A way to infinity

A movie script, version Dec 17^{th} 2015

0. animated observatory logo [0:20], 1. a drive to the observatory [0:40], 2. fisheye movie from the observatory [0:20]

In an everyday rush of our lives... there is not enough time to think... about something exceeding us... about something exceeding any limits... about infinity... but now the time has come.

3. A way to infinity [0:10], 4. infinity on a circle [0:40]

Infinity can be surprisingly close. It's hidden in a circle, for example, which can be orbited for ever, even though the circle itself is limited.

It's like finding ourselves in a locked labyrinth, we can only walk and walk. The symbol of sideways eight refers to this erratic, never-ending doing.

5. infinity beyond horizon [0:40]

Different infinity can be felt in distance, beyond horizon. It's unreachable, because the horizon is always running away from us.

We may also feel it in a river of time; let us imagine a future is formed in an apeiron, gives rise to an ephemeral present which immediately decays into a past and dives back to the apeiron.

6. infinity on a line [0:50]

Unbelievable infinity was discovered on a number line. Even though there is an infinite number of natural numbers, they do not suffice to count real numbers, not even those between zero and one.

If we try to mutually assign all of them, as Cantor did, we soon encounter a contradiction. One infinity, aleph one, is clearly larger than the other, aleph zero.

7. infinity as a limit [1:00]

Absolute infinity is an extremely useful abstraction, without which a modern mathematics would not exist. We regularly encounter divergent sequences, limits of functions at infinity, or infinite limits of functions in finite points.

"A limit of a function $f(x)$ for x approaching a is infinite, if for every y larger than zero, there exists δ larger than zero, such that for x from the δ surroundings of point a, the absolute value of $f(x)$ is larger than y." This is too one kind of infinity.

However, a big mystery remains: are infinites only potential, theoretical possibilities, or rather actual, really existing?

8. a sky with planets and ecliptic [0:30]

And when speaking of this... Is the Universe infinite? Is it infinite in space? Is it infinite in time? How can we answer these questions? Well, the only possibility seems to be we measure distances and ages of celestial bodies. The distances within our Solar System were measured most precisely...

9. Voyager trajectory in Uniview [0:30]

They can be reached by spacecrafts which broadcast telemetric data. They spread at the speed of light, almost 300 000 kilometres per second. Voyager 1, launched in 1977, is now so far that its radio signal travels back to the Earth almost 1 day.

10. Orion constellation, 11. the Earth, parallax measurement [0:50]

Foreign stars are much further away, their light has to travel years, or even thousands of years. These interstellar distances are measured by means of geometry.

We observe a star from two different places on the Earth's orbit about the Sun, separated by the distance d, approximately 300 million kilometres. We measure the corresponding change of direction towards the star, angle α. The unknown distance x is computed simply as $x = (d/2)/\tan(\alpha/2)$.

12. a dron flight away from the observatory [0:30]

In order to see more distant and fainter objects, we desperately need a dark sky. As far from civilization, as possible…

13. dark sky in the Eagle Mountains [0:40]

In the mountains we can spot a number of fuzzy "cloudlets". One of them, in the constellation of Hercules, is called M13. It's a globular cluster, composed of roughly 300 000 stars. The distances to stellar populations are easier to measure, using relative brightness and colour indices. We thus know the cluster is about 22 000 light years from us.

14. a view from the dome [0:20], 15. M33 galaxy [0:30]

Unfortunately, we do not see everything by naked eyes; there is not enough photons and too much noise. So let us use binoculars or an astronomical telescope. Then, we can find M33 in the Triangle constellation.

Soon, we realize that such "cloudlets" are distant islands full of stars, similar to our own Galaxy — Milky Way. We can even find similar types of stars, cepheids, novae, supernovae… only much fainter, because they are millions or even hundreds of millions light years away.

16. large-scale structure in Uniview [0:30]

The most distant object we can see by the telescope from the observatory is a seemingly ordinary quasar 3C 273. From the distance 2.4 billion light years, it can only be seen thanks to an immense radiation power, corresponding to $4 \cdot 10^{12}$ Suns, most likely generated by a giant black hole with an accretion disk.

17. a part of the VLT animation [0:30]

Using very large telescopes, such as the VLT, we would see even the faintest galaxies and most distant quasars, 13 billion light years away, but still, this is not the infinity…

18. Rigel star interior [1:00]

A measurement of age is a different problem.

We study stars using astrophysical models. The equation of continuity, hydrostatic equilibrium, thermal equilibrium and energy transfer enable us to see into their interior. We can compute the profiles of density, temperature, pressure, luminosity, and also determine the age.

For example the bright Rigel from Orion constellation, a blue supergiant, is 'only' 10 million years old. Today, it has a temperature 128 million kelvin in the centre, at which α particles, or helium nuclei, are combined to carbon nuclei. Moreover, protons change to α particles in the shell surrounding the centre.

19. a flight through M13 cluster [0:40]

On contrary, the oldest stars were found in the globular clusters. They are red dwarfs, stars with masses less than $0.9\,M_\odot$, where protons also change to α particles in the core, but very slowly. Their ages are almost 13 billion years.

13 billion years, 13 billion light years… It cannot be a coincidence. We have found light created long time ago and far away…

… however, to find infinity the light is not important, but the darkness!

20. Olbers paradox [0:30]

If the Universe would be infinite, if it would exist for infinite time, if the stars would shine forever, the whole sky would be as bright as surface of stars!

Instead, we are surrounded by night — Olbers' paradox, a proof that one or more of our assumptions is wrong.

21. a part of Illustris animation [0:20]

Today, we know that stars cannot shine forever. Today, we know that the Universe did not always exist. What is left, is the infinite space of the Universe.

22. Einstein field equations [1:00]

Infinity is considered ideal and, in a sense, simple. The simplest models of the Universe, based on the Einstein field equations, assume that the Universe was infinite, almost homogeneous and isotropic from the time $t > 0$.

Nevertheless, the space cannot be considered static! Spectroscopic measurements of radial velocities of galaxies, photometry of type Ia supernovae, tiny fluctuations of cosmic microwave background or observations of large-scale structures — all confirm that distances have to be multiplied by the expansion factor a, dependent on the time t.

Infinite Universe is thus expanding, but not enlarging. Infinity multiplied by a positive finite number is still the same — infinity with the same cardinality.

23. a surface of last scattering, coordinate axes continuing to infinity [0:40]

We, as observers of the Universe, are limited by the event horizon, the very existence of space and time, (13.8 ± 0.1) billion years. In spite of this, it seems more probable, almost inevitable, that the Universe continues beyond the horizon, beyond any limit.

Perhaps, someone of us may prove the opposite, in a never-ending quest to understand the Universe.

24. titles, sources [0:20], 25. Space Ends Here [0:15]