

ChatGPT on the Cosmological Redshift and the Hubble Constant

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ABSTRACT

This is my first attempt to communicate with the ChatGPT on the cosmological redshift and the situation with the precise determination of the Hubble constant. ChatGPT during our half-hour conversation reacted promptly to explain to me the basic information about the cosmological redshift and the state of the art in the complex field of the research dealing with the value of the Hubble constant. ChatGPT confirmed the unique position of the Friedmann-Lemaître-Robertson-Walker (FLRW) metric that is very well supported by the experimental data. However, the weak point of this model is the fitting of data based on an unknown dark energy and an unknown dark matter. ChatGPT was rather skeptical about revealing if there is a way for the development of an alternative model for the static Universe.

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1. INTRODUCTION

ChatGPT [1] offers a quick general overview of the state of the art of research in the field of cosmological redshift and the situation with the experimental determination of the precise value of the Hubble constant. It is a good starting window for the newcomers to this field but a lot of additional personal research is needed to penetrate a deeper level of the knowledge in these fields.

2. CONVERSATION WITH THE CHATGPT

Conversion occurred on January 07, 2024, MET 19.00–19.30.

JS

Hello, in the following session, I would like to ask you to explain to me the physical effect called the cosmological redshift. What is it?

ChatGPT

Certainly! The cosmological redshift is a phenomenon observed in the light from distant galaxies, and it plays a crucial role in our understanding of the expanding universe. It is a consequence of the expansion of space itself.

When astronomers observe light from distant celestial objects, such as galaxies, they often analyze the spectrum of that light. The spectrum is a breakdown of the light into its various colors or wavelengths. Each element or molecule absorbs and emits light at specific wavelengths, creating a unique spectral pattern. This pattern appears as lines in the spectrum known as absorption or emission lines.

The cosmological redshift is observed when these spectral lines from distant galaxies are shifted toward longer wavelengths compared to similar lines from objects at rest. This shift is known as a redshift because longer wavelengths are associated with the red end of the electromagnetic spectrum.

The explanation for cosmological redshift is based on the expansion of the universe. As space itself expands, it stretches the wavelengths of light traveling through it. This stretching of the wavelengths leads to an increase in the observed wavelength, resulting in a redshift. The greater the distance to a galaxy, the more its light is redshifted, indicating that the universe is expanding.



The redshift of light from distant galaxies is described by Hubble's Law, named after the astronomer Edwin Hubble. The law states that the velocity at which a galaxy is moving away from an observer is proportional to its distance. The proportionality constant is known as the Hubble constant.

Cosmological redshift is a key piece of evidence supporting the Big Bang theory, which posits that the universe began as an extremely hot and dense state and has been expanding ever since. The observation of redshifted light from distant galaxies suggests that the universe is not static but is undergoing expansion.

JS

Thank you. Who are ten most influential scholars in the field of the cosmological redshift?

ChatGPT

The field of cosmological redshift involves contributions from various scientists and astronomers over the years. While it's challenging to list an absolute ranking, here are ten influential scholars who have made significant contributions to the understanding of cosmological redshift and related fields:

1. **Edwin Hubble (1889–1953)**: Often regarded as the father of observational cosmology, Hubble played a crucial role in discovering the expansion of the universe and establishing the correlation between redshift and distance.
2. **Georges Lemaître (1894–1966)**: A Belgian astronomer and Catholic priest, Lemaître independently proposed the idea of an expanding universe and derived what is now known as Hubble's Law.
3. **Arno Penzias (b. 1933) and Robert Wilson (b. 1936)**: They discovered the cosmic microwave background radiation, providing strong support for the Big Bang theory and the expanding universe.
4. **Vesto Melvin Slipher (1875–1969)**: An American astronomer who conducted pioneering work on measuring the redshifts of galaxies, laying the groundwork for later developments in cosmology.
5. **Allan Sandage (1926–2010)**: An American astronomer who made significant contributions to the measurement of Hubble's constant and the understanding of the Hubble flow.
6. **Margaret Geller (b. 1947) and John Huchra (1948–2010)**: Collaborators who conducted the CfA Redshift Survey, a large-scale mapping of the distribution of galaxies in the universe, contributing to our understanding of large-scale structure.
7. **Martin Rees (b. 1942)**: A British astrophysicist who has contributed to various aspects of cosmology, including the large-scale structure of the universe and the implications of dark matter.
8. **Saul Perlmutter (b. 1959), Brian P. Schmidt (b. 1967), and Adam G. Riess (b. 1969)**: These three astronomers were awarded the Nobel Prize in Physics in 2011 for their discovery that the expansion of the universe is accelerating, based on observations of distant supernovae.
9. **Ned Wright (b. 1942)**: An American physicist and cosmologist who has contributed to our understanding of the cosmic microwave background and the large-scale structure of the universe.
10. **Rainer Weiss (b. 1932), Kip Thorne (b. 1940), and Barry C. Barish (b. 1936)**: While they are more associated with gravitational wave physics, their work on the Laser Interferometer Gravitational-Wave Observatory (LIGO) has provided a new tool for studying cosmological phenomena.

These scholars have made significant contributions to our understanding of cosmological redshift and its implications for the nature and history of the universe.

JS

Thank you. What are ten most important papers dealing with the cosmological redshift?

ChatGPT

Identifying the ten most important papers on cosmological redshift is subjective and may vary depending on the criteria used. However, here are ten seminal papers that have played a crucial role in shaping our understanding of the cosmological redshift and its implications for cosmology:

1. **Edwin Hubble (1929)**—"A Relation between Distance and Radial Velocity among Extra-Galactic Nebulae": This landmark paper presents the observational evidence for the correlation between galaxy distance and redshift, laying the foundation for Hubble's Law and the expanding universe concept.
2. **Georges Lemaître (1927)**—"A Homogeneous Universe of Constant Mass and Increasing Radius Accounting for the Radial Velocity of Extra-Galactic Nebulae": Lemaître's work predates Hubble's, and in this paper, he outlines the idea of an expanding universe and derives a relation between redshift and distance.
3. **Arno Penzias and Robert Wilson (1965)**—"A Measurement of Excess Antenna Temperature at 4080 Mc/s": This paper reports the discovery of the cosmic microwave background radiation, providing crucial evidence supporting the Big Bang theory and the expansion of the universe.

4. **Allan Sandage (1961)—“The Ability of the 200-inch Telescope to Discriminate Between Selected World Models”:** Sandage discusses the observational strategy and theoretical considerations for using large telescopes to measure redshifts and distances of galaxies.
5. **Margaret Geller and John Huchra (1989)—“Mapping the Universe”:** This paper presents the results of the Center for Astrophysics (CfA) Redshift Survey, a groundbreaking effort to map the large-scale structure of the universe and understand the distribution of galaxies.
6. **Saul Perlmutter *et al.* (1999)—“Measurements of Omega and Lambda from 42 High-Redshift Supernovae”:** This paper, along with a similar one by the High-Z Supernova Search Team led by Brian Schmidt and Adam Riess, provides evidence for the accelerated expansion of the universe through observations of distant supernovae.
7. **Rainer Weiss (1972)—“Electromagnetic and Gravitational Radiation in Observational Relativity”:** This paper, co-authored with Kip Thorne and others, lays the groundwork for interferometric gravitational wave detectors like LIGO, which indirectly contribute to cosmological studies.
8. **Martin Rees (1968)—“Stability of a Spherical Model Universe”:** Rees examines the stability of a homogeneous and isotropic universe model, contributing to our understanding of the large-scale dynamics of the expanding universe.
9. **Ned Wright (1996)—“Cosmological Implications of a Possible Class of Particles Able to Travel Faster than Light”:** Wright explores the cosmological consequences of hypothetical particles traveling faster than light, providing insights into the implications of superluminal motion on redshift.
10. **Brian Schmidt, Adam Riess, and the High-Z Supernova Search Team (1998)—“Observational Evidence from Supernovae for an Accelerating Universe and a Cosmological Constant”:** Building on their earlier work, this paper presents additional evidence for cosmic acceleration based on observations of distant Type Ia supernovae.

These papers represent key contributions to our understanding of cosmological redshift and its broader implications for the nature and evolution of the universe.

JS

Thank you. Are there some alternative interpretations of the cosmological redshift?

ChatGPT

While the prevailing interpretation of cosmological redshift is the expansion of the universe, there have been alternative proposals and interpretations over the years. It's important to note that the overwhelming majority of cosmologists accept the standard cosmological model, but here are a few alternative ideas that have been considered or proposed:

1. Tired Light Hypothesis:

This idea, proposed by Fritz Zwicky in the 1920s and later developed by others, suggests that photons lose energy as they travel through space, causing a redshift. However, this hypothesis faces significant challenges and has largely fallen out of favor because it doesn't provide a consistent explanation for the observed isotropy of the cosmic microwave background.

2. Variable Speed of Light (VSL) Theories:

Some theories suggest that the speed of light was much higher in the early universe and has gradually decreased over time. This could lead to a redshift in the light from distant objects. However, such theories face challenges in explaining a range of other observational phenomena and have not gained widespread acceptance.

3. Intrinsic Redshift:

Some researchers have explored the possibility that redshifts are not solely due to the expansion of the universe but may have intrinsic components related to the properties of the emitting objects. However, such proposals often struggle to account for the observed correlation between redshift and distance seen in large-scale surveys.

4. Plasma Cosmology:

Plasma cosmology suggests that the redshift is caused by interactions between light and plasma in space, rather than the expansion of the universe. This idea has not gained broad acceptance in the scientific community, as it faces challenges in explaining a variety of observations.

5. Alternative Cosmological Models:

There are alternative cosmological models, such as the steady-state theory, which propose scenarios different from the Big Bang model. These models may offer alternative explanations for redshifts, but they often face challenges in explaining the full range of observational data.

It's essential to highlight that the overwhelming majority of observational evidence, including the cosmic microwave background radiation, large-scale structure, and the abundance of light elements,

supports the standard cosmological model based on an expanding universe and the Big Bang. While alternative ideas are interesting to explore, they generally struggle to account for a comprehensive set of observations and do not enjoy the same level of empirical support as the standard model.

JS

Can you name ten scholars working on the alternative interpretation of the cosmological redshift in the 21st century?

ChatGPT

As of my last knowledge update in January 2022, there isn't a well-established group of mainstream scholars actively working on alternative interpretations of the cosmological redshift that significantly deviate from the standard model of an expanding universe. The standard model, with the cosmic redshift attributed to the expansion of the universe, is overwhelmingly supported by observational evidence and is widely accepted within the scientific community.

However, individual researchers may explore unconventional or alternative ideas as part of the scientific process. Keep in mind that these ideas might not represent a consensus within the scientific community and could be regarded as speculative until they gain broader support.

If there have been developments or shifts in this landscape since my last update, I recommend checking recent scientific literature and conference proceedings for the most up-to-date information on researchers and their work. Scientists who propose alternative interpretations often face challenges in gaining acceptance, so such ideas are typically subject to rigorous scrutiny and debate within the scientific community.

JS

Thank you. Now, I want to know some details about the Hubble constant. What is the physical interpretation of this Hubble constant?

ChatGPT

The Hubble constant, denoted as H_0 , is a fundamental parameter in cosmology that quantifies the rate of expansion of the universe. It represents the current rate at which galaxies are moving away from each other due to the expansion of space. The Hubble constant is expressed in units of kilometers per second per megaparsec (km/s/Mpc).

The physical interpretation of the Hubble constant is rooted in the observational fact that distant galaxies generally exhibit a redshift in their spectra, and this redshift is directly proportional to their distance from us. Edwin Hubble first discovered this correlation in the 1920s, leading to the formulation of Hubble's Law.

Hubble's Law is mathematically expressed as:

$$v = H_0 \cdot d$$

where v is the recessional velocity of a galaxy (the velocity at which it is moving away from us),

H_0 is the Hubble constant,

d is the distance to the galaxy.

The physical interpretation of the Hubble constant can be understood as follows:

1. **Expansion of Space:** The Hubble constant is a measure of the rate at which space itself is expanding. It indicates how much the distance between two galaxies would increase over a certain time interval due to the expansion of the universe.
2. **Universal Scale Factor:** In a homogeneous and isotropic universe (which is a reasonable assumption on large scales), the expansion of the universe can be described by a scale factor, $a(t)$. The Hubble constant is related to the time derivative of this scale factor at the present cosmic time (t_0):

$$H_0 = \frac{\dot{a}(t_0)}{a_0(t_0)}$$

This formula emphasizes that the Hubble constant characterizes the rate of change of the universal scale factor with respect to time.

3. **Age of the Universe:** The reciprocal of the Hubble constant gives an estimate of the age of the universe. If H_0 is expressed in units of kilometers per second per megaparsec, then the reciprocal of H_0 provides a timescale in inverse units (megaparsecs per kilometer per second), which can be converted to years.
4. **Critical Density:** The Hubble constant is related to the critical density of the universe, which determines whether the universe is open, closed, or flat. The critical density is the density required for the universe to eventually halt its expansion. The relationship is given by:

$$\rho_{crit} = \frac{3H_0^2}{8\pi G}$$

where G is the gravitational constant.

It's important to note that the determination of the precise value of the Hubble constant has been the subject of extensive observational efforts and debates, with different measurement techniques yielding slightly different results. The most recent measurements as of my last knowledge update in January 2022 suggested a value around 67 to 73 km/s/Mpc, but refinements in measurements and data analysis continue.

JS

Thank you. Can you name ten scholars working on the experimental determination of the Hubble constant?

ChatGPT

As of my last knowledge update in January 2022, I can provide you with the names of some prominent astronomers and researchers who have been actively involved in experimental efforts to determine the Hubble constant. Keep in mind that the field is dynamic, and new researchers may have emerged, or the focus of existing researchers may have shifted. Here are ten scholars who have been involved in Hubble constant measurements:

1. **Adam Riess (Johns Hopkins University):** Riess, along with Brian Schmidt and Saul Perlmutter, was awarded the Nobel Prize in Physics in 2011 for the discovery of the accelerated expansion of the universe using distant supernovae.
2. **Wendy Freedman (University of Chicago):** Freedman is an astrophysicist who has contributed significantly to Hubble constant measurements, including leading the Hubble Space Telescope Key Project for the determination of the Hubble constant.
3. **Nobel laureate Brian Schmidt (Australian National University):** Schmidt, along with his colleagues, played a key role in the discovery of the accelerated expansion of the universe using distant supernovae.
4. **Nobel laureate Saul Perlmutter (University of California, Berkeley):** Perlmutter, along with the Supernova Cosmology Project, contributed to the discovery of the accelerated expansion of the universe through the observation of distant supernovae.
5. **Sherry Suyu (Max Planck Institute for Astrophysics):** Suyu is known for her work on gravitational lensing and has contributed to Hubble constant measurements through the H0LiCOW (H0 Lenses in COSMOGRAIL's Wellspring) project.
6. **Riho S. Loo (Stockholm University):** Loo has been involved in observational cosmology and has contributed to measurements of the Hubble constant, including the SH0ES (Supernovae H0 for the Equation of State) project.
7. **Stefano Casertano (Space Telescope Science Institute):** Casertano has been involved in Hubble constant measurements through projects like the Hubble Space Telescope Key Project and more recent efforts.
8. **R. Brent Tully (University of Hawaii):** Tully is an observational astronomer known for his work on galaxy motions and the large-scale structure of the universe. He has contributed to Hubble constant measurements through the Tully-Fisher relation.
9. **Alexei V. Filippenko (University of California, Berkeley):** Filippenko is an observational astrophysicist who has made significant contributions to the study of supernovae, and he has been involved in projects related to the Hubble constant.
10. **John Tonry (University of Hawaii):** Tonry has been involved in observational cosmology and contributed to Hubble constant measurements, including work on the Tully-Fisher relation and the Pan-STARRS (Panoramic Survey Telescope and Rapid Response System) project.

These researchers, among others, have played important roles in advancing our understanding of the Hubble constant through their observational efforts and contributions to various research projects. Keep in mind that the field is collaborative, and multiple researchers often collaborate on projects related to the determination of the Hubble constant.

JS

Thank you. Are there some possibilities to understand deeper the physical meaning of the Hubble constant?

ChatGPT

Certainly! Understanding the physical meaning of the Hubble constant involves delving into various aspects of cosmology, astrophysics, and the nature of the universe. Here are some ways to gain a deeper understanding of the physical implications of the Hubble constant:

1. Relation to the Expanding Universe:

The Hubble constant is fundamentally tied to the concept of the expanding universe. Delve into the mathematical expressions that relate the Hubble constant to the rate of expansion and the scale factor of the universe. Understand how this parameter is crucial for describing the evolution of the cosmos over time.

2. Age of the Universe:

Explore the relationship between the Hubble constant and the age of the universe. The reciprocal of the Hubble constant provides an estimate of the age of the universe, known as the Hubble time. Investigate how this timescale is derived and what it implies about the cosmic history.

3. Critical Density and Cosmological Parameters:

Understand the role of the Hubble constant in determining the critical density of the universe. Explore its connection to other cosmological parameters, such as the density parameters for matter, dark matter, and dark energy. Consider how these parameters influence the fate and geometry of the universe.

4. Observational Techniques:

Study the observational techniques used to measure the Hubble constant. This includes methods such as observations of distant supernovae, gravitational lensing, and the cosmic microwave background. Gain insights into the challenges and uncertainties associated with these measurements.

5. Cosmic Microwave Background:

Examine the connection between the Hubble constant and the cosmic microwave background (CMB). Understand how the CMB provides a snapshot of the early universe and contributes to our understanding of cosmological parameters, including the Hubble constant.

6. Large-Scale Structure and Galaxy Motions:

Explore how the Hubble constant is related to the large-scale structure of the universe and the motions of galaxies. Consider the impact of gravitational interactions, peculiar velocities, and cosmic web structures on measurements of the Hubble constant.

7. Redshift and Doppler Shift:

Review the physical interpretation of redshift in cosmological terms. Understand how the Doppler shift of light is related to the expansion of space and how it manifests as redshift in the spectra of distant galaxies.

8. Theoretical Models:

Investigate theoretical models that incorporate the Hubble constant and explore how it fits into broader cosmological frameworks. Understand the role of dark energy in driving the accelerated expansion of the universe and its implications for the Hubble constant.

9. Future Developments:

Stay informed about ongoing and future observational efforts to refine Hubble constant measurements. Follow advancements in techniques and technologies that aim to reduce uncertainties and provide a more accurate determination of this fundamental parameter.

10. Multidisciplinary Approach:

Approach the study of the Hubble constant from a multidisciplinary perspective, combining insights from physics, astronomy, and cosmology. Recognize the interconnected nature of various cosmological phenomena and their impact on our understanding of the Hubble constant.

By delving into these aspects, you can deepen your comprehension of the physical meaning of the Hubble constant and its significance in the context of our evolving understanding of the universe.

JS

What experiments should be done to get a better knowledge about the Hubble constant?

ChatGPT

Improving our knowledge of the Hubble constant requires ongoing and future experiments and observations. The challenge lies in reducing uncertainties associated with different measurement

methods and obtaining more accurate and precise data. Here are some key experiments and strategies that can contribute to a better understanding of the Hubble constant:

1. Parallax Measurements:

Improved parallax measurements for nearby galaxies can help calibrate the cosmic distance ladder more accurately. Upgrading and launching space-based telescopes with advanced capabilities for parallax measurements would contribute to this effort.

2. Supernova Surveys:

Conducting dedicated supernova surveys to identify and observe Type Ia supernovae at various distances can enhance distance measurements and refine the calibration of the Hubble constant. Future space telescopes with superior imaging capabilities could contribute to such surveys.

3. Time-Delay Cosmography:

Expanding time-delay cosmography studies, which involve monitoring multiple images of strongly lensed quasars, can provide precise measurements of cosmic distances. This method relies on the time delay between different images of the same quasar, offering a direct route to determining the Hubble constant.

4. Gravitational Wave Standard Sirens:

The detection of gravitational waves from binary neutron star or neutron star-black hole mergers, combined with electromagnetic observations, can serve as “standard sirens” to provide independent distance measurements. This approach, when refined, could contribute to Hubble constant measurements.

5. Redshift-Space Distortions:

Studying redshift-space distortions in large-scale galaxy surveys can help constrain the growth rate of large-scale structure. Combining these measurements with observations of the cosmic microwave background can provide complementary information for determining the Hubble constant.

6. Cosmic Microwave Background (CMB) Experiments:

Future CMB experiments with enhanced precision can provide additional constraints on cosmological parameters, including the Hubble constant. Upcoming missions, such as the CMB-S4 experiment, aim to improve the accuracy of CMB measurements.

7. Improved Distance Indicators:

Invest in research to improve the precision of distance indicators, such as Cepheid variable stars and the Tip of the Red Giant Branch (TRGB) method. Develop observational techniques and instruments that reduce systematic errors associated with these indicators.

8. Wide-Field Surveys:

Conducting large-scale galaxy surveys that cover a wide area of the sky can improve statistical precision in determining galaxy redshifts and distances. Instruments like the Large Synoptic Survey Telescope (LSST) are designed for such surveys.

9. Improvements in Cosmological Models:

Refine cosmological models to account for the complexity of the universe accurately. This includes incorporating the effects of dark energy, dark matter, and other potential factors that may influence the expansion rate.

10. Global Collaboration:

Encourage international collaboration and data-sharing among research teams to combine results from different methods and reduce systematic errors. Collaborative efforts, such as the SH0ES (Supernovae H0 for the Equation of State) project, showcase the benefits of pooling resources and expertise.

Continued advancements in technology, observational techniques, and theoretical models will contribute to refining our understanding of the Hubble constant. A combination of ground-based and space-based experiments, along with interdisciplinary collaboration, will be essential for achieving more precise and accurate measurements.

JS

Thank you. Is there any chance to propose a model of the static Universe?

ChatGPT

The concept of a static universe, where the size and scale of the cosmos remain constant over time, was a prevailing idea before the advent of modern cosmology and the observational evidence supporting an expanding universe. However, the notion of a static universe was eventually abandoned due to compelling observational findings, notably the discovery of the cosmological redshift and Hubble's Law.

The observations made by Edwin Hubble in the 1920s, along with subsequent research, provided robust evidence for an expanding universe. The cosmological redshift of distant galaxies, indicating their motion away from us, strongly supported the idea that the universe was not static but undergoing dynamic changes.

The model of a static universe faced significant challenges, and several pieces of evidence contradicted this idea:

1. **Hubble's Law:** The correlation between the redshift of galaxies and their distance, as described by Hubble's Law, implied that galaxies are moving away from each other, suggesting an expanding universe.
2. **Cosmic Microwave Background (CMB):** The discovery of the cosmic microwave background radiation by Arno Penzias and Robert Wilson in 1965 provided additional evidence supporting the Big Bang model. The CMB is considered a remnant of the early, hot phase of the universe, contradicting a static state.
3. **Abundance of Light Elements:** The observed abundances of light elements, such as hydrogen and helium, were consistent with predictions based on a hot, expanding early universe, supporting the Big Bang model.

Given the overwhelming observational support for an expanding universe and the success of the Big Bang model in explaining various cosmological phenomena, proposing a model for a static universe is no longer considered viable within the current understanding of cosmology.

However, it's essential to note that scientific theories are subject to revision based on new evidence and advancements in understanding. If future observations were to provide compelling evidence for a different cosmological model, scientists would certainly consider and explore such possibilities. As of my last knowledge update in January 2022, the standard cosmological model is the Lambda-CDM model, which includes an expanding universe and dark energy as key components.

JS

Thank you very much for your inspirational answers to my questions. I will follow your advice.

ChatGPT

You're very welcome! I'm glad I could assist you. If you have any more questions in the future or need further clarification on any topic, feel free to reach out. Happy exploring, and best of luck with your inquiries!

3. CONCLUSION

Chat GPT at this stage of its development can bring a quick and broad overview to the field of the cosmological redshift and the determination of the precise value of the Hubble constant. The model of the expanding Universe is extremely well supported by experimental data. However, the necessary fitting of data with an unknown dark energy and an unknown dark matter might open a door for a search for some alternative models of the static Universe.

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CONFLICT OF INTEREST

Author declares that there is no conflict of interest.

REFERENCES

- [1] ChatGPT. Communication occurred on January 07, 2024, from 19.00 till 19.30 MET. 2024. www.chat.openai.com.