

# The Shape of the Universe

DLDK U3A

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# Outline

- Scale of the universe of stars and galaxies
- Dark bands in light emerging from a prism
- Distances and velocities of the visible stars
- Gravity theory of 1915 applied to Universe
- Universe may contract or expand forever
- The mathematical constant  $\pi$  (perimeter)
- Dark matter and the search for particles

# Scale of the Universe

|    |     |                         |
|----|-----|-------------------------|
| Xm | 27  | Observable universe     |
| Em | 18  | Globular star cluster   |
| Gm | 9   | Sun (a typical star)    |
| m  | 0   | Animal 1 metre in size  |
| nm | - 9 | DNA base pair           |
| am | -18 | Size studied by LHC     |
| xm | -27 | Unification of forces ? |

# Joseph Fraunhofer (1787-1826)

1817 Found dark lines in the Sun's spectrum and in stars viewed through a telescope



1860 Dark lines corresponded to bright lines seen with chemical elements in a flame

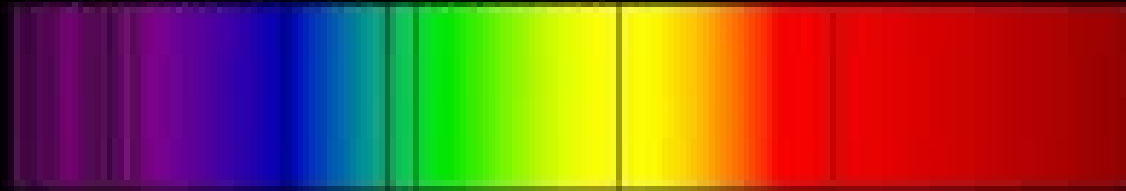


# Christian Doppler (1803-1853)

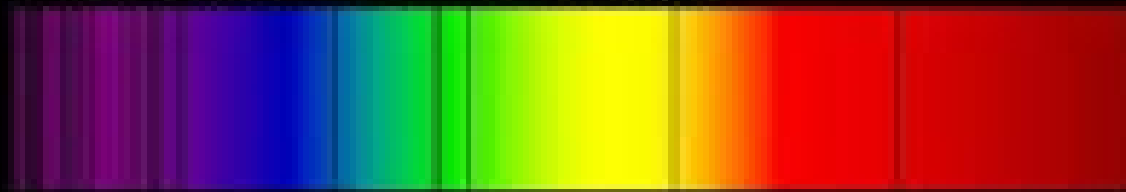
- 1842 The colour of a star alters when the star changes its velocity; e.g., in a binary star one star approaches - the other recedes
- 1953 Echocardiograms and ultrasonographs routinely use the Doppler Effect today to measure blood flow and fluid flow.

# Solar dark lines and the redshift of dark lines for a receding galaxy

Absorption Lines from our Sun



Absorption Lines from a supercluster of galaxies, BASS1  
 $v = 0.07 c$ ,  $d = 1$  billion light years



# Henrietta Leavitt (1869-1921)

- 1900 Studied 1777 stars of variable brightness from Harvard's photographic plates of the Magellanic Clouds seen by telescope
- 1912 She found that, the brighter the variable star she measured, the longer was the time period of its peak to peak variation

# Maximum and Minimum Brightness

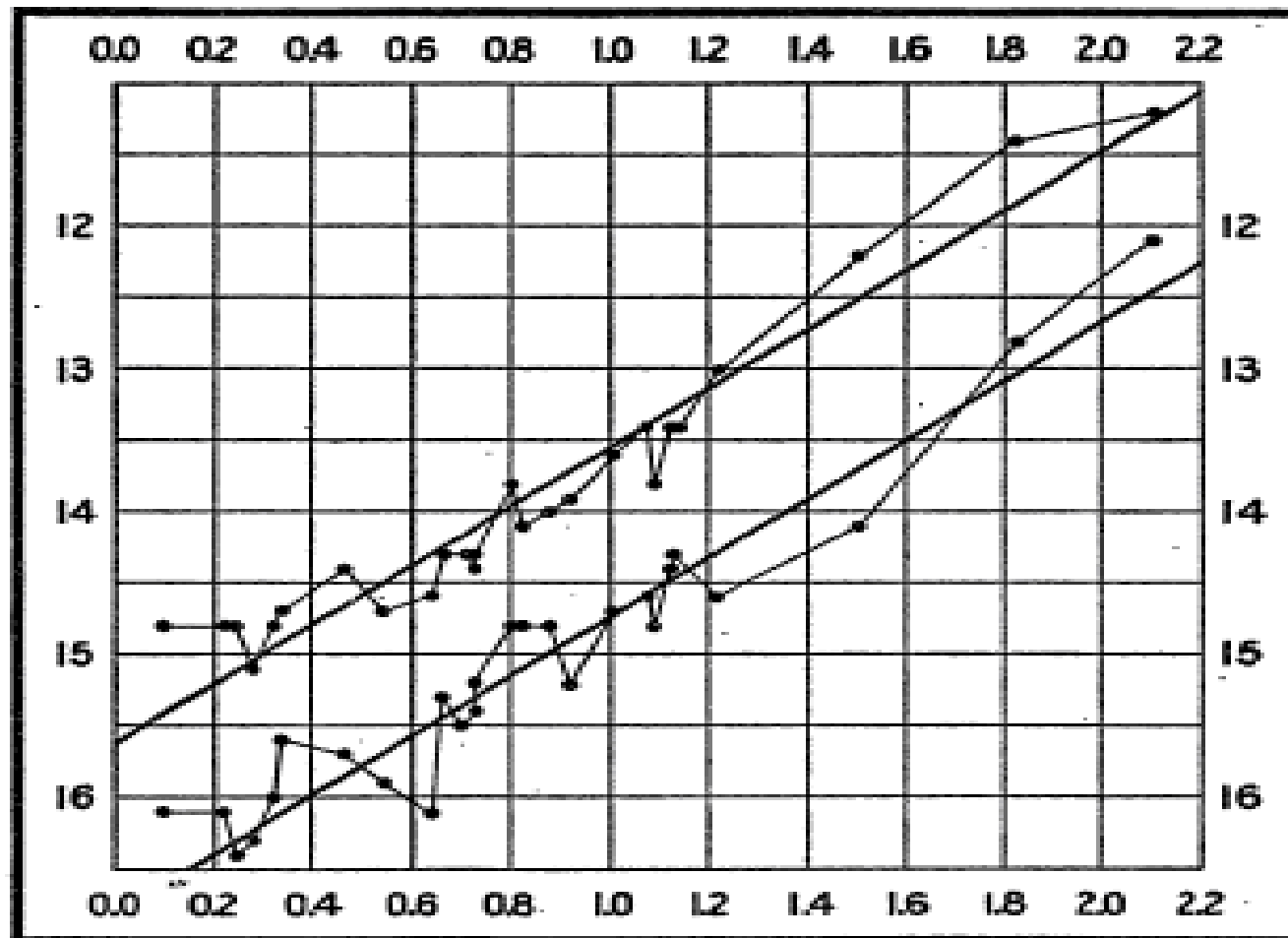
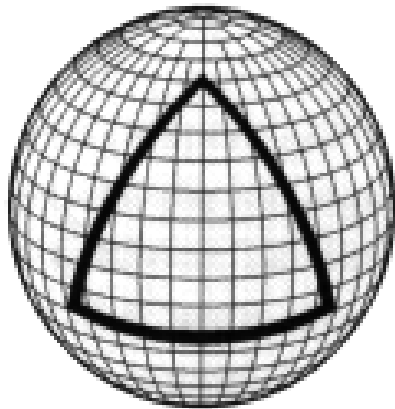


FIG. 2.

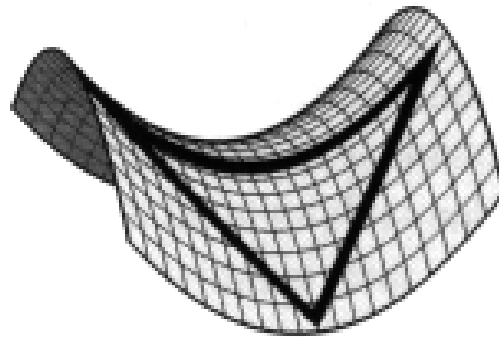
*Figure from (Leavitt 1912)*

# Albert Einstein (1879-1955)

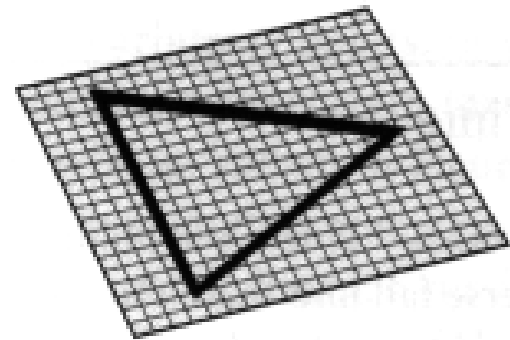
used his general theory of relativity to find in 1917 that the universe's shape can have the three angles of a triangle summing to either greater than, or less than, or  $= 180$  degrees



**Positive Curvature**



**Negative Curvature**



**Flat Curvature**

“The most incomprehensible thing about the world is that it is comprehensible”

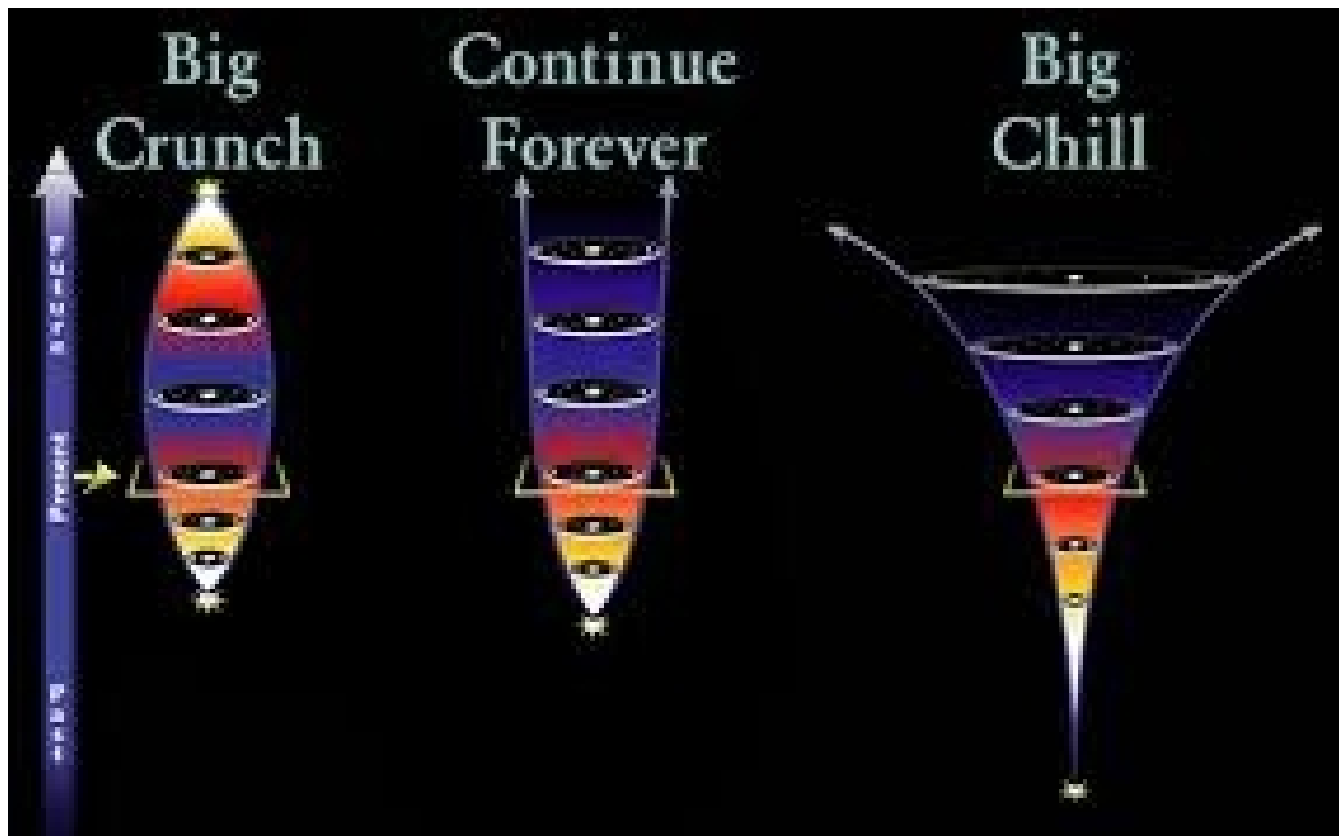
Albert Einstein

"The unreasonable effectiveness of mathematics in the natural sciences"

Eugene Wigner

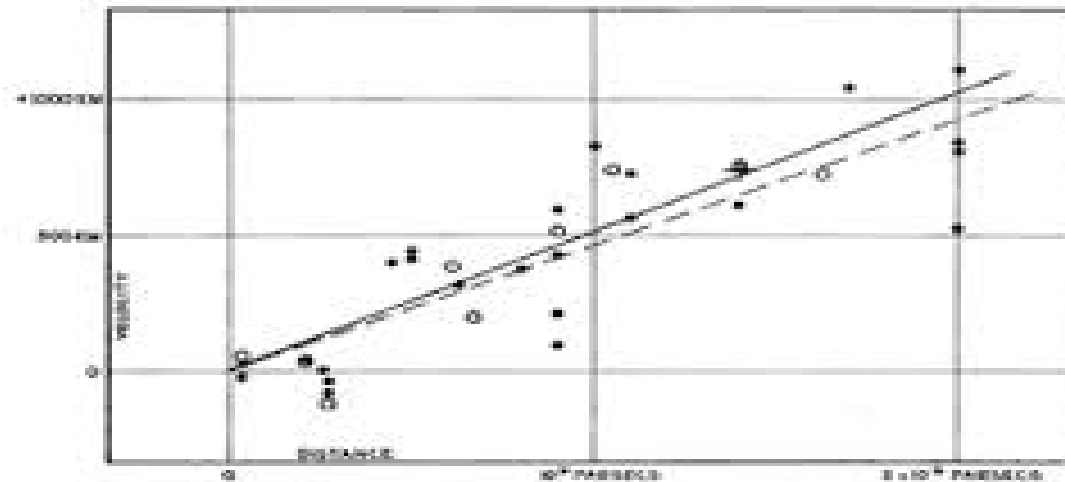
1922 Alexander Friedmann (1888-1925)

1927 Georges Lemaître (1894-1966)



# Edwin Hubble (1889-1953)

- 1924 Used variable stars to show that there were galaxies beyond the Milky Way
- 1929 Found a relation between distance and the velocity of many receding galaxies



Velocity-Distance Relation among Extra-Galactic Nebulae.

*Figure from (Hubble 1929)*

# John Wheeler (1911-2008)

expressed the gravity equation of general relativity:

“spacetime tells matter how to move;  
matter tells spacetime how to curve”

$$c^4 \times \text{Curvature} = 8 \times \pi \times G \times \text{Energy}$$

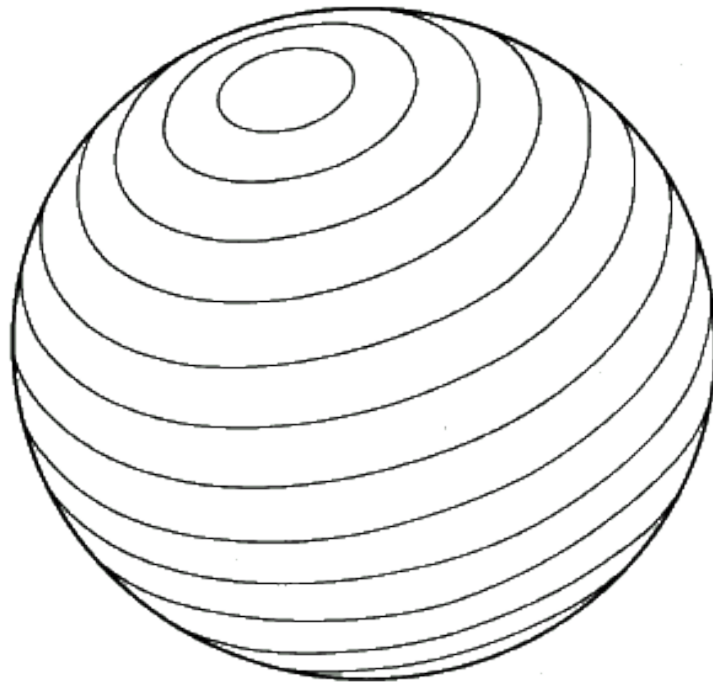
The top of Lugnaquilla ages faster than its base by  
about 20 mins over its 420 million year existence.

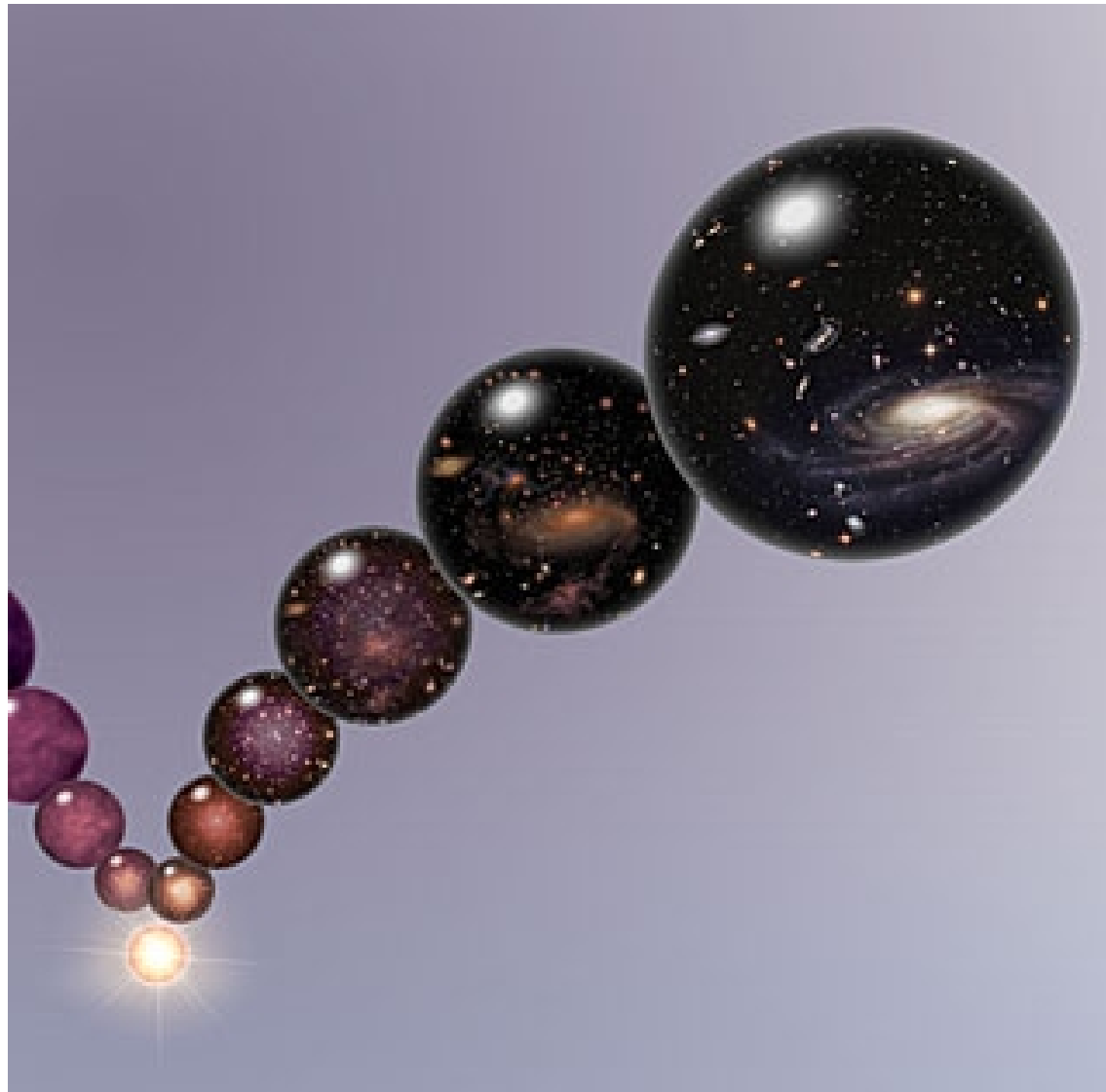
“Time is Nature's way to keep everything  
from happening all at once”

# Dante Alighieri (c. 1265 – 1321)

Paradiso: Canto XXX – Line xii

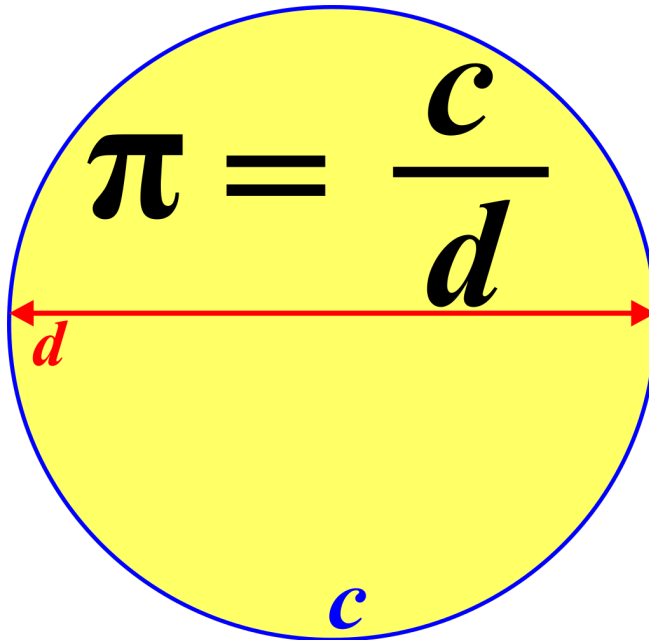
Seeming enclosed by what itself encloses  
(parendo inchiuso da quel ch'elli 'nchiude)





How I wish I could calculate  
of circle round  
the exact relation  
ArXimedes found

3.14 159 265 358 979



# William Jones (1675-1749)

introduced the symbol  $\pi$  - with number of digits

|      |   |            |        |
|------|---|------------|--------|
| -250 | 3 | Archimedes | Sicily |
|------|---|------------|--------|

|     |   |             |       |
|-----|---|-------------|-------|
| 480 | 7 | Zu Chongzhi | China |
|-----|---|-------------|-------|

|      |    |         |       |
|------|----|---------|-------|
| 1400 | 10 | Madhava | India |
|------|----|---------|-------|

|      |    |                  |      |
|------|----|------------------|------|
| 1424 | 17 | Jamshid al-Kashi | Iran |
|------|----|------------------|------|

|      |    |                   |              |
|------|----|-------------------|--------------|
| 1615 | 32 | Ludolf van Ceulen | Dutch-German |
|------|----|-------------------|--------------|

|      |     |             |         |
|------|-----|-------------|---------|
| 1706 | 100 | John Machin | England |
|------|-----|-------------|---------|

|      |             |             |             |
|------|-------------|-------------|-------------|
| 2016 | 22 trillion | Peter Trueb | Switzerland |
|------|-------------|-------------|-------------|



# Vera Rubin (1928 – 2016)

- found that galaxies and stars are immersed in the gravitational grip of vast clouds of dark matter that do not emit any detectable radiation
- showed that galaxies must contain at least six times as much dark matter as ordinary matter by studying the velocities of the stars within
- many devices are seeking the nature of the weakly interacting massive particles that appear to prevent peripheral fast stars from exiting

# History of the Universe

