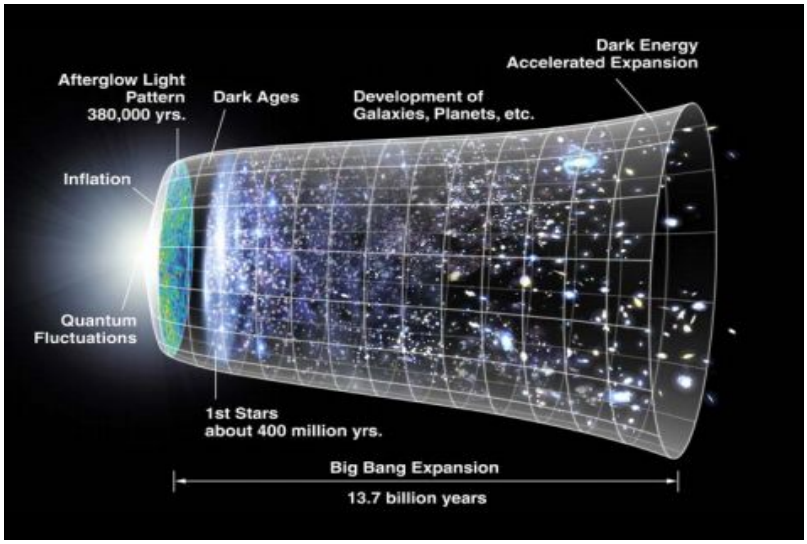
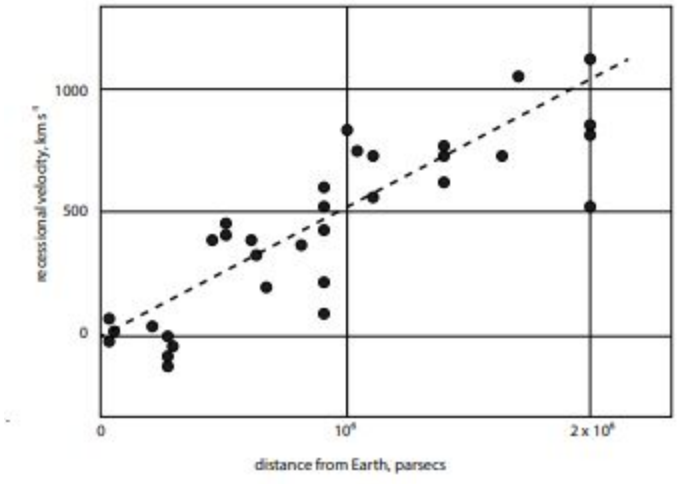
Ans 1.) The **Big Bang theory** is a model of how our Universe expanded from an initial state of extremely high density and high temperature.This model describes how the Universe came into being from a spacetime singularity and has been expanding ever since.



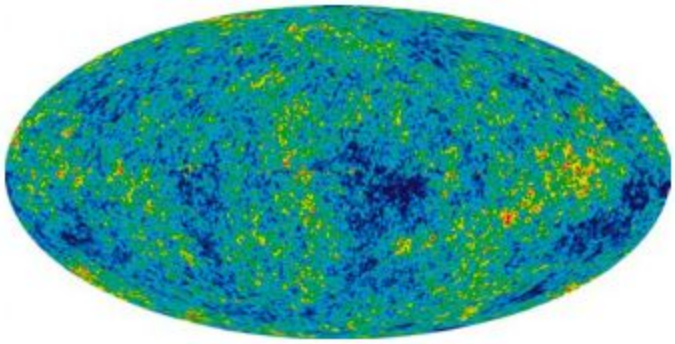

Some of the evidences in support of Big Bang are:

- **Hubble–Lemaître law** - The law states that galaxies are moving away from the Earth at speeds proportional to their distances from Earth.The farther they are , the faster they are moving away.This was determined by observing the redshifts in the lights emitted by the galaxies.Extrapolating this expanded Universe backwards through time , we end up with a high density and high temperature small region of space that the Big Bang theory predicts.




- **Cosmic Microwave Background Radiation** - According to the Big Bang theory, the Universe was initially very hot and dense.Protons and electrons could not combine at such high temperatures and the radiation could be scattered off electrons.But as the Universe expanded , it cooled and favoured the formation of hydrogen atoms.These

newly formed atoms could not scatter the photons and hence the radiation travelled through space in straight lines.This radiation was captured in the antena of Bell Telephone Laboratories , Murray Hill , New Jersey , as noise by Arno Penzias and Robert Wilson.The noise came uniformly all over the sky.This suggested that it might be the CMB and was later confirmed supporting the Big Bang theory.



nine-year microwave sky image from WMAP
credit: NASA/WMAP Science Team

- **Olber's Paradox** - We all see that the night sky is dark.What Olber's paradox says is that the darkness of the night sky **conflicts** with the assumption of an **infinite** and **eternal static** Universe.This suggests that the Universe cannot be static.Had it been static , the night sky would have been completely illuminated and very bright.Big Bang theory very easily accommodates this observation.An expanding Universe would suggest redshift in the light emitted by stars which can have wavelength much longer than visible light , rendering the night sky dark to us.This can only be explained by an expanding Universe theory which the Big Bang theory suggests.

- **Observed Abundance of primary elements like Hydrogen and Helium** - According to the Big Bang theory , as the Universe expanded it cooled.This would suggest that at the very beginning after the Big Bang , elements like deuterium,helium-4,helium-4 and lithium-7 were formed.The predicted ratios of these elements with respect to hydrogen strongly matches the observed ratios today.Big Bang theory is the only theory which provides a reasonable explanation for these ratios.

Ans 2.) The Big Bang theory is unique in several ways.There were a number of theories about the universe like the Geocentric model , the Heliocentric model , Kepler's Planetary model etc. Why Big Bang theory was different from the above theories is given below:

- **Accommodating the fact that there is no center of the Universe -** Many of the earlier theories like the Geocentric model proposed by Aristotle or the Heliocentric model proposed by Copernicus put Earth or Sun at the center of the Universe.Later it was

observed that galaxies are distributed uniformly and the same in all directions implying that the Universe has neither a center nor an edge.Big Bang theory accommodates this fact.

- **Hubble–Lemaître law** - As stated in the previous answer , galaxies farther away are moving faster than galaxies near to us.This causes **redshift** in the light emitted by the galaxies.Big Bang theory very aptly accommodates this fact by proposing an expanding model of the Universe.It was because of this law that several other competing theories like the **Steady State theory** were discarded.
- **Incorporating General Theory of Relativity** - Although Newton's Law of Gravitation is a very good approximation of gravity , it does not give us the real picture.The Big Bang theory is built upon **Einstein's General Theory of Relativity** and hence gives us a much more accurate picture of reality rather than the other theories.
- **Abundance of primordial elements** - Using Big Bang theory it is possible to calculate the concentration of **helium-3** , **helium-4** , **lithium-7** etc. with respect to **hydrogen**.The measured abundances agree quite strongly with the predicted values and it is only theory that provides the explanation for the ratios.No other theory explains why the particular ratios occur.

Ans 3.) The answer for this question is given in the picture below:

No.
Date

From Kepler's Third law:

$$T^2 \propto a^3$$

where $T$ = orbital period
$a$ = semi-major axis

More precise formula is:

$$\boxed{\frac{a^3}{T^2} = \frac{G(M+m)}{4\pi^2}}$$

where $M$ = mass of Sun
$m$ = mass of planet

For Venus, $T = 225$ days

For practical reasons, $M \gg m$

Hence, $M + m \approx M$

So, $\frac{a^3}{T^2} \approx \frac{GM}{4\pi^2} = \frac{(6.67 \times 10^{-11})(1.98 \times 10^{30}) \frac{Nm^2}{kg}}{4\pi^2}$

$$\Rightarrow \frac{a^3}{T^2} \approx 7.496 \times 10^{-6} \frac{AU^3}{(days)^2}$$

$$\Rightarrow a^3 \approx 379,485 \times 10^{-6} (AU)^3$$

$$\Rightarrow a \approx 72.39 \times 10^{-2} AU \approx 7.239 \times 10^{-1} AU$$

desmos

Ans 4.) The Universe is indeed **expanding**.This expansion of the Universe is completely different from the common expansions that we see around us.It is a metric expansion , whereby the scale of space itself changes.

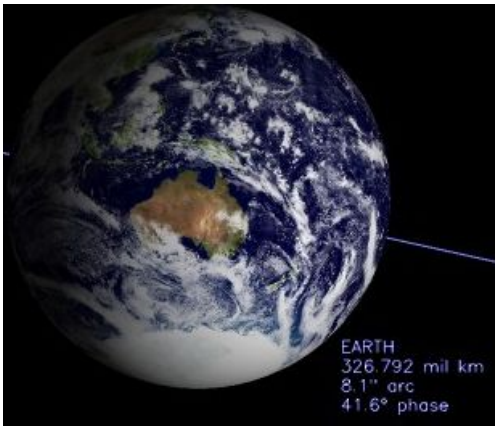
There are several theories and experiments that indicate that the Universe is expanding:

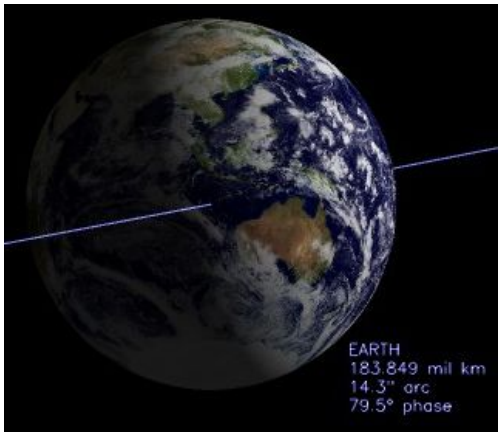
- **Hubble's Law** - As stated in earlier answers , Hubble showed that all objects are moving away from us, and that their speed is proportional to their distance, a feature of metric expansion.
- **Friedmann Equations** - In 1922 , Alexander Friedmann derived a set of equations known as the Friedmann Equations that the Universe can expand and also presented the rate of expansion.All this of course follows from General Relativity of Einstein.With the experimental evidence of Hubble's Law , scientists started accepting the expanding Universe model.
- **Cosmic Inflation** - This theory states that the Universe expanded exponentially fast in the early stages , about $10^{-33}$ or $10^{-32}$ seconds after the singularity.Later the Universe expanded slowly.In 1979, Alan Guth suggested that this theory could solve potentially many problems like the Horizon problem , Flatness problem or the Magnetic Monopole problem.
- **Olber's Paradox** - As stated in the first answer , this paradox describes how a static universe cannot lead to a dark night sky.For the night sky to be dark , the Universe must be dynamic , expanding.
- **Uniform cooling of the Cosmic Microwave Background Radiation** - As stated in the earlier answers , the CMB was discovered as a radiation noise by Arno Penzias and Robert Wilson.Since then it has been found by observing distant galaxies and intergalactic clouds in thermal equilibrium with CMB , that the CMB was hotter in the past.Its eventual cooling evidently supports the expansion of the Universe.

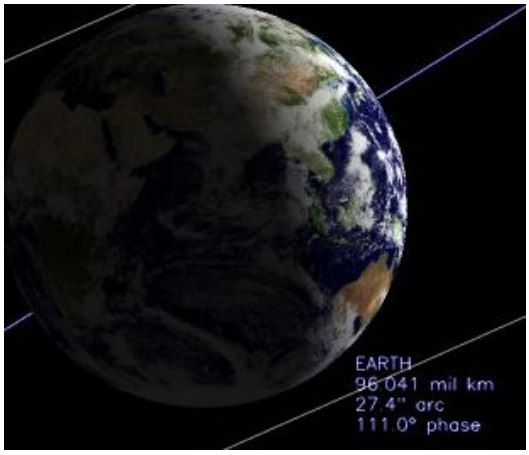
Ans 5.) Answer is option **(a.) Mercury , Earth and Venus**

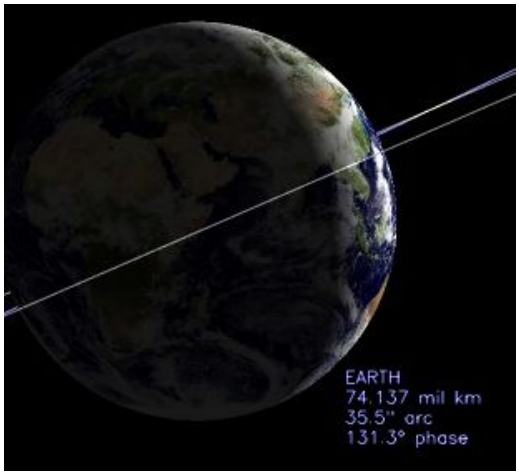
I have selected the photos depicting the phases , from the simulator at
https://space.jpl.nasa.gov/
which was given in the slides.

**Earth:**


EARTH
326.792 mil km
8.1" arc
41.6° phase

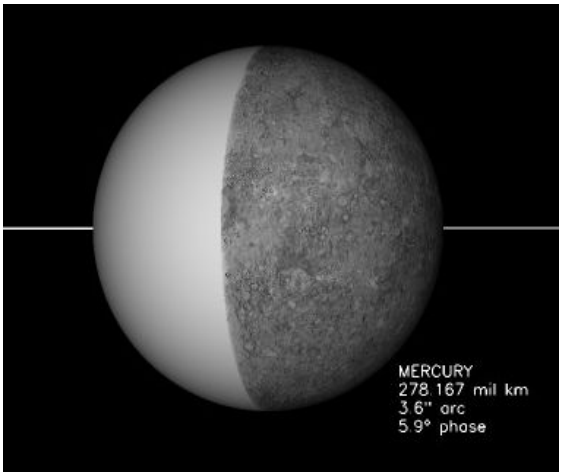

EARTH
183.849 mil km
14.3" arc
79.5° phase

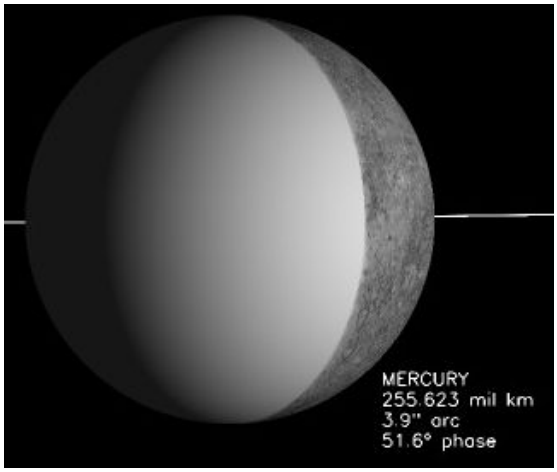

EARTH
96.041 mil km
27.4" arc
111.0° phase

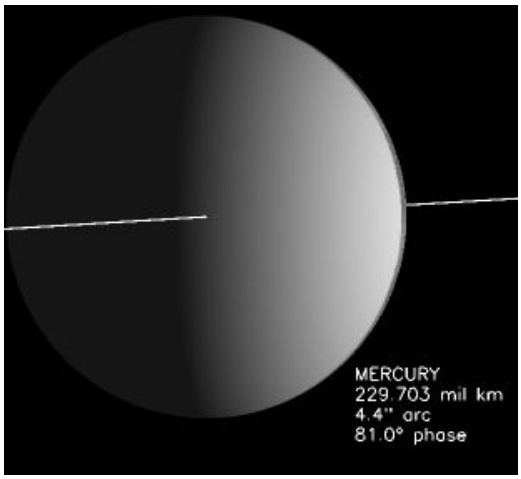

EARTH
74.137 mil km
35.5" arc
131.3° phase

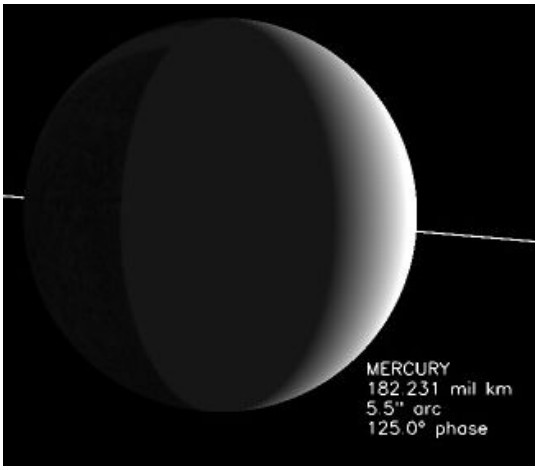

EARTH
62.425 mil km
42.1" arc
162.8° phase

**Mercury:**

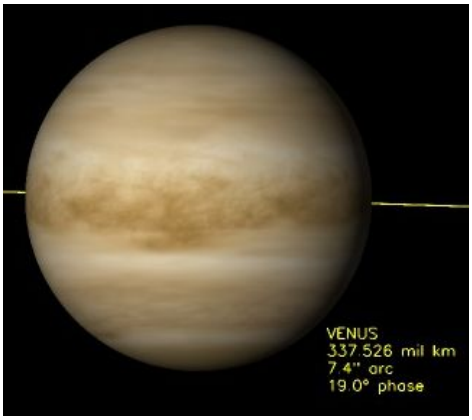

MERCURY
278.167 mil km
3.6" arc
5.9° phase

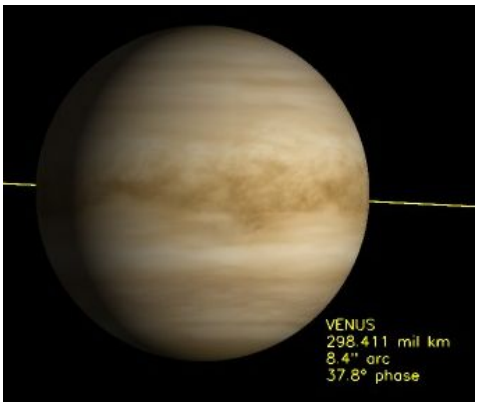

MERCURY
255.623 mil km
3.9" arc
51.6° phase

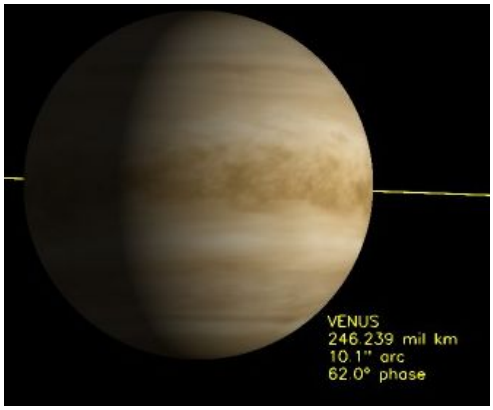

MERCURY
229.703 mil km
4.4" arc
81.0° phase

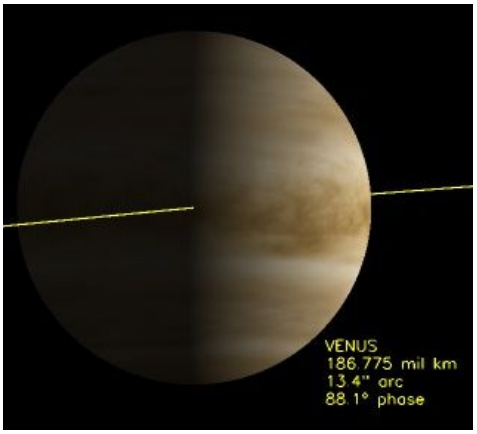

MERCURY
182.231 mil km
5.5" arc
125.0° phase

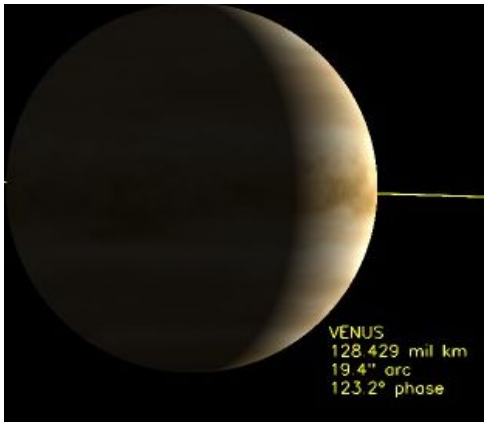
**Venus :**


VENUS
337.526 mil km
7.4" arc
19.0° phase

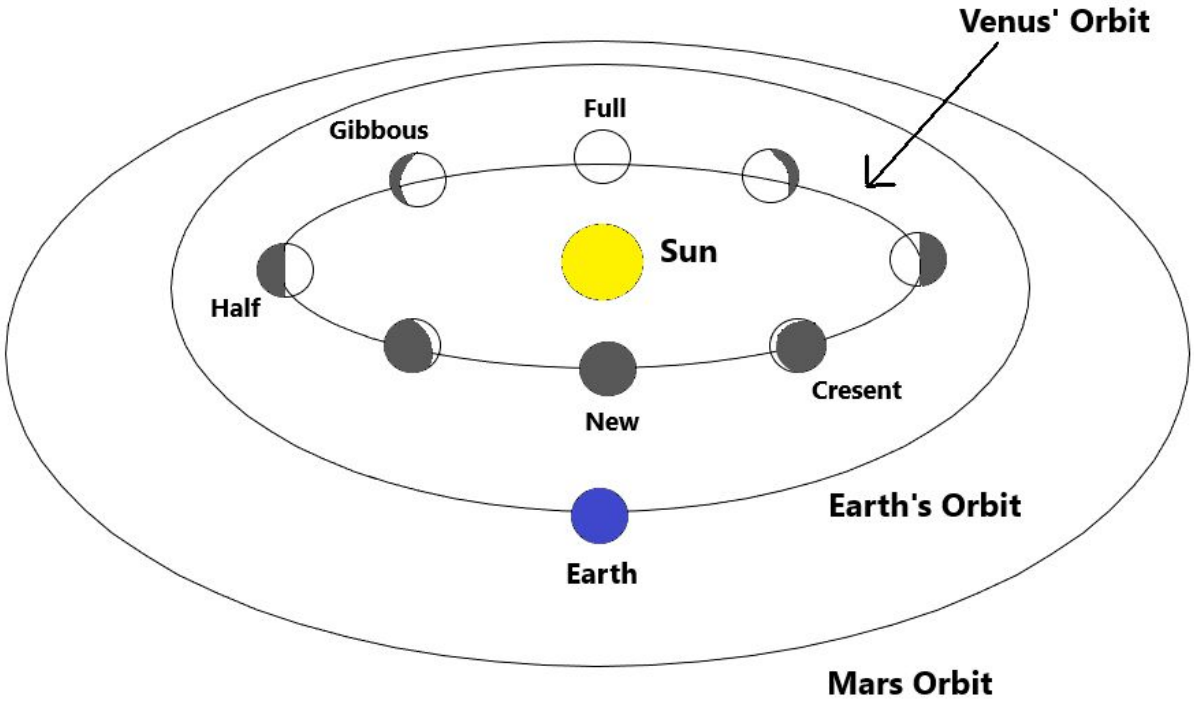

VENUS
298.411 mil km
8.4" arc
37.8° phase


VENUS
246.239 mil km
10.1" arc
62.0° phase


VENUS
186.775 mil km
13.4" arc
88.1° phase


VENUS
128.429 mil km
19.4" arc
123.2° phase

Ans 6.)


Venus' Orbit
Full
Gibbous
Sun
Half
Cresent
New
Earth's Orbit
Earth
Mars Orbit