MOLECULES CAN EXPLAIN THE EXPANSION OF THE UNIVERSE

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ABSTRACT

The Hubble diagram continues to remain one of the most important graphical representations in the realm of astronomy and cosmology right from its genesis that depicts the velocity-distance relation for the receding large-scale structures within the Universe; it is the diagram that helps us to understand the Universe's expansion. In this paper I introduce the molecular expansion model in order to explain the expansion of the Universe. The molecular expansion model considers the large-scale structures as gas molecules undergoing free expansion into the vacuum. Large-scale structures being ensemble of atoms must behave like molecules possessing finite amount of energy. Since metric expansion of space cannot be tested practically and can only be observed indirectly due to the presence of observable entities, therefore, instead of considering the metaphysics of expanding space, the paper emphasizes upon the actual recession of large-scale structures as the most natural reason to explain the observed expansion. I show in this paper that the linear velocity-distance relation or the Hubble diagram is actually a natural and a characteristic feature of different gas molecules undergoing free expansion into the vacuum at the same time. Different gas molecules have different velocities, and, molecules being natural entities provide a natural and a scientifically-viable explanation better than metaphysics. The study conducted in this paper finds the recessional behaviour of large-scale structures to be consistent with the recessional behaviour of molecules. The free expansion of different gas molecules into the vacuum is found to be homogeneous, isotropic and in agreement with the Copernican principle. Redshift-distance relationship has been plotted for 580 type Ia supernovae from the Supernova Cosmology Project data and the reason for the deviation of the Hubble diagram from linearity at high redshifts has been explained without any acceleration by introducing the concept of differential molecular expansion.

Key words: cosmology: theory – dark energy – Hubble's law – molecular data – molecular expansion.

1 INTRODUCTION

The revolutionizing discovery by Sir Edwin Hubble in 1929 from his observations of distant galaxies from Mount Wilson Observatory in California not only proved that the Universe was expanding, it also paved a new way for modern astronomy and cosmology. The light from all the galaxies that were being observed was found to be redshifted, suggesting that the galaxies were moving away; the Universe was expanding; it was not at all "static" as was previously being considered.

Sir Edwin Hubble obtained a linear diagram by plotting the velocity-distance relation for the receding galaxies. It was the diagram that changed our perspective of the Universe forever – the Hubble diagram. The linear relationship obtained while plotting the Hubble diagram depicts the Hubble's law according to which the recessional velocity of a large-scale structure is proportional to its distance, that is, the further away a large-scale structure is, the faster it will be receding away from us. The slope of the straight line yields the Hubble constant which was originally denoted by Sir Edwin Hubble by the letter *K*. The Hubble constant gives the rate of expansion of the Universe while its inverse gives the Hubble time or the age of the Universe.

The aim of this paper is to explain the expansion of the Universe on the basis of the molecular expansion model which has been introduced in Section 2. It is shown through this model that the expansion pattern of the Universe is similar to the pattern of different gas molecules undergoing free expansion into the vacuum. Section 3 looks into the energy that causes the recession of large-scale structures. Section 4 shows that large-scale structures recede by the virtue of the energy possessed by them. The recessional behaviour of large-scale structures is found to be in agreement with the recessional behaviour of molecules, thereby suggesting the actual recession of large-scale structures. In Section 5, I discuss that the observed redshifts exhibited by the large-scale structures are due to their actual recession rather than expansion of space between them. Section 6 brings actual gas molecules into consideration to further study and compare the recessional behaviour of large-scale structures with expanding gas molecules; calculations show that different gas molecules undergoing free expansion into the vacuum at the same time exhibit a linear velocity-distance relation or the Hubble diagram. Section 7 explains the reason for the observed homogeneous distribution of large-scale structures within the Universe. Section 8 looks at the deviation of Hubble diagram from linearity at high redshifts, while Section 9 introduces the concept of differential molecular expansion to explain the observed deviation of the Hubble diagram from linearity at high redshifts without any acceleration.

2 EXPANSION OF THE UNIVERSE AND THE EXPANSION OF GAS MOLECULES: THE MOLECULAR EXPANSION MODEL

Certain questions that should undoubtedly arise while looking at the Hubble diagram are – why is the Hubble diagram linear? In fact, why should it be linear? The Hubble diagram and therefore the expansion of the Universe can be explained very effectively if we consider the large-scale structures as different gas molecules undergoing free expansion into the vacuum. Since gas molecules recede by the virtue of the energy possessed by them, therefore, the large-scale structures can also be expected to be receding by the virtue of the energy possessed by them instead of energy being possessed by empty space. Also, gas molecules undergo actual expansion instead of space undergoing metric expansion between them.

Since large-scale structures are constituted by atoms and molecular matter, therefore, there is more probability that they will be possessing energy instead of energy being possessed by empty space. Now if receding large-scale structures are being considered as gas molecules, then they must exhibit certain properties or behaviour that should perfectly match with the properties or behaviour of actual gas molecules undergoing free expansion.

3 ENERGY THAT CAUSES THE RECESSION OF A LARGE-SCALE STRUCTURE: WHY SHOULD A LARGE-SCALE STRUCTURE RECEDE?

The energy possessed by an object moving with velocity v is given as,

$$E = \frac{1}{2}mv^2 \quad (1)$$

Equation (1) can be expressed in terms of velocity as,

$$v = \sqrt{\frac{2E}{m}} \quad (2)$$

Equation (2) suggests that an object possessing sufficient amount of energy will recede with certain velocity. This is exactly what we observe for a molecule, that is, if the molecule gains more energy than before (by an increase in temperature), then according to equation (2) the velocity of the molecule will increase. Equation (2) is in agreement with the actual velocity equations for gas molecules as given by equation (4) and equation (5). Now, if a large-scale structure possesses sufficient amount of energy (Section 4), then such structure will recede with a velocity according to equation (2).

In an environment where gravitational force is stronger, like on Earth's surface, the energy possessed by an object will not cause the object to recede, as gravitational force takes over, however, a molecule is an exception in this case. Since the mass of a molecule is minuscule, therefore, a molecule is not influenced significantly by Earth's gravitational force; the energy possessed by a molecule turns out to be greater than the gravitational force acting upon it, and therefore the molecule recedes solely by the virtue of the energy possessed by it at particular temperature. Similarly, in deep space environment since the large-scale structures readily recede away from one another, therefore, the gravitational influence between them has to be weaker than the energy possessed by the large-scale structures that causes them to recede away from one another.

According to equation (2), for a large-scale structure to exhibit higher recessional velocity, the energy possessed by it should be sufficiently large and the mass should be less. So if equal amount of energy is possessed by a galaxy and a galaxy cluster, then the galaxy will exhibit higher recessional velocity as compared to the galaxy cluster. On the other hand, if the recessional velocity of a galaxy and a galaxy cluster are equal, then the galaxy will be found to possess less amount of energy as compared to the galaxy cluster (Section 4).

4 THE ENERGY POSSESSED BY A LARGE-SCALE STRUCTURE

If large-scale structures are behaving like expanding gas molecules, then they are receding by the virtue of the energy possessed by them instead of energy being possessed by empty space. To confirm this claim, consider a "baryonic" galaxy cluster with mass of about 2 x 10^{15} M$_\odot$ (4 x 10^{45} kg). From this mass we obtain the total number of protons making the cluster to be 2.3914 x 10^{72}.

The temperature of massive galaxy clusters is dominated by the extremely hot intracluster medium (ICM) at 10^8 K. The energy per molecule is given as,

$$E = \frac{3}{2}kT \quad (3)$$

where k is the Boltzmann constant and T is the temperature. Using this equation, the energy per proton corresponding to a temperature of 10^8 K turns out to be 2.0709 x 10^{-15} J, therefore, the total energy possessed by this galaxy cluster equates to 4.9523 x 10^{57} J.

With this much amount of energy being possessed by the cluster, its recessional velocity according to equation (2) will be 1.5736 x 10^6 m s^{-1}. This is just an approximation. For comparison, the recessional velocity of Norma Cluster is 4.707 x 10^6 m s^{-1} (NED 2006 results). Higher recessional velocities are also possible if the energy possessed by the large-scale structure is sufficiently large and the mass is less. For instance, for a 2 x 10^{15} M$_\odot$ (4 x 10^{45} kg) galaxy cluster to exhibit recessional velocity of 7 x 10^6 m s^{-1}, the energy possessed by it must be 9.8 x 10^{58} J. On the other hand, for a 10^{10} M$_\odot$ (2 x 10^{40} kg) galaxy or a quasar to exhibit an equal recessional velocity of 7 x 10^6 m s^{-1}, the energy possessed by them must be 4.9 x 10^{53} J (2 x 10^5 times less energy than the energy possessed by the massive galaxy cluster).

It is always observed that the highest recessional velocities are exhibited by the most distant galaxies and quasars and not by galaxy clusters as evident from their redshifts. Galaxy clusters being extremely massive are unable to efficiently utilize the energy possessed by them to exhibit such high recessional velocities as those exhibited by such distant galaxies and quasars which comparatively are very much less massive than galaxy clusters (a massive structure will recede faster than a lighter structure only if the energy possessed by it is high enough). This is in perfect agreement with the recessional behaviour of molecules, that is, a lighter molecule recedes faster as compared to a massive molecule even when they both possess an equal amount of energy (see Table 2; Figure 2 and Table 3; Figure 3). A lighter molecule will therefore cover a larger distance with time as compared to the massive molecule; a lighter molecule will therefore become the most distant molecule as compared to the massive molecule (see Figures 2 to 6). Galaxies and quasars being less massive than galaxy clusters exhibit higher recessional velocities and therefore they manage to become the most distant structures within the observable Universe. The recessional behaviour of large-scale structures being consistent with the recessional behaviour of molecules suggests the actual recession of large-scale structures and confirms the molecular expansion model to some extent.

5 REDSHIFTS: COSMOLOGICAL OR DOPPLER?

It is firmly believed that large-scale structures are stationary while the distance between them increases due to metric expansion of space. The wavelength of light emitted by the large-scale structures gets "stretched" due to metric expansion of space (cosmological redshift). Such firm belief involving the concept of metric expansion of space arises undoubtedly due to special relativity that restricts superluminal (faster than light) recessional velocities. However, according to Davis and Lineweaver (2004), "it is well accepted that general relativity, not special relativity, is necessary to describe cosmological observations". Furthermore, according to

Chodorowski (2007), "we know that, as he was constructing GR, Einstein was greatly influenced by the thoughts of German physicist and philosopher Ernst Mach. In the words of Rindler (1977), for Mach 'space is not a 'thing' in its own right; it is merely an abstraction from the totality of distance-relations between matter'. Therefore, the idea of expanding space 'in its own right' is very much contrary to the spirit of GR".

All large-scale structures exhibiting redshift suggests that they all are receding away from us, and, since we are not located in any special or preferred place (center of expansion), all large-scale structures ought to be receding away from each other as well, this provides a very compelling evidence in favour of metric expansion of space between them, furthermore, an expansion that is homogeneous (looks same at every location), isotropic (looks same in every direction) and in agreement with the Copernican principle (no preferred center) also confirms metric expansion of space. Recessional velocity of large-scale structures being proportional to their distance (Hubble's law) is also a characteristic feature of metric expansion of space. However, it is shown in this paper that free expansion of different gas molecules into the vacuum of the Universe also exhibits such remarkable features without considering metric expansion of space.

If the large-scale structures are actually receding away from each other, just like expanding gas molecules, then the light emitted by them would still undergo redshifting due to the involvement of actual recession rather than expansion of space between them (Doppler redshift). In fact, Bunn and Hogg (2009) have found that the redshifts are kinematic (Doppler redshifts) and not cosmological; according to them, the most natural interpretation of the redshift is kinematic. Regarding the concept of "expanding space", in the words of Milne (1934), "This concept, though mathematically significant, has by itself no physical content; it is merely the choice of a particular mathematical apparatus for describing and analysing phenomena".

The concept of metric expansion of space is explained by considering certain models. Some of the very popular and dominant models that try to explain the expansion of the Universe include, expanding loaf of raisin bread, stretching rubber sheet, inflating balloon, and so on. Although these models provide a theoretical insight to explain the observed expansion of the Universe, these models are not scientifically-appealing in any way. The phrase, "metric expansion of space" is extensively used in the cosmic literature, however, the exact mechanism behind such expansion remains unexplained. According to Francis et al. (2007), "the very meaning of the phrase expanding space is not rigorously defined despite its widespread use in teaching and textbooks. Hence, it is prudent to be wary of predictions based on such a poorly defined intuitive frameworks".

Another observation according to me that questions the concept of metric expansion of space comes from the low redshifts of remote supernovae given their larger-than-expected distances from us (Figure 9). According to the well-accepted concept of metric expansion of space, the more the space between the distant object and the observer, the higher will be the redshift as light has to travel through more "stretched" space. Larger-than-expected distances to the remote supernovae clearly indicate larger-than-expected stretched space between them and the observer. Therefore, the question is – why is the redshift of remote supernovae not adequately high enough at such large distances if more-than-expected space has stretched between them and the observer due to metric expansion?

6 PLOTTING THE GAS MOLECULES

Consider a spherical metallic vessel filled with gas molecules. The mass of every gas molecule inside this vessel is different. This vessel is placed somewhere in the Universe. To ensure that gas molecules expand freely in every direction, imagine that the walls of this metallic vessel disappear. As soon as the walls disappear, the molecules will expand freely in every direction (Figure 10). The molecules will move along that direction along which they were moving when the walls of the vessel disappeared. Since the molecules were moving in all possible directions when they were contained, therefore, as soon as the walls of the vessel vanish, the molecules will expand freely in every direction. When the molecules expand freely, the probability that they will collide with one another is extremely low; the collision probability between the molecules decreases with time during free expansion, it is exactly zero when the distance between the molecules becomes significantly large over time as the expansion proceeds (Figure 10 G).

With such arrangement available, eleven gaseous elements from the Periodic Table, right from Hydrogen to Radon have been considered to prove the molecular expansion model. The mass of the gas molecules has been obtained in Table 1. The mass of gas molecules increases from Hydrogen onwards; Hydrogen being the least massive molecule, whereas Radon being the most massive molecule. Hydrogen molecule can therefore be considered analogous to a galaxy or a quasar, whereas Radon molecule can be considered analogous to a massive galaxy cluster. All these gas molecules are initially contained before they are allowed to expand freely into the vacuum. The gas molecules will expand freely and recede into the vacuum by the virtue of the energy possessed by them at particular temperature as given by equation (3), while their recessional velocity due the energy possessed by them is given by equation (2). Equation (2) is in agreement with the actual velocity equations for gas molecules given as,

$$v = \sqrt{\frac{3RT}{M}} \tag{4}$$

and,

$$v = \sqrt{\frac{3kT}{m}} \tag{5}$$

where R is the gas constant, T is the temperature, M is the molecular mass (kg mol^{-1}) of the gas, that is, M/1000 (see M from Table 1), k is the Boltzmann constant and m is the mass of the molecule in kg.

In Table 2, all gas molecules are at same temperature of 303 K, the energy possessed by every molecule will therefore be equal. The recessional velocity of the molecules is obtained from equation (2) and the distance covered by them in 1 second (observation time) has been calculated. In Table 3, all molecules are still at the same temperature of 303 K, however, the observation time has been increased to 60 seconds. In Table 4, the observation time is 1 second, and every molecule is at a different temperature, therefore, the energy possessed by every molecule will also be different, although not by a significant amount since the temperature difference between the molecules is not large enough. In Table 5, every molecule is still at a different temperature, however, the observation time has been increased to 60 seconds. In Table 6, the observation time is 60 seconds, and every gas molecule is subjected to a very high temperature. It is also made sure in this case that the temperature difference between the molecules is large enough so that the energy possessed by every molecule is different by a significant amount as compared to the previous settings.

Based upon calculations (Table 2 to Table 6), the velocity-distance relation for expanding gas molecules has been plotted (Figure 2 to Figure 6). The straight line obtained for expanding gas molecules is remarkably similar to the straight line obtained for large-scale structures according to the Hubble diagram (depiction of Hubble's law) (Figure 1). According to the Hubble's law, the recessional velocity of a large-scale structure is proportional to its distance, that is, the further away a large-scale structure is, the faster it will be receding away from us. Therefore, according to the Hubble's law,

$$v = H \text{ x } D \tag{6}$$

and,

$$D = \frac{v}{H} \tag{7}$$

where v is the recessional velocity of the large-scale structure, D is its distance from us and H is the Hubble constant. The inverse of the Hubble constant ($1/H$) gives us the Hubble time which is the age of the Universe.

Now all of this is found to be obeyed by the expanding gas molecules under consideration as well. From the tables (Table 2 to Table 5) and figures (Figure 2 to Figure 5), it can be seen that the highest recessional velocity is exhibited by the Hydrogen molecule, followed by the Helium molecule, whereas the lowest recessional velocity is found to be exhibited by the Radon molecule. Hydrogen molecule being less massive exhibits higher recessional velocity as compared to the massive Radon molecule (naturally, a molecule with the highest recessional velocity will manage to become the most distant molecule during free expansion. The second most distant molecule will be the second fastest molecule. Therefore, velocity increasing with distance is a characteristic and natural feature of different gas molecules undergoing free expansion). In Table 6; Figure 6, the highest recessional velocity is still being exhibited by the Hydrogen molecule. Helium which previously remained the second fastest receding molecule behind Hydrogen has been replaced by Nitrogen. Similarly, Radon which previously remained the slowest receding molecule has been replaced by Xenon. Such change has occurred due to the involvement of large temperature differences. Such large differences in temperature influence the energy possessed by the molecules, thereby affecting their recessional velocities too. But no matter how the data changes for the gas molecules, the molecular plots continue to remain linear. Therefore, just like the Hubble's law, the recessional velocity of gas molecules is proportional to their distance – the further away a molecule is, the faster it is receding away from us. The Slope of this straight line is also remarkably similar to the Hubble constant (H) (the slope of Hubble diagram) since its inverse gives us the observation time in seconds, just like the Hubble time obtained from the inverse of H. Furthermore, the following equations that are obeyed by the large-scale structures,

$$v = Slope \text{ x } D \tag{8}$$

and,

$$D = \frac{v}{Slope} \tag{9}$$

are also found to be obeyed by the expanding gas molecules. In the above equations, v is the recessional velocity of the molecules and D is the distance covered by them within the given time frame. Since the velocity-distance relation plot for receding large-scale structures is similar to the velocity-distance relation plot for expanding gas molecules, therefore, the molecular expansion model appears to be a valid model for the receding large-scale structures; the expansion pattern of the Universe is similar to the pattern of gas molecules undergoing free expansion into the vacuum.

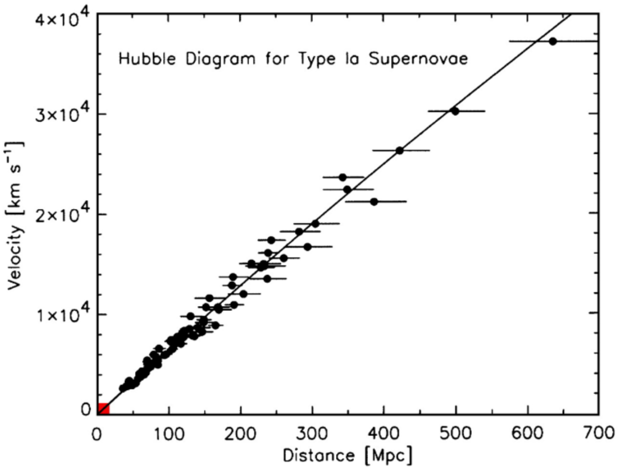


Figure 1. The Hubble diagram or the velocity-distance relation plot for type Ia supernovae (compilation of type Ia supernovae by Jha 2002). (Illustrated from Kirshner (2004) with permission from P.N.A.S. (© 2004 National Academy of Sciences, U.S.A.)). The slope of the straight line yields the Hubble constant (H). The inverse of the Hubble constant ($1/H$) gives us the age of the Universe (Hubble time). The Hubble diagram depicts the Hubble's law according to which the recessional velocity of large-scale structures is proportional to their distance. The velocity-distance relation plots for freely expanding gas molecules (Figure 2 to Figure 6) are exactly like the velocity-distance relation plot for the receding large-scale structures according to the Hubble diagram; the molecules receding slowly are closer to us whereas the molecules receding faster are further away from us.

Plotting the velocity-distance relation for expanding gas molecules is same as plotting the velocity-distance relation for the receding large-scale structures (the Hubble diagram). If we plot the velocity-distance relation for the expanding gas molecules while being situated upon any one of the molecule that is part of the overall expansion, then we will get the Hubble diagram. Also, it can be seen from the molecular plots that no matter on which molecule we would be situated upon, all other molecules will exhibit redshift.

The interpretation of the observed redshifts as Doppler shifts would not confer upon us any special place or centre of expansion, for instance, in Figure 6, since free expansion of gas molecules happens in every direction, therefore, being situated upon any receding molecule, say, Argon molecule, molecules such as Neon, Helium, Oxygen, Nitrogen and Hydrogen will exhibit redshift since they are receding away from the Argon molecule with recessional velocities that are higher than the recessional velocity of the Argon molecule. Similarly, molecules such as Krypton, Radon, Fluorine, Chlorine and Xenon will exhibit redshift since the Argon molecule is receding away from them with comparatively higher recessional velocity, therefore, every molecule will be exhibiting redshift, there is expansion in every direction, there is no preferred centre. This is in agreement with the Copernican principle, as well as with homogeneous and isotropic expansion.

The similar linear relationship obtained while plotting the velocity-distance relation for the expanding gas molecules is neither any coincidence nor any adjustment, it is only because the large-scale structures behave like expanding gas molecules that the velocity-distance relation plots turn out to be remarkably same.

Since expanding gas molecules exhibit Hubble diagram and obey all Hubble equations solely due to their recession by the virtue of the energy possessed by them, therefore, the large-scale structures that are known to exhibit Hubble diagram and obey all Hubble equations have to be receding solely by the virtue of the energy possessed by them.

7 HOMOGENEOUS DISTRIBUTION OF LARGE-SCALE STRUCTURES AND GAS MOLECULES DURING FREE EXPANSION

The mass of every large-scale structure that we observe to be receding away from us is different, however, if the energy possessed by them was equal, then their velocity-distance relation would have been in such a way, that the most distant structure would be the lightest and the fastest, whereas the structure nearest to us would be the most massive and the slowest. This can be seen in the molecular plots (Figure 2; Table 2 and Figure 3; Table 3), the mass of every molecule is different, but the energy possessed by them is equal, therefore, the mass of the molecules is decreasing with distance, while their recessional velocities are increasing with distance.

Now this is obviously not the actual case when we look at the Universe – the large-scale structures are distributed homogeneously throughout the Universe irrespective of their mass. Therefore, to address why the distribution of large-scale structures within the Universe is homogeneous, we will consider the results obtained in Figure 6; Table 6. According to the results, the energy possessed by every molecule is different and so is their mass, therefore, during free expansion, the molecules get distributed homogeneously irrespective of their mass. This is consistent with actual observations pertaining to the receding large-scale structures within the observable Universe. Since the energy possessed by every receding large-scale structure is different and so is their mass, therefore, we observe a homogeneous distribution of large-scale structures within the Universe.

Table 1. Mass of different gas molecules.

Gaseous Elements	Atomic Mass (A) a.m.u. or g mol^{-1}	Molecular Mass (M) a.m.u. or g mol^{-1}	Mass of Molecule $(M/N_A)/1000$ kg
H	1.0079	2.0158	3.3473×10^{-27}
He*	4.0026	8.0052	1.3292×10^{-26}
N	14.0067	28.0134	4.6517×10^{-26}
O	15.9994	31.9988	5.3135×10^{-26}
F	18.9984	37.9968	6.3095×10^{-26}
Ne*	20.1797	40.3594	6.7018×10^{-26}
Cl	35.4530	70.9060	1.1774×10^{-25}
Ar*	39.9480	79.8960	1.3267×10^{-25}
Kr*	83.7980	167.5960	2.7829×10^{-25}
Xe*	131.2930	262.5860	4.3603×10^{-25}
Rn*	222.0000	444.0000	7.3727×10^{-25}

$N_A = 6.02214199 \times 10^{23}$ (Avogadro constant)

Note: * are the non-reactive noble gases, they do not form molecules and remain in monoatomic state, however, since molecular expansion model is the emphasis of this paper, therefore, they have been considered as molecules too.

Table 2. Energy possessed by the gas molecules at same temperature of 303 K, their recessional velocities and the distance covered by them in 1 second **(Figure 2)**.

Gaseous Elements	Temperature (T) K	Energy possessed by molecule (E) J	Recessional Velocity (v) m s^{-1}	Distance covered in 1 second (D) m
H	303	6.2750×10^{-21}	1936.30	1936.30
He*	303	6.2750×10^{-21}	971.68	971.68
N	303	6.2750×10^{-21}	519.41	519.41
O	303	6.2750×10^{-21}	485.99	485.99
F	303	6.2750×10^{-21}	445.98	445.98
Ne*	303	6.2750×10^{-21}	432.73	432.73
Cl	303	6.2750×10^{-21}	326.48	326.48
Ar*	303	6.2750×10^{-21}	307.56	307.56
Kr*	303	6.2750×10^{-21}	212.36	212.36
Xe*	303	6.2750×10^{-21}	169.65	169.65
Rn*	303	6.2750×10^{-21}	130.46	130.46

Table 3. Energy possessed by the gas molecules at same temperature of 303 K, their recessional velocity and the distance covered by them in 60 seconds **(Figure 3)**.

Gaseous Elements	Temperature (T) K	Energy possessed by molecule (E) J	Recessional Velocity (v) m s^{-1}	Distance covered in 60 seconds (D) m
H	303	6.2750 x 10^{-21}	1936.30	116178.0
He*	303	6.2750 x 10^{-21}	971.68	58300.8
N	303	6.2750 x 10^{-21}	519.41	31164.6
O	303	6.2750 x 10^{-21}	485.99	29159.4
F	303	6.2750 x 10^{-21}	445.98	26758.8
Ne*	303	6.2750 x 10^{-21}	432.73	25963.8
Cl	303	6.2750 x 10^{-21}	326.48	19588.8
Ar*	303	6.2750 x 10^{-21}	307.56	18453.6
Kr*	303	6.2750 x 10^{-21}	212.36	12741.6
Xe*	303	6.2750 x 10^{-21}	169.65	10179.0
Rn*	303	6.2750 x 10^{-21}	130.46	7827.6

Table 4. Energy possessed by the gas molecules at different temperature, their recessional velocity and the distance covered by them in 1 second **(Figure 4)**.

Gaseous Elements	Random Temperature (T) K	Energy possessed by molecule (E) J	Recessional Velocity (v) m s^{-1}	Distance covered in 1 second (D) m
H	306	6.3371 x 10^{-21}	1945.86	1945.86
He*	310	6.4200 x 10^{-21}	982.85	982.85
N	313	6.4821 x 10^{-21}	527.91	527.91
O	305	6.3164 x 10^{-21}	487.59	487.59
F	311	6.4407 x 10^{-21}	451.83	451.83
Ne*	303	6.2750 x 10^{-21}	432.73	432.73
Cl	308	6.3786 x 10^{-21}	329.16	329.16
Ar*	312	6.4614 x 10^{-21}	312.09	312.09
Kr*	304	6.2957 x 10^{-21}	212.71	212.71
Xe*	307	6.3578 x 10^{-21}	170.76	170.76
Rn*	309	6.3993 x 10^{-21}	131.75	131.75

Table 5. Energy possessed by the gas molecules at different temperature, their recessional velocity and the distance covered by them in 60 seconds **(Figure 5)**.

Gaseous Elements	Random Temperature (T) K	Energy possessed by molecule (E) J	Recessional Velocity (v) m s^{-1}	Distance covered in 60 seconds (D) m
H	306	6.3371 x 10^{-21}	1945.86	116751.6
He*	310	6.4200 x 10^{-21}	982.85	58971.0
N	313	6.4821 x 10^{-21}	527.91	31674.6
O	305	6.3164 x 10^{-21}	487.59	29255.4
F	311	6.4407 x 10^{-21}	451.83	27109.8
Ne*	303	6.2750 x 10^{-21}	432.73	25963.8
Cl	308	6.3786 x 10^{-21}	329.16	19749.6
Ar*	312	6.4614 x 10^{-21}	312.09	18725.4
Kr*	304	6.2957 x 10^{-21}	212.71	12762.6
Xe*	307	6.3578 x 10^{-21}	170.76	10245.6
Rn*	309	6.3993 x 10^{-21}	131.75	7905.0

Table 6. Energy possessed by the gas molecules at high temperature with large differences in temperature, their recessional velocity and the distance covered by them in 60 seconds **(Figure 6)**.

Gaseous Elements	Random Temperature (T) K	Energy possessed by molecule (E) J	Recessional Velocity (v) m s^{-1}	Distance covered in 60 seconds (D) m
H	1000	2.0709 x 10^{-20}	3517.60	211056.0
He*	2000	4.1419 x 10^{-20}	2496.43	149785.8
N	10000	2.0709 x 10^{-19}	2983.93	179035.8
O	9000	1.8638 x 10^{-19}	2648.64	158918.4
F	900	1.8638 x 10^{-20}	768.62	46117.2
Ne*	8000	1.6567 x 10^{-19}	2223.52	133411.2
Cl	800	1.6567 x 10^{-20}	530.48	31828.8
Ar*	9000	1.8638 x 10^{-19}	1676.20	100572.0
Kr*	10000	2.0709 x 10^{-19}	1219.96	73197.6
Xe*	700	1.4496 x 10^{-20}	257.85	15471.0
Rn*	15000	3.1064 x 10^{-19}	917.97	55078.2

Table 7. Energy possessed by the gas molecules at high temperature with large differences in temperature, their recessional velocity and the distance covered by them during differential molecular expansion **(Figure 7)**.

Gaseous Elements	Random Temperature (T) K	Energy possessed by molecule (E) J	Recessional Velocity (v) m s^{-1}	Observation time (t) Seconds	Distance covered in (t) seconds (D) m
H	1000	2.0709 x 10^{-20}	3517.60	1.9	6683.44
N	10000	2.0709 x 10^{-19}	2983.93	1.8	5371.074
O	9000	1.8638 x 10^{-19}	2648.64	1.7	4502.688
He*	2000	4.1419 x 10^{-20}	2496.43	1.6	3994.288
Ne*	8000	1.6567 x 10^{-19}	2223.52	1.5	3335.28
Ar*	9000	1.8638 x 10^{-19}	1676.20	1.4	2346.68
Kr*	10000	2.0709 x 10^{-19}	1219.96	1.3	1585.948
Rn*	15000	3.1064 x 10^{-19}	917.97	1.2	1101.564
F	900	1.8638 x 10^{-20}	768.62	1.1	845.482
Cl	800	1.6567 x 10^{-20}	530.48	1.0	530.48
Xe*	700	1.4496 x 10^{-20}	257.85	1.0	257.85

Table 8. Energy possessed by the gas molecules at high temperature with large differences in temperature, their recessional velocity and the distance covered by them during differential molecular expansion **(Figure 8)**.

Gaseous Elements	Random Temperature (T) K	Energy possessed by molecule (E) J	Recessional Velocity (v) m s^{-1}	Observation time (t) Seconds	Distance covered in (t) seconds (D) m
H	1000	2.0709 x 10^{-20}	3517.60	1.9	6683.44
He*	2000	4.1419 x 10^{-20}	2496.43	1.8	4493.574
N	10000	2.0709 x 10^{-19}	2983.93	1.7	5072.681
O	9000	1.8638 x 10^{-19}	2648.64	1.6	4237.824
F	900	1.8638 x 10^{-20}	768.62	1.5	1152.93
Ne*	8000	1.6567 x 10^{-19}	2223.52	1.4	3112.928
Cl	800	1.6567 x 10^{-20}	530.48	1.3	689.624
Ar*	9000	1.8638 x 10^{-19}	1676.20	1.2	2011.44
Kr*	10000	2.0709 x 10^{-19}	1219.96	1.1	1341.956
Xe*	700	1.4496 x 10^{-20}	257.85	1.0	257.85
Rn*	15000	3.1064 x 10^{-19}	917.97	1.0	917.97

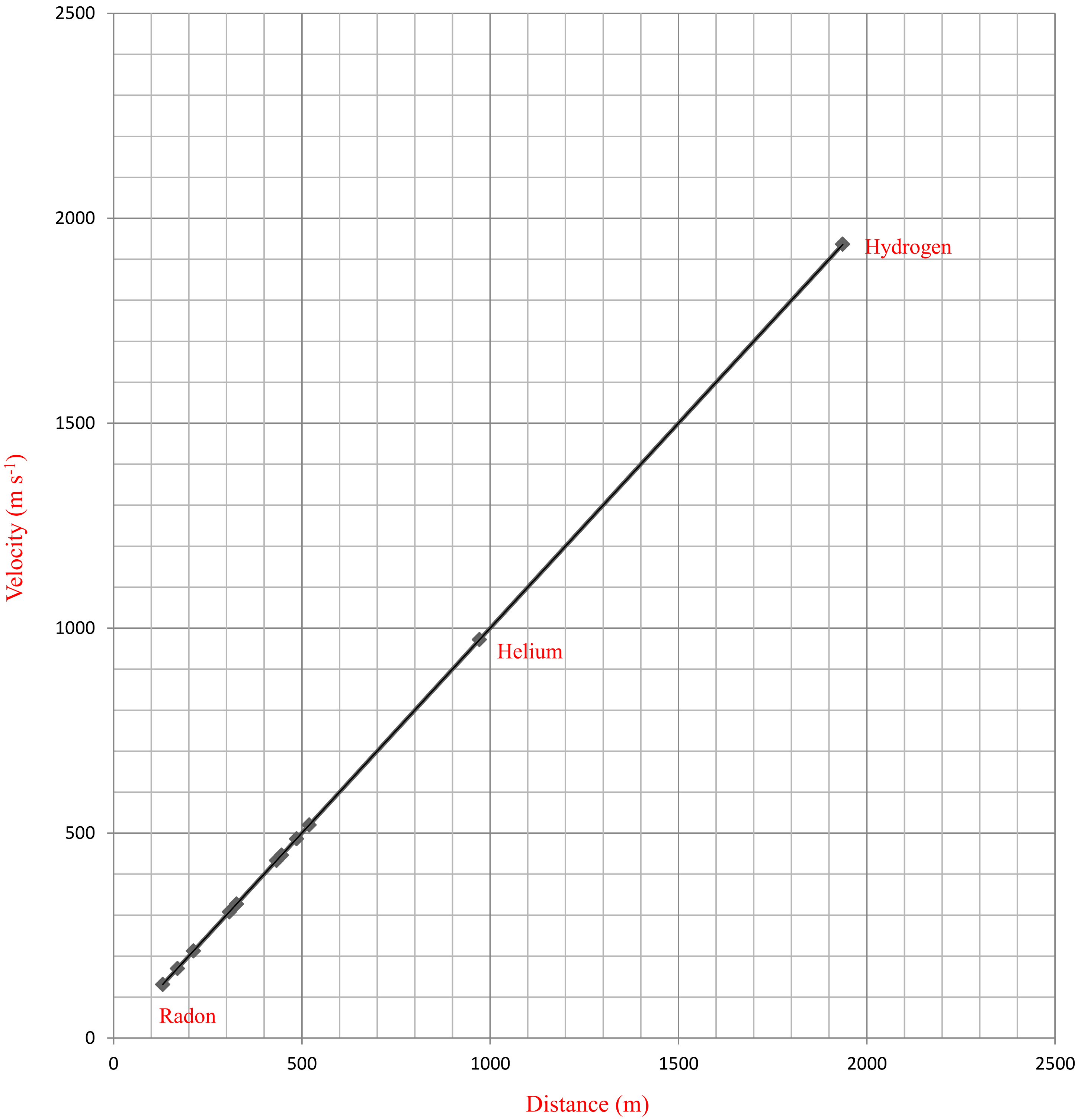


Figure 2. Velocity-distance relation plot for molecules expanding at same temperature (303 K). Observation time = 1 second **(Table 2)**

(Calculated Slope = 1 m s^{-1} m^{-1} or 1 s^{-1})

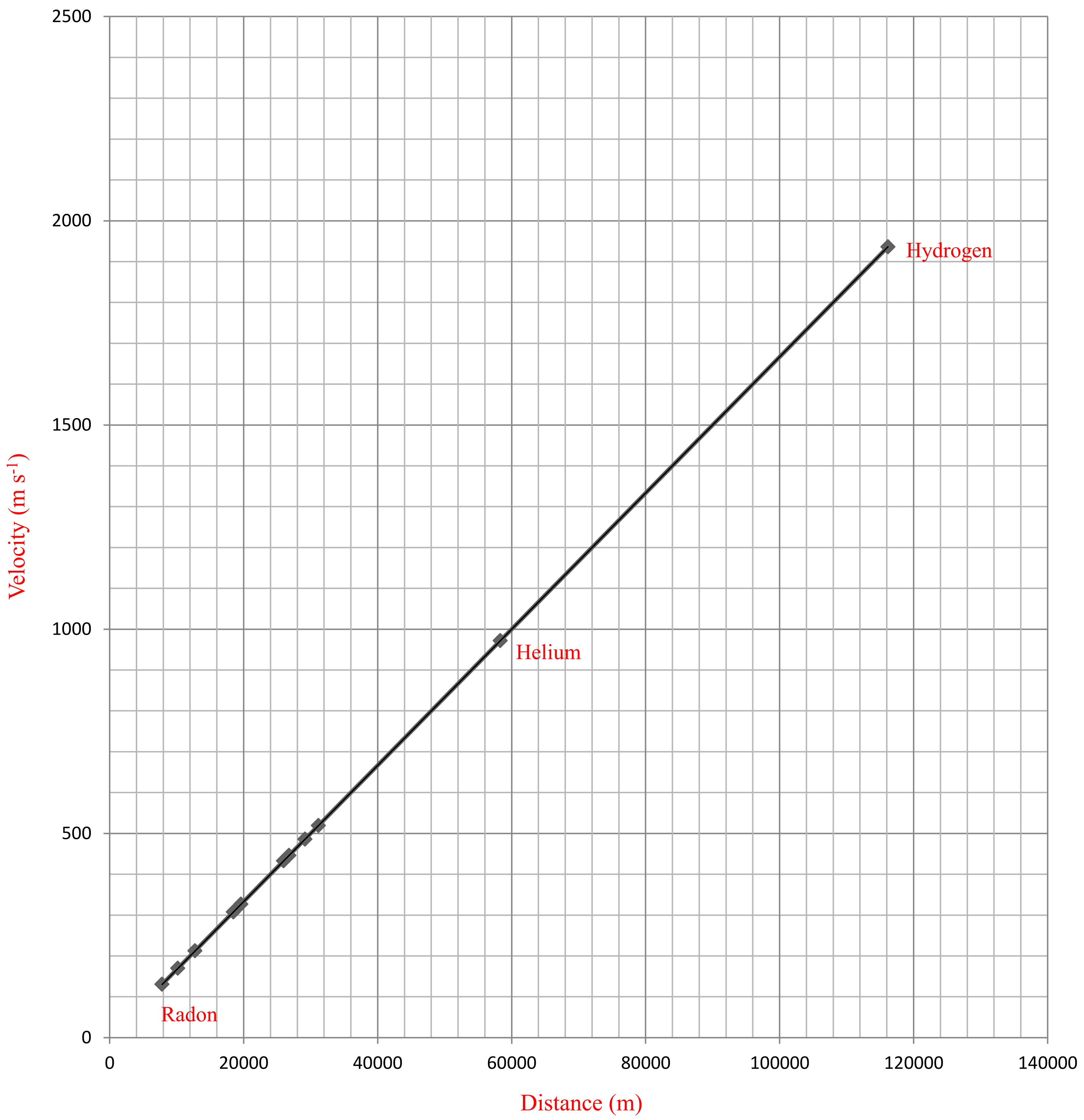


Figure 3. Velocity-distance relation plot for gas molecules expanding at same temperature (303 K). Observation time = 60 seconds **(Table 3)**

(Calculated Slope = 0.016666666 m s^{-1} m^{-1} or 0.016666666 s^{-1})

In Figure 2, after 1 second of free expansion, the distance between the two molecules, Hydrogen and Helium is 964.62 m, whereas in Figure 3, after 60 seconds, the distance between them is 57,877.2 m. It appears that as time progressed, the space between these two molecules, in fact, the space between all other molecules as well, underwent an expansion; there is more space between the molecules after 60 seconds than was previously after 1 second. However, from a practical perspective, it is the freely expanding gas molecules that begin to occupy more space and therefore more volume as time progresses due to their own expansion into the prevailing emptiness – a characteristic feature of molecules undergoing free expansion. This is something that we observe for the receding large-scale structures within the Universe as well; the distance between them is increasing over time. The Slope of the molecular plots also decreases as time progresses, but no matter how the Slope changes, its inverse gives back the original observation time in seconds.

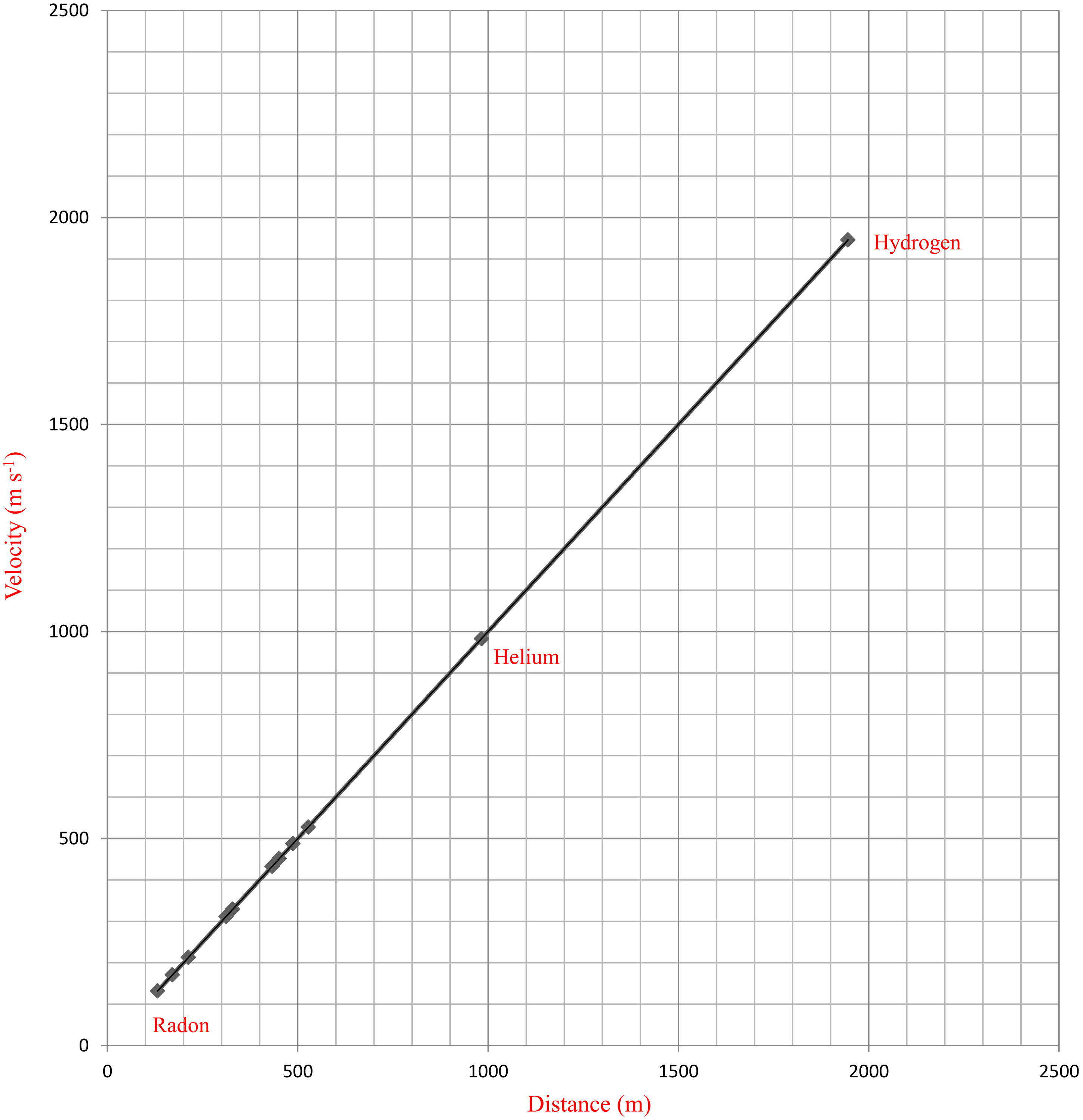


Figure 4. Velocity-distance relation plot for gas molecules expanding at different temperature. Observation time = 1 second **(Table 4)**

(Calculated Slope = 1 m s^{-1} m^{-1} or 1 s^{-1})

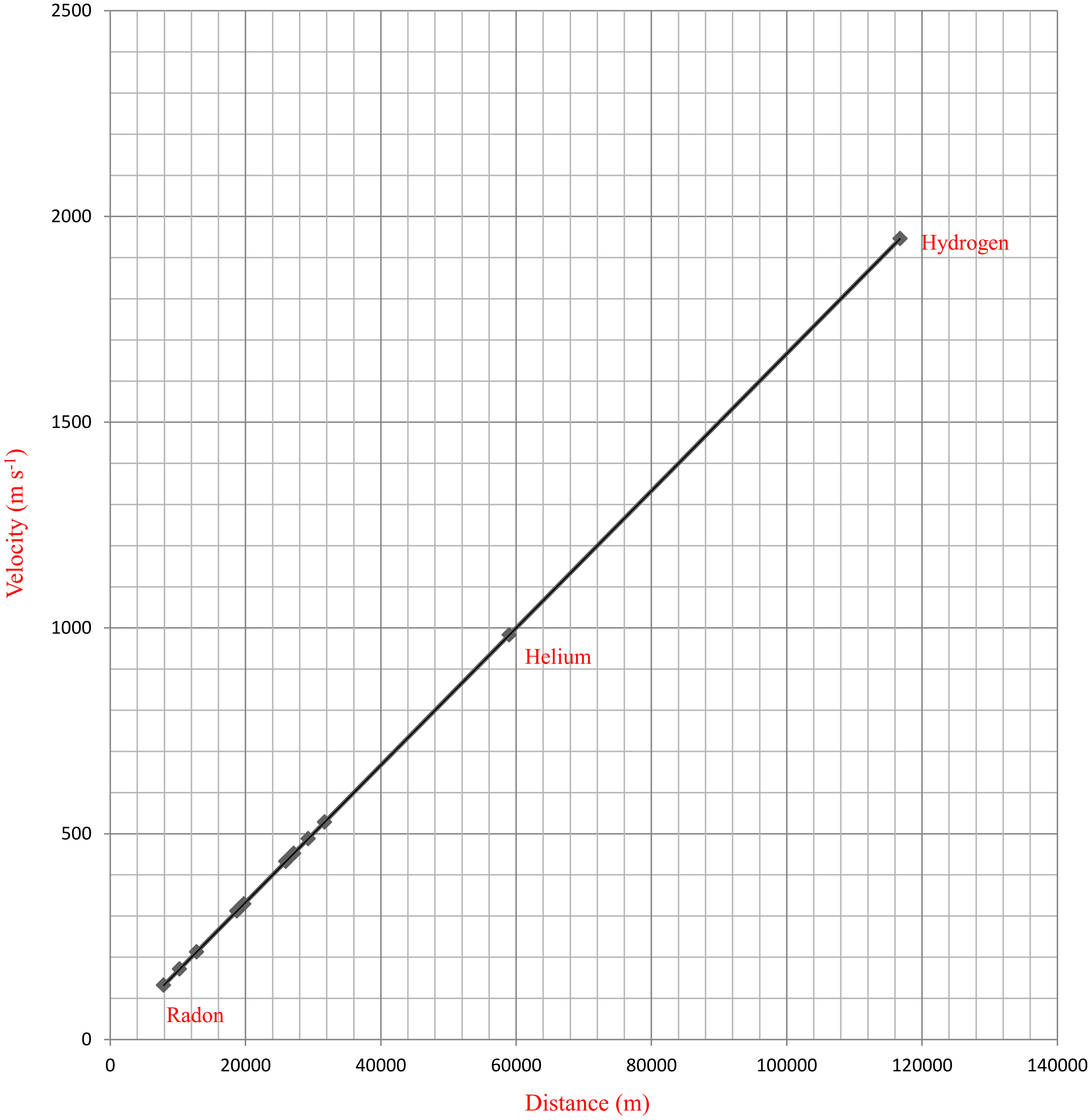


Figure 5. Velocity-distance relation plot for gas molecules expanding at different temperature. Observation time = 60 seconds **(Table 5)** (Calculated Slope = 0.016666666 m s^{-1} m^{-1} or 0.016666666 s^{-1})

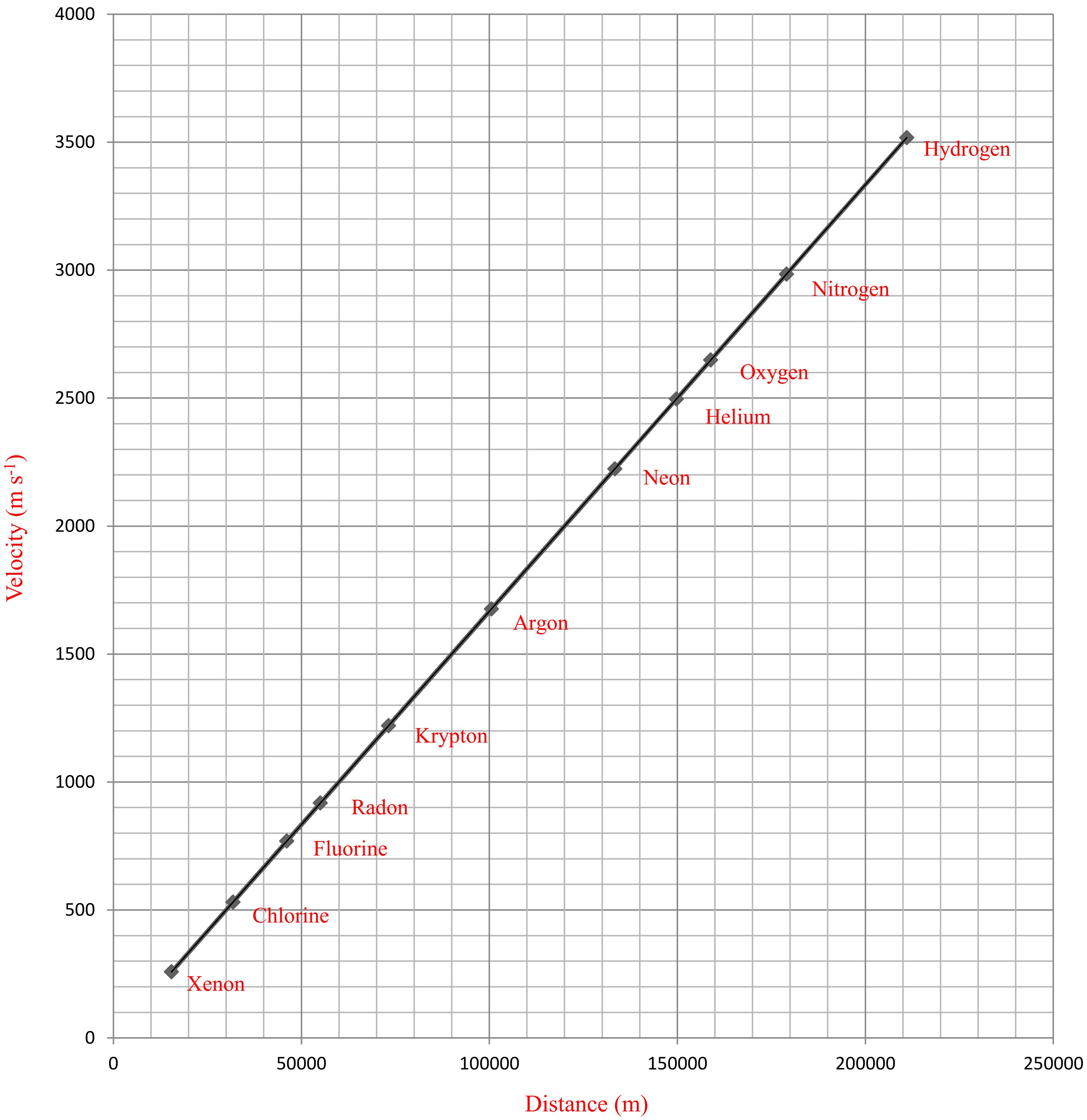


Figure 6. Velocity-distance relation plot for molecules expanding at very high temperature with large differences in temperature. Observation time = 60 seconds **(Table 6)**

(Calculated Slope = 0.016666666 m s^{-1} m^{-1} or 0.016666666 s^{-1})

During free expansion, being situated upon any receding molecule that is part of the overall expansion, say, Argon molecule, molecules such as Neon, Helium, Oxygen, Nitrogen and Hydrogen will exhibit redshift since they are receding away from the Argon molecule with recessional velocities that are higher than the recessional velocity of the Argon molecule. Similarly, molecules such as Krypton, Radon, Fluorine, Chlorine and Xenon will exhibit redshift since the Argon molecule is receding away from them with comparatively higher recessional velocity, therefore, every molecule will be exhibiting redshift, there is expansion in every direction, there is no preferred centre. Therefore, the interpretation of the observed redshifts as Doppler shifts does not confer upon us any special place or centre of expansion. The expansion is homogeneous (looks same at every location), isotropic (looks same in every direction) and in agreement with the Copernican principle (no preferred center).

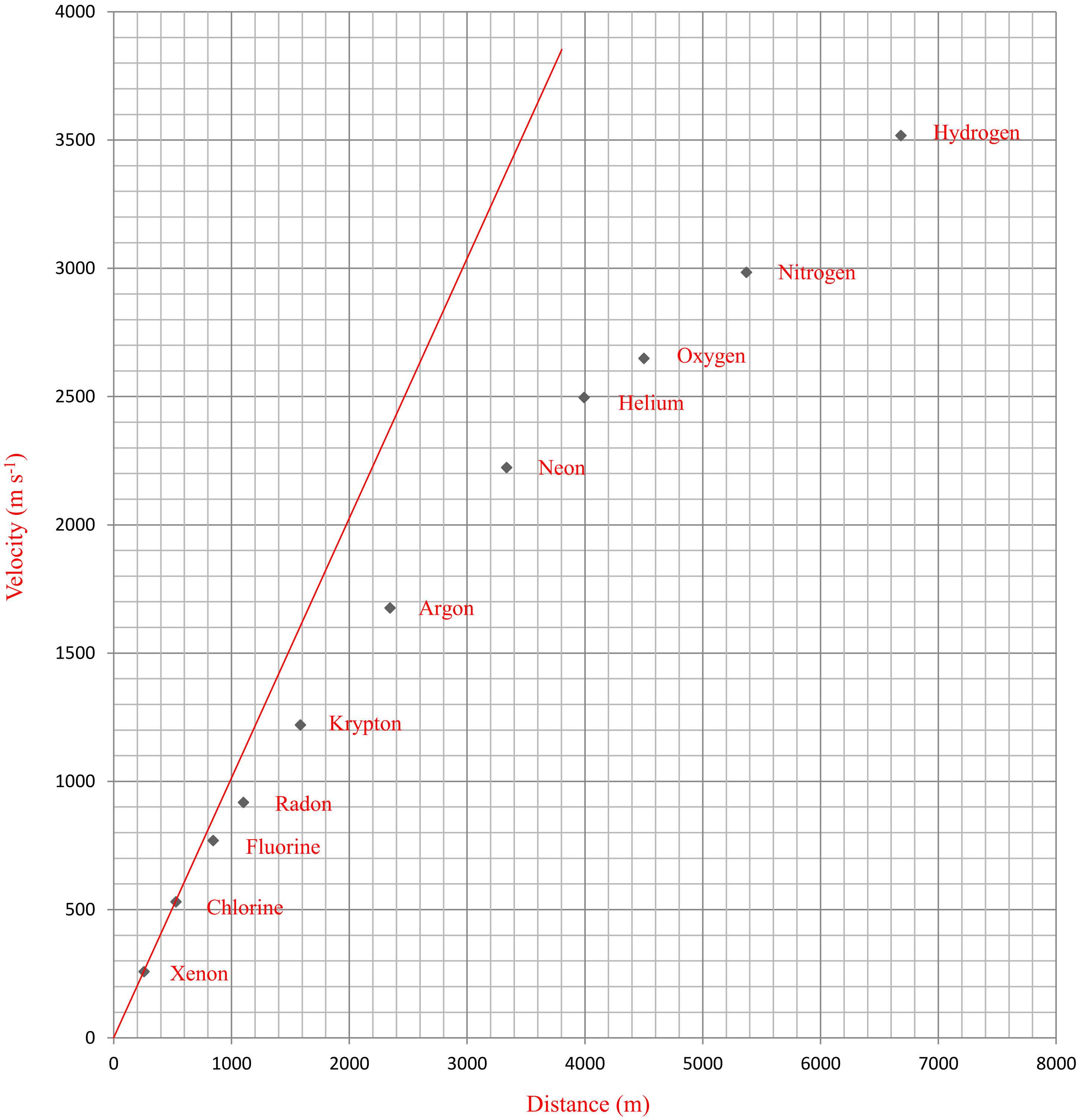


Figure 7. Velocity-distance relation plot for gas molecules expanding differentially (differential molecular expansion) **(Table 7)**. Local molecules, Xenon and Chlorine are allowed to expand at the same time and therefore they exhibit a linear velocity-distance relation. The remote molecules are allowed to expand differentially and therefore they deviate from exhibiting a linear velocity-distance relation. Such differential expansion causes the distance of remote molecules to be larger than expected with respect to the local molecules without any acceleration. In other words, expansion initiated for the remote molecules before it did for the local molecules.

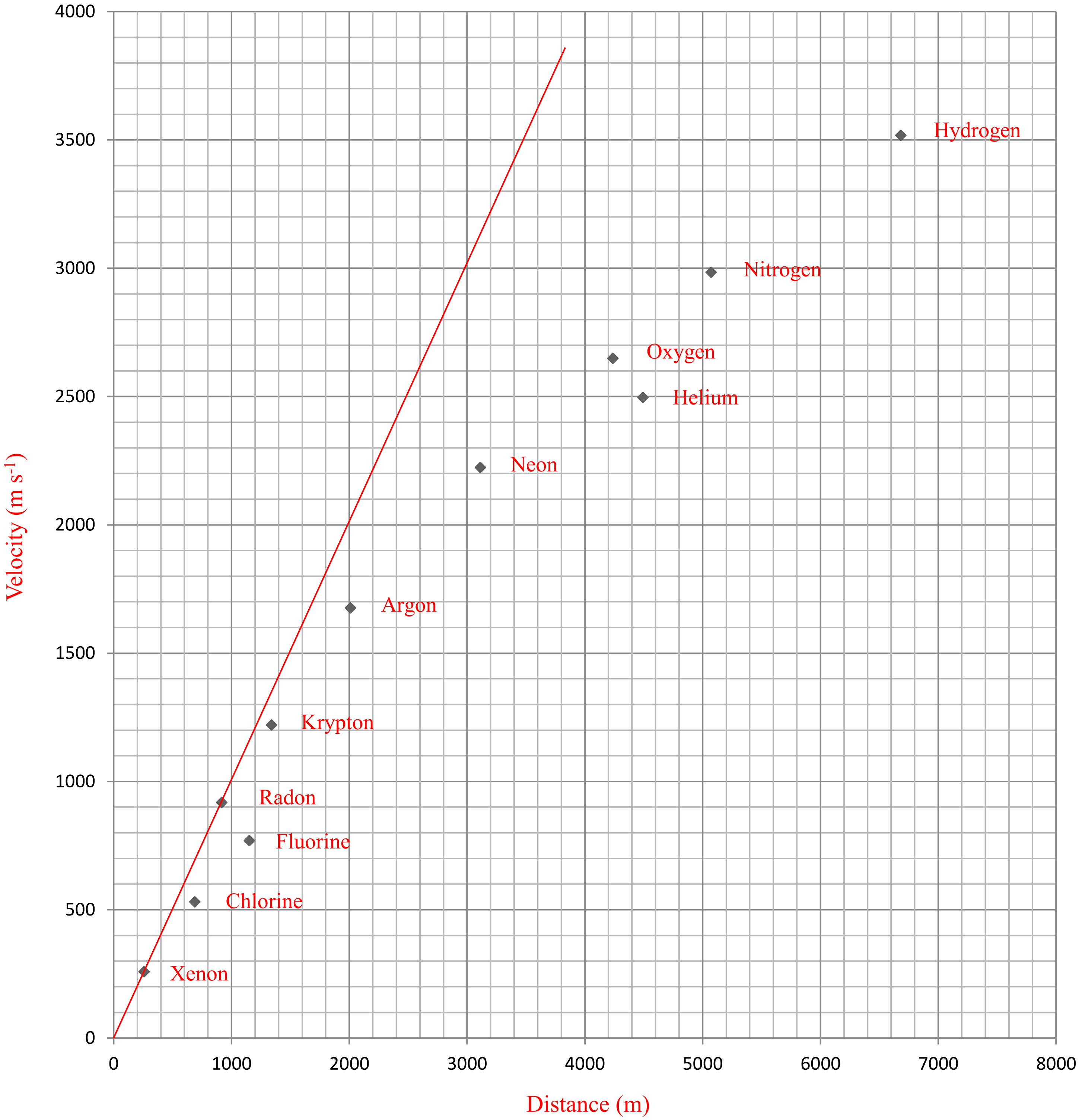


Figure 8. Velocity-distance relation plot for gas molecules expanding differentially (differential molecular expansion) **(Table 8)**. Local molecules, Xenon and Radon are allowed to expand at the same time and therefore they exhibit a linear velocity-distance relation. The remote molecules are allowed to expand differentially and therefore they deviate from exhibiting a linear velocity-distance relation. Such differential expansion causes the distance of remote molecules to be larger than expected with respect to the local molecules without any acceleration. In other words, expansion initiated for the remote molecules before it did for the local molecules.

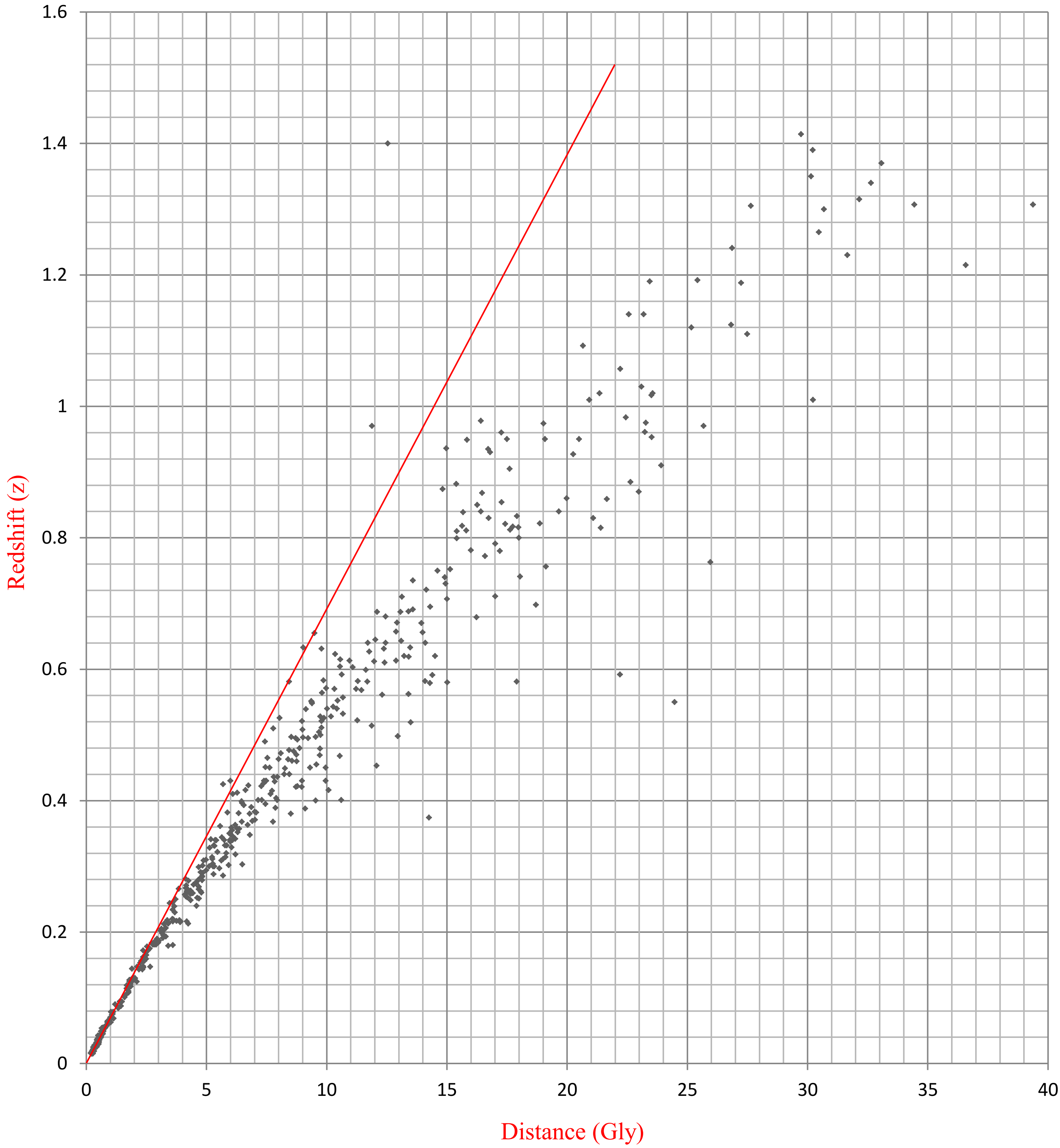


Figure 9. The redshift-distance relationship for 580 type Ia supernovae plotted by using the data (Union 2 and Union 2.1) from the Supernova Cosmology Project. The straight red line indicates the linear redshift-distance relationship exhibited by the structures within the local Universe. The deviation from linearity at high redshifts indicates an accelerating expansion of the Universe since the distances to the remote supernovae are larger than expected with respect to the nearby supernovae belonging to the local Universe.

8 THE DEVIATION OF THE HUBBLE DIAGRAM FROM LINEARITY AT HIGH REDSHIFTS AND THE ACCELERATING EXPANSION OF THE UNIVERSE

The independent research conducted by the High-Z Supernova Search Team in the 1998 (Riess et al.) and by the Supernova Cosmology Project team in the 1999 (Perlmutter et al.) by using type Ia supernovae as standard candles resulted into a very surprising discovery that made the team members win the 2011 Nobel Prize in Physics. By comparing the brightness of the very distant supernovae with the brightness of the nearby ones, distant supernovae were found to be 10% to 25% fainter than expected, suggesting that the distances to them were larger than expected. A surprising feat was being displayed by the Universe, a feat that was so extraordinary that the remarkable results obtained were not even expected. It was the remarkable discovery of Universe expanding at an accelerating rate. A research that was actually aimed at observing the expected deceleration of the Universe was welcomed by something completely unexpected.

A mysterious energy that rightfully got coined as dark energy is considered responsible for causing the Universe to expand at an accelerating rate. Acceleration of the Universe began with the introduction of dark energy 5 billion years ago (Frieman, Turner and Huterer 2008). According to Durrer (2011), “our single indication for the existence of dark energy comes from distance measurements and their relation to redshift. Supernovae, cosmic microwave background anisotropies and observations of baryon acoustic oscillations simply tell us that the observed distance to a given redshift is larger than the one expected from a locally measured Hubble parameter”.

The expansion of the Universe is best depicted by the Hubble diagram that exhibits a linear velocity-distance relation or a linear redshift-distance relation for the local Universe, that is, for the large-scale structures that exhibit lower redshifts and are comparatively closer to us than the structures that exhibit higher redshifts or the most distant ones that belong to the remote Universe. It is for these structures belonging to the remote Universe that the Hubble diagram deviates from exhibiting a linear redshift-distance relation as shown in Figure 9 which has been plotted by using the Supernova Cosmology Project data from Union 2 (Amanullah et al. 2010) and Union 2.1 (Suzuki et al. 2012).

The observed deviation from linearity in Figure 9 at high redshifts indicates an accelerating expansion of the Universe since the distances to the remote supernovae are larger than expected with respect to the nearby ones.

9 DIFFERENTIAL MOLECULAR EXPANSION

Gas molecules expanding into the vacuum at the same time exhibit a linear velocity-distance relation consistent with the Hubble diagram for the local structures belonging to the local Universe. Since freely expanding gas molecules recede by the virtue of the energy possessed by them to exhibit a linear velocity-distance relation or the Hubble diagram, therefore, the large-scale structures that are known to exhibit the same linear diagram have to be receding by the virtue of the energy possessed by them. Therefore, it is very unlikely that an unknown and a mysterious form of energy would be responsible for the overall expansion. After all, the free expansion of gas molecules into the vacuum by the virtue of dark energy has never been heard off, such claim if considered to be true would only suggest that gas molecules do not possess any energy; the velocity of gas molecules, as evident from equation (2), equation (4) and equation (5) depends upon their mass and the energy possessed by them.

Having considered the velocity-distance relation for gas molecules undergoing free expansion at the same time into the vacuum, it is now imperative to consider their velocity-distance relation during a differential expansion. If gas molecules are released and allowed to expand consecutively into the vacuum, one molecule after another, then the gas molecules will be undergoing a differential molecular expansion.

Based upon calculations, the data for gas molecules undergoing a differential expansion has been tabulated in Table 7. We will consider the same apparatus that was discussed in Section 6 (spherical metallic vessel filled with gas molecules). Initially the Hydrogen molecule is released and allowed to expand freely into the vacuum, 0.1 second later, Nitrogen molecule is allowed to expand freely, the release of Nitrogen molecule is followed by the release of Oxygen molecule after another 0.1 second. Differential release and expansion of gas molecules is continued in the same way for Helium, Neon, Argon, Krypton, Radon and Fluorine. Chlorine and Xenon are the last molecules to be released, and they are released at the same time into the prevailing emptiness of the Universe and observed for 1 second. By the time these last two molecules are released and observed for 1 second, Hydrogen molecule has already been receding for 1.9 second and the Nitrogen molecule for 1.8 second, this becomes their respective observation time.

The velocity-distance relation for differentially-expanding gas molecules has been plotted in Figure 7 and Figure 8. All molecules that expand differentially deviate from exhibiting the expected velocity-distance linearity. Only Xenon and Chlorine molecules in Figure 7 follow a linear velocity-distance relation since they were allowed to expand at the same time. Similarly, in Figure 8, Xenon and Radon molecules follow the linear velocity-distance relation.

The molecules that deviate from exhibiting velocity-distance linearity are analogous to the distant remote structures belonging to the remote Universe, these molecules can therefore be termed as remote molecules, whereas the molecules that follow a linear velocity-distance relation and are therefore analogous to the local structures can be termed as local molecules. Based upon calculations, the velocity-distance relation plots for differentially-expanding gas molecules (Figure 7 and Figure 8) are found to be similar to the redshift-distance or the velocity-distance relationship for 580 type Ia supernovae as shown in Figure 9. The observed deviation from linearity is a characteristic feature of molecules undergoing differential expansion. The distances to the remote molecules are larger than expected with respect to the local molecules, and this is not because of acceleration of molecules, but because of differential expansion of molecules.

The value of the Slope obtained for the local molecules, Xenon and Chlorine (Figure 7) and Xenon and Radon (Figure 8) is 1 m s^{-1} m^{-1} or 1 s^{-1}. The inverse of this gives us the original observation time of 1 second for these local molecules. The recessional velocities of remote molecules are not high enough for them to have covered such large distances within such time frame of 1 second (1 second being the observation or the expansion time frame for the local molecules). For instance, in Figure 7, Hydrogen molecule with a recessional velocity of 3517.60 m s^{-1} would have just covered a distance of 3517.60 m in 1 second and not 6683.44 m. The deviation from linearity in Figure 7 and Figure 8 clearly indicates that the distances to the remote molecules are large, but their recessional velocities are not adequately high enough for them to have covered such large distances within the 1 second expansion time frame of the local molecules. Had the recessional velocities of remote molecules been adequately high enough for such large distances, or had the expansion initiated for all the molecules into the vacuum of the Universe at the same time, then there would have been no deviation from linearity. Therefore, the only possible way for the remote molecules to have covered such large distances with such inadequate recessional velocities is by having their expansion being initiated into the vacuum of the Universe before the expansion got initiated for the local molecules. In fact, the value of the Slope obtained for the most distant remote molecule in Figure 7, that is, Hydrogen molecule, is found to be 0.5263 m s^{-1} m^{-1}, thereby giving us the original observation time of 1.9 second. Similarly, the Slope for an intermediately-distant remote molecule in Figure 7, that is, Argon molecule, turns out to be 0.7142 m s^{-1} m^{-1}, thereby giving us the original observation time of 1.4 second (the slope of a straight line is constant throughout, however, the slope of a curve changes at every point). The value of the Slope for the remote molecules being lower than the value of the Slope for the local molecules yields a larger observation time for the remote molecules. This strongly indicates that the remote molecules had their expansion initiated into the vacuum before the local molecules began expanding (value of the Slope decreases with time).

Since the expansion initiated for the remote molecules before it did for the local molecules, therefore, the value of the Slope for the remote molecules is lower than the value of the Slope for the local molecules (value of Slope decreases with time. A higher value of Slope (steeper Slope) gives a lower expansion time as compared to a lower value of Slope (shallower Slope) that gives a higher expansion time). It therefore appears that local molecules are expanding at a faster rate as compared to the remote molecules. One would therefore believe that local molecules, as compared to remote molecules, are accelerating due to a higher value of their Slope.

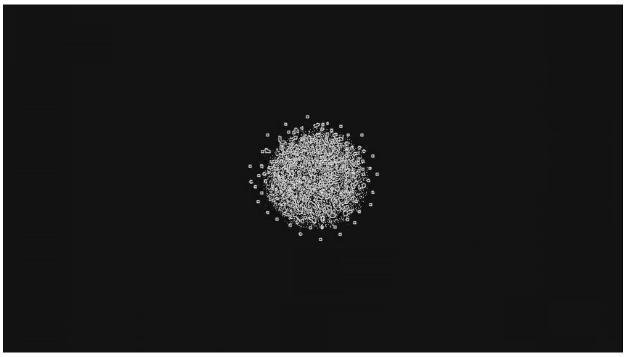
In Figure 7 and Figure 8, the remote molecules began expanding before the expansion of local molecules initiated, therefore, the distances to the remote molecules are larger than expected with respect to the local molecules without any acceleration. Since the local molecules began expanding at the same time, therefore, they follow a linear velocity-distance relation. If all molecules had expanded freely at the same time, or had the recessional velocities of remote molecules been adequately high enough for their large distances, then their velocity-distance relation would have been linear.

This can be verified for the large-scale structures expanding into the Universe as well. The value of the slope (H) (slope of the red line) for a local structure in Figure 9, is found to be 2.2202 x 10^{-18} m s^{-1} m^{-1}, this yields a Hubble constant of 68.5087 km s^{-1} Mpc^{-1}. This gives us an observation time, or to be more precise, an expansion time of 14.2820 x 10^{9} years. The deviation from linearity in Figure 9 clearly indicates that the distances to the remote structures are large, but their recessional velocities are not adequately high enough for them to have covered such large distances within the expansion time frame of the local structures, that is, 14.2820 x 10^{9} years. The value of the slope for the most distant remote structure in Figure 9 is 1.0521 x 10^{-18} m s^{-1} m^{-1}, this gives us a Hubble constant of 32.4646 km s^{-1} Mpc^{-1} and an expansion time of 30.1392 x 10^{9} years. Similarly, the value of the slope for an intermediately-distant remote structure in Figure 9 is 1.5475 x 10^{-18} m s^{-1} m^{-1} which yields a Hubble constant of 47.7512 km s^{-1} Mpc^{-1} and an expansion time of 20.4908 x 10^{9} years. The value of the slope for the remote structures being lower than the value of the slope for the local structures yields a larger observation time for the remote structures. This strongly indicates that the remote structures had their expansion initiated into the Universe before the local structures began expanding (value of the Slope decreases with time and so does the value of the Hubble constant).

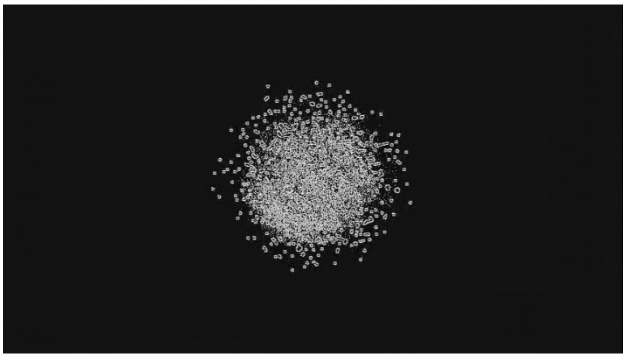
Since remote structures began expanding into the Universe before the expansion initiated for the local structures, therefore, the remote structures yield a lower value of Hubble constant as compared to the local structures that began expanding later (the value of Hubble constant decreases with time; a higher value of Hubble constant gives a lower expansion time as compared to a lower value of Hubble constant that gives a higher expansion time).

Since the inverse of Hubble constant gives us the expansion time of structures into the Universe, therefore, the structures that began expanding before (remote structures) should naturally yield a lower value of Hubble constant and therefore a higher expansion time. Since the expansion time is less for the local structures, therefore, local structures naturally yield a higher value of Hubble constant and it appears that the local Universe is expanding at a faster rate as compared to the remote Universe. One would therefore believe that "Universe is accelerating now, and had a slower expansion in the past".

The structures belonging to the remote Universe began expanding into the Universe before the local structures began expanding; the distances to the remote structures are therefore larger than expected with respect to the local structures belonging to the local Universe without any acceleration. The structures that follow the linear velocity-distance relation started expanding at the same time. Had the expansion initiated for all the structures into the Universe at the same time, or had the recessional velocities of remote structures been adequately high enough for their large distances, then the Hubble diagram would have been linear.



A



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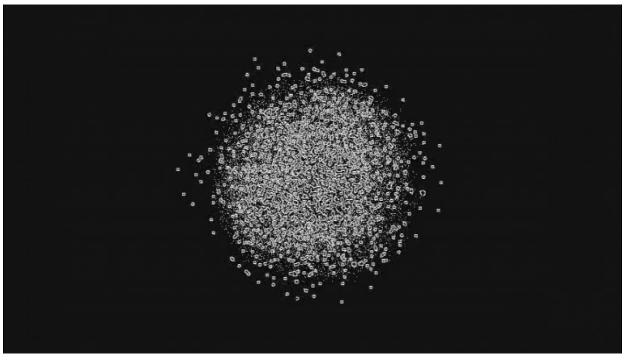

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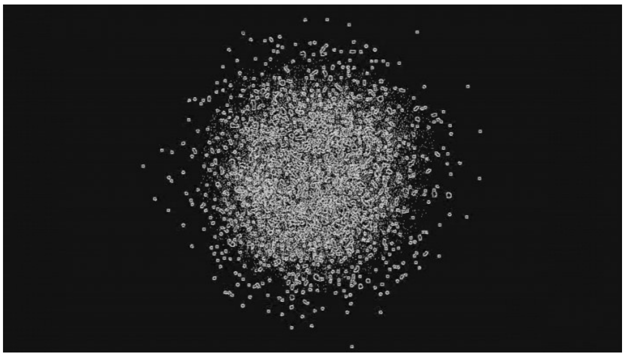

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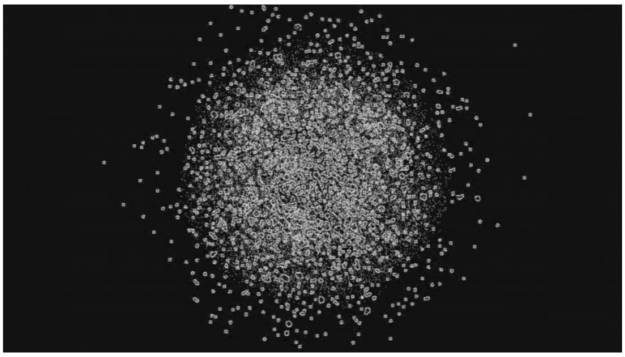

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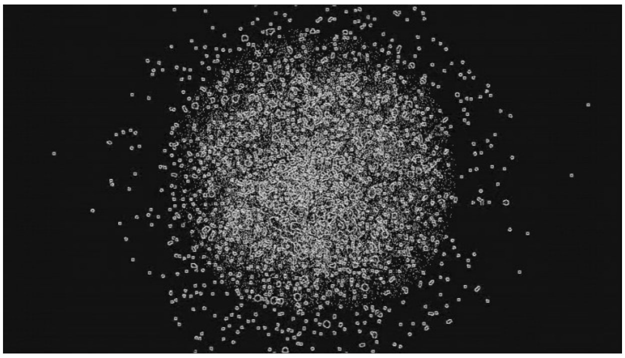

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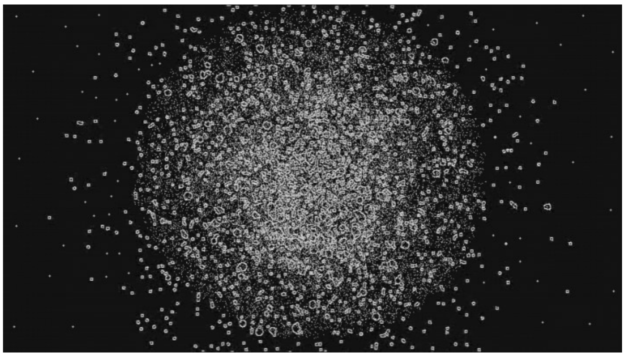

G

Figure 10. Free expansion of different gas molecules into the vacuum of the Universe (A to G). Free expansion of gas molecules initiates as the walls of the containment vessel vanish. The distance between gas molecules keeps on increasing over time during free expansion. The collision probability between the molecules becomes exactly zero over time as the process of molecular expansion proceeds. It can also be seen that some of the molecules begin to expand before other molecules begin expanding (differential molecular expansion), these molecules that begin expanding before cover larger than expected distances (remote molecules) with respect to the molecules that have not expanded yet (local molecules); remote molecules are therefore further away than expected with respect to the local molecules. As compared to the remote molecules, local molecules began expanding at the same time, therefore, they exhibit a linear velocity-distance relationship (the velocity-distance relationship obtained for expanding gas molecules (Figure 7 and Figure 8) being identical to the redshift-distance/velocity-distance relationship for type Ia supernovae (Figure 9) confirms this). Since remote molecules began expanding before the expansion initiated for the local molecules, therefore, the expansion time for the remote molecules is more as compared to the expansion time for the local molecules, remote molecules for this reason naturally yield a lower value of Slope (a shallower Slope) as compared to the value of the Slope obtained from the local molecules for which the expansion time being less, a higher value of Slope (a steeper Slope) is obtained. Based upon this differential molecular expansion scenario, one would be forced into believing that the local molecules, as compared to the remote molecules, are accelerating. Also, an interesting thing that further needs to be considered here is the reverse of this molecular expansion process. If we reverse the molecular expansion (**G to A**), all molecules would get closer and closer together, and after a certain period of time, we would have reached the initial stage where free expansion of molecules was just about to happen. The best and the most professional cosmologists at times say, "If the expansion of the Universe is reversed, then all the objects within the Universe would get closer and closer together, and after a certain period of time we would have reached the initial stage of the Universe when everything in the Universe was much closer – the Big Bang".

10 CONCLUSIONS

(1) Cosmology is dominated by certain models that are readily used in order to explain the expansion of the Universe. These models include, expanding loaf of raisin bread, stretching rubber sheet, inflating balloon, and so on. Although these models provide a theoretical insight or an overview to explain the expansion of the Universe, these models are not scientifically-appealing in any way. Being reliant on such models suggest that we lack a scientific and a practically-feasible model that can explain the expansion of the Universe, an expansion that is found to be homogeneous, isotropic, and in agreement with the Copernican principle.

(2) The concept of metric expansion of space is extensively used in the literature of cosmology. However, the exact mechanism behind such expansion remains unexplained. Is space between the structures "growing" due to "cell division", or is space between the structures "expanding/stretching" due to "elasticity"?

(3) Metric expansion of space can only be observed indirectly due the presence of observable entities, therefore, of what significance is the concept of metric expansion of space without the presence of any observable entity? Can metric expansion of space be tested practically in a laboratory, or is it merely a concept of a metaphysical domain just required to explain the observations?

(4) The expansion of the Universe has been explained in this paper by conducting a detailed study based upon the molecular expansion model that considers the large-scale structures as gas molecules undergoing free expansion into the vacuum. The molecular expansion model shows that the linear velocity-distance relation or the Hubble diagram is a natural and a characteristic feature of different gas molecules undergoing free expansion into the vacuum at the same time.

(5) Different gas molecules naturally have different velocities, and, if different gas molecules are allowed to expand into the vacuum at the same time, then the molecule with the highest recessional velocity will naturally manage to become the most distant molecule. The molecule with the second highest recessional velocity will naturally become the second most distant molecule. Therefore, velocities increasing with distance will be observed naturally during free expansion of different gas molecules into the vacuum. Once velocities are found to be increasing with distance, all molecules and large-scale structures will be observed exhibiting redshift.

(6) The recessional behaviour of large-scale structures is found to be consistent with the recessional behaviour of gas molecules; the free expansion of gas molecules is found to be homogeneous, isotropic and in agreement with the Copernican principle.

(7) Gas molecules and large-scale structures being natural entities and exhibiting the natural tendency of undergoing expansion into the vacuum should behave similarly during an expansion process. Large-scale structures being constituted by atoms and molecules should behave like molecules. There should not be any problem if we consider the large-scale structures as expanding gas molecules since such consideration is more scientifically-appealing, practically-feasible and provides a viable solution that is consistent with actual observations.

(8) Large-scale structures would resemble molecules if compared to the colossal size of the Universe. In fact, the large-scale structures that we see today have evolved by colliding and merging with one another during the initial phase of the Universe when the distance between them was much smaller than what is today. The expansion of structures into the Universe has increased the distance between them and has decreased their collision probability, much like gas molecules that collide before they are allowed to expand freely into the vacuum. Expansion of gas molecules into the vacuum of Universe increases the distance between them and decreases their collision probability as time progresses.

(9) According to the molecular expansion model, the distance between the large-scale structures is increasing due to their actual recession by the virtue of the energy possessed by them; large-scale structures recede with velocity corresponding to the total amount of energy that they possess. For a large-scale structure to exhibit higher recessional velocity the energy possessed by it should be sufficiently large and the mass should be less.

(10) The highest recessional velocities are always found to be exhibited by the most distant galaxies and quasars and not by galaxy clusters. This observation is consistent with the recessional behaviour of molecules according to the kinetic theory of gases, that is, a lighter molecule recedes faster than a massive molecule even when they both possess an equivalent amount of energy (a massive molecule will recede faster than a lighter molecule only if the energy possessed by it is high enough). Such consistent recessional behaviour suggests the actual recession of large-scale structures rather than metric expansion of space between them. Since galaxies and quasars are less massive than galaxy clusters, therefore, galaxies and quasars exhibit higher recessional velocities than galaxy clusters. For this reason, galaxies and quasars manage to become the most distant structures within the observable Universe.

(11) From the tables and the molecular plots it becomes very evident that the behaviour of receding large-scale structures is similar to the behaviour of freely expanding gas molecules into the vacuum. The velocity-distance relation plot for expanding gas molecules is consistent with the velocity-distance relation plot for the receding large-scale structures obtained according to the Hubble diagram which depicts the Hubble's law. Such consistency also suggests the actual recession of large-scale structures rather than expansion of space between them; if space between the large-scale structures was expanding, then the velocity-distance relation plot for the receding large-scale structures and the expanding gas molecules would have been completely different from one another.

(12) According to the concept of metric expansion of space, the more the space between the distant object and the observer, the higher will be the redshift as light has to travel through more "stretched" space. Distances to the remote structures in Figure 9 being larger than expected imply more-than-expected stretched space between them and the observer, therefore, there should be more-than-expected "stretching" of light and higher should be the redshifts. However, the redshifts of remote structures are not adequately high enough for such large distances. This observation casts doubt upon the concept of metric expansion of space and suggests actual recession of large-scale structures.

(13) The molecular plots are exactly like the Hubble diagram; the molecules receding slowly are closer to us, whereas the molecules receding faster are further away from us. The distribution of molecules in Figure 6 is relatable to the homogeneous distribution of large-scale structures within the observable Universe since the molecules are distributed homogeneously irrespective of their mass.

(14) The gas molecules have deliberately been subjected to random temperature differences to see if the molecules deviate from exhibiting a linear velocity-distance relation. No matter how randomly the data changes for the gas molecules, the velocity-distance relation plots continue to exhibit the linear behaviour just like the Hubble diagram.

(15) The value of the Slope obtained from the velocity-distance relation plot for the expanding gas molecules is similar to the Hubble constant (*H*) (the slope of Hubble diagram), since its inverse gives us the observation time in seconds, just like the Hubble time obtained from the inverse of (*H*).

(16) From the velocity-distance relation plot for the gas molecules it is found that the further away a gas molecule is, the faster it will be receding away from us, that is, the recessional velocity of gas molecules is proportional to their distance, therefore, the Hubble's law and all Hubble equations are obeyed by the expanding gas molecules, Hubble equations like, $v = H \times D$, $D = v/H$, $t_{\mathrm{H}} = 1/H$; where v is the recessional velocity, H is the Hubble constant, D is the distance and t_H is the Hubble time. For expanding gas molecules the corresponding equations are, $v = \text{Slope} \times D$, $D = v/\text{Slope}$, $t = 1/\text{Slope}$.

(17) For molecules undergoing free expansion, no matter on which molecule we would be situated upon, all other molecules will exhibit redshift, therefore, there is expansion in every direction; there is no preferred centre. This is consistent with observation since all receding large-scale structures exhibit redshift except for some exceptionally rare ones.

(18) By knowing the values of the Slope and the distance covered by the receding gas molecules, their recessional velocity can be recalculated. Similarly, by knowing the values of the Slope and the recessional velocity of gas molecules, the distance covered by them can be recalculated. This is again consistent with the Hubble diagram.

(19) Since expanding gas molecules exhibit Hubble diagram and obey all Hubble equations solely due to their recession by the virtue of the energy possessed by them, therefore, the large-scale structures that are known to exhibit Hubble diagram and obey all Hubble equations have to be receding solely by the virtue of the energy possessed by them.

(20) Since the mass of every large-scale structure is different and so is the energy possessed by them, therefore, the large-scale structures get distributed homogeneously throughout the Universe irrespective of their mass. This is relatable to the homogeneous distribution of gas molecules during free expansion as shown in Figure 6.

(21) Plotting the velocity-distance relation for the receding large-scale structures is same as plotting the velocity-distance relation for expanding gas molecules.

(22) Expanding gas molecules will always exhibit Hubble-diagram. Since receding large-scale structures behave like receding gas molecules; justified by identical velocity-distance relation plots, the Hubble diagram therefore simply is the velocity-distance relation plot for different gas molecules undergoing free expansion into the vacuum of the Universe.

(23) Based upon the concept of differential molecular expansion, the observed deviation of the Hubble diagram from linearity at high redshifts has been explained without acceleration. Differential molecular expansion model suggests that the expansion of remote structures initiated into the Universe before the expansion of the local structures initiated. The remote structures are therefore further away than expected with respect to the local structures. Such differential expansion is the actual reason for the deviation of the Hubble diagram from linearity at high redshifts without any acceleration. Structures that began expanding into the Universe at the same time exhibit a linear velocity-distance relation. If all the structures had their expansion initiated into the Universe at the same time, or had the recessional velocities of remote structures been adequately high enough for their large distances, then the Hubble diagram would have been linear.

(24) The value of the Slope obtained for the remote molecules in Figure 7 and Figure 8 is found to be lower than the value of the Slope obtained for the local molecules. This gives us a larger observation time for the remote molecules as compared to the local molecules. This proves that the remote molecules began expanding into the vacuum of the Universe before the local molecules began expanding since the value of Slope decreases with time. Higher value of Slope (steeper Slope) for the local molecules as compared to the lower value of Slope (shallower Slope) for the remote molecules makes us believe that local molecules are expanding at a faster rate as compared to the remote molecules, that is, local molecules are accelerating. This has been found to be consistent with the values of the slope and Hubble constant for the local and remote structures in Figure 9. The value of the Hubble constant obtained for the local and remote structures is 68.5087 km s^{-1} Mpc^{-1} (slope: 2.2202 x 10^{-18} m s^{-1} m^{-1}) and 32.4646 km s^{-1} Mpc^{-1} (slope: 1.0521 x 10^{-18} m s^{-1} m^{-1}) respectively. Lower value of slope and Hubble constant for the remote structures strongly indicates that the remote structures had their expansion initiated into the Universe before the expansion got initiated for the local structures since the value of slope and Hubble constant decreases with time. Higher value of Hubble constant for the local Universe as compared to the value of the Hubble constant for the remote Universe makes us believe that the Universe is expanding faster now, that is, “Universe is accelerating now, and had a slower expansion in the past”.

(25) The deviation from velocity-distance linearity in Figure 7, Figure 8 and Figure 9 clearly indicates that the distances to the remote objects (molecules and structures) are large, but their recessional velocities are not adequately high enough for them to have covered such large distances within the expansion time frame of the local objects, unless the remote objects began expanding before the expansion began for the local objects. Had the recessional velocities of remote objects been adequately high enough for such large distances, or had the expansion initiated for all the objects into the vacuum of the Universe at the same time, then there would have been no deviation from linearity.

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