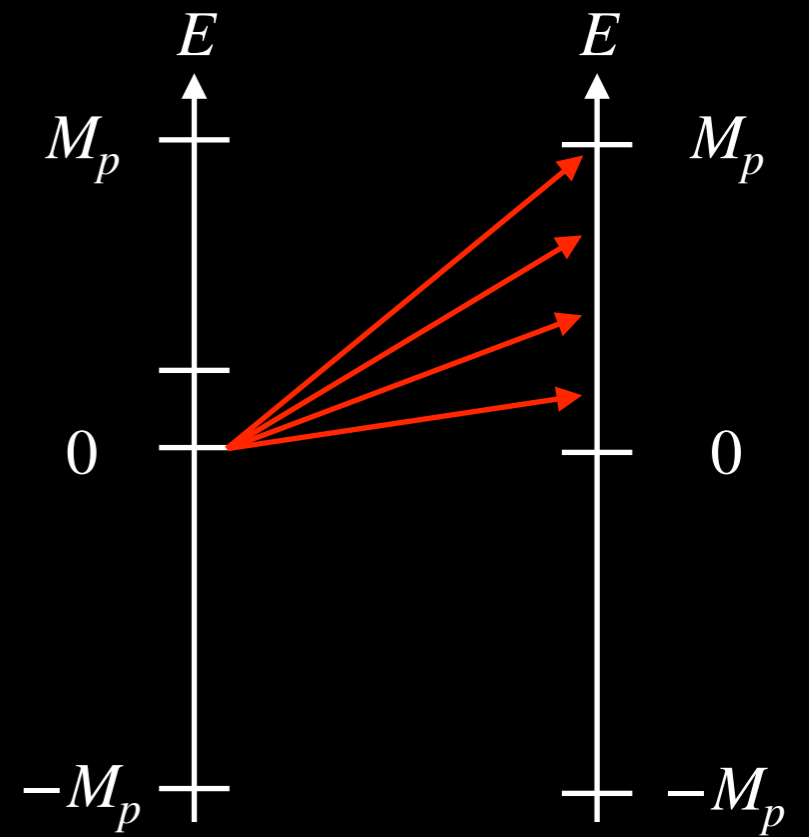
Populating the String Landscape

- Transitions and up-tunnelling.



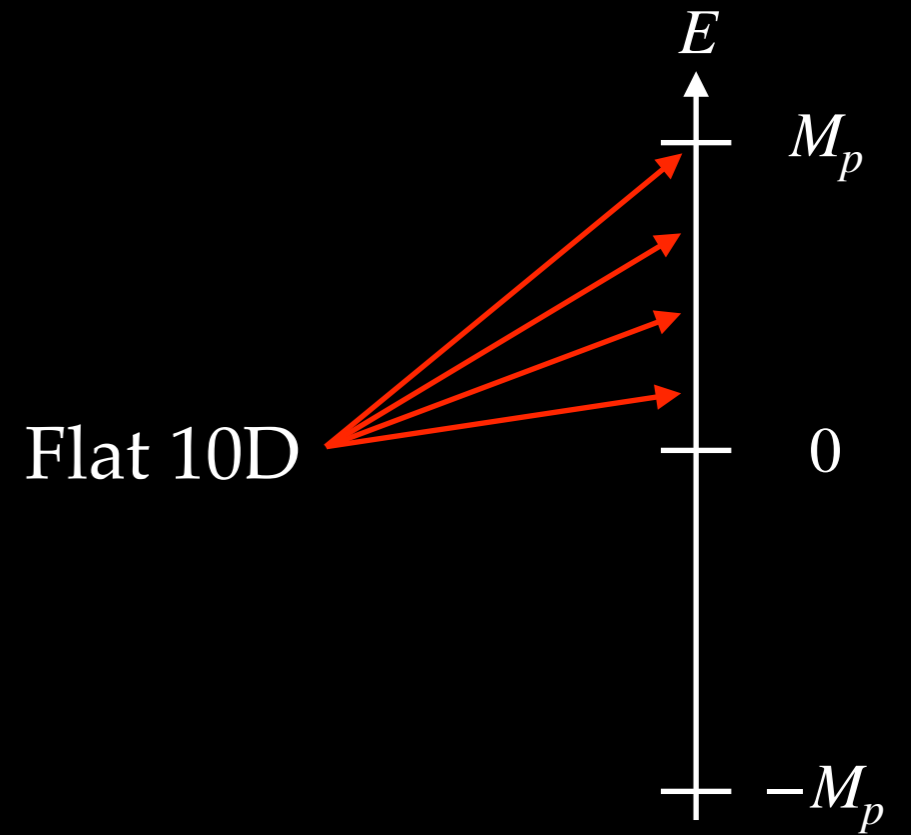
Populating the String Landscape

- Transitions and up-tunnelling.
- Transitions from flat space.



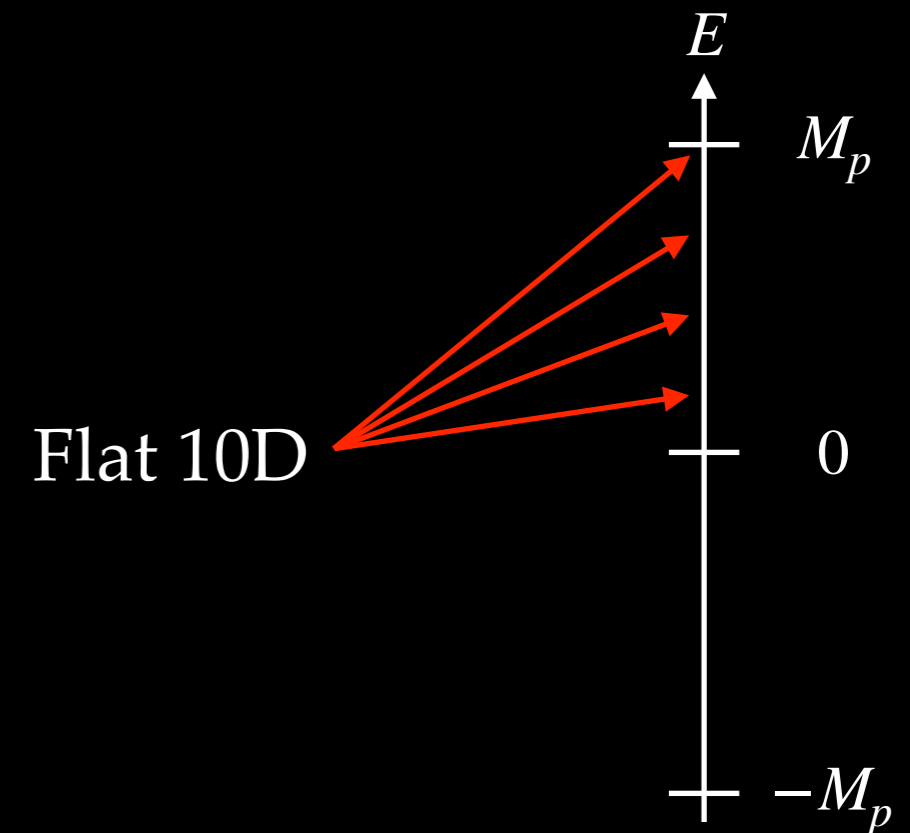
Populating the String Landscape

- Transitions and up-tunnelling.
- Transitions from flat space.
- Spontaneous compactification from 10D.



Populating the String Landscape

- Transitions and up-tunnelling.
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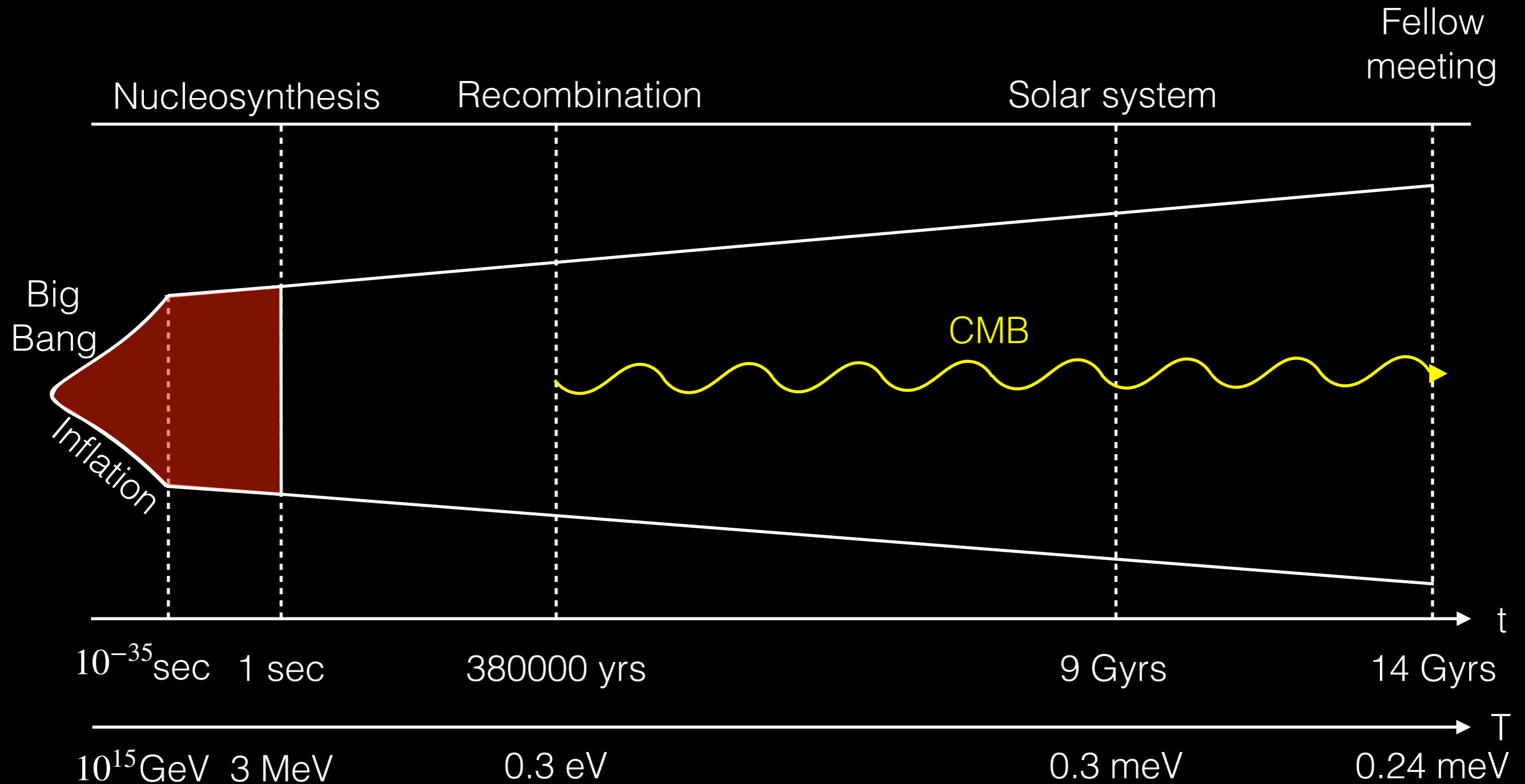
**Is Coleman-De Luccia
reliable at all?**

[Blanco-Pillado, Deng, Vilenkin, '19]

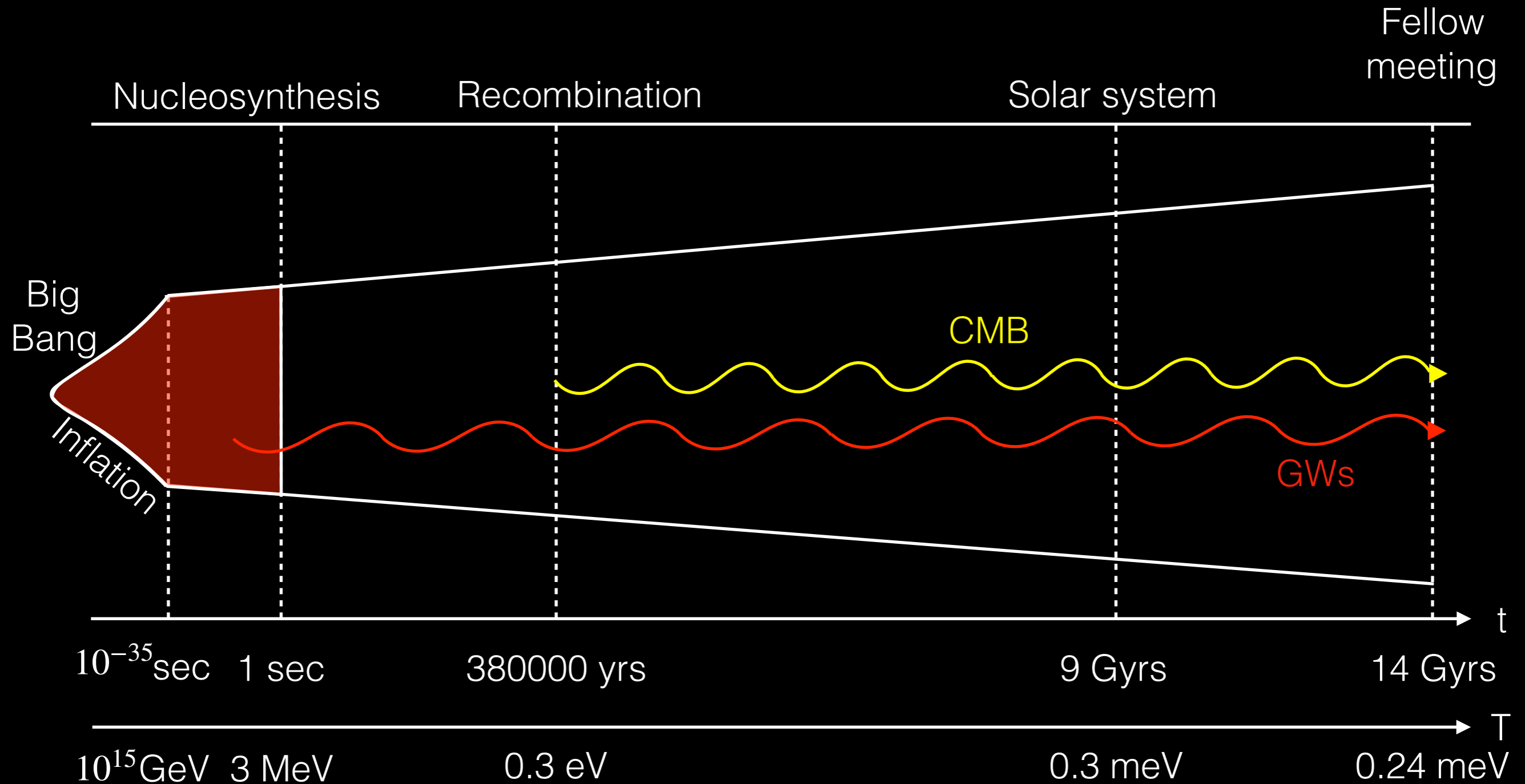
[11]. It should be noted, however, that while Coleman's flat space calculation was solidly based on first principles, the CdL formula (1) was proposed in [8] essentially by analogy with the flat space case, so its validity is open to question.

After Inflation

After Inflation



After Inflation



Post-inflationary dynamics

“We concluded that we need lattice simulations.”

[Many model-builders, including myself]

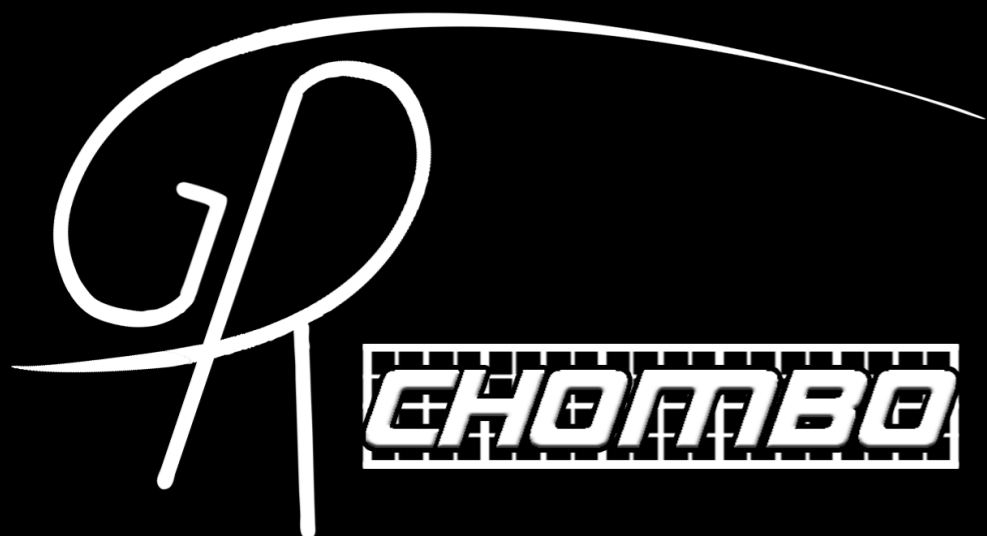
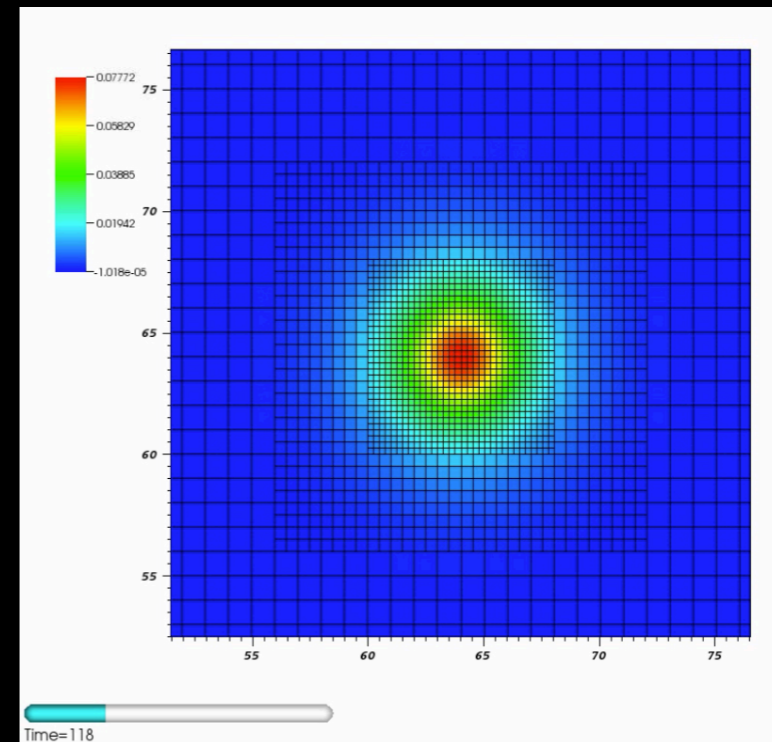
- **Preheating**
- **Phase transitions**
- **PBH formation**
- **Early matter era**

Post-inflationary dynamics

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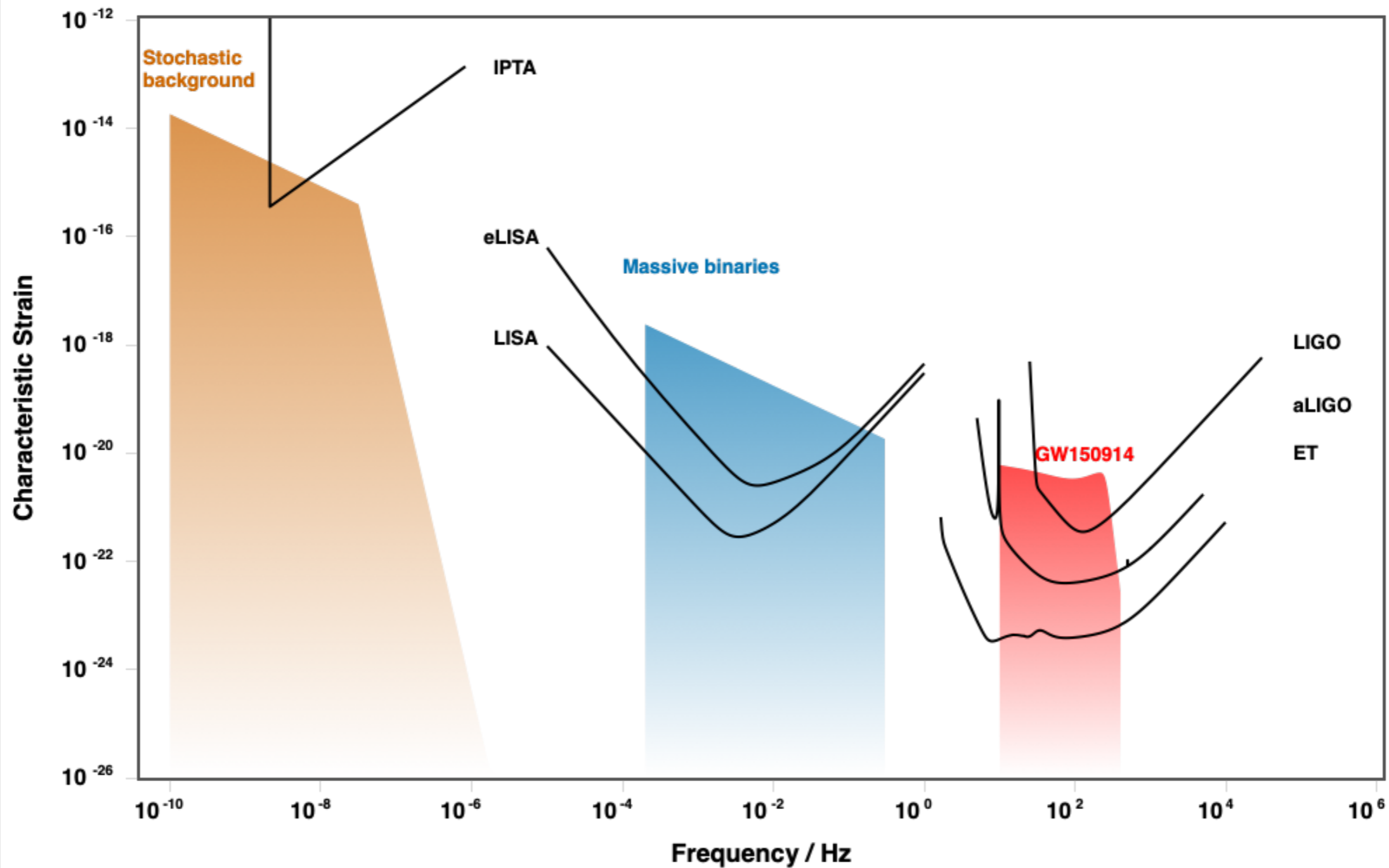
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Numerical GR
+
Adaptive Mesh Refinement

Dream for the future



Challenges and Opportunities of High Frequency Gravitational Wave Detection



14 - 16 October 2019
Trieste, Italy

Further information:
<http://indico.ictp.it/event/9006/>
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**Organized with: Valerie Domcke (DESY), Fernando Quevedo (Cambridge),
Jessica Steinlechner (Maastricht), Sebastian Steinlechner (Maastricht)**

**Speakers: O. Aguiar (INPE), A. Bauswein (GSI), M. Cruise (Birmingham),
D. Figueroa (IFIC), A. Geraci (Northwestern University),
M. Goryachev (University of Western Australia), H. Grote (Cardiff),
M. Hindmarsh (University of Sussex), D. Ottaway (Adelaide), M. Peloso (Padova)**

Thank you!