Kosmologi

- Jagat Raya merupakan tempat yang senantiasa berubah
- Bintang lahir dari debu, membakar bahan bakarnya, dan akhirnya mati. Ada siklus hidup bintang.
- Galaksi memperlihatkan pergeseran merah (red shift) hal ini berarti bahwa galaksi bergerak saling menjauh.

Siklus hidup

Alam semesta tempat dinamis

Apakah ada awalnya?

Apakah akan berakhir?

Pertanyaan Mendasar

- Bila alam semesta ada awal dan ada akhirnya, apa yang terjadi sebelum dan sesudahnya?
- Apakah alam semesta terbatas atau tak terbatas?
- Bila alam semesta terbatas, apa tepiannya?
- Apakah ada alam semesta lain diluar alam semesta ini?

Bagaimana Astronomi menjawab?

Gunakan metoda sains:

1. Menetapkan pertanyaan (stated earlier).
2. Ambil data (we have lots of data already).
3. Buat hipotesis untuk menyatakan apa yang kita ketahui, dan buat prediksi untuk lainnya.
4. Uji hipotesis – actually return to step 2.

Hipotesis yang mungkin:

- God created the universe and made it look the way it does.
- Steady State: Alam semesta tidak punya awal dan akhir. It is always the same (on average).
- Big Bang: Alam semesta dimulai dengan ledakan besar dari massa yang densitas sangat tinggi.

Uji Hipotesis

Hipotesis 1: God created the universe and made it look the way it does.

It is hard to make any predictions based on this hypothesis – it is really untestable and so non-scientific. It may be true, but it is out of the realm of what science can deal with..

Uji Hipotesis

Hipotesis 2: Steady State: Alam semesta tidak punya awal dan akhir– selalu sama (on average).

Pada kenyataannya bintang-bintang secara kontinu membakar hydrogen, hidrogen baru haruslah diciptakan dan debu (elemen berat) harus dirubah. Sementara energi panas yang dilepaskan saat pembakaran harus dirubah pula.

Uji Hipotesis

Hypothesis 3: Big Bang
Alam semesta dimulai dengan ledakan besar dari massa dengan densitas yang luar biasa sangat tinggi

It may keep on expanding or it may slow down and eventually collapse due to gravity. It may have started with a finite amount of mass in a finite volume, or with an infinite amount of mass in an infinite volume..

Teori Pendukung Bigbang

George Gamow, 1948:

- Bila melihat cukup jauh ke alam semesta, kita akan melihat radiasi latar belakang sisa dari bigbang.
- Radiasi ini akan teramati di Bumi sebagai radiasi gelombang pendek (microwave)

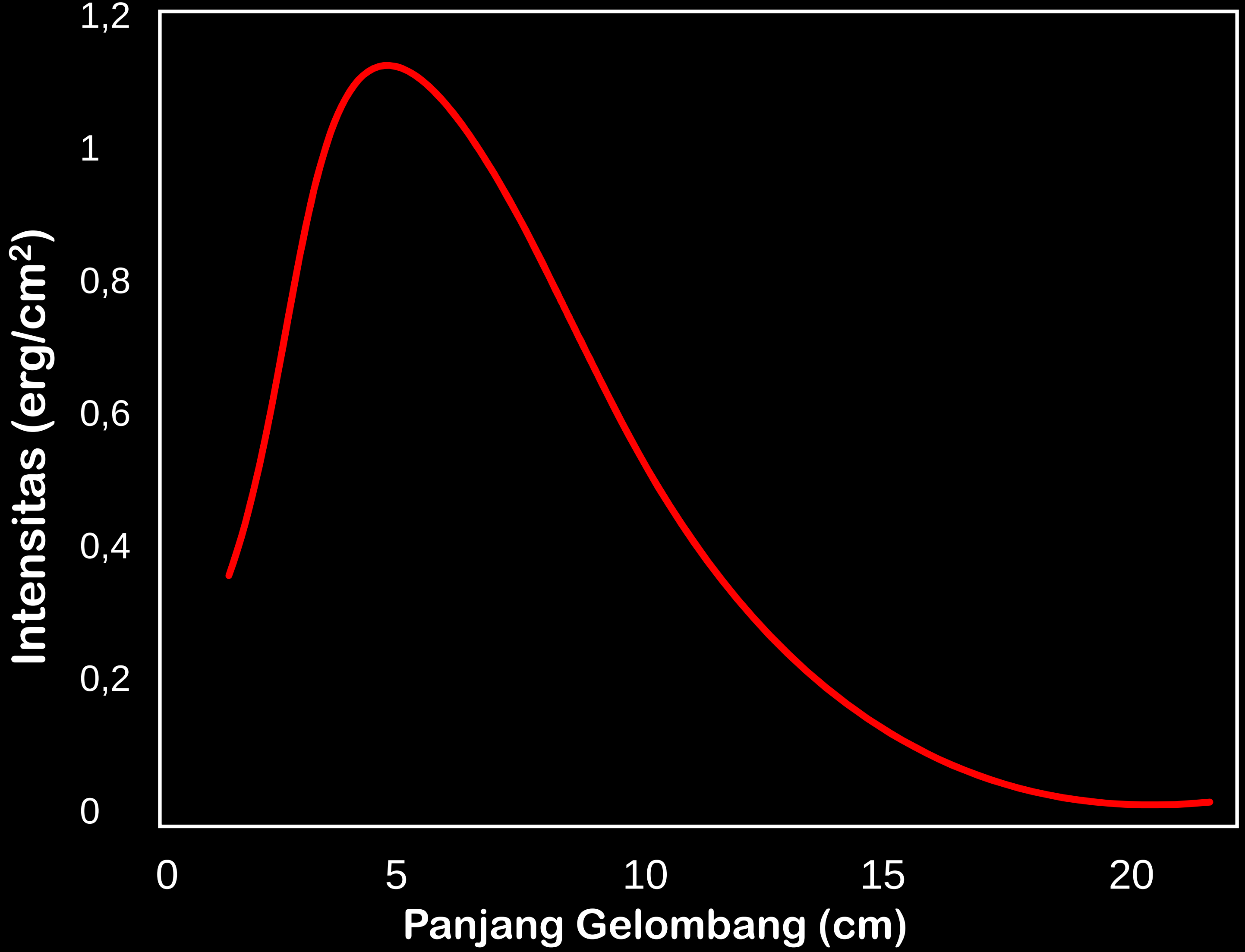
Sedikit Data Penting

- Armo Penzias & Robert Wlison, 1965:
  Dalam mencoba menghilangkan noise pada detektor radio, mencatat adanya sinyal noise yang tak bisa dihilangkan.
- Robert Dicke, Universitas Princston:
  Noise tsb berasal dari tepi jagat raya.
  Cosmic Microwave Background, CMB
- A. Penzias & R. Wlison, 1978: Nobel Fisika

Sedikit Data Penting

- Satelit COBE (Cosmic Background Explorer),1991:
  Temperatur CMB 2,742 K.
  Radiasi CMB uniform.
  Ketelitian 10^{-4}.
- Seandainya mata kita peka terhadap CMB:
  Langit akan berwarna putih, mulus sempurna.
  Sesuai dengan prinsip homogen dan isotropik.
- Satelit WMAP (Wilkinson Microwave Anisotropy Probe), 2003:
  Mempelajari fluktuasi CMB.

Spektrum CMB dari COBE



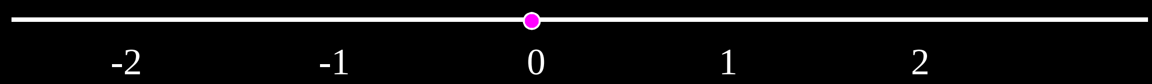
Dimensions

Sebelum kita lihat salah satu hipotesis Steady State atau the Big Bang, kita perhatikan kemungkinan dimensi ruang.

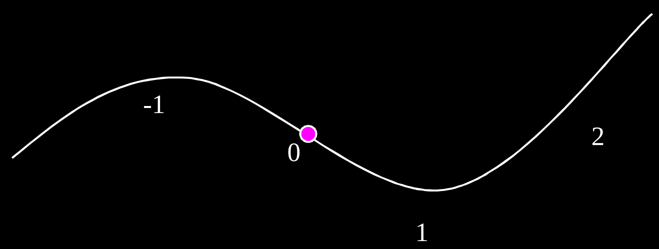
Titik merupakan dimensi nol, karena itu kita tak dapat bergerak mengelilingi titik.

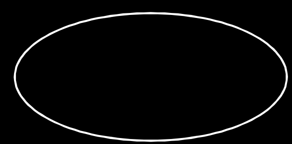
1-D

Sebuah garis punya dimensi satu: Kita dapat bergerak maju mundur. Garis tidak harus lurus. Beberapa lokasi pada garis dapat dinyatakan dengan nomor tunggal – diukur dari titik acuan tertentu



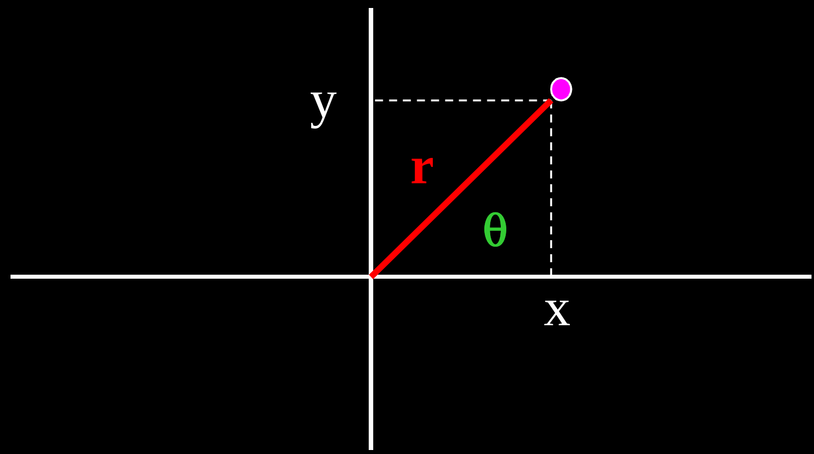
Garis lurus dapat terbatas dengan dua ujung, atau tak terbatas pada ujung salah satu atau keduanya, atau terbatas tanpa ujung.





2-D

Permukaa punya dua dimensi: anda dapat bergerak maju mundur atau naik turun. Permukaan tidak harus datar. Setiap titik di permukaan dapat dinyatakan dengan pasangan nomor (x,y) – diukur dari titik acuan tertentu-, atau juga dengan pasangan jarak dan sudut (r,θ).



2-D (cont.)

A flat plane is either finite (with edges) or infinite (with some edges or with no edges).

A curved plane can either be finite (with edges), infinite (with some or with no edges), or it can be finite with no edges if it bends back on itself – such as the surface of a sphere or football.

It is easy to see that the earth is a 2-D surface with no edges but with a finite amount of area. This is especially easy if we look down from space. On the earth, we use latitude and longitude as the two numbers to specify a location.

3-D

A volume has three dimensions: you can move forward or backward, up or down, and in or out. The volume does NOT have to be "flat" but this is hard to see without going into a "fourth" spatial dimension – like we saw the surface of the earth from above the earth.

Any location in the volume can be specified by a set of three numbers – measurements from some specified origin (starting place). The common three numbers are the x, y and z coordinates. Another possible set is the distance and two angles: compass angle, angle of elevation, and distance.

3-D

A volume can be finite with boundaries, or it can be infinite with some or no boundaries. Can we imagine a finite volume without boundaries? If we go by analogy with the spherical earth, the answer is yes – but we would need a "warped" or curved space to have this happen (like the curved surface of the earth in 2-D). We can't "see" this because we don't know how to get beyond our current 3-D space to "see" it from a fourth dimension.

4-D

Dapatkah kita membayang ruang empat dimensi? Yes, but we haven't been able to enter into that fourth dimension. As far as science knows, we live in a 3-D space.

Tampaknya lucu untuk berspekulasi –alam semesta kita mungkin salah satu dari beberapa ruang empat dimensi, – seperti bumi merupakan satu dari beberapa permukaan dua dimensi dalam alam semesta tiga dimensi.

Untuk pergi dari satu permukaan ke permukaan lainnya, kita harus masuk kedalam dimensi ke tiga.

Untuk pergi dari satu alam semesta ke alam semesta lainnya, kita harus masuk ke dalam dimensi ke empat.

Space: flat or warped?

Pada geometri regular (Euclidean), garis sejajar tidak pernah bertemu. Tetapi di permukaan bumi, garis bujur yang sejajar bertemu di kutub utara.

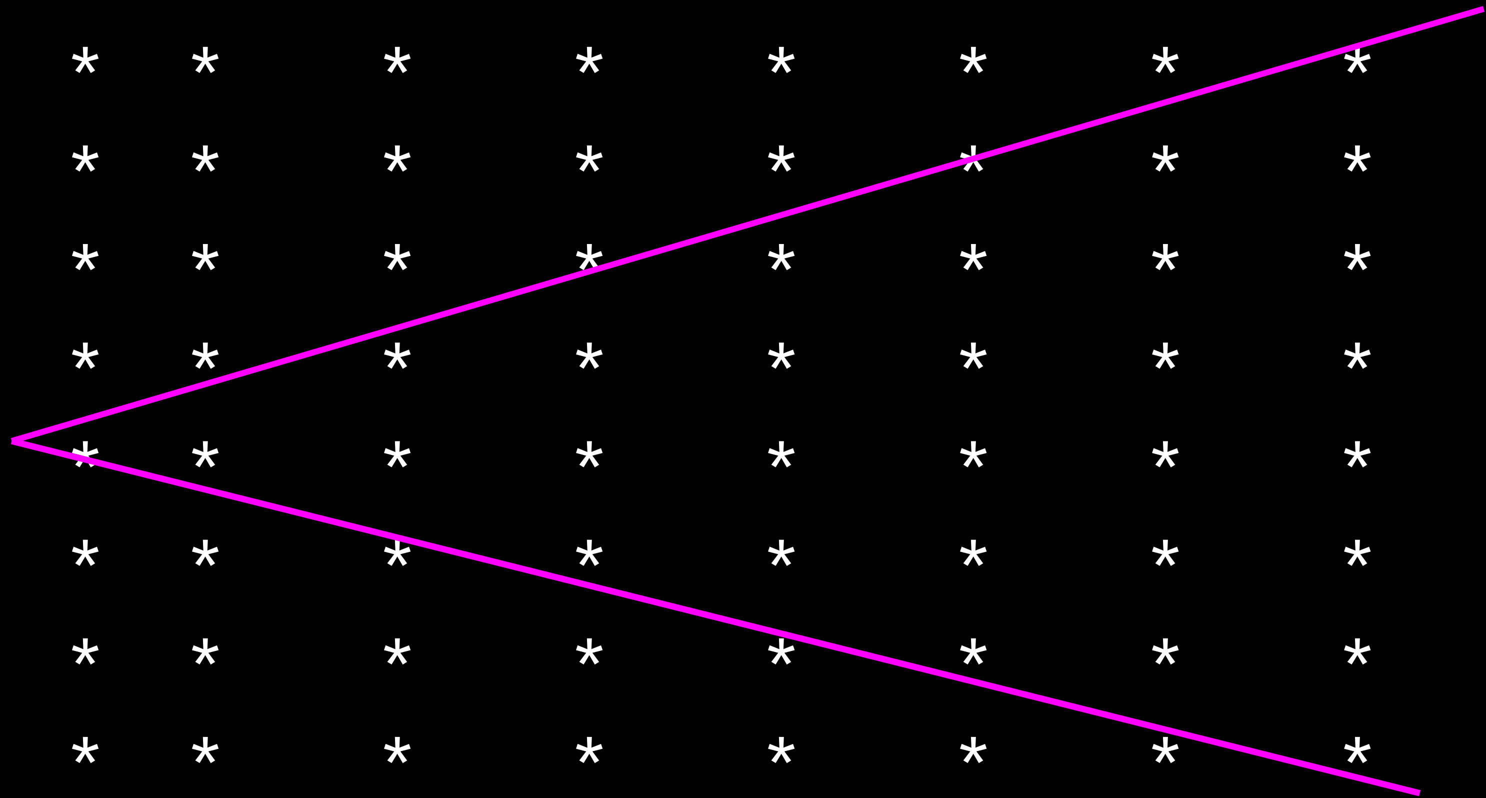
Apakah ruang di alam semesta ini Euclidean (garis sejajar tak pernah bertemu), or is it “warped” (seperti permukaan bumi)? Can we tell?

Space: flat or warped?

Can you tell if the earth's surface is "flat" or "round" without jumping off into space? One way is to keep going East, and you will end up back where you started! Another way is to walk North with a friend a few miles East of you and see if you gradually get closer together as you approach the North pole.

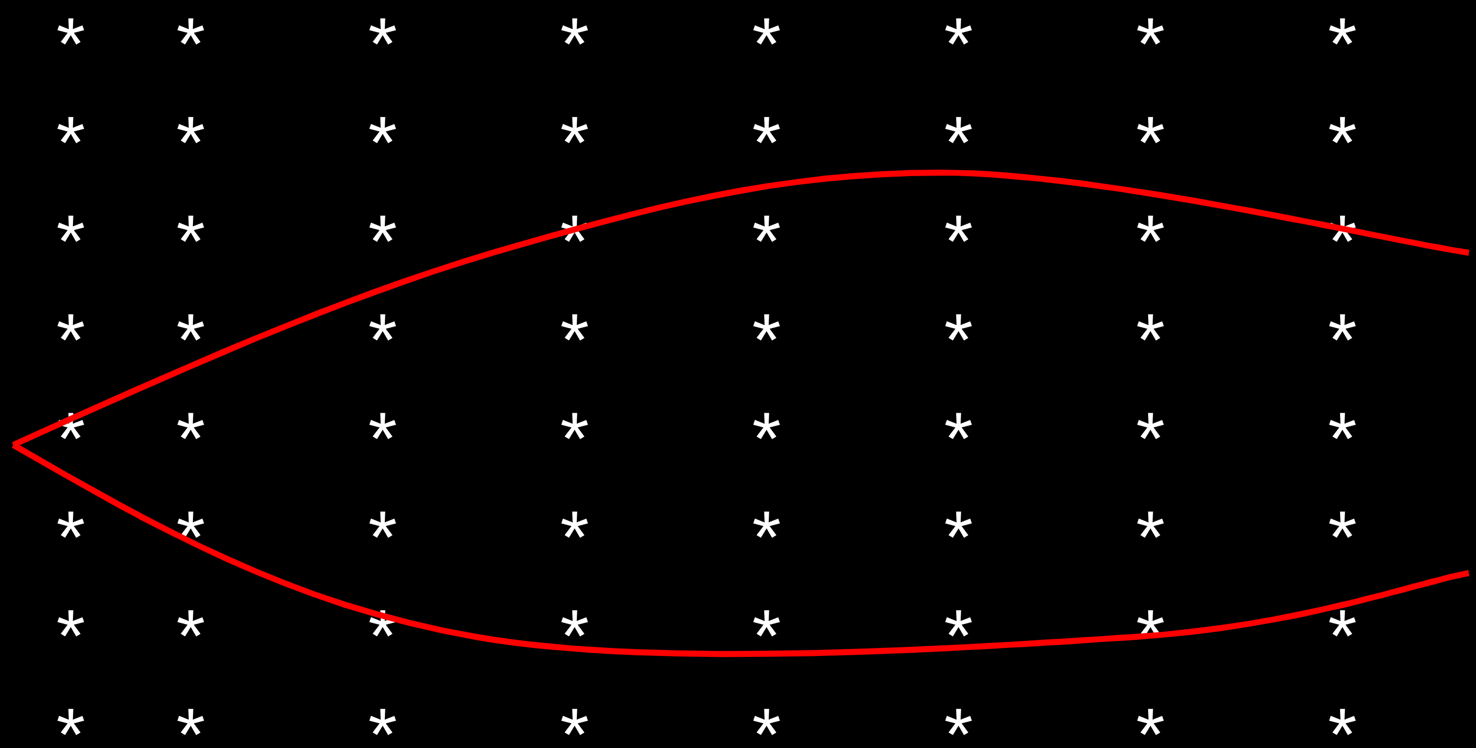
We can try the same sort of thing with 3-D space. If we look out through a small angle formed by "straight" lines, we should see more and more galaxies as we proceed out. (Look at next slide for a diagram.)

Space: “flat” or warped?



There are more and more galaxies (*) the further out you go in a “flat” space.

Space: flat or warped?



In a curved or “warped” space, the number of galaxies (*) at first increases but then decreases if we go out far enough.

Space: flat or warped?

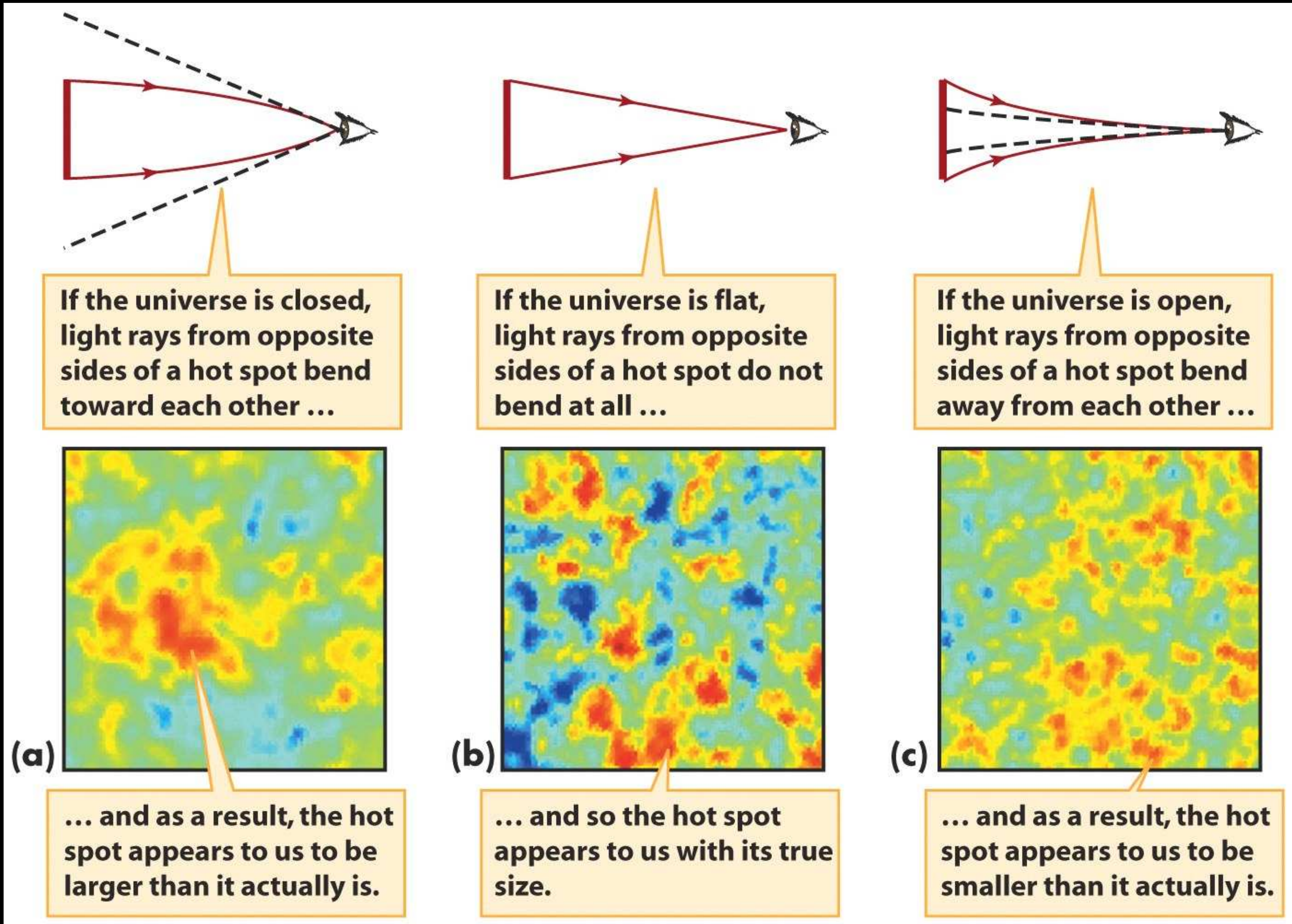
As far as we can tell by doing this type of observation, space is very, very flat. It may not, however, be perfectly flat.

Einstein's theory of general relativity, which has some major successes predicting things we have been able to measure, predicts that mass can warp the space. It predicts that if there is enough mass in the universe, then the space will be warped enough to make it finite (still without any edges – just like the surface of the earth is finite without edges).

Space: flat or warped?

The amount of visible mass (from stars) right now accounts for only about 10% of the mass necessary to have a finite (closed) universe.

However, when we look at the motions of the galaxies, we find that there appears to be more mass in them than the stars can account for. This “dark matter” may be enough to “close” the universe and make it finite. It is still too close to call with confidence.


If the universe is closed, light rays from opposite sides of a hot spot bend toward each other …
If the universe is flat, light rays from opposite sides of a hot spot do not bend at all …
If the universe is open, light rays from opposite sides of a hot spot bend away from each other …
(a)
(b)
(c)
… and as a result, the hot spot appears to us to be larger than it actually is.
… and so the hot spot appears to us with its true size.
… and as a result, the hot spot appears to us to be smaller than it actually is.

Steady State or Big Bang?

We've considered space. Now **what about time?** Did the universe have a beginning, and will it have an end?

The Steady State theory says that there is no beginning and no end. The universe stays the same (on average) for all time.

The Big Bang says there was a beginning and there may or may not be an end.

Steady State or Big Bang?

We start with data:

1. The night sky is dark.
2. The red shift indicates that all galaxies are moving away from one another.
3. Space itself has a temperature – about 3K.

Steady State or Big Bang?

1. Why is most of the sky dark at night? Whether the universe is infinite or not, shouldn't there be a star along any line of sight? If the dust absorbs the light, then wouldn't the dust get hot eventually and radiate light?

- The Steady State theory would have to have some mechanism for removing this light (or heat).
- The Big Bang theory says no - the universe only started a finite time ago and light does not have time to travel from the more distant stars.

Steady State or Big Bang?

2. Why do the galaxies further away show a bigger red shift?

The Steady State theory doesn't explain the motion, but it does say that hydrogen is "created" in the vast areas of space on a continuing basis to keep the density the same as the universe expands.

The Big Bang theory says that the motion of the galaxies is what would be expected after the "big bang" blew things apart.

Steady State or Big Bang?

3. What causes the 3K background radiation coming from space?

The Steady State theory does not have any explanation for this background radiation.

The Big Bang theory says this heat from space is just the left over heat from the big bang – it is so cool now because the universe has expanded so much.

Big Bang

Because of its good explanations to these three pieces of experimental data (dark sky, red shift, 3K background radiation), the Big Bang theory is the generally accepted scientific theory now.

What does the Big Bang theory predict for the beginning of the universe – the moment of the big bang?

The moment of the big bang begins the universe. What happened before then? The theory says we can't know because all information from anything previous has been wiped out by the explosion

When did the big bang happen?

We can get estimates of ages by several ways:

1. The universe has to be at least as old as its parts.
   - The earth, from radioactive dating and sedimentation rates indicates an age of about 4.5 billion years.
   - The age of globular clusters (based on where stars are leaving the main sequence) have an age of about 10-12 billion years.
   - We can see quasars at an apparent distance (red shift based) of about 12 billion light years.
2. The universe is expanding. If we trace the expansion backwards, we should arrive at the time of the beginning. This depends on the Hubble Constant, the constant that relates the red shift (speed) to the distance. This gives a starting time of about 13 billion years.

Big Bang and the ending

The Big Bang theory says the universe is expanding, but that gravity will tend to slow the expansion down.

Is there enough gravity (mass density) to stop the expansion and have it collapse, or is there not enough so that the expansion will continue on forever?

The Big Bang theory along with general relativity indicates that if there is enough mass density to make the universe finite (closed universe), then there is also enough mass to reverse the big bang expansion and have the universe collapse back down again.

If there is not enough mass density to make the universe finite, then there isn't enough to make the universe collapse and it will expand forever.

Big Bang and the ending

As we indicated earlier, the question about the mass density is very close to the line separating a **closed** (finite in space and finite in time) universe from an **open** (infinite in space and infinite in time) universe. We do not have enough evidence yet to clearly decide.

Extraterrestrial Life

Untuk melihat kemungkinan kehidupan di luar bumi, kita harus melihat kondisi untuk hidup seperti yang kita ketahui.

Hidup seperti yg kita ketahui merupakan alam biokimia.

Bisa jadi ada kemungkinan lain untuk hidup: salah satunya berdasarkan pada gravitasi gelombang radio sebagai bagian komunikasi (like we have nerve paths), atau mungkin berdasarkan gaya nuklir.

Extraterrestrial LIFE

Gravitasi: gravitasi begitu lemah, bentuk kehidupan akan sangat besar (a nebula?), dan gerakan komponennya relatif sangat lambat terhadap ukurannya, ruang waktu untuk kehidupan juga secara ekstrim lambat.

Nuclear force: nuclear forces are extremely strong but are short ranged. A life form based on this would have to be tiny and the time scale would be extremely fast.

Extraterrestrial LIFE

Biochemistry based life:

1. Life as we know it is based on carbon because carbon bonding allows long and complex molecules to form.
2. Life as we know it uses water as the primary liquid to transport food and waste and to regulate temperature.

Are there other possibilities?

Carbon and life

1. Carbon bonding is the result of its ability to bond with itself so strongly. Other elements in the same position in the periodic table of the elements might also be able to do this. Carbon is the lightest element in this position. Silicon is the next heaviest. Overall, though, carbon is better than silicon in its binding properties.

   Organic Chemistry is really the chemistry of the carbon bond. That is why Organic Chemistry is so important in the health fields.

Water and life

2. Water is important to transport food and waste to the cells and to regulate heat. Could other liquids do the job as well or better?

Material	Melting (^0C)	Boiling (^0C)	latent heat (J/gr)	heat capacity (J/gr-^oC)	Density (gr/cc)
Water	0	100	2,260	4.2	1.00
Ammonia	-78	-33	1,371	2.2	0.68
Ethyl alcohol	-114	78	854	2.4	0.81
Methane	-182	-161	510	2.2	0.43

Water and life

2a. Water has the best liquid temperature range for the earth.

2b. Water has the highest latent heat (used for evaporative cooling) and the highest heat capacity (used for keeping the temperature constant), so it is best for temperature regulation.

2c. Water is the best liquid for dissolving chemicals (like sugar and salt). We only use other “additives” to help us clean some things.

Abundance of Elements

(Numbers indicate percent)

Sun:	H93.4 He6.5 O.06 C.03 N.011 Ne.010 Mg.003 Si.003 Fe.002
Earth:	O 50 Fe 17 Si 14 Mg 14 S 6 Ni 1.1 Al 1.1 Ca 0.74
Crust:	O 47 Si 28 Al 8.1 Fe 5.0 Ca 3.6 Na 2.8 K 2.6 Mg 2.1
Atmosphere:	N 78 O 21 Ar .93 C .011 Ne .0018 He .00052
Bacteria:	H 63 O 29 C 6.4 N 1.4 P .12 S .06
Humans:	H 61 O 26 C 10.5 N 2.4 Ca .23 P .13 S .13

Abundance of Elements

- The amount of helium and the other elements and the age of the earth, indicate that the sun is about 4.5 billion years old.
- The age of the globular (closed) clusters based on their H-R diagrams is about 10-12 billion years old.
- The sun is not a first generation star but rather formed after other stars added heavier elements to the nebula from which it formed.
- When the first stars formed, there probably were not a lot of heavy elements (anything above helium) in existence yet, so there might not have been many rocky planets able to form.

Abundance of Elements

- Hydrogen dan Helium: melimpah di matahari, sedikit di bumi. Dalam bentuk gas sangat ringan, gravitasi bumi tak bisa menahannya. Tidak demikian halnya untuk Jupiter dan planet gas lainnya.
- Besi dan Nikel: elemen berat, tenggelam di dalam bumi.
- Bakteri dan manusia: Konsentrasi Hydrogen and Oxygen sangat besar(sekitar 2 banding 1 seperti pada air H_2O). Carbon dan Calsium koncentrasinya cukup besar.
- Fakta: konsentrasi elemen yang jarang pada bacteria dan manusia (in all earth life forms) sesuai dengan konsentrasi di lautan.

Conditions for Life

1. Biochemical life is the most likely, and would correspond best with our time scale.
2. Carbon is probably the most likely element for making complex molecules used in biochemical life.
3. Water is best, but it requires a temperature very near that of earth. Other liquids may work, but probably not as well.

Life in the Solar System?

- So far we have not found any signs of life developing anywhere other than on the earth.
- Venus is too hot, as is Mercury. Mars and the various moons are too cold and do not have liquid water.
- We have found life on earth in all kinds of (what would seem to be) hostile environments, so there may still be some possibilities out there.

Extraterrestrial Life

For life to develop somewhere other than on earth, the best possibilities would involve:

1. Rocky planets (right size) – probably only in spiral arms of spiral galaxies or in irregular galaxies.
2. Right temperature range for liquid water
   a. right star – not too hot (not a blue giant since there would be too much UV) and not part of a tight binary (this would cause an unstable orbit)
   b. right distance from star
   c. right orbit – not too extreme (not too elliptical)
3. There is some thought now that the moon has played an important part in keeping the earth's spin and tilt more constant than would normally be the case. This would be important to keep the earth's climate more in balance to give life more of a chance to develop.

Extraterrestrial Intelligence

Bila ada kehidupan *di luar sana*, apakah kehidupan yang berintelegensi? Apakah ada *tambahan kondisi* untuk membangun kehidupan berintelegensi?

1. Apakah hidup secara alami berkembang menjadi kehidupan berintegelensi? Kita benar-benar tidak tahu.
2. Bila kehidupan membangun intelegensi, perlu waktu lebih lama dari pada sekedar untuk kehidupan. Planet atau bintang mestinya stabil untuk selang waktu yang lebih lama.
3. Apakah kehidupan berintegelensi pernah ada cukup lama untuk membangun perjalanan atau komunikasi antar bintang?

Extraterrestrial Intelligence

3. Apakah kehidupan berintegelensi pernah ada dan berkembang sampai saat tertentu, kemudian punah karena bencana perang atau polusi?
5. Jarak antar bintang sangat ekstrim, belum ada teknologi komunikasi yang mendekatkan bintang-bintang.

Extraterrestrial Intelligence

Untuk memperoleh idea kemungkinan ETI, kita perlu memperhatikan kemungkinan setiap kondisi. After that, we can get some idea of the expected distance to the nearest intelligent life.

The problem is, we really don't know what each of the probabilities is for each of the conditions.

Review of Astronomical Distances

Jarak	km	AU	LY
Dia. Bumi			
Bumi-Bulan			
Bum- Mth			
Mth-Pluto			
Mth-Btg terdekat			
Dia. Bimasakti			
Ke Andromeda			
Gugus galaksi			

Review of Astronomical Distances

Distance	miles	A.U.	light years
Circumference of earth	25,000		
Earth-moon	250,000		
Earth-sun	93,000,000	1	
Sun-Pluto		40	
Sun-nearest star		250,000	4
Diameter of Milky Way			100,000
To Andromeda			2,000,000
To center of our supercluster		60,000,000	
Furthest quasar			12,000,000,000

Relativity

We've already talked about the possibilities of "curved" space and even a fourth spatial dimension. There is one more aspect that is really strange: Einstein's famous theory of relativity. This theory starts out from a very simple point of view: All the laws of physics should appear the same, regardless of motion, if you are in an inertial (non-accelerating) frame.

Relativity

You can tell if you are accelerating by looking for “strange” forces. For instance, you can tell when you are slowing down, speeding up, or turning in a car because you feel the seat or the door “pushing” on you. However, when you are traveling at a constant speed in a straight line, you really don’t notice it.

Relativity

The really strange thing about relativity is that **it says that ALL the laws of physics, including the speed of light, apply equally in all frames of reference**, even those that are moving (in a straight line with a constant speed). To be more explicit: if you are “stationary”, you measure the speed of light to be 670 million miles per hour. If someone else is going 600 million miles per hour past you, that person also measures the same light as going 670 million miles per hour regardless of whether that person is approaching the light or receding from it.

Relativity

The normal experience is that if the person runs toward an object moving toward them, the object seems to be going faster, and if the person runs away from an object moving toward them, then the object appears to be going slower. Light doesn't work that way. Experiments have shown that everyone, regardless of motion, measures the same speed for light!

Relativity

We don’t notice this fact because we don’t ever go anywhere near the speed of light (at least relative to the speed of the earth).

But when we work out the consequences theoretically for this (in the theory of relativity), we find three really surprising results that have implications for travel in the universe.

Strange Consequences

Strange Consequences of relativity:

1. **Time dilation**: time seems to go slower for moving objects than for stationary ones.
2. **Length contraction**: lengths seem to get shorter the faster we go.
3. **Mass increase**: masses seem to get more massive the faster than go.

Relativity

All of these effects only are significant if we go at a speed close to that of light, that is, we go at speeds close to 670 million miles per hour! Since we don’t usually do this, we don’t notice these effects.

However, these effects have been confirmed for tiny objects that we can accelerate up to very, very high speeds. They have also been confirmed for objects going at human scale speeds (flying in an airplane), but it requires extremely precise clocks.

Relativity and Space Travel

Implications for space travel:

1. You can’t ever reach the speed of light (unless you are light). As an object’s speed approaches the speed of light, its mass increases making it even harder to make it go faster.

Relativity and Space Travel

2. However, as the object's speed approaches the speed of light, it's time seems to slow down. Objects seem to live longer (to us) when they are moving at such high speeds.
3. Also, as the object's speed approaches the speed of light, distances appear to shrink as viewed by the moving object.

Relativity and Space Travel

These last two items lead to a strange apparent paradox: Suppose we have twins. One leaves on a spaceship and travels close to the speed of light to the nearest star (about 4 light years away) and returns. To the twin on the earth, the time of travel is about 8 years. However, to the twin on the spaceship, the time of travel would be a lot less, and the spaceship twin would in fact come back younger than her earth-bound twin.

Relativity and Space Travel

In theory, then, we could actually live long enough to visit anywhere in the galaxy, even to the far reaches thousands of light years away, without going faster than light and without living more than a few tens of years – if we were able to travel very, very close to the speed of light.

Relativity and Space Travel

However, if we were able to do this, when we came back from our travels, the earth would be thousands of years older!

Warp Engines and Hyperspace

Another "possibility" is that space is not flat (warped), and that we could eventually control the warping and somehow find a shortcut to make the distances manageable. Our we could enter the "fourth dimension" or hyperspace and also make the distances manageable. These are among the ideas in some of the science fiction moves and books. But this is still "science fiction" based loosely on science possibility, not firmly accepted theory.