

The Universe, it's smaller than you think

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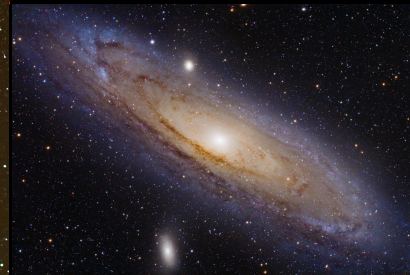




closest star - 4 light years
 Milky Way center - 25,000 light years
 Milky Way size - 100,000 light years



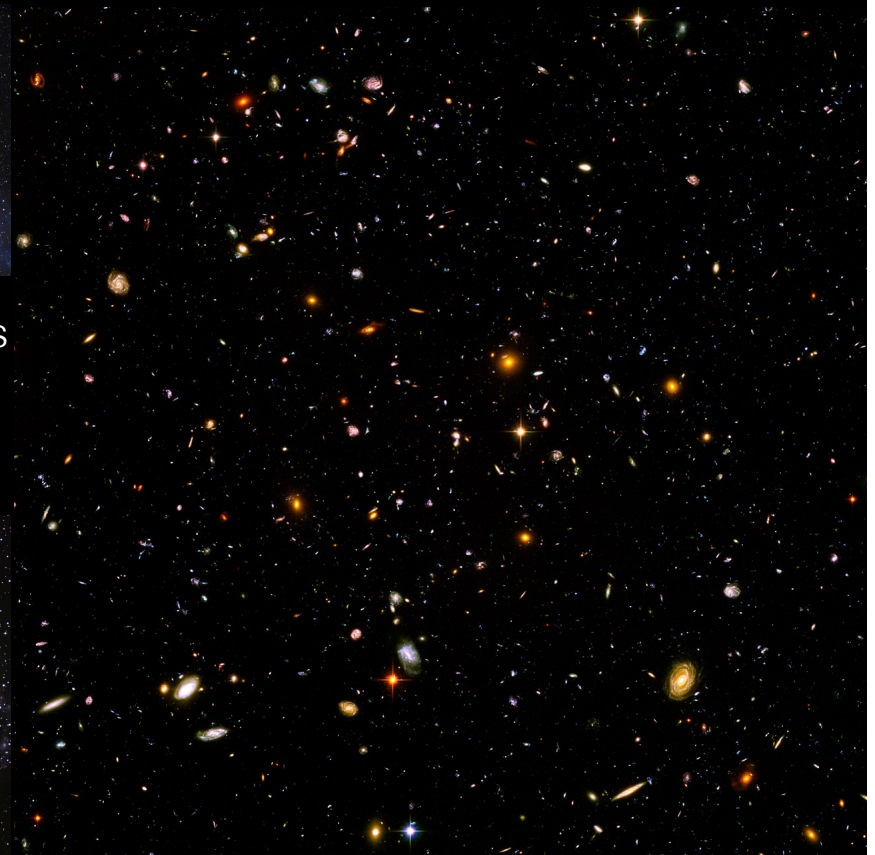
Large and Small Magellanic Clouds
 150,000 light years



2.5 million light years
 Andromeda Galaxy
 Lorenzo Comolli



30 million light years
 NGC 6744, ESO



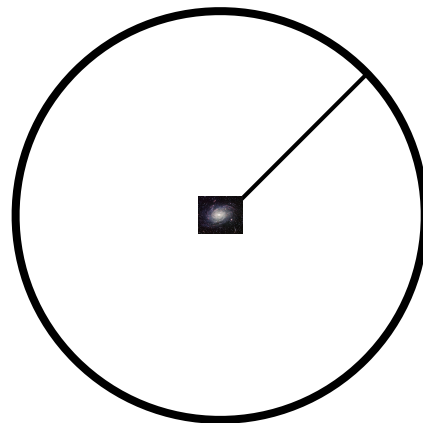
Billions of light years
 NASA/ESA

Two questions

- How big is the universe today?
- How big will the universe ever be?

How big is the universe today?

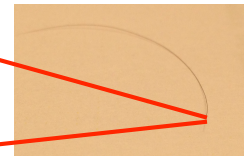
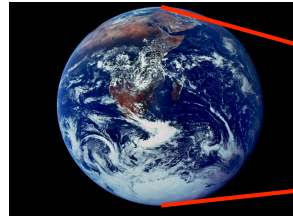
- The universe is 13.8 billion years old
- Light has only had this much time to travel to us
- We can only see a part of the universe today



46.6 billion light years
in radius

How big is the universe today?

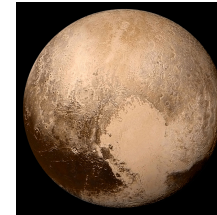
- If we made the Earth as wide as a human hair...



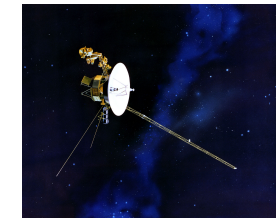
- The moon would be 30 hairs away
- The Sun would be 40 centimeters away
- Pluto would be 10 meters away
- Voyager 1 would be 27 meters away
- 1 light year would be 12.6 kilometres away
- The nearest star would be 55 kilometers away
- The center of the Milky Way would be at the moon



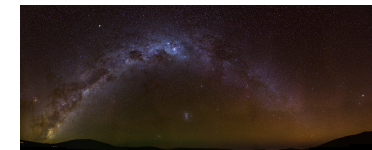
P-M Heden



NASA/JHU



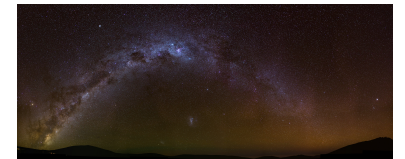
NASA/JPL



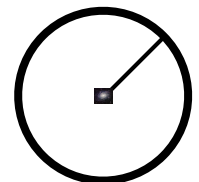
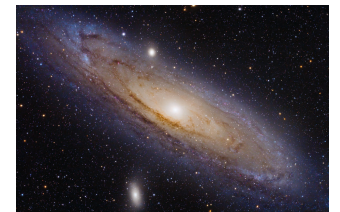
So the Milky Way is pretty big compared to Earth

How big is the universe today?

- If we made the Milky Way as big as you...



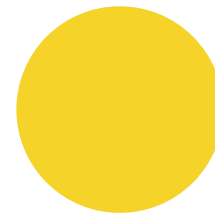
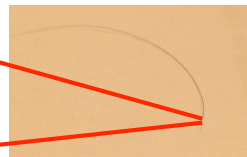
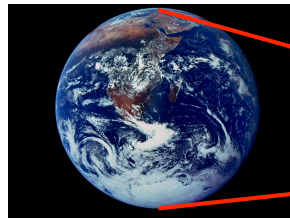
- The Large and Small Magellanic clouds would be 1.6 meters away
- The Andromeda galaxy would be 25 meters away
- The observable size of the universe would go out to Edinburgh, 480 kilometers away



The universe is not that big compared to the Milky Way

How big is the universe today?

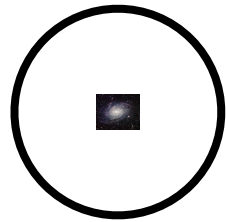
- How much gold is there in the universe we see?
- Gold is made in stars and we can estimate how many stars are in the universe we see
- All the gold would fit into a ball slightly larger than Pluto's orbit



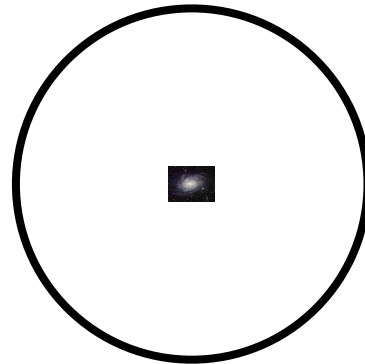
26 meter ball
of gold

How big will the universe ever be?

- As more time passes, there is more time for more light to travel



Now



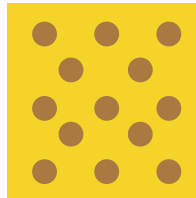
Future

- However, the universe is also expanding

Time=0.48 Billion Years

How big will the universe ever be?

- Like baking a cake with raisins inside:
 - As the cake cooks, the batter expands but the raisins stay the same size



Past

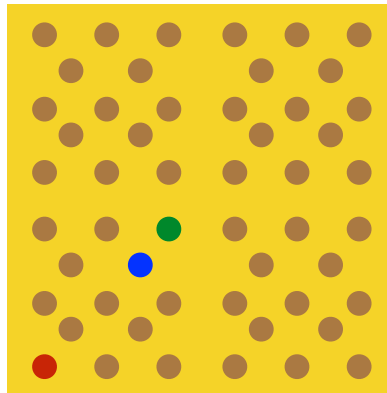


Present

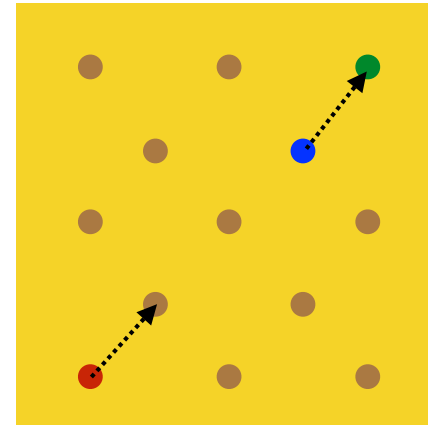
- All of the raisins move away from each other
- There is no center
- The farther apart the raisins, the faster they move apart

How big will the universe ever be?

- The speed of light is only so fast



Past

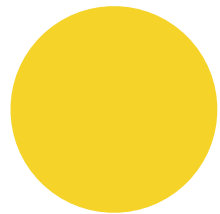
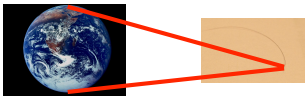


Present

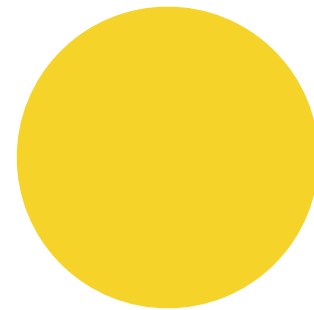
- We will only be able to see galaxies that are not too far away
- So, we will only see a patch of our universe

How big will the universe ever be?

- As time goes on, we will see a bigger volume of our universe
- But we will only be able to see a finite number of galaxies (or stars/planets/raisins) within this volume



Now:
26 meter ball
of gold

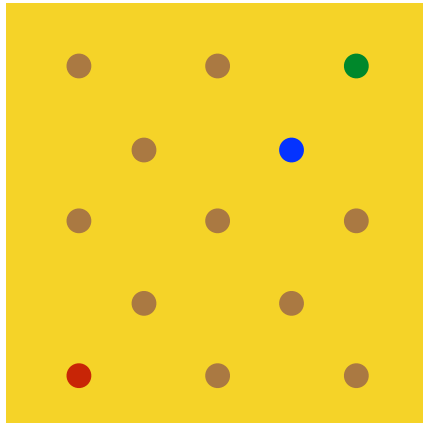


If we wait forever:
38 meter ball
of gold

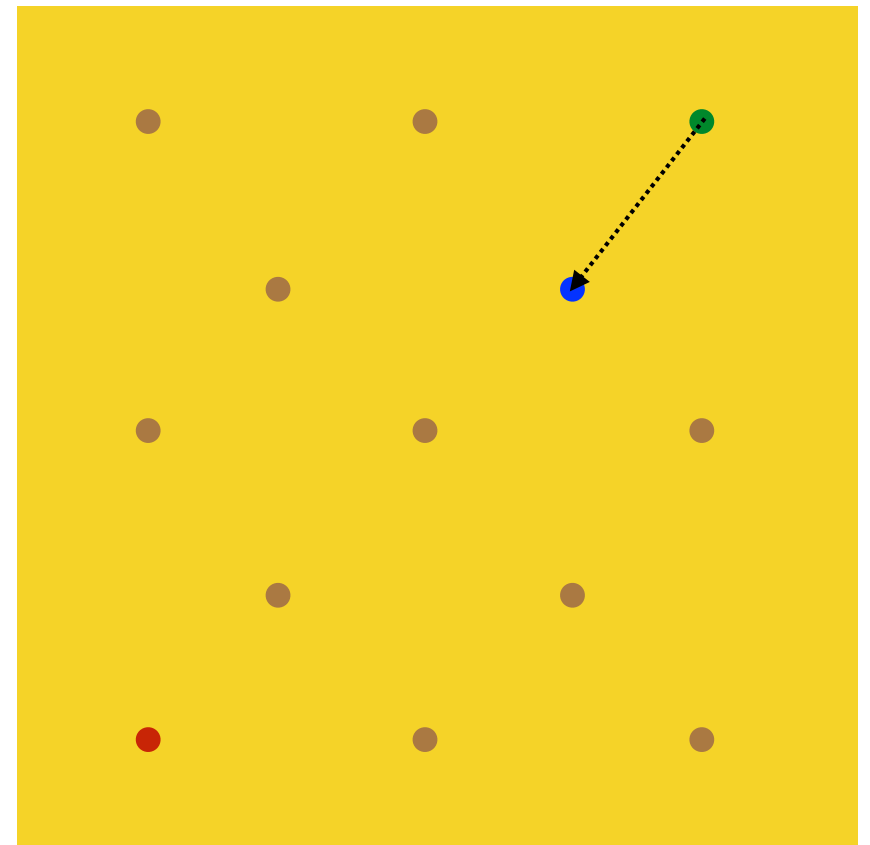
How big will the universe ever be?

- How many of these galaxies could we ever reach?

Present

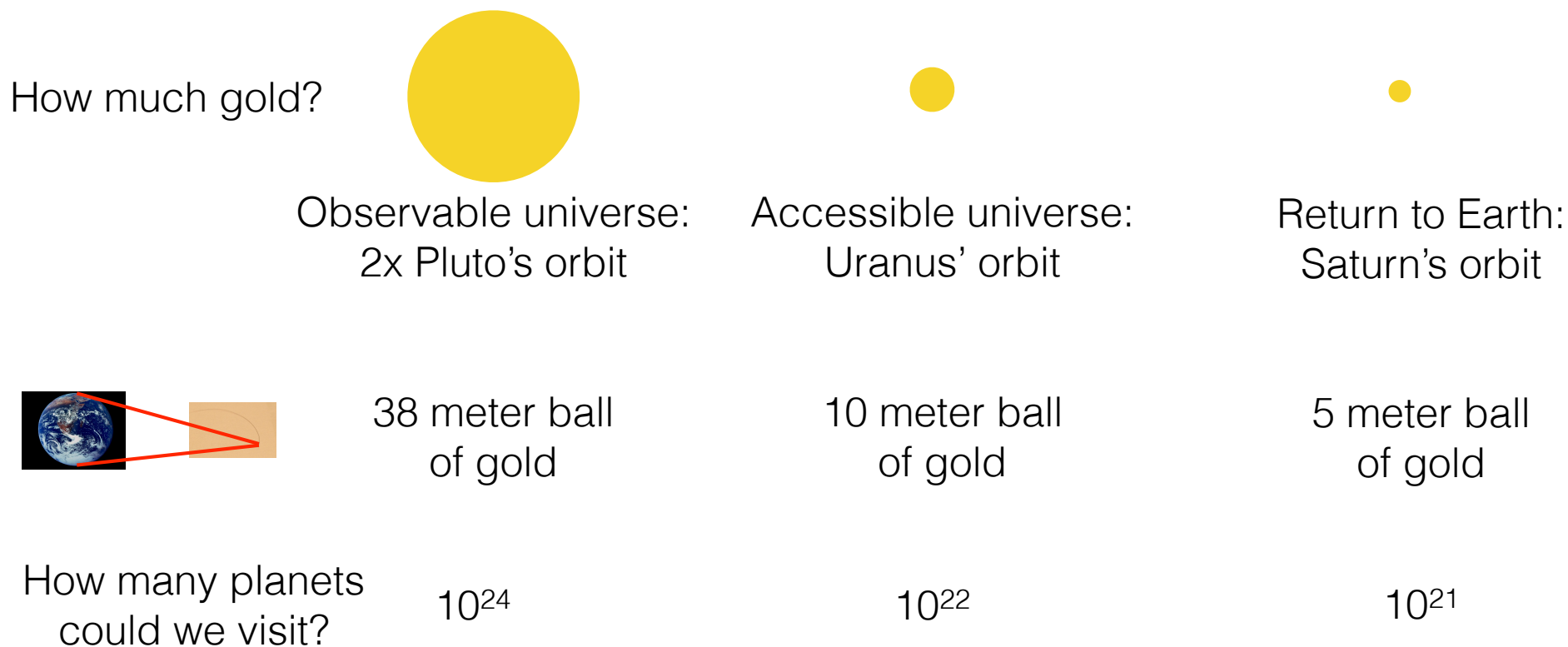


Future



How big will the universe ever be?

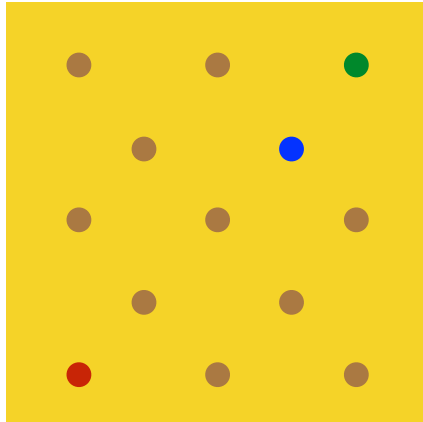
- So we can only ever get to a finite number of galaxies, stars, planets, gold, raisins, etc.



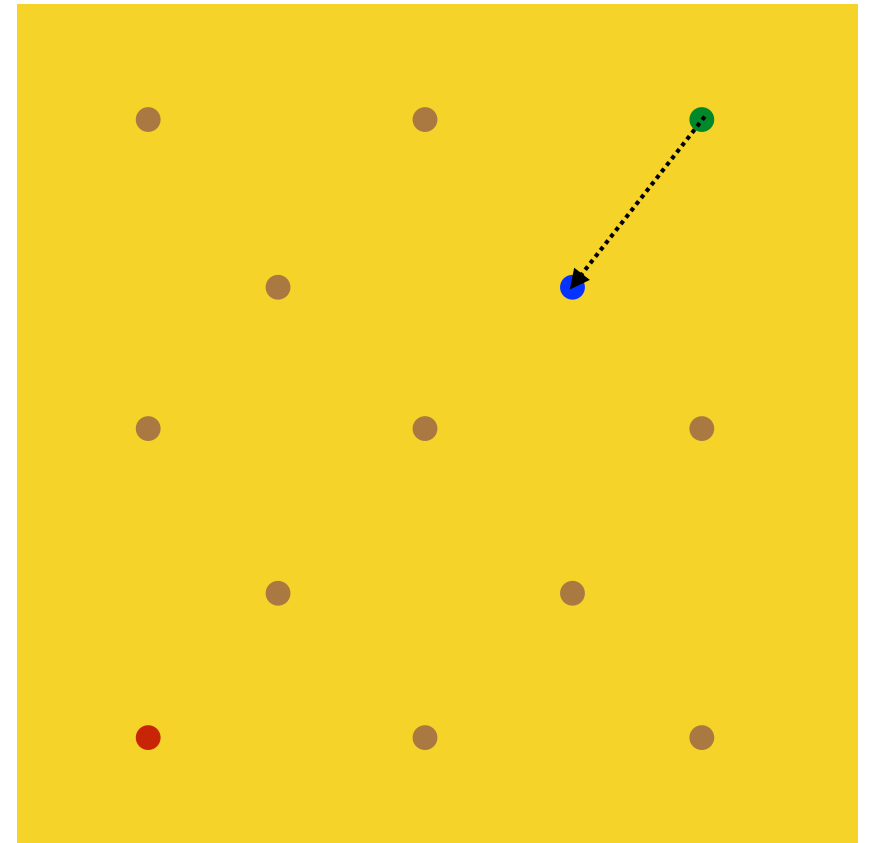
How big will the universe ever be?

- The number of galaxies we can access gets smaller the longer we wait

Present

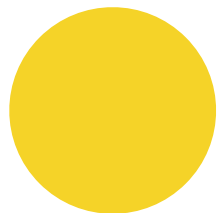


Future



How big will the universe ever be?

- How much gold could we bring back to Earth?



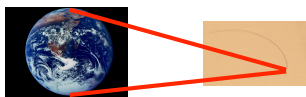
Leave now:
Saturn's orbit



Leave in 10 billion years:
Jupiter's orbit



Leave in 100 billion years:
10x the size of the Sun



5 meter ball
of gold

2.8 meter ball
of gold

1.5 centimeter ball
of gold

How many planets
could we visit?

10^{21}

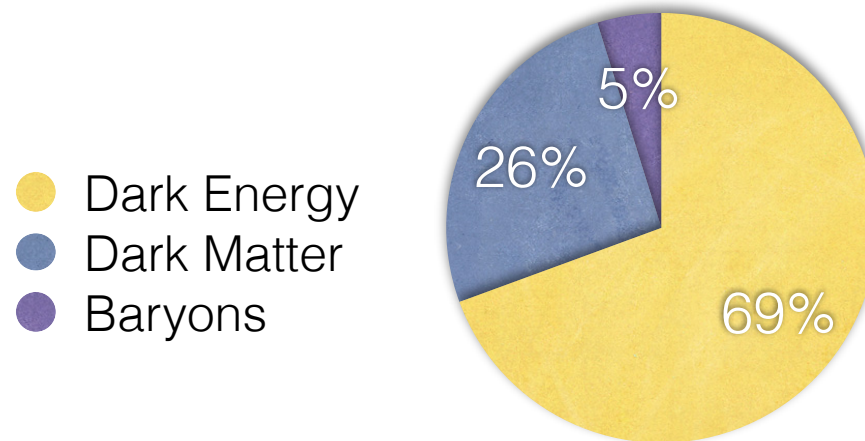
10^{20}

10^{13}

How big will the universe ever be?

- This surprising conclusion is due to dark energy

Current energy budget of our universe



- If there was only matter, the expansion rate would decrease, and we could access everything

Two questions

- How big is the universe today?
 - If you were the size of the Milky Way, the observable universe would be out to Edinburgh
- How big will the universe ever be?
 - The universe will become arbitrarily large, but we will only be able to see and access a finite number of galaxies, planets, raisins