On the history of the Universe expansion: Edwin Hubble, Georges Lemaître and Vesto Slipher

Emili Elizalde

ICE Pizza-Lunch Seminar, March 1, 2019
Electronic vote on the Resolution B4
“on a suggested renaming of the Hubble Law”

Voting Results for the Vote on Resolution B4 "on a suggested renaming of the Hubble Law"

<table>
<thead>
<tr>
<th>Option</th>
<th>No. of Votes</th>
</tr>
</thead>
<tbody>
<tr>
<td>I approve the Resolution B4</td>
<td>3169</td>
</tr>
<tr>
<td>I reject the Resolution B4</td>
<td>798</td>
</tr>
<tr>
<td>Abstain</td>
<td>93</td>
</tr>
<tr>
<td><strong>Total Number of Votes</strong></td>
<td><strong>4,060</strong></td>
</tr>
</tbody>
</table>

Background

Five Resolutions were proposed for approval at the XXXth IAU General Assembly (Vienna, August 20th – 31st, 2018). They were announced and posted on the IAU web site on June 20th (see https://www.iau.org/news/announcements/detail/ann18029/) and initially they did not generate any comments by the members.

The Chair of the Resolution Committee presenting the Resolution B4
L'expansió de l'Univers:
Un dels descobriments més importants en tota la Història de la Humanitat
1917

✓ Universe: eternal
✓ Universe = Milky Way
✓ Universe: static why?

Einstein field equations with $\Lambda$

“Eine Größe Eselei”

Beginning of (Theoretical) Modern Cosmology
Apr 26, 1920: The Great Debate – Shapley vs Curtis
Harlow Shapley – the Milky Way was the entire Universe
Heber Curtis – many novae in Andromeda: “island Universe” (I Kant)
FINDS SPIRAL NEBULAE ARE STELLAR SYSTEMS; Dr. Hubbell Confirms View That They Are 'Island Universes' Similar to Our Own

WASHINGTON, Nov. 22. -- Confirmation of the view that the spiral nebulae, which appear in the heavens as whirling clouds, are in reality distant stellar systems, or "island universes," has been obtained by Dr. Edwin Hubbell of the Carnegie Institution's Mount Wilson observatory, through investigations carried out with the observatory's powerful telescopes.

In 1929 Hubble formulated the Redshift Distance Law, Hubbell's law

Image of H335H shows the glass side of the photographic plate, on which Hubble marked novae and, eventually, the first Cepheid in ink.Hubble variable number one, or V1, two million light-years away in the outer regions of the neighboring Andromeda galaxy, or M31.
Ernst J. Öpik

Estonian astronomer and astrophysicist (1893-1985) worked at the Armagh Observatory in Northern Ireland. In 1922 published a paper estimating the distance to Andromeda using an original method based on observed rotational velocities of the galaxy: 450 kpc. Was the first to calculate the density of a white dwarf.

His result was closer to recent estimates (775 kpc) than Hubble's result (285 kpc) of Nov 23, 1924; E Öpik, ApJ 55, 406, 1922.
Year 1912

The Beginning of Modern Cosmology

- Distances Henrietta S. Leavitt (Cepheids)
- Velocities Vesto M. Slipher (redshifts)

7 April 1912: Victor Hess discovers cosmic rays
Henrietta S Leavitt 1912 period-luminosity relationship of Cepheid variable stars: linear dep luminosity vs log of period of variab stars (Eddington valve) “standard candles" for measuring H
On September 17, 1912, obtained the first radial velocity of a "spiral nebula" - Andromeda. Using the 24-inch telescope at Lowell Observatory, AZ, he got more Doppler shifts, establishing that large velocities, usually in recession, were a general property of the spiral nebulae.

Slipher presented his results of the speed of 15 nebulae to the Am Astronomical Society in 1914, and received a standing ovation.
By 1917 Slipher ...

had 25 results, 4 of them blueshifts, and he gave an interpretation on the enormous receding mean velocity, of nearly 500 km/s, of these objects: “This might suggest that the spiral nebulae are scattering but their distribution on the sky is not in accord with this since they are inclined to cluster.”

And he added that: “... our whole stellar system moves and carries us with it. It has for a long time been suggested that the spiral nebulae are stellar systems seen at great distances ... This theory, it seems to me, gains favor in the present observations.”
In 1924 Karl Lundmark, by making the assumption that galaxies were standard objects, used their size and brightness to infer their distance from us.

He then tried to find a relationship between the Slipher’s redshifts and the distances and concluded that there might be one, but this was not clear enough.

Actually, Hubble did also make the same assumption but improved the table of distances by using Cepheid variable stars, when they were available (and again Slipher’s redshifts). In this way he found a clear correlation.
Table 1: Radial velocities in km/s of 25 spiral nebulae published by VM Slipher in 1917

At large scale, the dominant movement of our Universe is dictated by the law:

\[ V = H_0 D \]

\[ H_0 = (67.8 \pm 0.9) \text{ km/s/Mpc} \quad [500 \text{ Hubble, 1929}] \]

**Interpretation:**

1. Proper movement of the galaxies
2. Movement of the reference system, of space-time

Both are right! –But the second prevails at large distances
Hubble acknowledged Slipher's seminal contribution to his own work by declaring that:

“... the first steps in a new field are the most difficult and the most significant. Once the barrier is forced further development is relatively simple.”

[Biographical Memoirs, Vol 52, National Academy of Sciences (U.S.)]
In a letter by Hubble to Willem De Sitter in 1931, he stated his thoughts about the velocities by saying

"... we use the term 'apparent velocities' in order to emphasize the empirical feature of the correlation. The interpretation, we feel, should be left to you and the very few others who are competent to discuss the matter with authority."

Sten Odenwald and Rick Fienberg, "Redshifts Reconsidered", Sky Pub Co (1993)

Einstein was convinced in `31 by Eddington, Tolman, and de Sitter (not by Hubble) of the facts that his static model was unstable and that the universe was expanding.


Hubble never said the universe was expanding! http://cecelia.physics.indiana.edu/life/redshift.html
It took Einstein 10 years to understand …

Albert Einstein and the Friedmann Equations, 8.286, 9/27/07: Alan Guth

Publication of the Friedmann Equations

- “On the Curvature of Space”, A. Friedmann, Petersburg
  Received June 29, 1922, Zeitschrift für Physik

  “the Universe may expand since General Relativity equations admit dynamical solutions”

- Remark on the work of A. Friedmann, ZfP 1922, “On the Curvature of Space”
  A. Einstein, Berlin
  Received September 18, 1922, Zeitschrift für Physik
June 29, 1922: Friedmann's paper received at Zeitschrift für Physik

September 18, 1922: Einstein's refutation received at Zeitschrift für Physik

December 6, 1922: Friedmann learns about Einstein's objection from his friend, Yuri A. Krutkov, who is visiting in Berlin. Friedmann writes a detailed letter to Einstein. Einstein is traveling and does not read it.

May, 1923: Einstein meets Krutkov in Leiden, both attending the farewell lecture by Lorentz, who was retiring.

Krutkov's letters to his sister: "On Monday, May 7, 1923, I was reading, together with Einstein, Friedmann's article in the Zeitschrift für Physik." May 18: "I defeated Einstein in the argument about Friedmann. Petrograd's honor is saved!"

May 31, 1923: Einstein's retraction of his refutation is received at Zeitschrift für Physik.

Big Bang

“Condició primigènia en la qual existien unes condicions d'una infinita densitat i temperatura” [Wikipedia CAT]

“At some moment all matter in the universe was contained in a single point” [Wikipedia]

Georges Lemaître (1894-1966)

Theory, 1927: Solution (Friedmann’s) of Einstein’s Eqs
Annales Société Scientifique Bruxelles 47, 49 (1927), Eddington MNRAS (1930)

Observational evid.: V. Slipher redshifts + E. Hubble distancies

"hypothèse de l'atome primitif" Nature 127, 706 (1931)

primeval atom, cosmic egg

James Peebles: "The discovery that the U is expanding", Madrid 21/4/15

(Translated by permission from “Annales de la Société scientifique de Bruxelles;” Tome XLVII, série A, première partie.)

1. Introduction.

According to the theory of relativity, a homogeneous universe may exist such that all positions in space are completely equivalent; there is no centre of gravity. The radius of space $R$ is constant; space is elliptic, i.e. of uniform positive curvature $1/R^2$; straight lines starting from a point come back to their origin after having travelled a path of length $\pi R$; the volume of space has a finite value $\pi^2 R^3$; straight lines are closed lines going through the whole space without encountering any boundary.

Two solutions have been proposed. That of de Sitter ignores the existence of matter and supposes its density equal to zero. It leads to spatial difficulties and is based on highly indeterminate solutions.

Mar. 1931. Homogeneous Universe of Constant Mass. 483
“All That Matter ... in One Big Bang ...,”
& Other Cosmological Singularities

E Elizalde

Galaxies 2018, 6, 25; doi:10.3390/galaxies6010025

Reasons in Favor of a Hubble-Lemaître-Slipher’s (HLS) Law

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Symmetry 2019, 11(1), 35; https://doi.org/10.3390/sym11010035
Thank You !