Analysis of the universal expansion

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Aim:

This study aims to analyze the expansion of the universe using the data of supernovae type 1a (distance and redshift) to find out if that the acceleration of the universe constant or changing with time and if it was changing what is the number of derivatives that lead to a constant function to know what is the order of this acceleration(linear, parabolic or exponential).

Collected Data:

The data collected mainly is the supernovae with its corresponding distance and redshift.

Supernova	Redshift	log(redshift)	luminosity distance	Distance (MegaParsec)
1995D	0.008	-2.10	32.79	36.14
1995E	0.012	-1.92	33.73	55.72
1992al	0.014	-1.85	34.13	66.99
1995bd	0.016	-1.80	34.00	63.10
1996C	0.028	-1.55	35.82	145.88
1992bh	0.045	-1.35	36.87	236.59
1990af	0.050	-1.30	36.67	215.77
1993O	0.052	-1.28	37.31	289.73
1992bs	0.064	-1.19	37.63	335.74
1992bp	0.080	-1.10	37.96	390.84
1992aq	0.101	-1.00	38.33	463.45
1996ab	0.124	-0.91	39.10	660.69
1996J	0.300	-0.52	40.99	1577.61
1996K	0.380	-0.42	42.21	2766.94
1996E	0.430	-0.37	42.03	2546.83
1996U	0.430	-0.37	42.34	2937.65
1997ce	0.440	-0.36	42.26	2831.39
1995K	0.480	-0.32	42.49	3147.75
1997cj	0.500	-0.30	42.70	3467.37
1996I	0.570	-0.24	42.83	3681.29
1996H	0.620	-0.21	43.01	3999.45
1997ck	0.970	-0.01	44.30	7244.36

imagine.gsfc.nasa.gov

Method:

1. calculate the velocity from redshift data.

$$v = \frac{(z+1)^2 - 1}{(z+1)^2 + 1} c$$

- for each SN it is at a large distance then the light that comes to our eyes indicates how it was in the past, it was at this distance at the past and this velocity was at the past.

2. calculate this time to know how long ago these conditions (velocity and distance happen).

$$t = d/c$$

- from the definition of Hubble low, for an elastic expanding material at a certain time, any distance between 2 points is directly proportional to the relative velocity of one point to the other.

3. we can consider earth is a point on the rubber and the SN is another point at distance “d”, the relative velocity of SN to us is “v”, now we can calculate the Hubble constant for that rubber through H=v/d.

4. at different times Hubble constant is different, and now as we get “H” for each different SN, and “t” when which this “H” was achieved, we can make a plot of points of “t” vs “H”.

5. MATLAB will be used to deal with these operations for 22 data, also it will be used in curve fitting and equation getting.

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```
%general Data
z=[0 0.008 0.012 0.014 0.016 0.028 0.045 0.050 0.052 0.064 0.080 0.101 0.124 0.300 0.380 0.430 0.430 0.440
0.480 0.500 0.570 0.620 0.970];
d_MPars=[0 36.14 55.72 66.99 63.10 145.88 236.59 215.77 289.73 335.74 390.84 463.45 660.69 1577.61
2766.94 2546.83 2937.65 2831.39 3147.75 3467.37 3681.29 3999.45 7244.36];
d_meter=(3.08567758*(10^16)*(10^6))*d_MPars;
vel=(((z+1).^2-1)./((z+1).^2+1)).*299792458;
%calculating time of each SN
t=-d_meter/299792458;  %with zero represents the present and negative represents the past
%calculating Hubble constant in discrete method
H=vel./d_meter;
%calculate Hubble in diferentiation method
vel_d_meter=fit(d_meter',vel','poly2');
h=differentiate(vel_d_meter,d_meter);
%considiring inflation
H_infl=[0,H];
h_infl=[0,h'];
```

```
t_infl=[-20*10^17,t];   %assuming that universe begining(static ball) doesnt start as extention of existing SN, and assume a point from a very long time.
%data fit,, open MATLAP APPS>curve fitting> and choose variables you want.
```

1. now we have H(t), and to get x(t) we use these calculations:

   in these calculations, we analog to an elastic rubber pivoted at one end and someone holding the other end and move it with velocity”v” and “d” is the distance between this moving end and the pivot.

$$\boldsymbol{v(t) = H(t)d(t)}$$

$$,,\frac{dd(t)}{dt} = H(t)dt,,\frac{dd}{d(t)} = H(t)dt,,\int_{d=d_0}^{d=d_c}\frac{dd}{dt} = \int_{t=t_0}^{t=t_c} H(t)d\,t\,,,$$

$$\ln(d_c) - \ln(d_0) = \int_{t=t_0}^{t=t_c} H(t)dt$$

$$,,\ln\left(\frac{d_c}{d_0}\right) = \int_{t=t_0}^{t=t_c} H(t)dt\ ,,e^{\ln\left(\frac{d_c}{d_0}\right)} = e^{\int_{t=t_0}^{t=t_c} H(t)dt},$$

$$d_c = d_0 e^{\int_{t=t_0}^{t=t_c} H(t)dt} \quad (1)$$

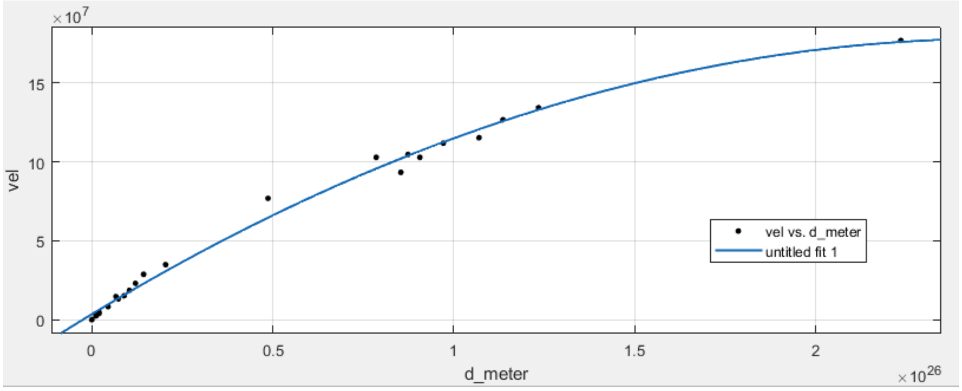
where d_c:current distance from the pivot to the end, d_0: the initial distance from the point at the end to the pivot, t_c: the current time, t_0: the initial time.

- to examine the validity of the methods we calculate the Hubble constant these days we will find out that they are close(not the exact because of graph regression), also if we put universe inflation into consideration we find that the method makes it possible when we assume that universe(static ball) does not start as an extension of existing SN, and assume a point from a very long time.
- the validity checkers above doesn't work if I used the graph between distance and velocity and differentiate it to get Hubble constant so this method excluded.

results:

all in SI units.

velocity versus time:



Linear model Poly2:

f(x) = p1*x^2 + p2*x + p3

Coefficients (with 95% confidence bounds):

p1 = -2.773e-45 (-3.24e-45, -2.305e-45)

p2 = 1.392e-18 (1.305e-18, 1.479e-18)

p3 = 3.473e+06 (5.516e+05, 6.395e+06)

Goodness of fit:

SSE: 4.094e+14

R-square: 0.9938

Adjusted R-square: 0.9932

RMSE: 4.524e+06

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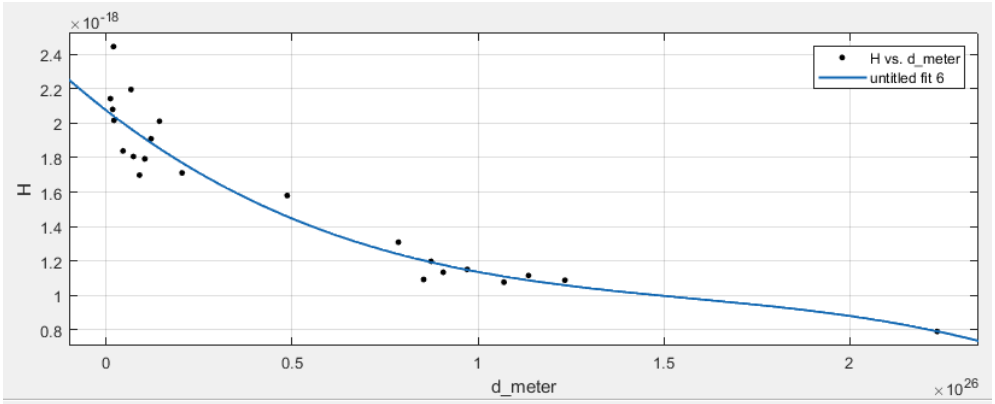
Hubble versus distance:



Linear model Poly3:

f(x) = p1*x^3 + p2*x^2 + p3*x + p4

Coefficients (with 95% confidence bounds):

p1 = -1.969e-97 (-6.532e-97, 2.595e-97)

p2 = 9.314e-71 (-5.471e-71, 2.41e-70)

p3 = -1.672e-44 (-2.772e-44, -5.709e-45)

p4 = 2.074e-18 (1.951e-18, 2.198e-18)

Goodness of fit:

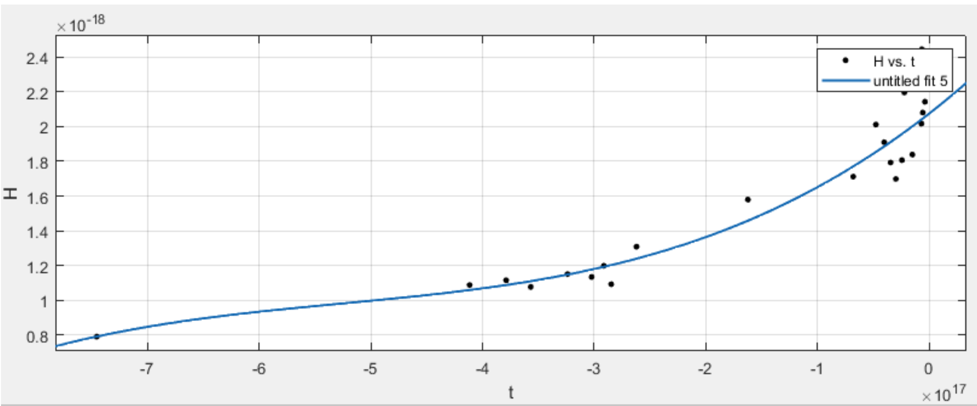
SSE: 3.777e-37

R-square: 0.9166

Adjusted R-square: 0.9027

RMSE: 1.448e-19

Hubble versus time:



Linear model Poly3:

f(x) = p1*x^3 + p2*x^2 + p3*x + p4

Coefficients (with 95% confidence bounds):

p1 = 5.304e-72 (-6.993e-72, 1.76e-71)

p2 = 8.371e-54 (-4.917e-54, 2.166e-53)

p3 = 5.011e-36 (1.711e-36, 8.311e-36)

p4 = 2.074e-18 (1.951e-18, 2.198e-18)

Goodness of fit:

SSE: 3.777e-37

R-square: 0.9166

Adjusted R-square: 0.9027

RMSE: 1.448e-19

as we see that now (t=0) the H=2.074

It is not the exact Hubble constant calculated because it seems that the method they used is to get the average Hubble constant of the recent SN ignoring the past ones, but here the intersection does not represent the average of the recent SN but it represents a fitting of the past and recent SN.

conclusion:

from equation(1); the only way for the expansion is not exponential is that the H should decrease with time, and we see that it is not true for the universe, so the universe expands exponentially in time.

now we can say that the aim of the study has achieved as we can conclude that *the radius of the universe increase as "e to the power some polynomial of time"* which means that the acceleration of the universe is not only constant but it will continue in change forever.

from the plot H VS t, if we assume that the static condition(H=0) is achieved at the beginning of the universe(extrapolation of curves). we can consider that the age of the universe is at least the time when H=0 (intersection with t) which contradicts with the method of considering the age of the universe is just "1/H" for recent SN. The only way to make both results go with each other is to consider the inflation which happened at the beginning of the universe.

Data source:

https://imagine.gsfc.nasa.gov/educators/programs/cosmictimes/downloads/lessons/2006/Measure_DE_Data_File.pdf