Title: Public Lecture: The Universe in a Box - Andrew Pontzen

Speakers:

Collection/Series: Public Lecture Series

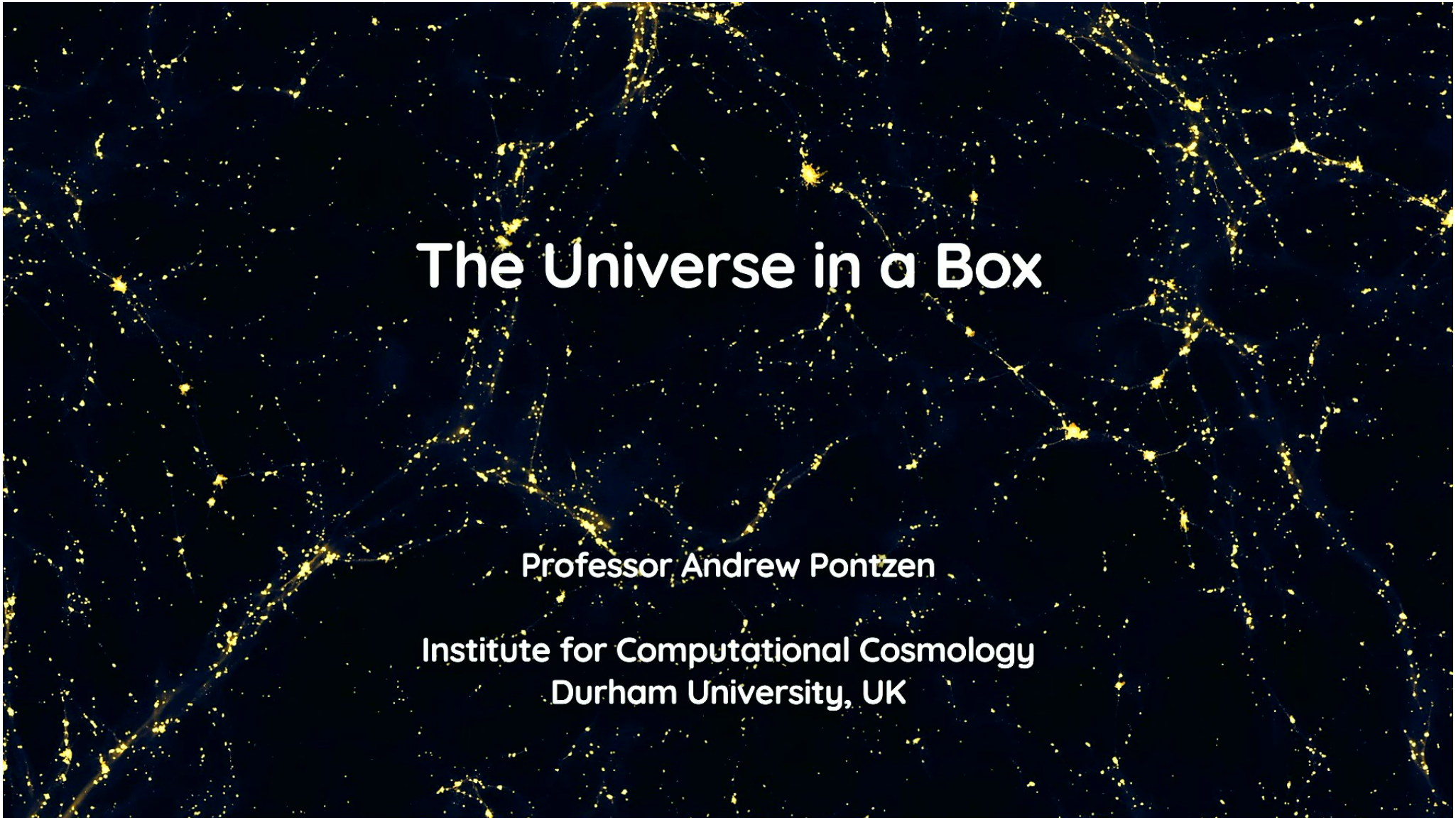
Date: July 30, 2025 - 7:00 PM

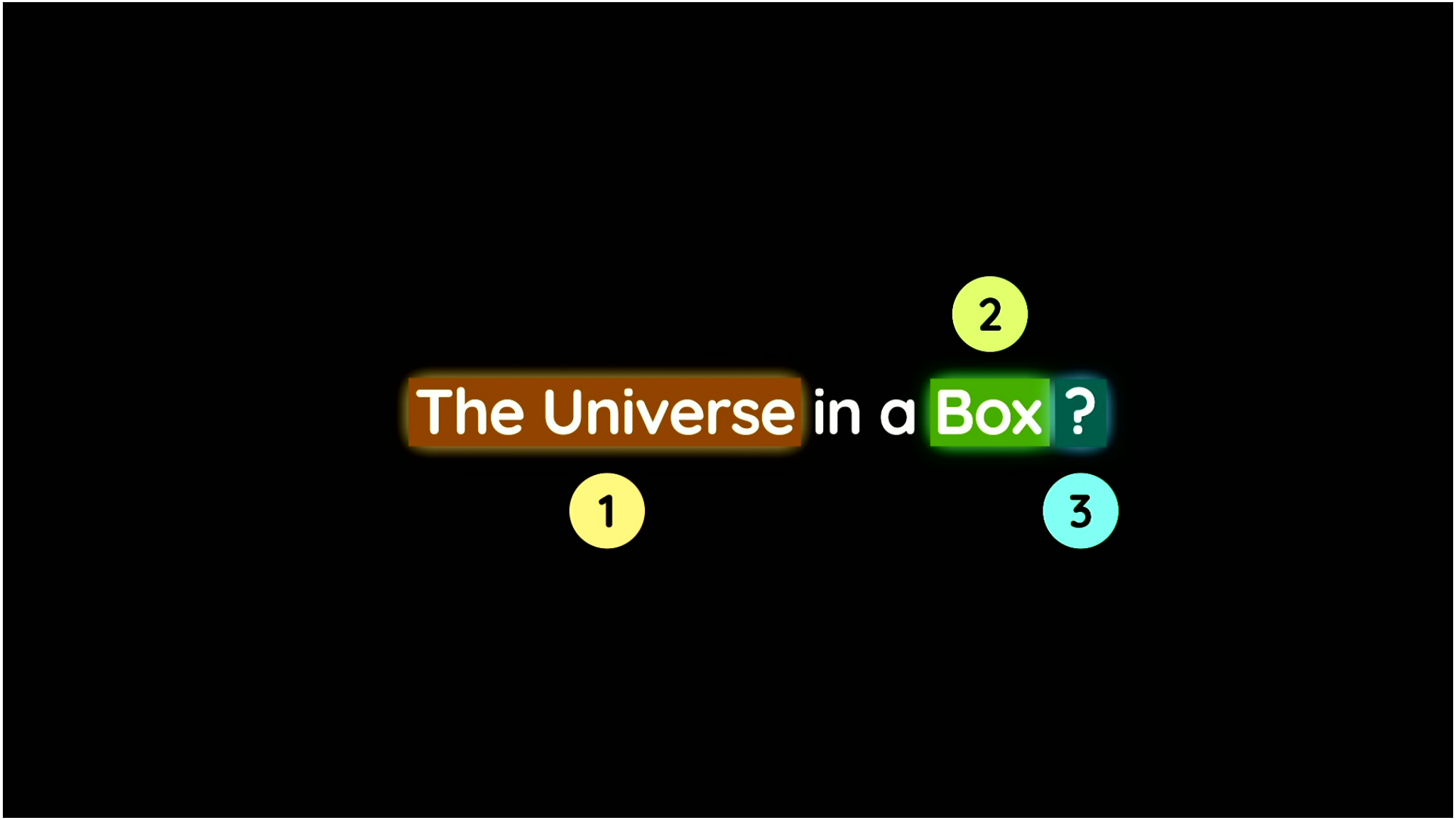
URL: https://pirsa.org/25070060

Abstract:

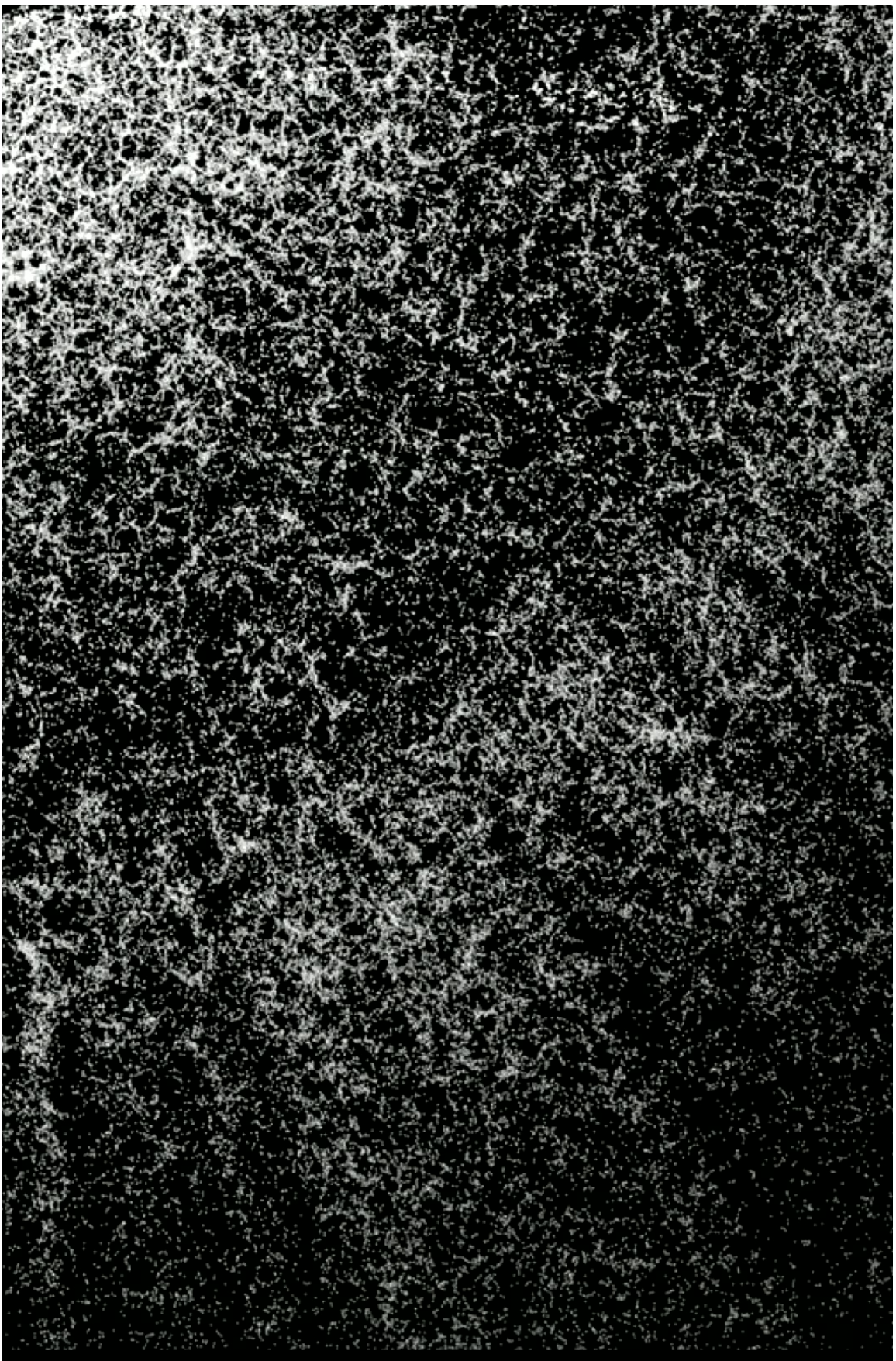
Abstract – Merging black holes, collapsing dark matter, giant supernova explosions: a tapestry of cosmic events stretching over the past 13.8 billion years have shaped our existence in a vast universe. Faced with this complexity, humanity has increasingly turned to computers to help extract a clear understanding of the cosmos and our place within it. This lecture will explore how the history of how these tools have developed, in parallel with more down-to-earth computational pursuits like weather forecasting. We will see how the resulting codes have unlocked our understanding of the universe, from galaxies and black holes to the essence of matter. And the lecture will conclude with a look at a contentious idea put forward by some philosophers and scientists – that we may already be living inside a simulation.

Bio – Andrew Pontzen is a professor of cosmology, and from January 2026 will direct Durham University's Institute for Computational Cosmology. His research concerns how structure formed in our universe, from its opening moments to the present day. He has written for the New Scientist, BBC Sky at Night and BBC Science Focus; lectured at the Royal Institution; appeared on BBC, Amazon Prime and Discovery Channel documentaries; and contributed to BBC Radio 4 programmes including Inside Science and The Curious Cases of Rutherford & Fry. He is also the author of The Universe in a Box which dives into the role of simulations in cosmology and beyond, recently published to critical acclaim.


The Universe in a Box
Professor Andrew Pontzen
Institute for Computational Cosmology
Durham University, UK


2
The Universe in a Box ?
1
3


NSF–DOE Vera C. Rubin Observatory



D. Schlegel / DESI / Lawrence Berkeley National Laboratory /
M. Zamani, NSF's NOIRLab.

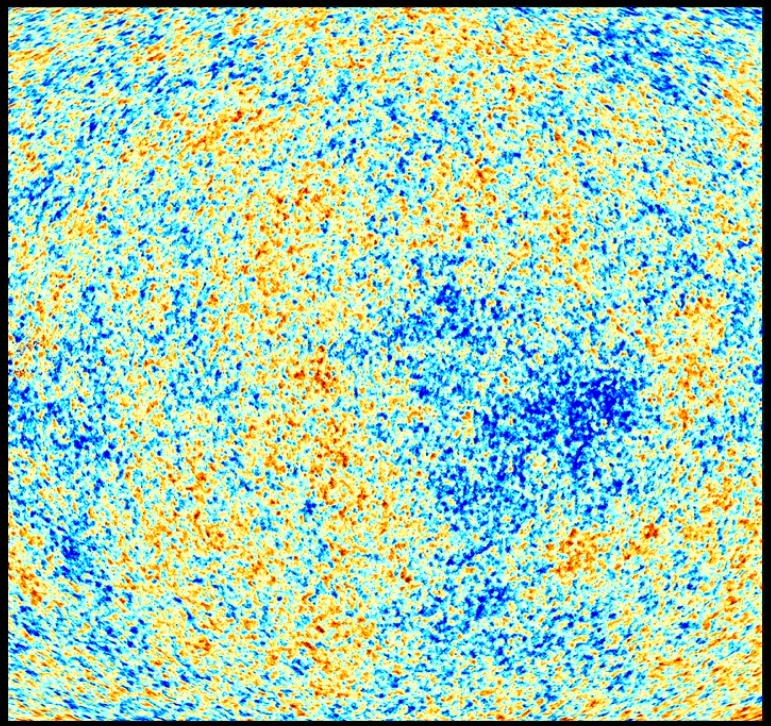
Early universe

Today (13.8 billion years old)

?

NASA/ESA/CSA/M. Zamani (ESA/Webb)

Early universe

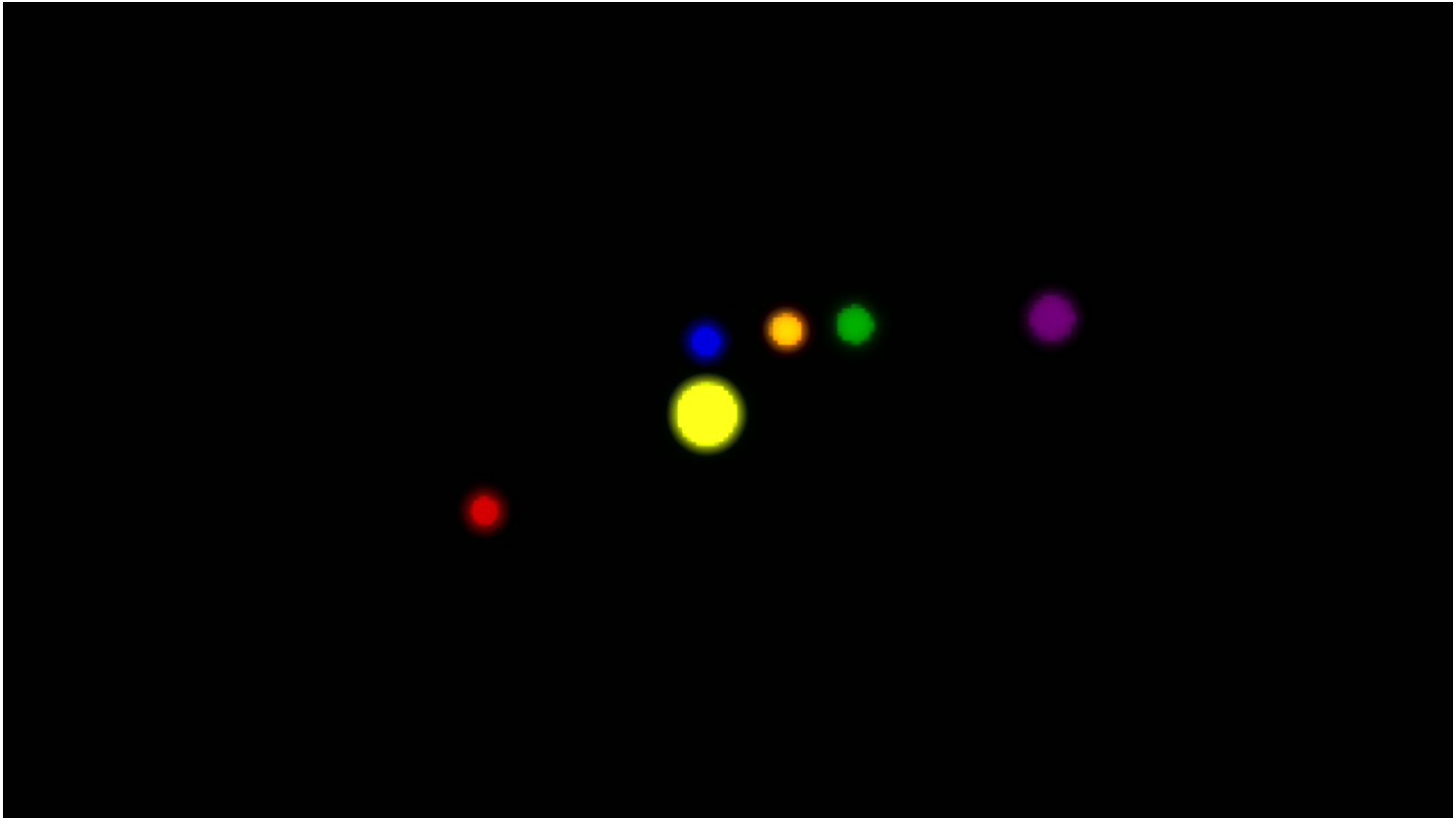


Planck Collaboration

Today (13.8 billion years old)

NASA/ESA/CSA/M. Zamani (ESA/Webb)


sinclair
ZX Spectrum
ZX Spectrum



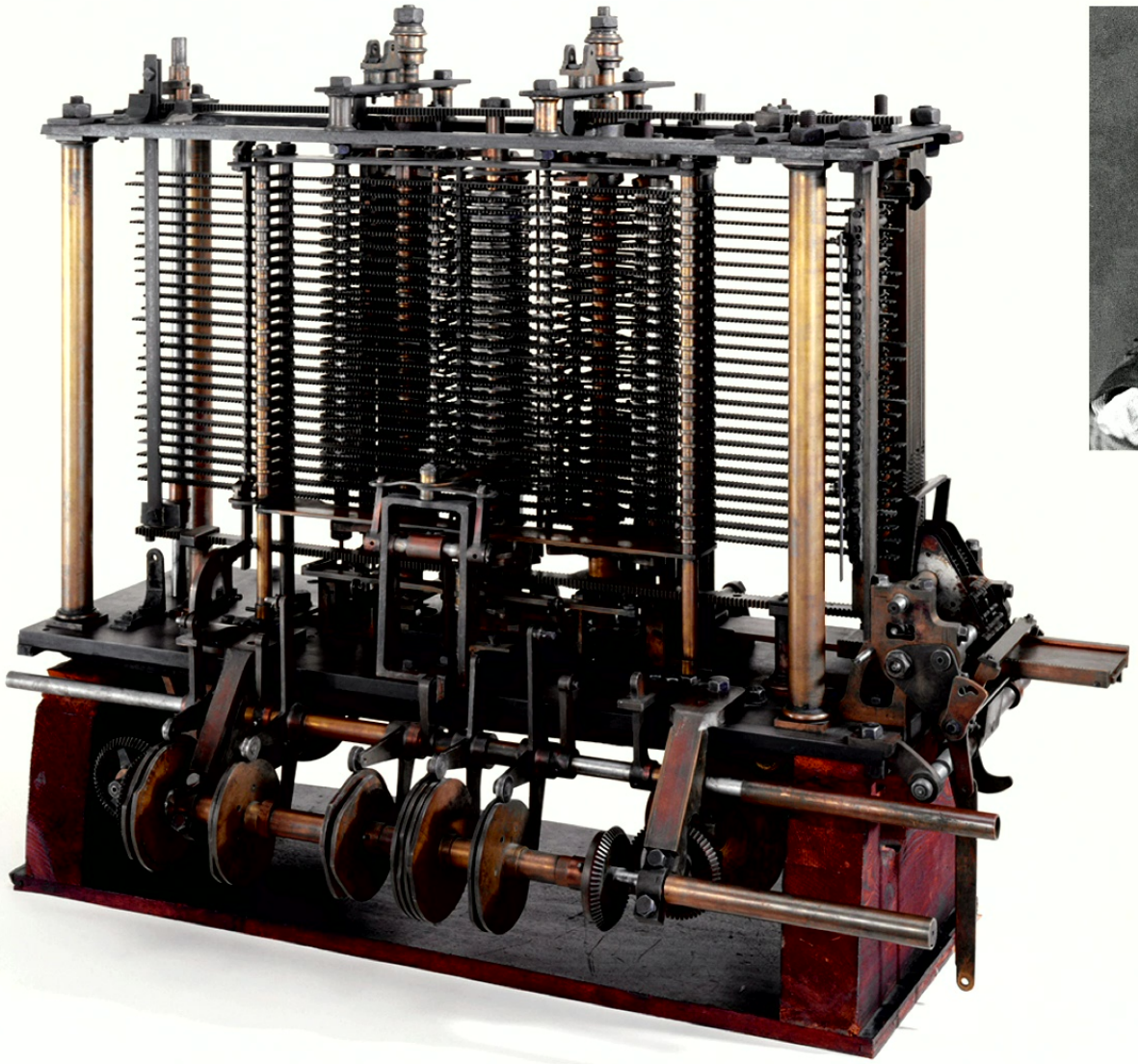
Antikythera Mechanism

(c. 50 BCE)

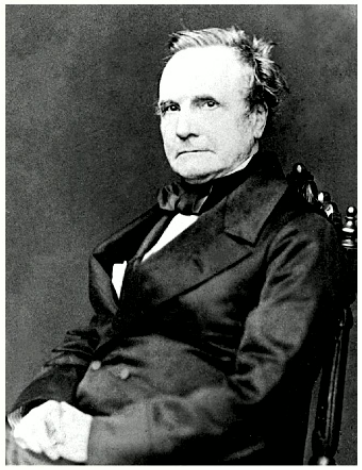
National Archaeological Museum, Athens

Analytical Engine

(c. 1871)



London
Science Museum

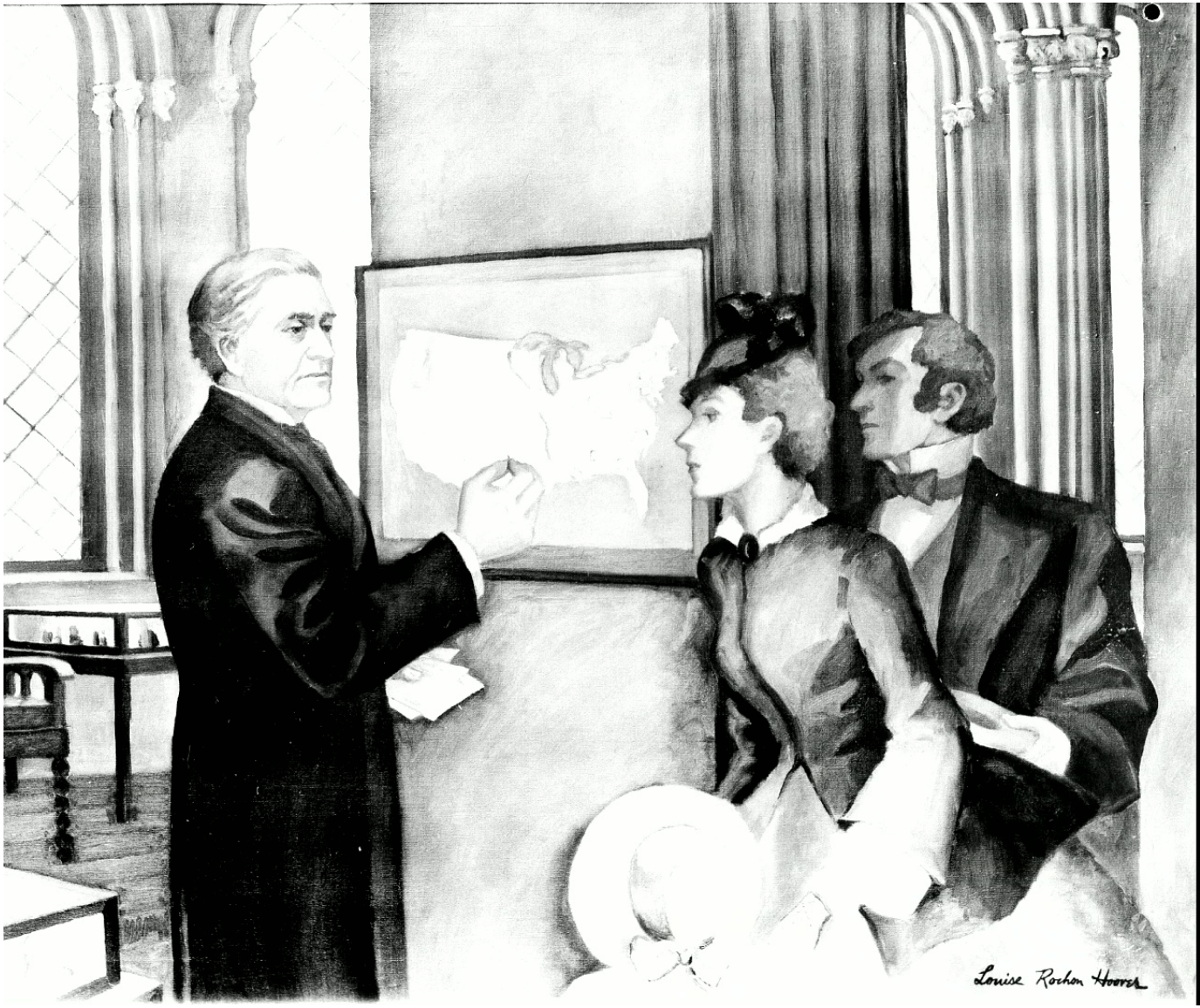


Charles Babbage

Ada Lovelace

Physics is computable...

"not merely a vast body of abstract and immutable truths"

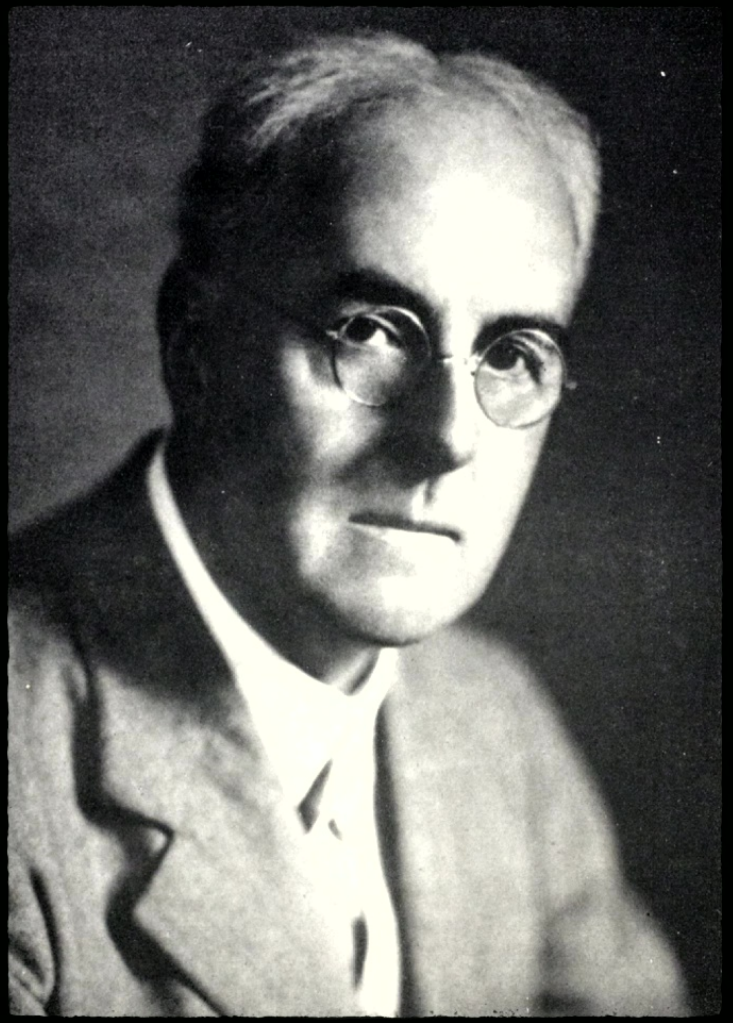


… but you also need initial conditions

Joseph Henry's weather map

1858

Lewis Fry Richardson's numerical forecasting 1919



192 AN EXAMPLE WORKED ON COMPUTING FORMS Ch. 9/2

COMPUTING FORM P v. For Solar Radiation in the grouped ranges of wave-lengths known as *REMAINDER*

Longitude *11° East*, Latitude *5400 km North*. Time from *1910 May 20d 4h* to *10h G.M.T.*, Interval *6 hours*. Mean cos $\zeta = 0.535$. Solar constant $= 1.16 \times 10^{11}$ ergs cm^{-2} day^{-1}. Incident radiation during interval in whole spectrum *1550*

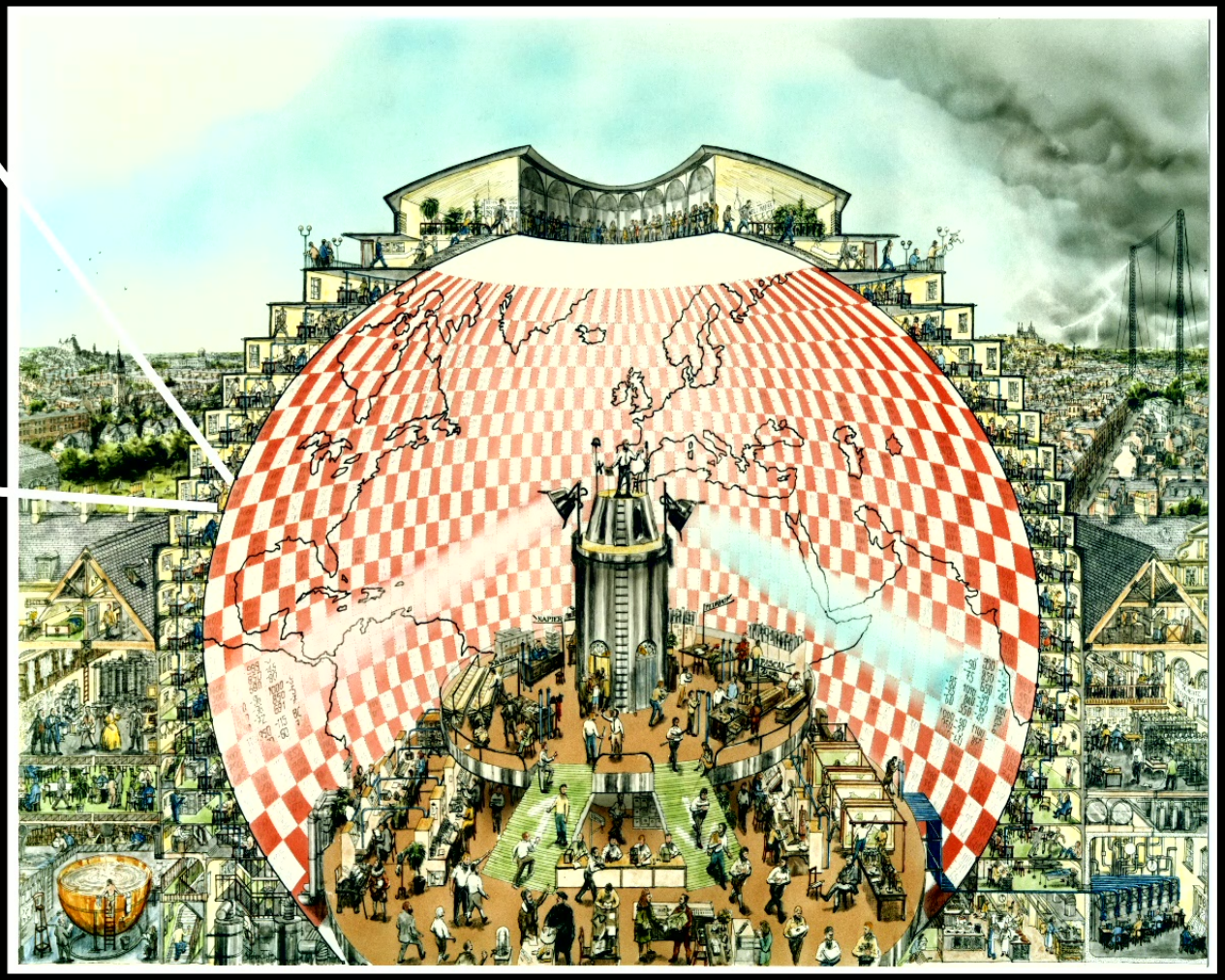
Unit for radiation during interval of time is throughout 10^5 ergs cm^{-2} = 1 joule cm^{-2}

For masses per area of stratum, water per area of stratum and amount of continuous and detached cloud see Forms P II, P III.

LEVEL	DIRECT BEAM			LOSSES from Direct beam		DIFFUSE DOWNWARDS			DIFFUSE UPWARDS			TOTAL AMOUNT ABSORBED
	Fractions of initial for stratum		Flux	Amount absorbed	Amount scattered	Flux	Fraction absorbed	Amount absorbed	Flux	Fraction absorbed	Amount absorbed	
	Absorbed	Scattered										
h_0			*1320*			*0*			*257*			
	0·009	*0·059*		*12*	*78*		*0·008*	*0*		*0·008*	*2*	*14*
h_2			*1239*			*39*			*220*			
	0·009	*0·059*		*11*	*72*		*0·008*	*0*		*0·008*	*1*	*12*
h_4			*1147*			*75*			*185*			
	0·010	*0·060*		*11*	*69*		*0·009*	*1*		*0·009*	*1*	*13*
h_6			*1067*			*109*			*152*			
	0·013	*0·064*		*14*	*68*		*0·012*	*1*		*0·012*	*2*	*17*
h_8			*985*			*142*			*120*			
	0·018	*0·071*		*18*	*70*		*0·017*	*2*		*0·017*	*1*	*21*
h_t			*897*			*175*			*86*			
	*0·92**	Reflected *0·08**		*825*	Reflected *72*		*0·92**	*161*		*0·92**	*0*	*986*
h_a												

* Arbitrary reflectivity assumed for illustration.

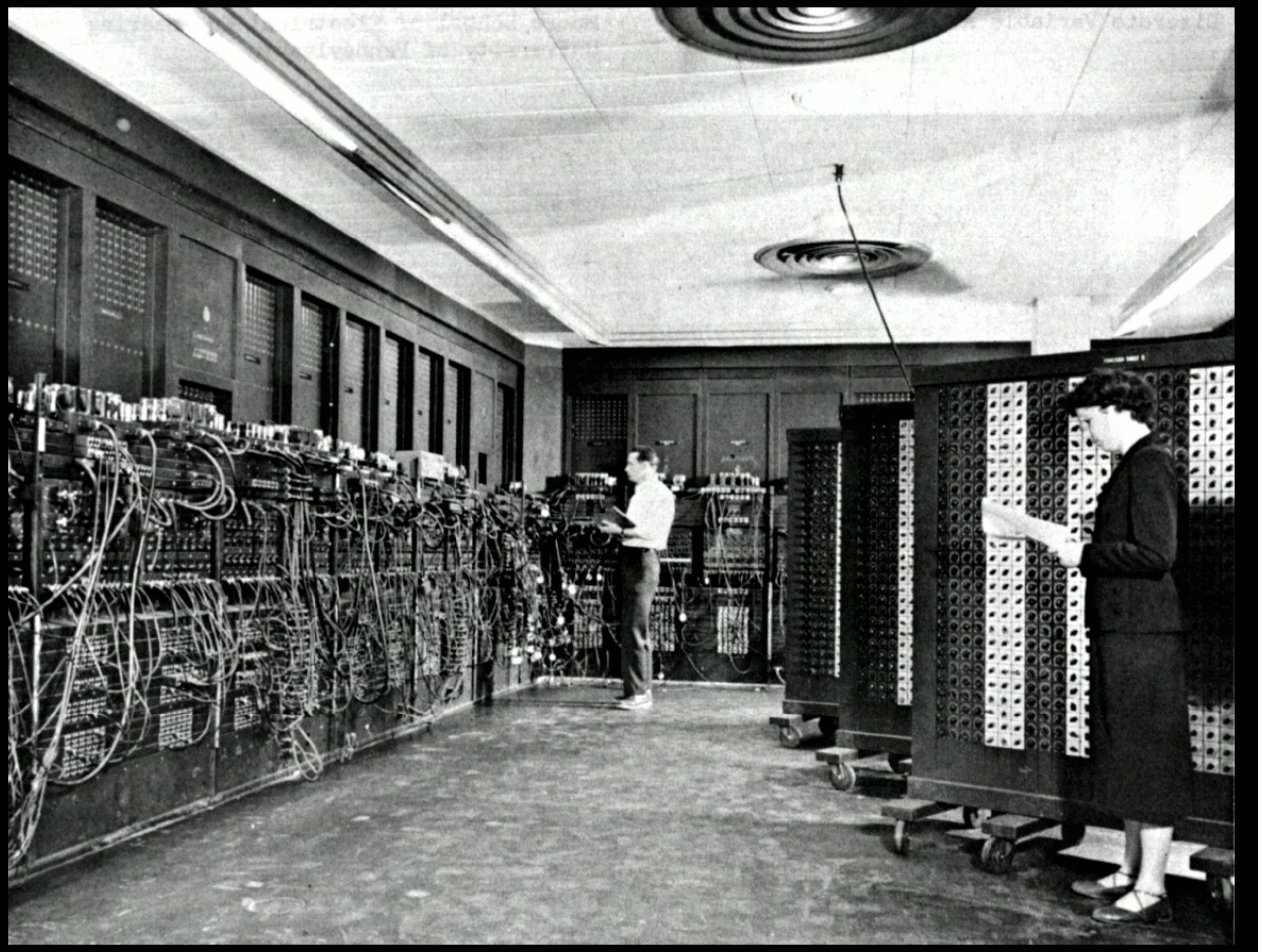
ABSORBED, SUM *1063*
TO SPACE *257*
SUM = INCIDENT *1320*



“Weather Forecasting Factory”
by Stephen Conlin, 1986
after Richardson (1922)

First successful numerical weather forecast

Jule Charney + team (including Klara Dan Von Neumann) 1950



Beatrice Tinsley simulates the colour and brightness of galaxies over time **1968**

...upends the consensus that the universe will end

Sykuro Manabe

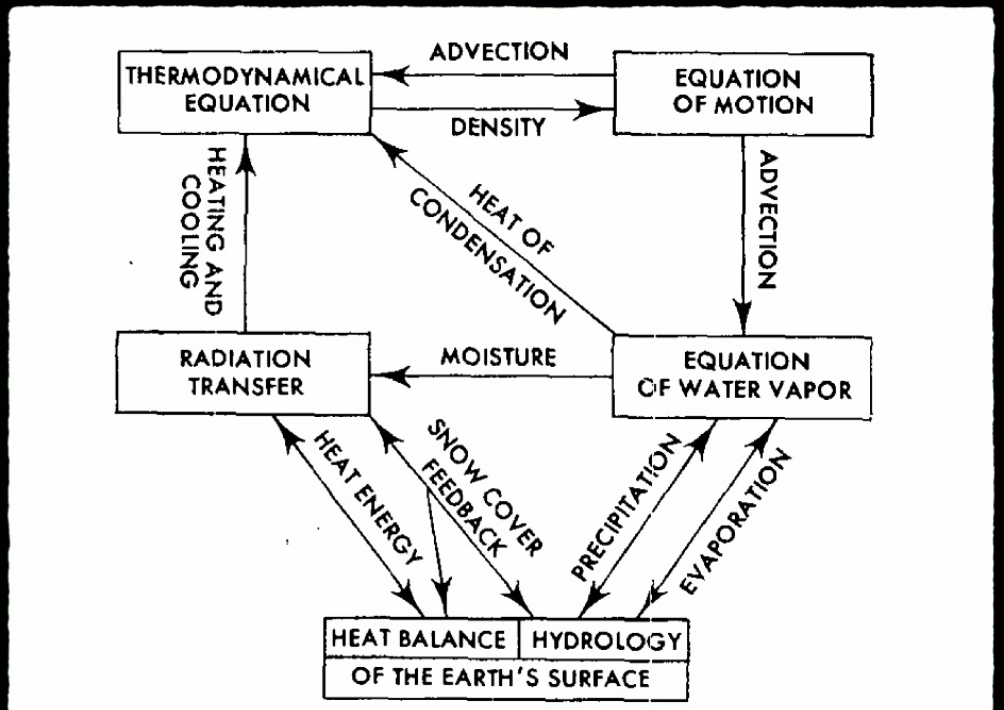
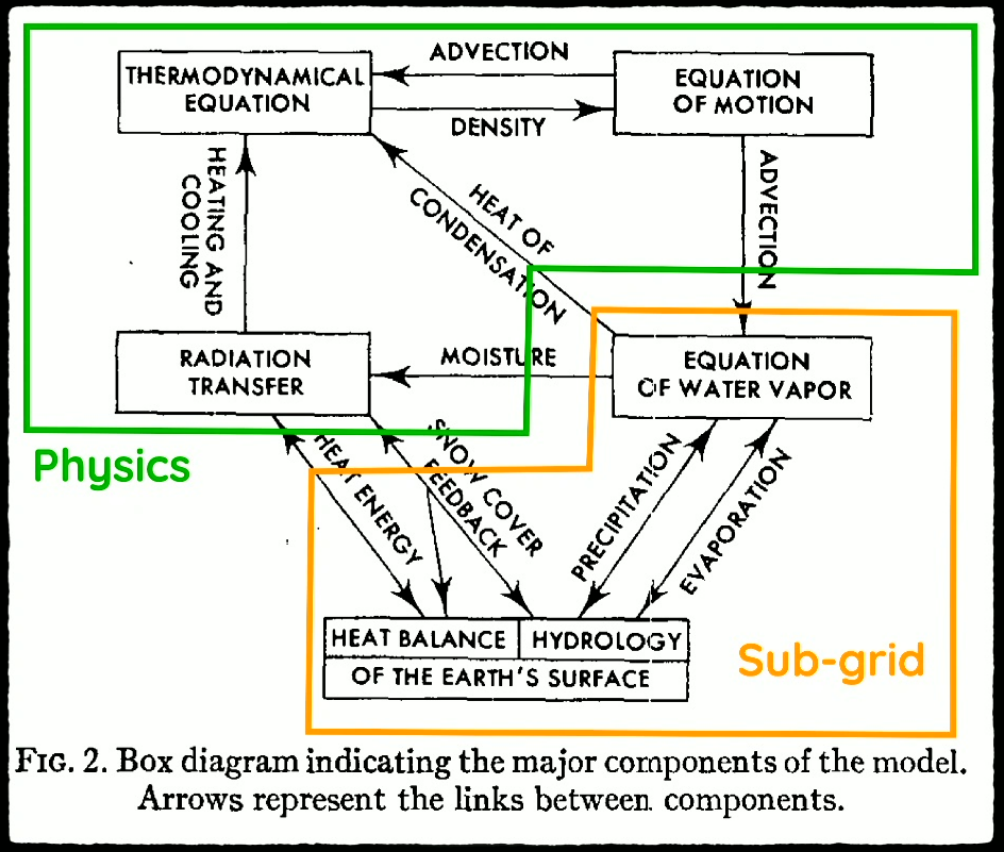


FIG. 2. Box diagram indicating the major components of the model. Arrows represent the links between components.

Manabe & Wetherald 1975

Sykuro Manabe



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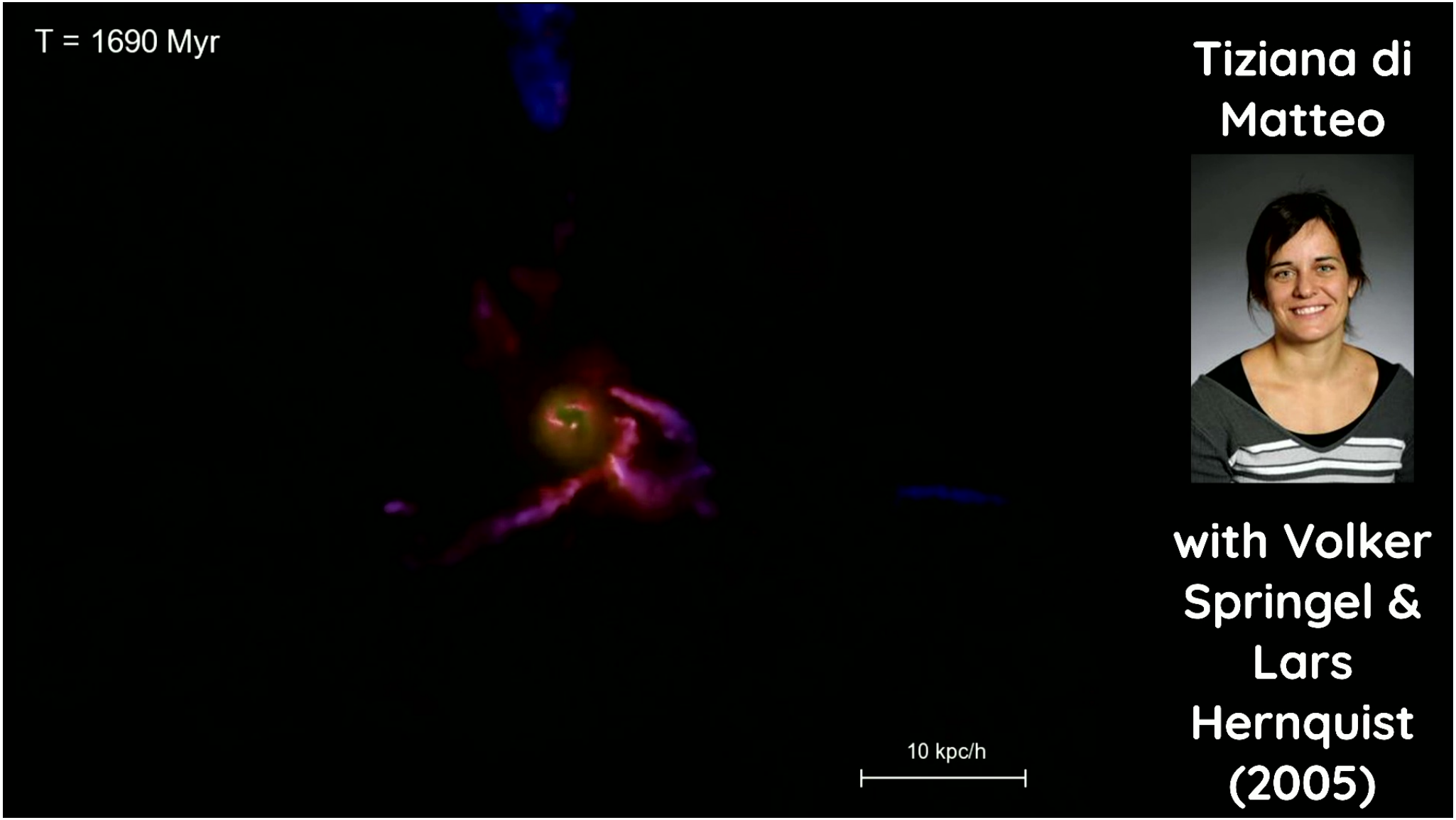
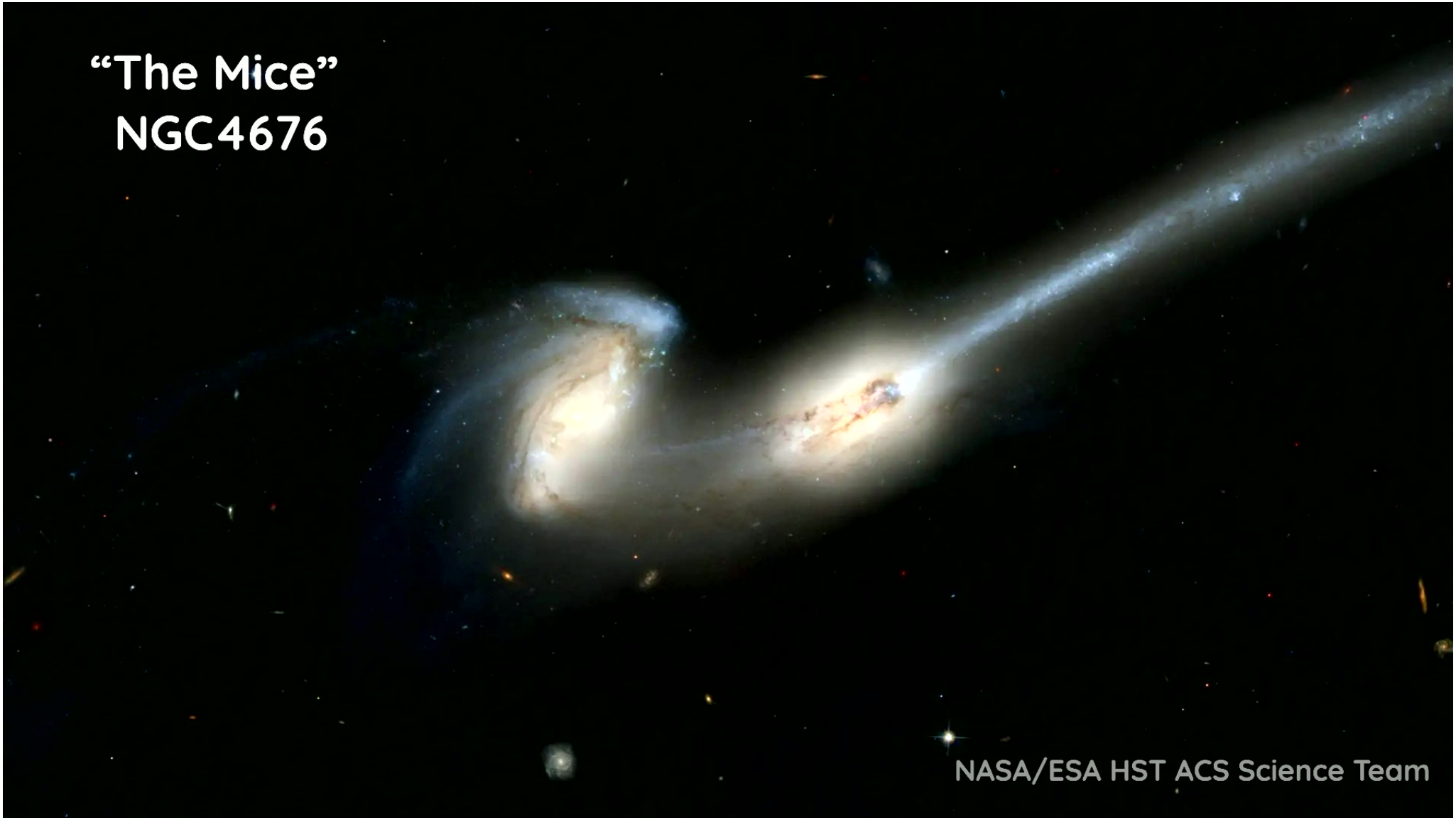
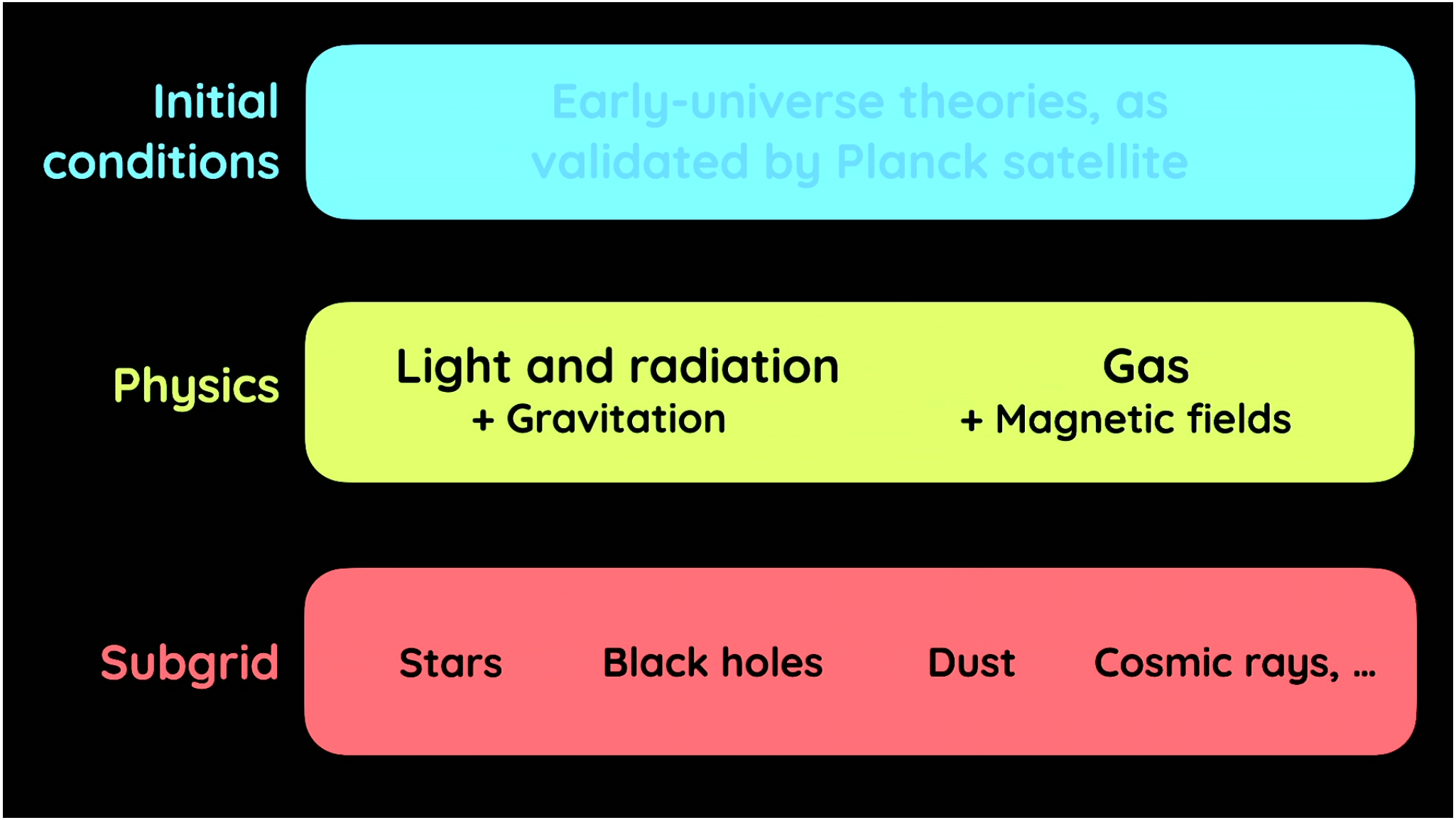
Manabe & Wetherald 1975

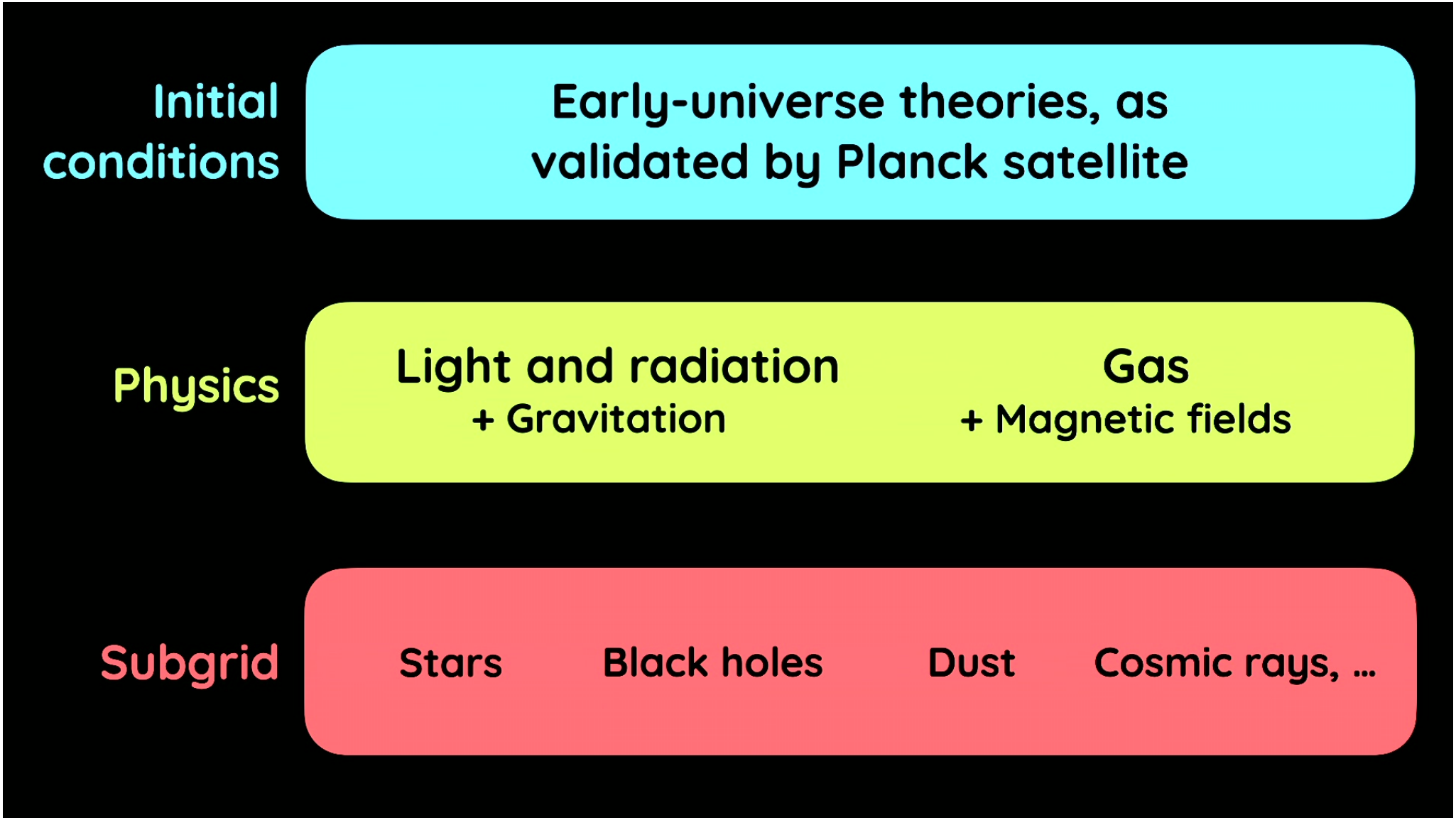


Tiziana di Matteo

with Volker Springel & Lars Hernquist (2005)


“The Mice”
NGC4676
NASA/ESA HST ACS Science Team


Initial conditions
Early-universe theories, as validated by Planck satellite
Physics
Light and radiation
+ Gravitation
Gas
+ Magnetic fields
Subgrid
Stars
Black holes
Dust
Cosmic rays, ...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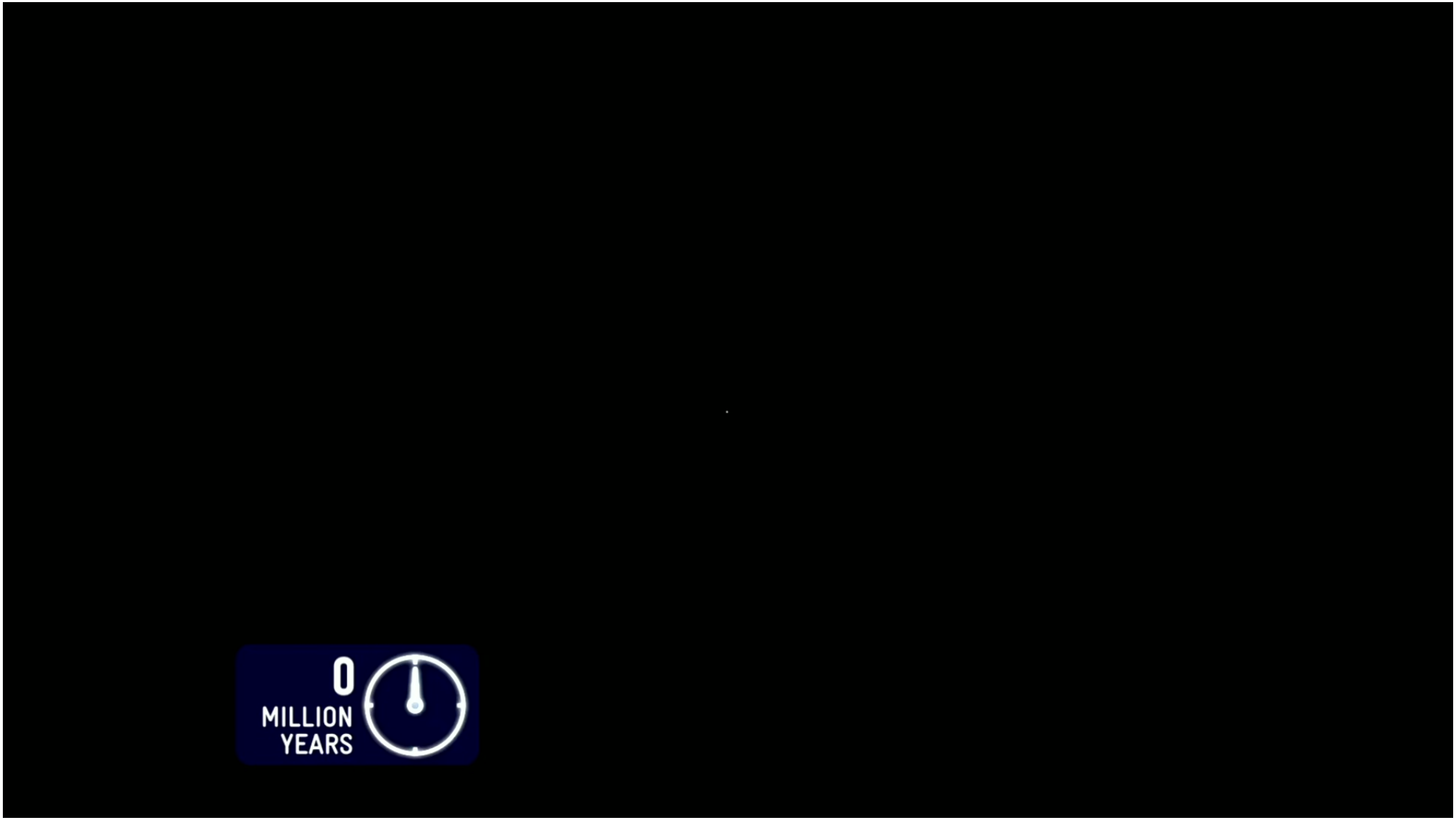
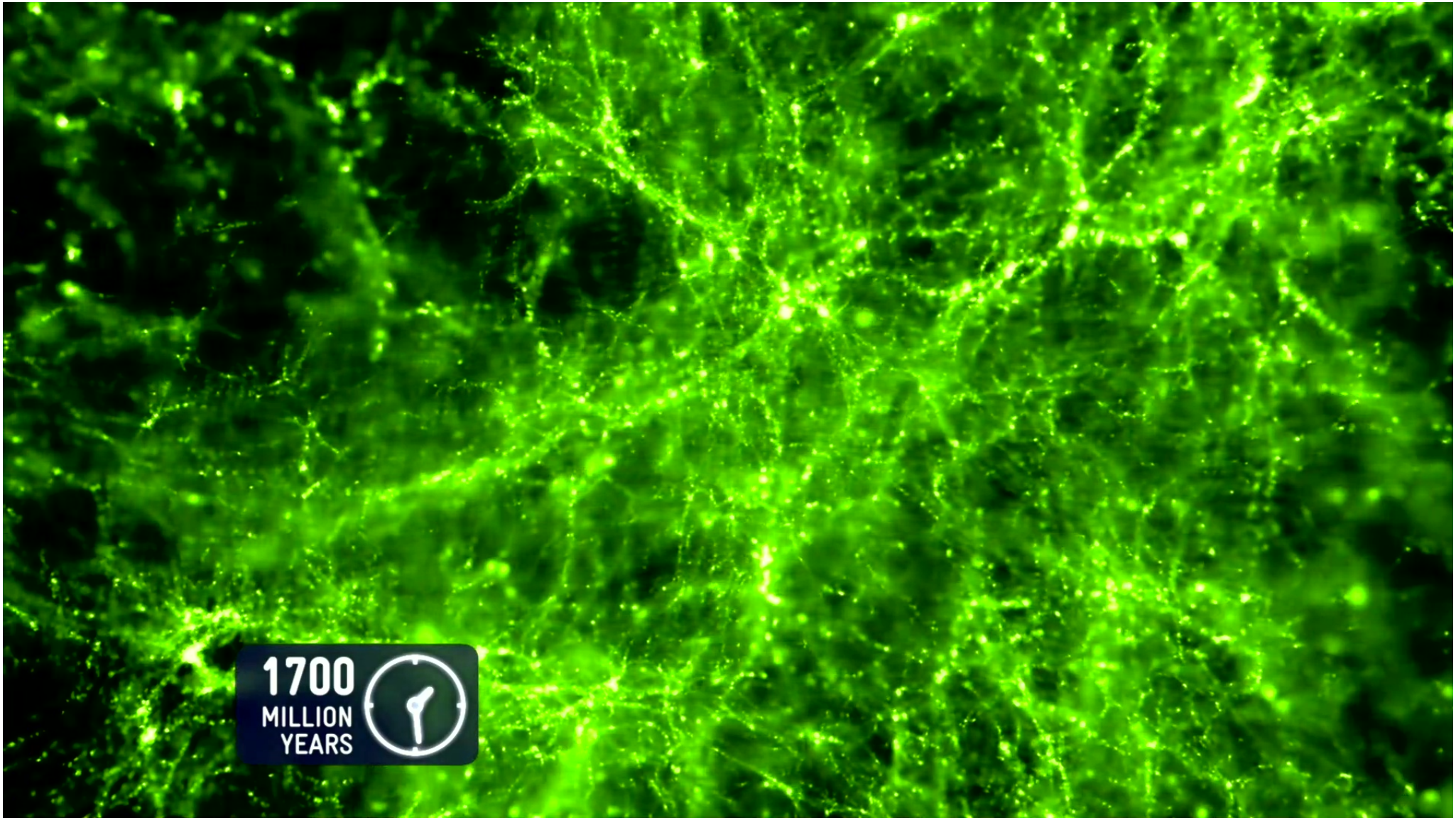
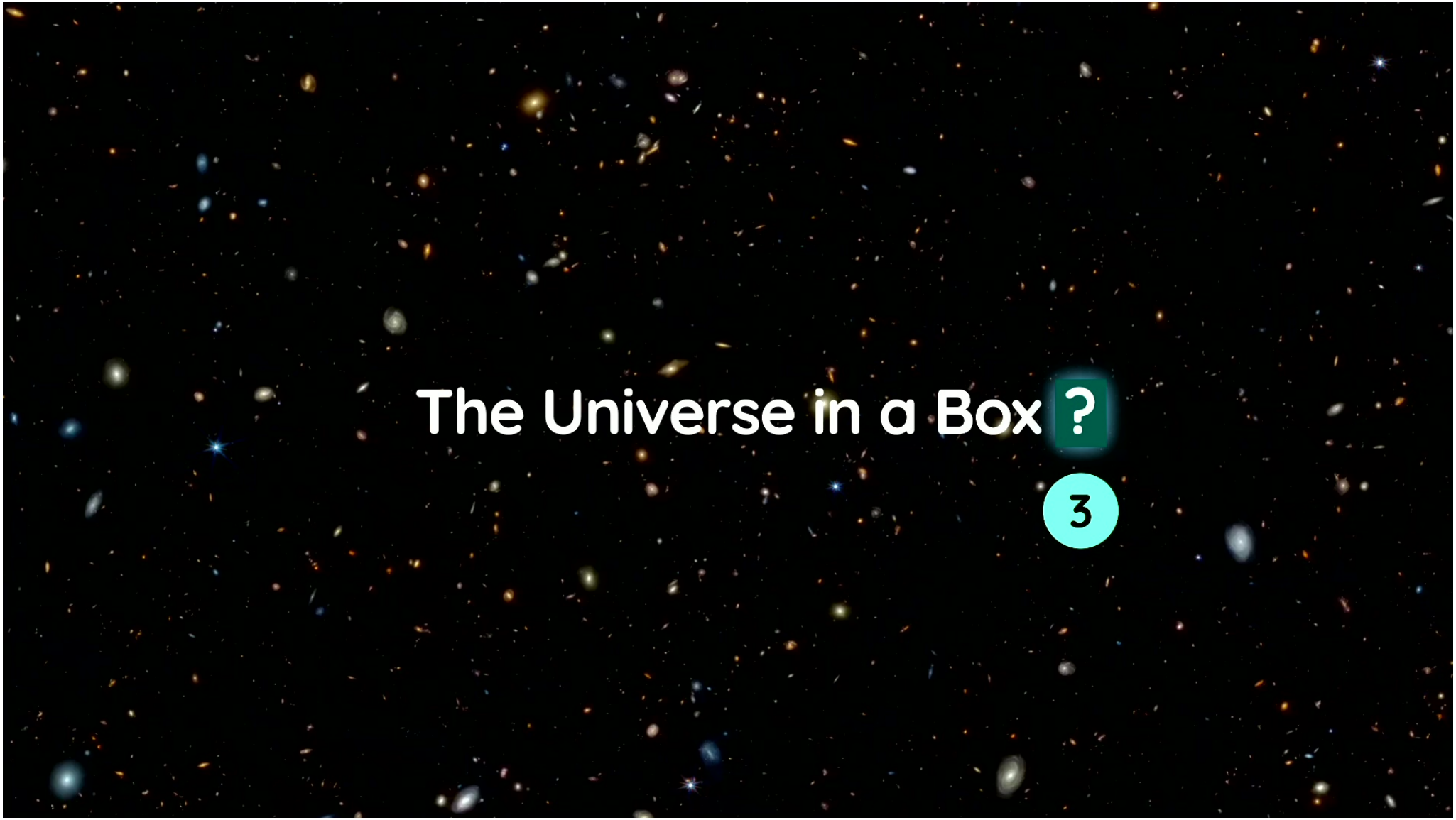
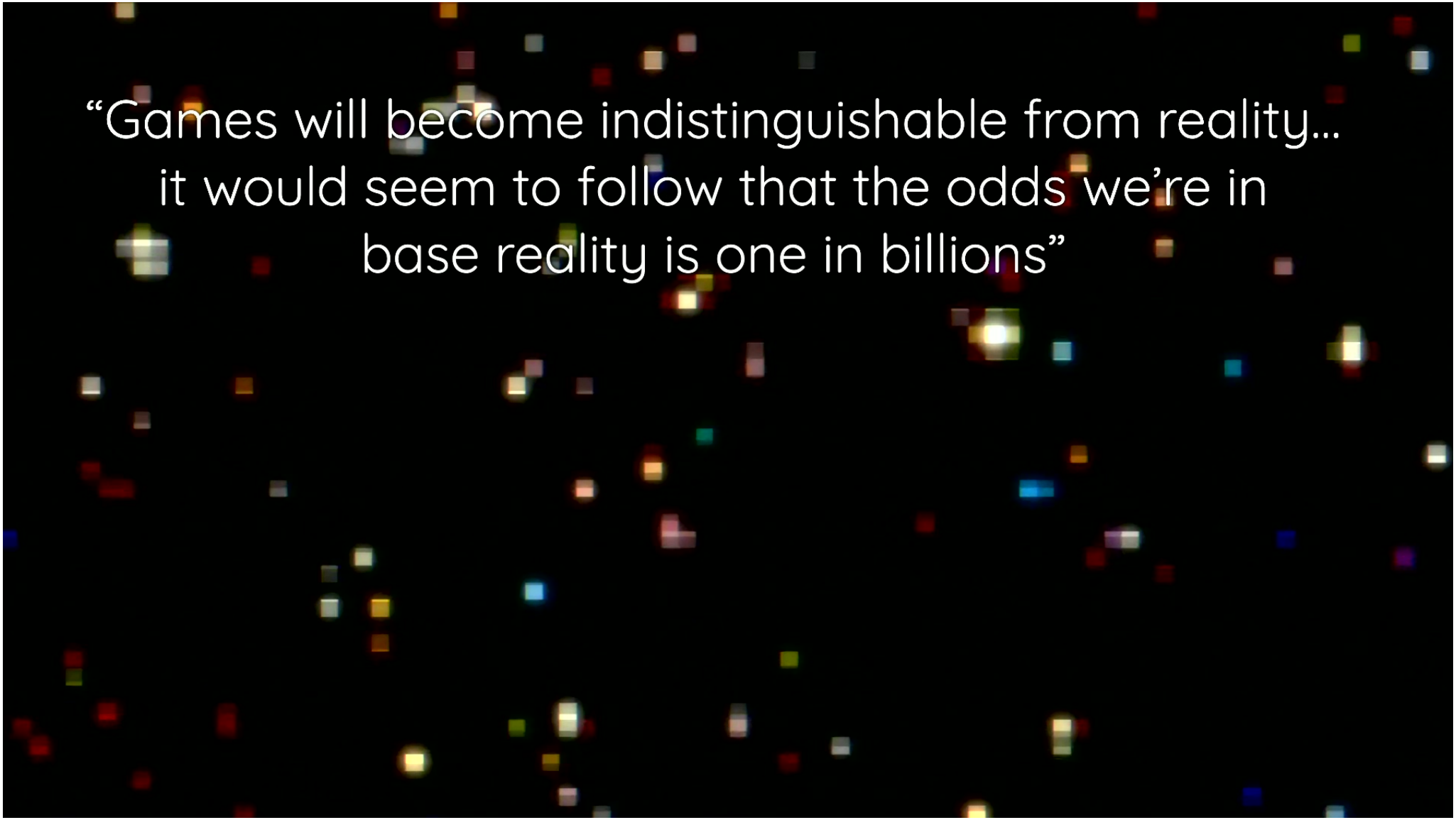
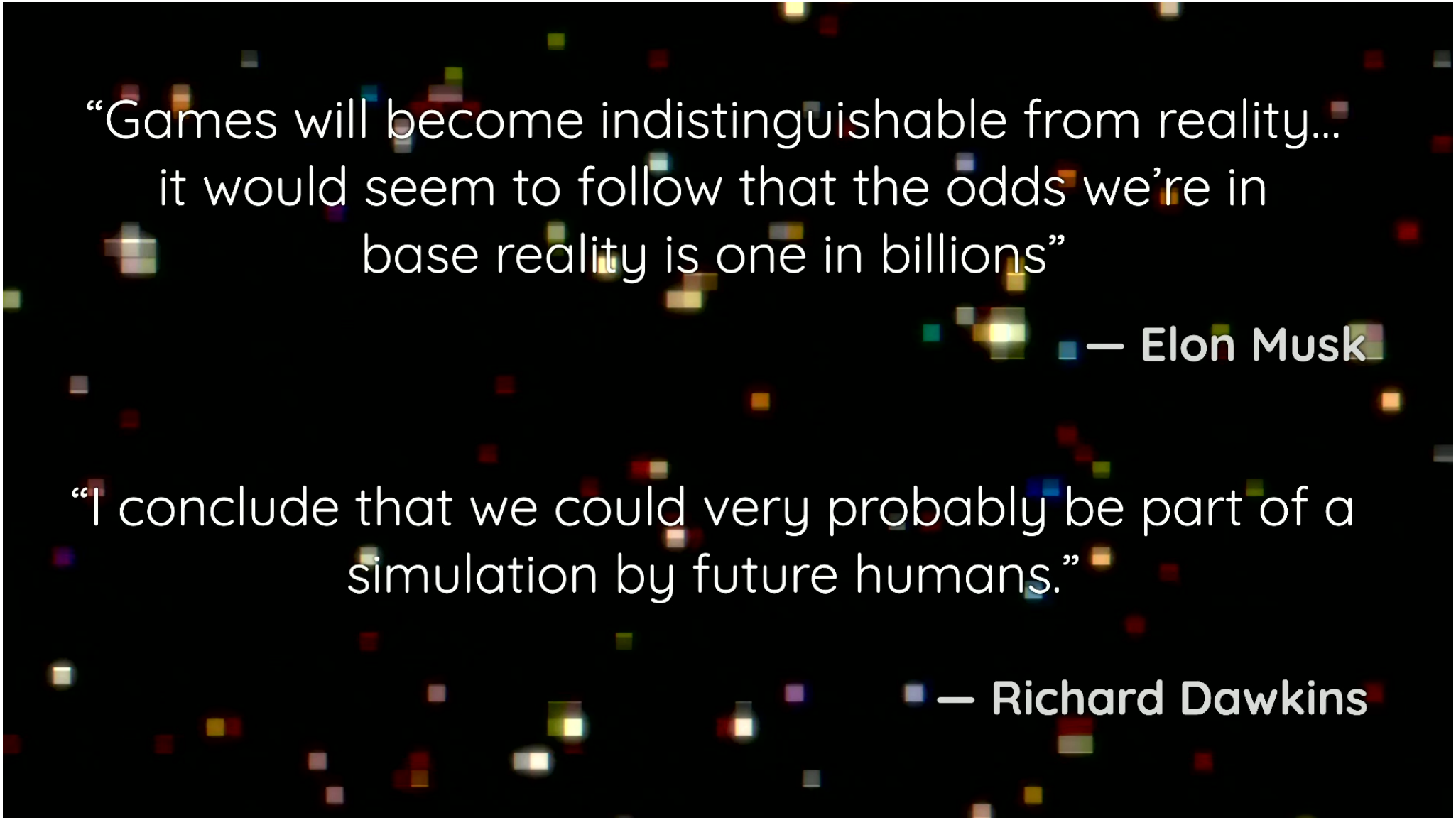

0
MILLION
YEARS


1700
MILLION
YEARS


13750
MILLION
YEARS


The Universe in a Box ?
3

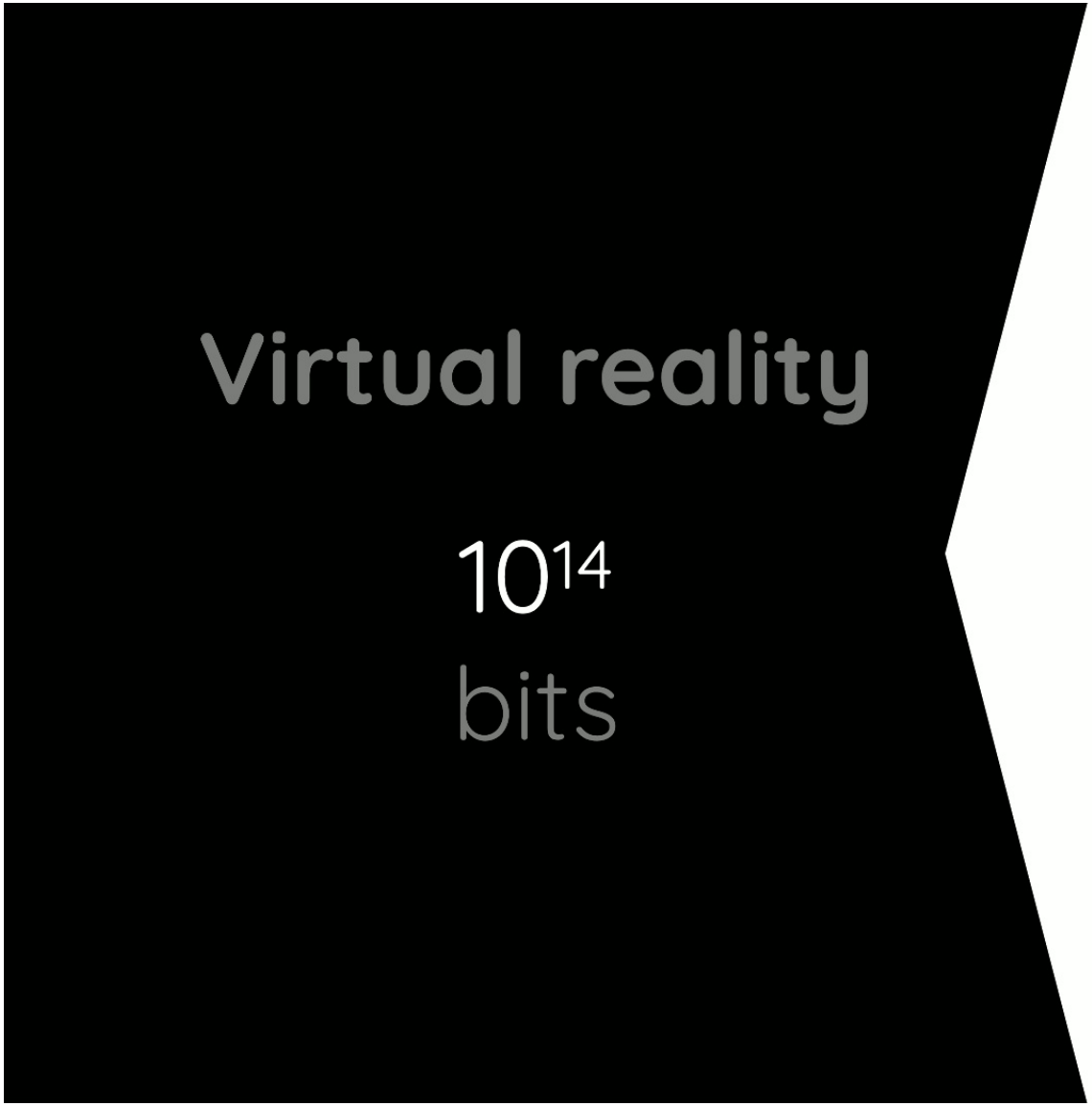

“Games will become indistinguishable from reality…
it would seem to follow that the odds we’re in
base reality is one in billions”


“Games will become indistinguishable from reality... it would seem to follow that the odds we’re in base reality is one in billions”
— Elon Musk
“I conclude that we could very probably be part of a simulation by future humans.”
— Richard Dawkins

Virtual reality

10^{14}

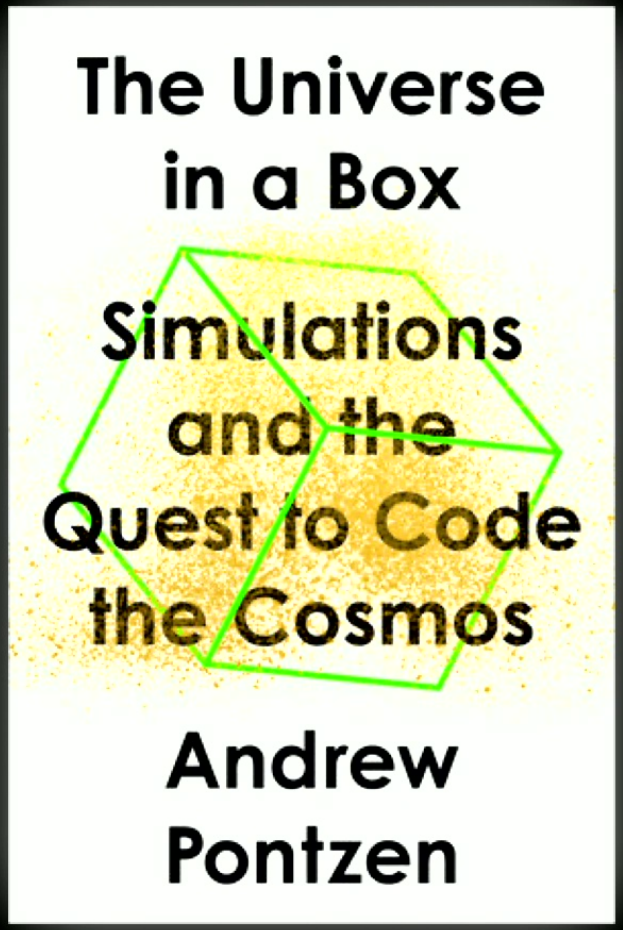
bits



Reality

10^{124}

qubits



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