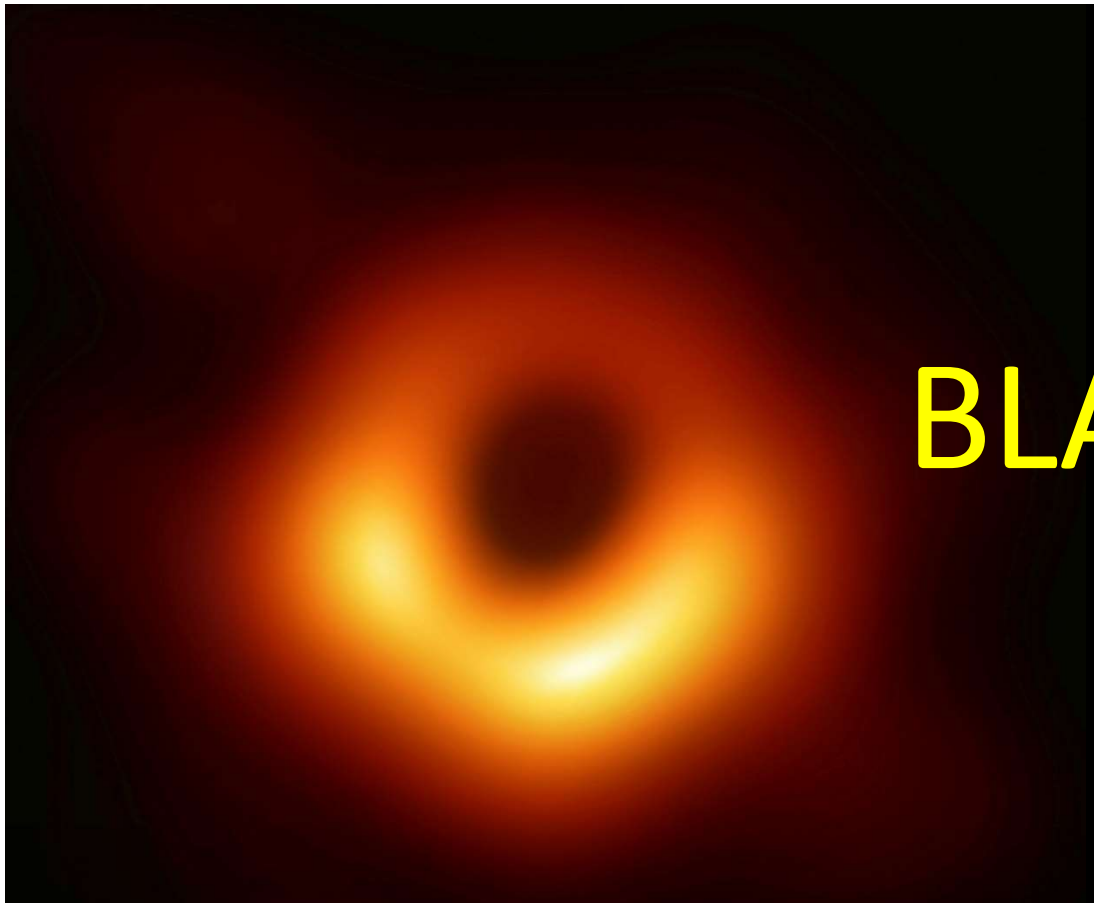


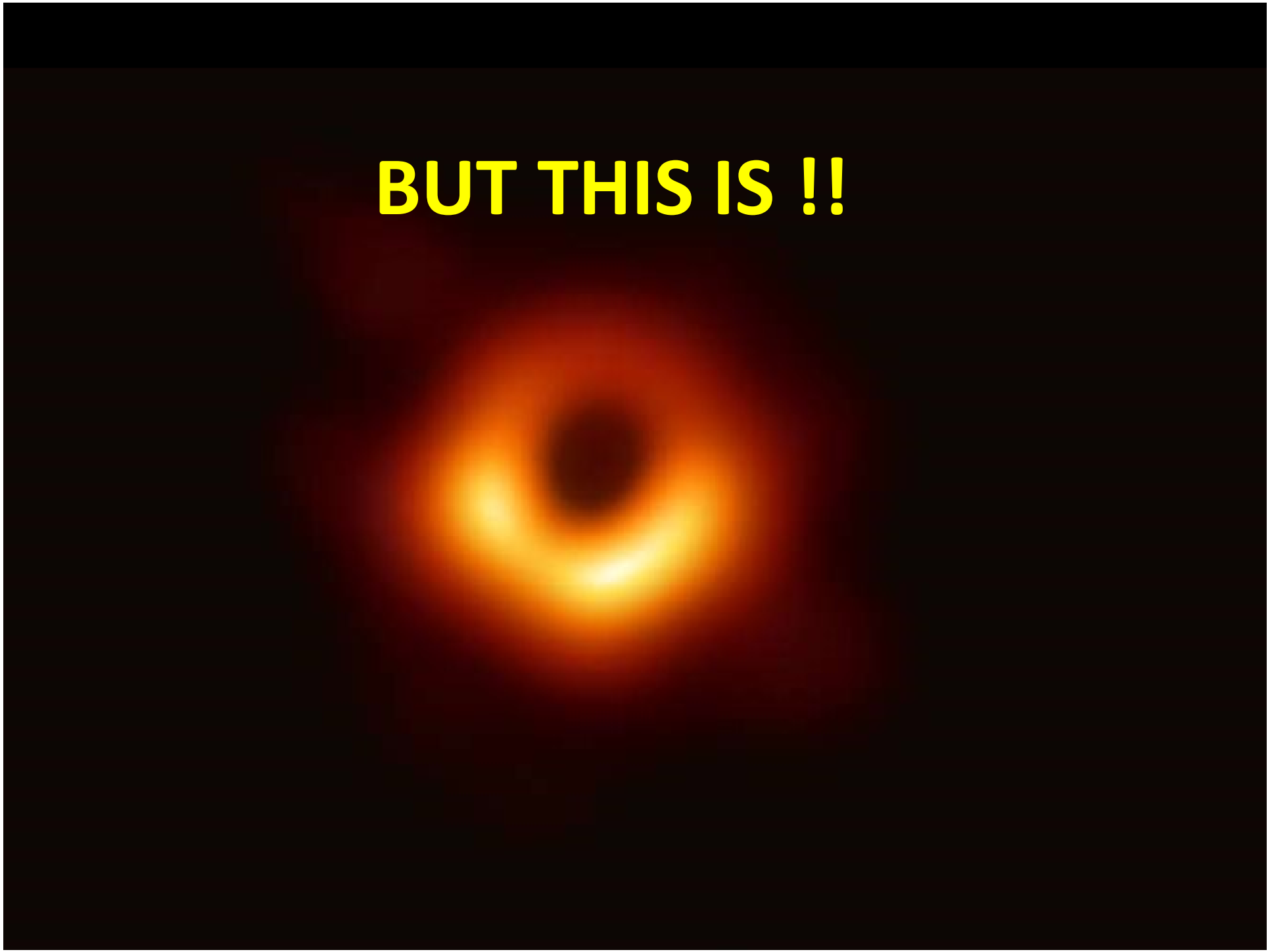
BLACK HOLES:

A ONE-WAY TRIP INTO THE COSMIC ABYSSS

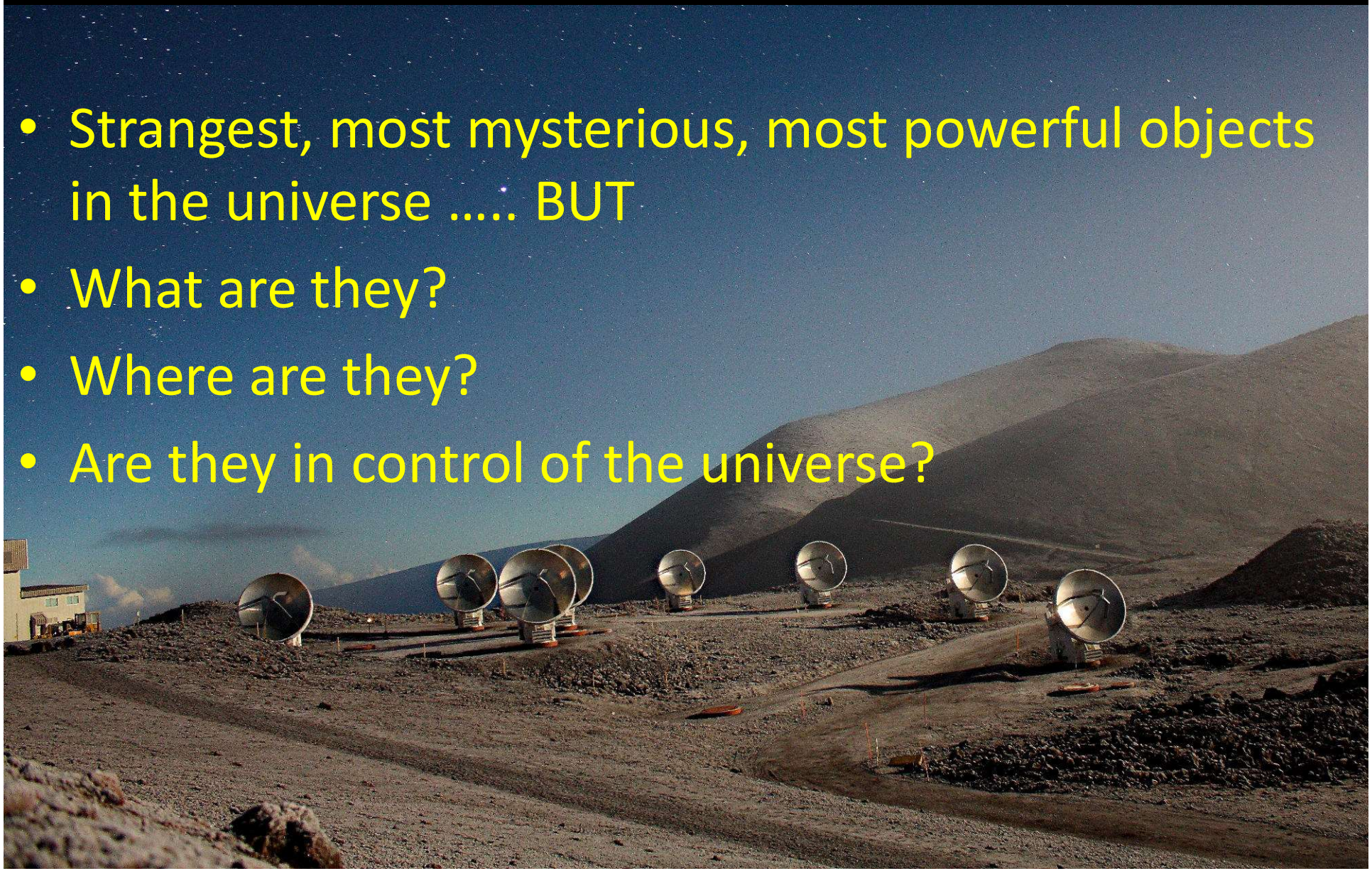
LtCol Ken Verderame, USAF (Ret)


THIS IS NOT A BLACK HOLE …

BUT THIS IS !!



BLACK HOLES



- Strangest, most mysterious, most powerful objects in the universe ….. BUT
- What are they?
- Where are they?
- Are they in control of the universe?

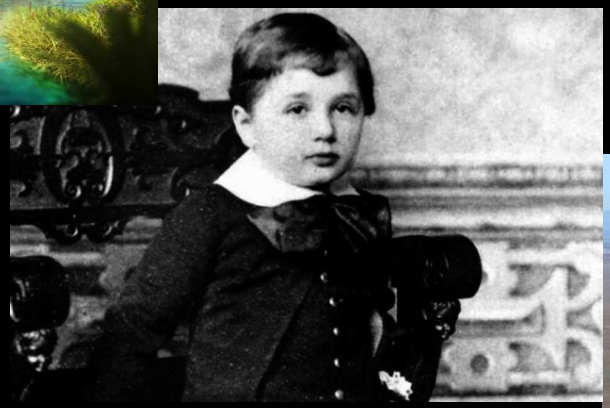
1 Billion Years ago …

On Sept 14, 2015 astronomers record a ‘chirp’

This ‘chirp’ is actually a gravity wave that has been traveling in space for 1 billion years & was the result of 2 Black Holes colliding

Wave reaches our Milky Way galaxy ~ the time of the dinosaurs

Wave reaches our nearest stars when Einstein is in 6th grade



Wave reaches LIGO (Laser Interferometer Gravity Observatory) Sept 14, 2015

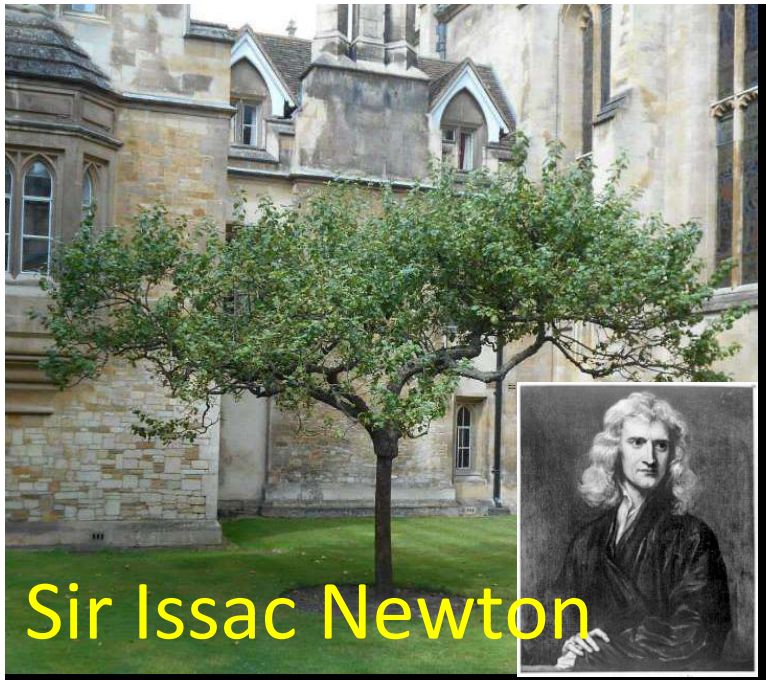
First direct evidence that Black Holes actually do exist!

So what are Black Holes?

- They are not an object
- They are holes in the very fabric of space
  - A place where there is nothing but gravity

Ok, so what exactly is gravity?

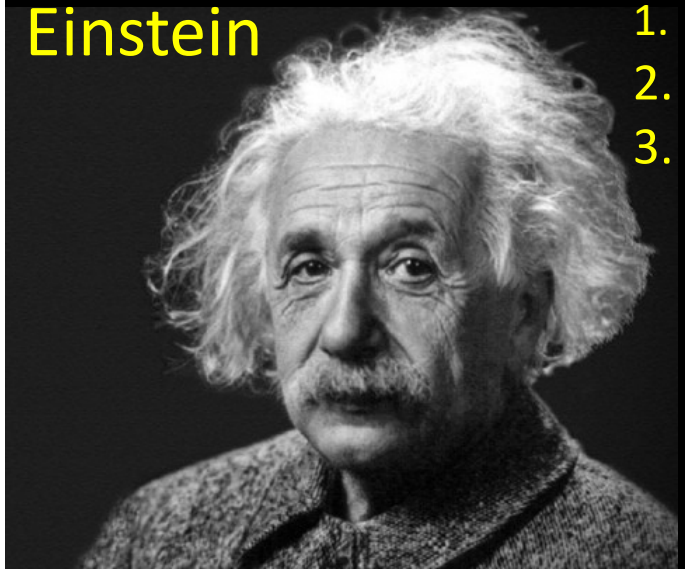
Time for a short history lesson …….



- 300 years ago Newton was fascinated by the motion of objects
- This became his 3 laws of motion

but …

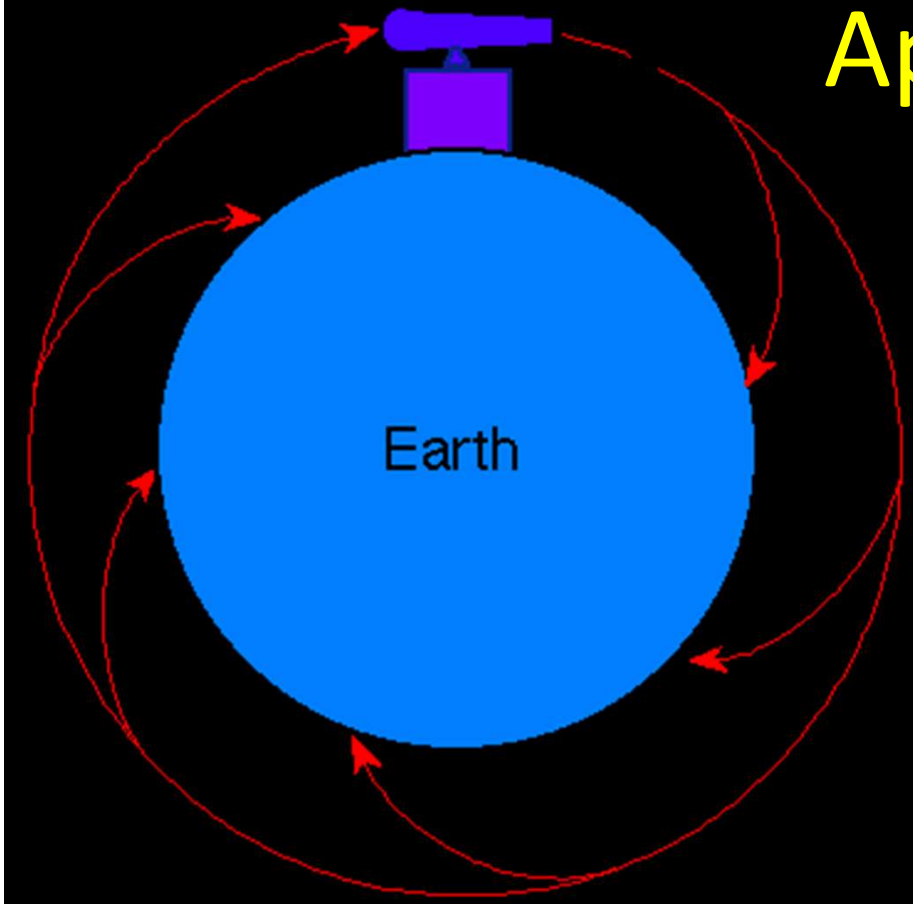
these laws only describe gravity's effect, not what it is



1. Objects don't move unless you touch them
2. What if you drop it? It falls towards the earth
3. What if you remove the earth? Object just keeps falling

SO … gravity has something to do with falling

Apples & AstroPhysics



Throw an apple & it moves in a curved path
-- the faster it moves the bigger the curve

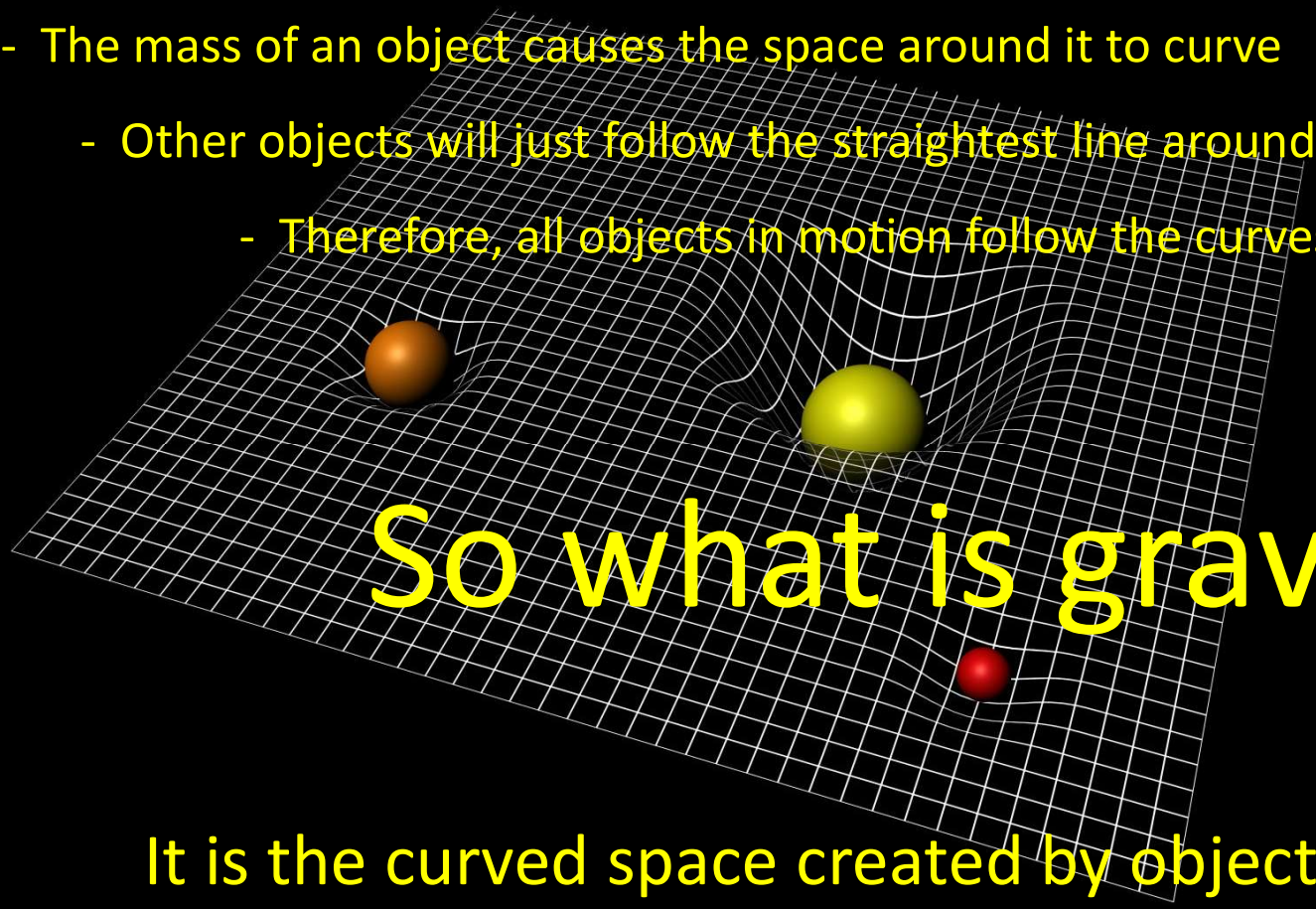
- Get it moving 17,000 mph & it's path matches the curvature of the earth – it's literally falling around the earth – astronomers call this an "orbit"

So our apple is just continually falling along a curved path around the earth – just like the astronauts in the ISS

Ok, but what makes the paths curved?

The Mass of the Earth

- The mass of an object causes the space around it to curve
  - Other objects will just follow the straightest line around these objects
    - Therefore, all objects in motion follow the curves in space

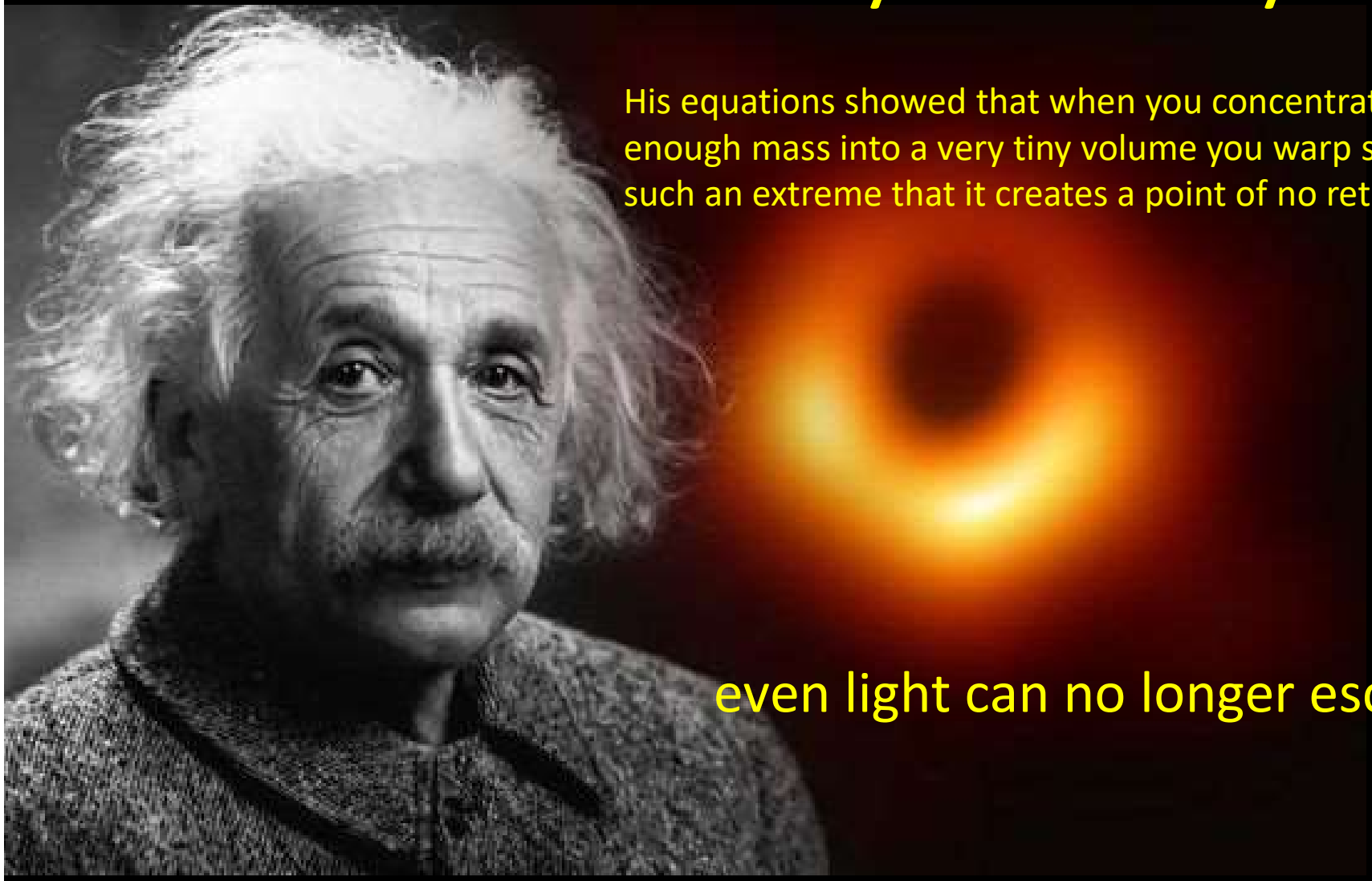


So what is gravity?

It is the curved space created by objects in space
Einstein's 'Theory of Gravity'

And this as we'll see will lead us directly to Black Holes!

Einstein's Theory of Gravity



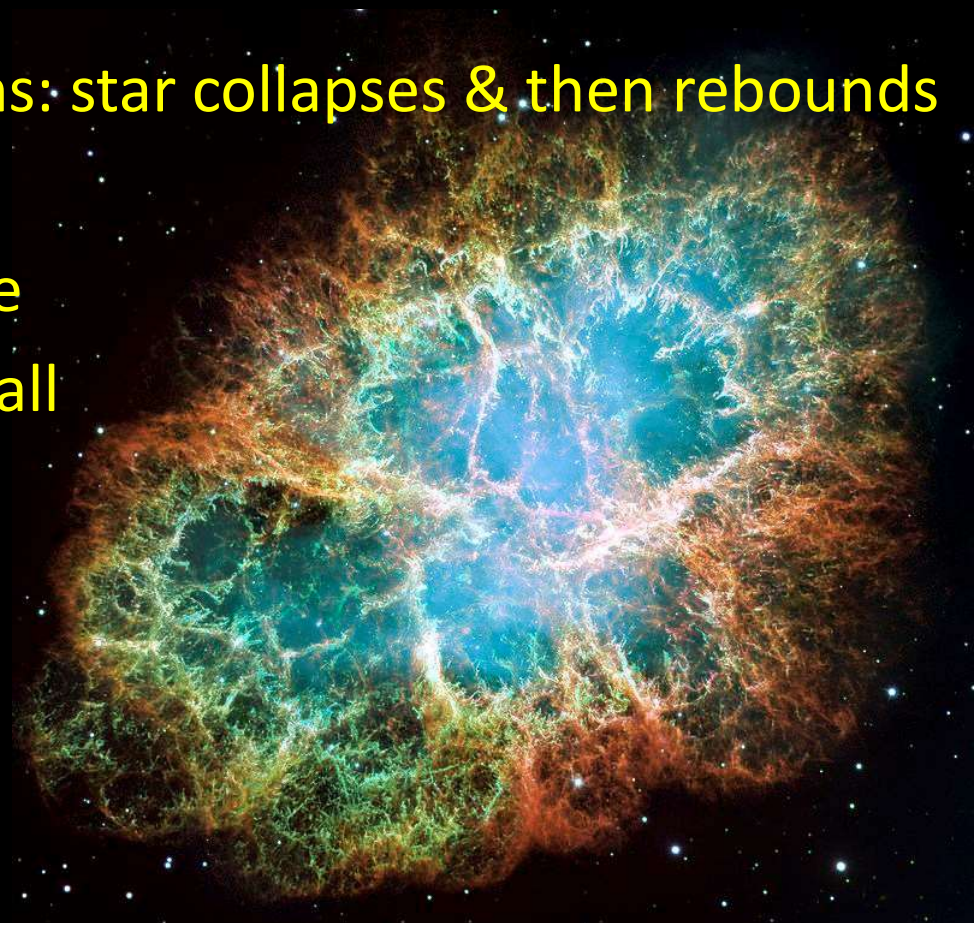
His equations showed that when you concentrate a large enough mass into a very tiny volume you warp space to such an extreme that it creates a point of no return

even light can no longer escape!

This region of space is what we call a 'Black Hole'

Super Novas & Black Holes

- Massive stars end their lives differently than small ones
- Enormous gravity generated by star balances forces created by fusion, keeping star stable.
- Once all H used up, gravity wins: star collapses & then rebounds into a Super Nova explosion
- No known force in the universe can counteract the collapse of all that mass into an infinitely small point - a Black Hole



Neutron Stars & Black Holes

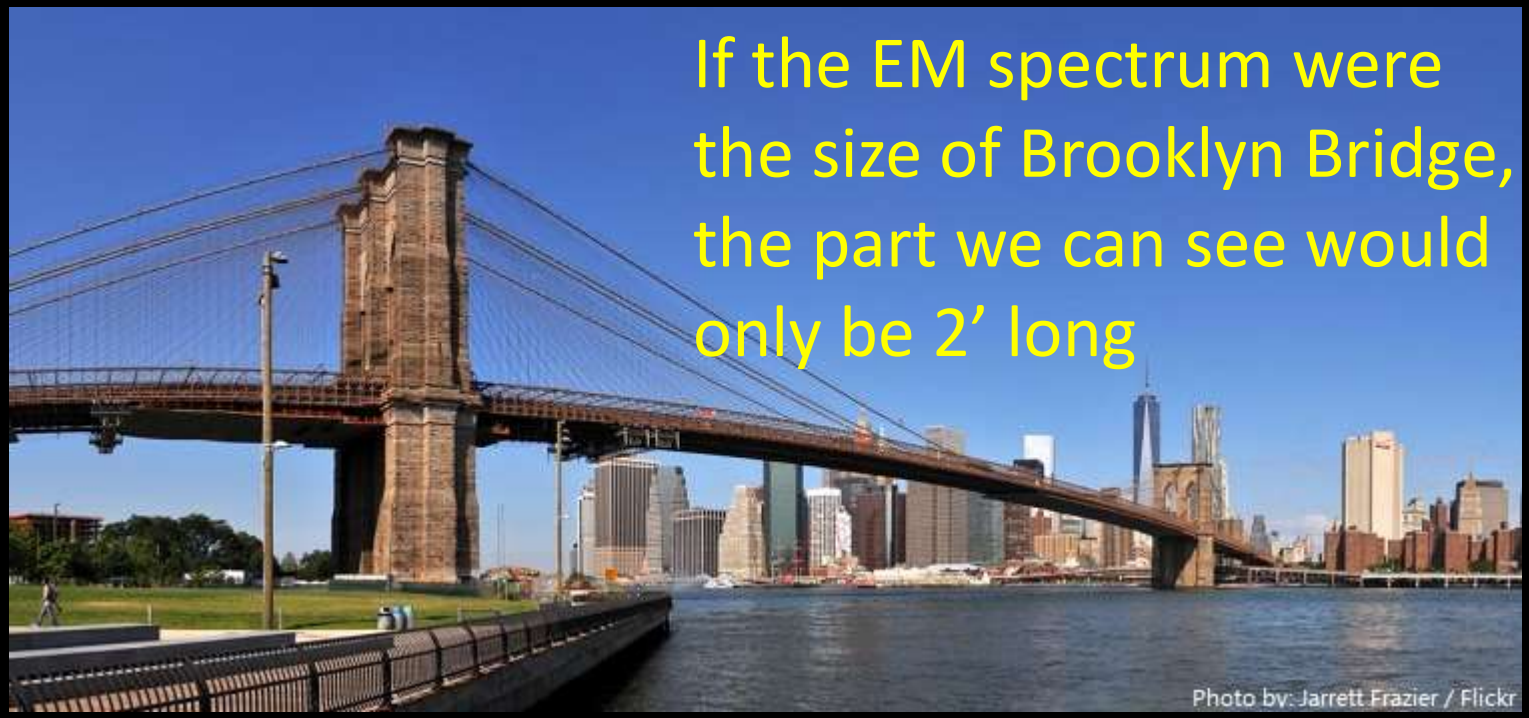
- Einstein's theory not taken seriously until 1960's
- Joslin Bell discovers a tiny dead star giving off almost no light – neutron star
- This provides scientists with the confidence that an even denser collapsed star may exist – a Black Hole

But We Can't See Them ….

2 discoveries ~ WWII will radically change astronomy:

1. Radio impluse found coming from the heart of MW
2. Giger counted mounted on a captured V-2 rocket discovers the cosmos is full of X-rays

Our eyes can only see a very tiny portion of the EM spectrum

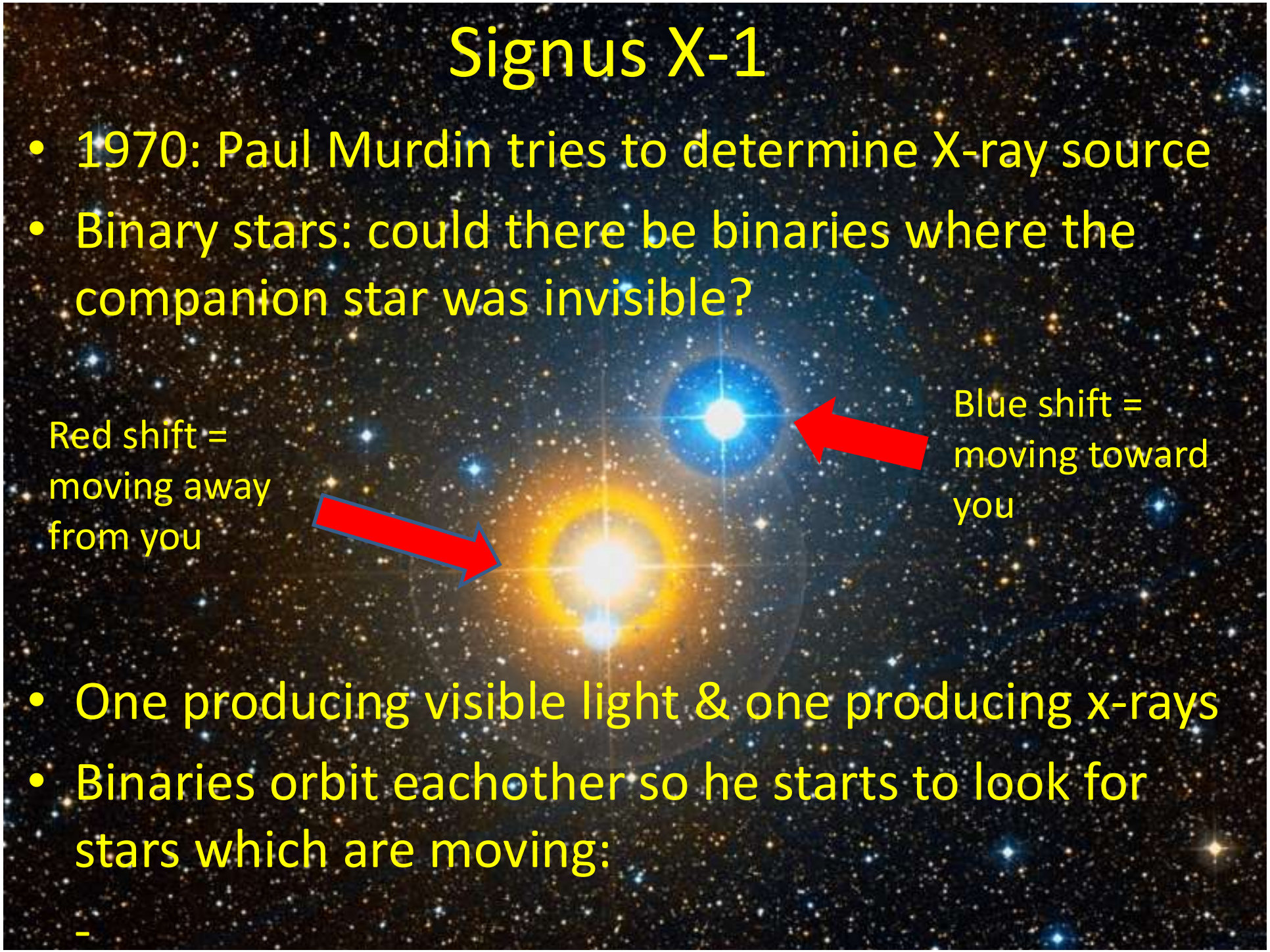


Radio/Microwave/Infrared/UV/X-Ray/Gamma Ray telescopes show numerous invisible objects blasting out energy in the universe

What is creating all this energy that is invisible to ordinary telescopes?

Signus X-1

- 1970: Paul Murdin tries to determine X-ray source
- Binary stars: could there be binaries where the companion star was invisible?



- One producing visible light & one producing x-rays
- Binaries orbit eachother so he starts to look for stars which are moving:
-

The First Black Hole?

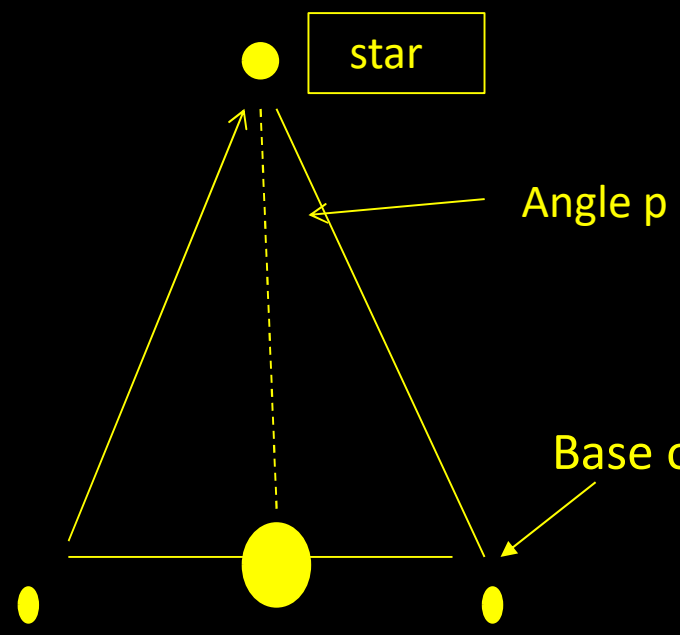
He finds a star clearly orbiting something with a Period = 5.6 days

- Enough mass present to keep the star in orbit around it but emitting no light!
- A Black Hole? Possibly, but only if object is at least 3 solar masses
- He determined it to be 6 solar masses …..

  not definitive due to large error band

Cruise Ship AstroPhysics

You can determine the mass of objects via Keppler's equations but ……. it requires knowing the precise distance to the object



Smaller than the angle of Lincoln's nose on a penny as seen from SF to NY

Base of triangle = earth orbit (185.92 M miles)

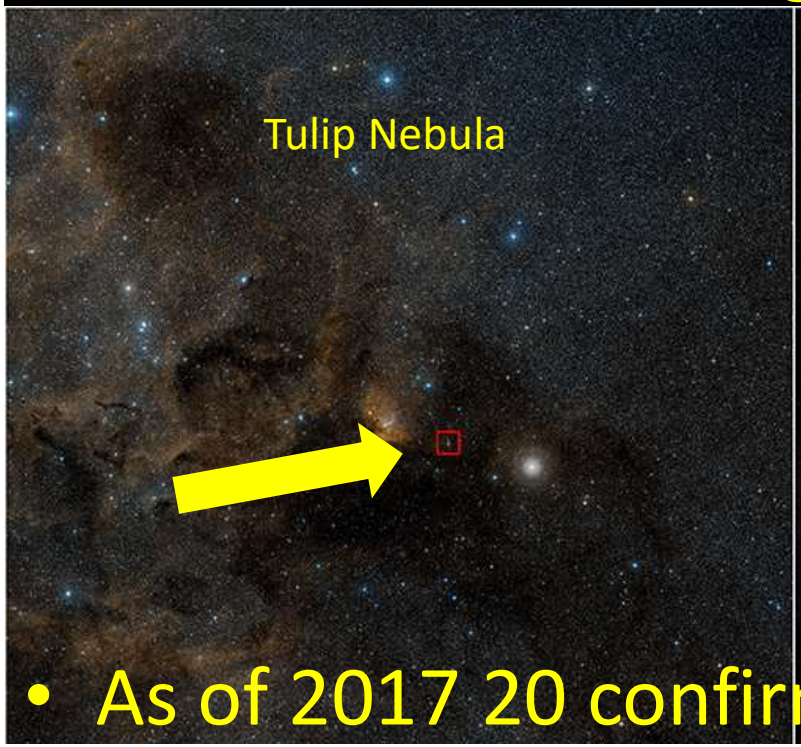
Star: 6,000 LYs away = 15 solar masses – easily big enough to be a BH!

So we have confirmed existence of 1st Black Hole!

Cygnus X-1

Particles collide: heated to millions of degs emit x-rays

- Material is being pulled off blue super giant & into acreation disk. Some enters & some does not.
- 2 parallel jets shooting material out from acceration disk at light speed



- As of 2017 20 confirmed Black Holes in our galaxy

QUASARS (**QUAS**i-stell**AR** radio source**S**)

Radio telescopes detect hot spots emitting radio energy from what look like stars but at radio frequencies

Stars or not?

Step 1: determine make-up of object using spectroscopy

This reveals gibberous!

Someone finally recognizes the fingerprint of hydrogen but at an extreme red shift

This could only mean one thing: Quasars moving away at fantastic speeds: light shifted to such a degree as to be unrecognizable

BUT why? Legacy of an event that occurred 14B yrs ago – the Big Bang!

Furthest object ever seen - to see it it has to be unimaginably luminous

2B LY away emitting the energy of 2 trillion suns/sec!

What's powering them?
Where does the energy come from?

Chemical/nuclear reactions can't put out this amount of energy so they can't be stars

Gravity: only engine that can produce this much energy

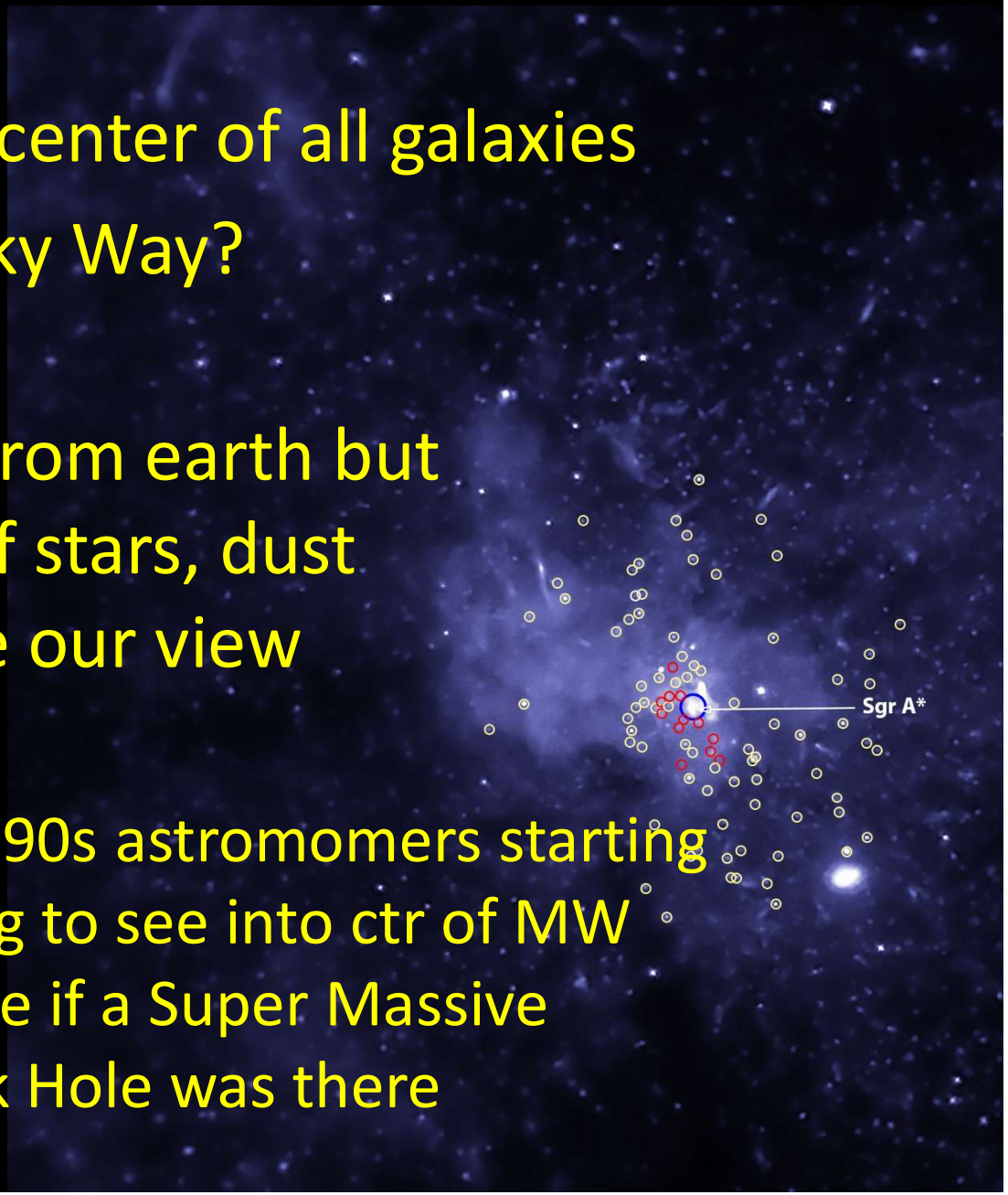
Could energy be coming from the accretion disks around Black Holes?

Would need to be millions or billions of times heavier than the Sun: Signus X-1 is only 15 times heavier

Super Massive Black Holes

- Appear to be at the center of all galaxies
- What about the Milky Way?

- Center is 26,000 LY from earth but there are millions of stars, dust & gas which obscure our view

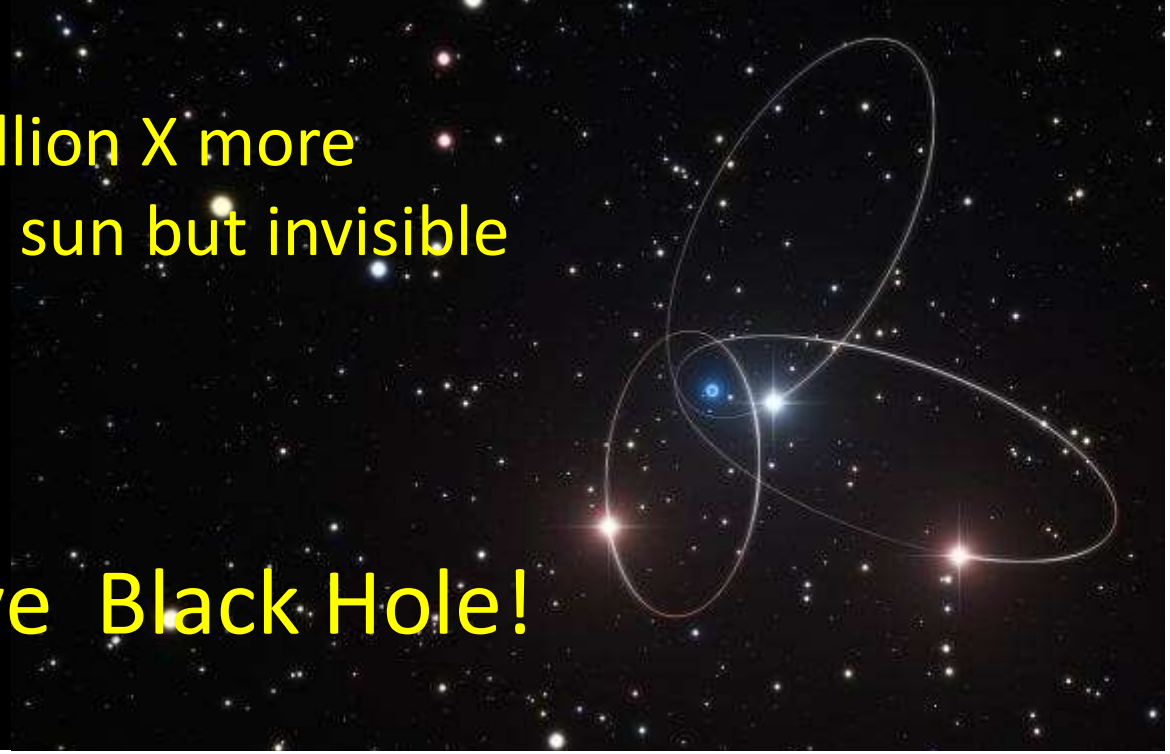


- In 1990s astromomers starting trying to see into ctr of MW to see if a Super Massive Black Hole was there

The Milky Way's Super Massive Black Hole

- Track individual star orbits around galaxy center –
  -- not possible until adaptive optics in 1995
- Yearly images made into a time lapse movie of star orbits
  - Discovered stars are moving at up to 10M mph!
  - That speed only possible if orbiting something massive
  - This thing is 4 million X more
    massive than the sun but invisible
  - What is it ?

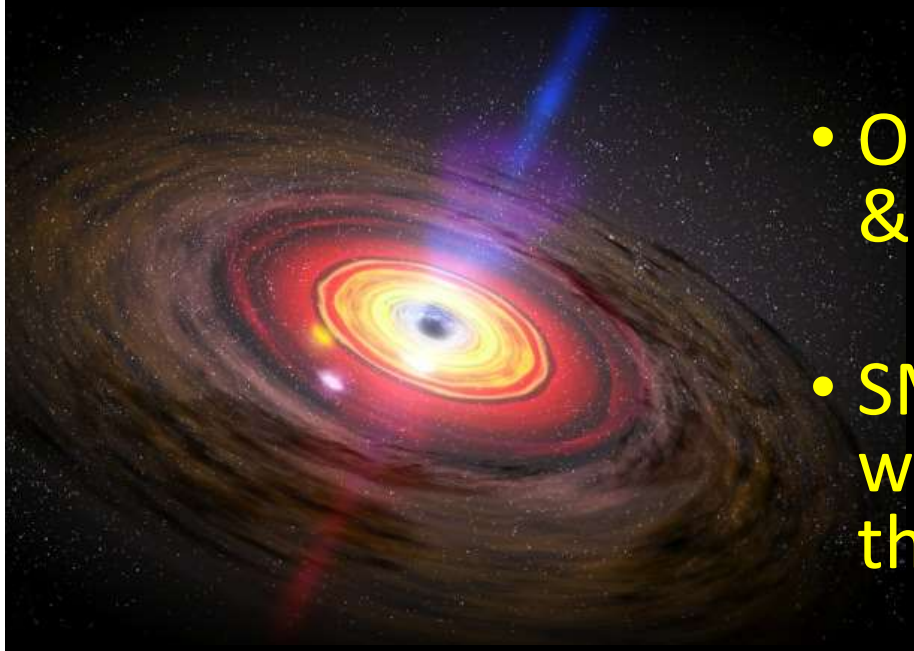
A Super Massive Black Hole!



Stars orbiting the black hole at the center of the Milky Way

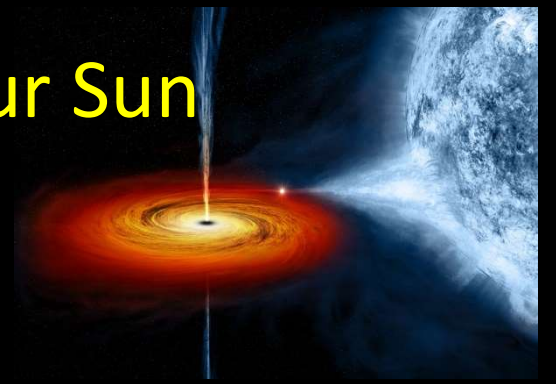
Theory vs Observations

- Ordinary stellar mass black holes predicated by theory
- Super Massive black holes are not



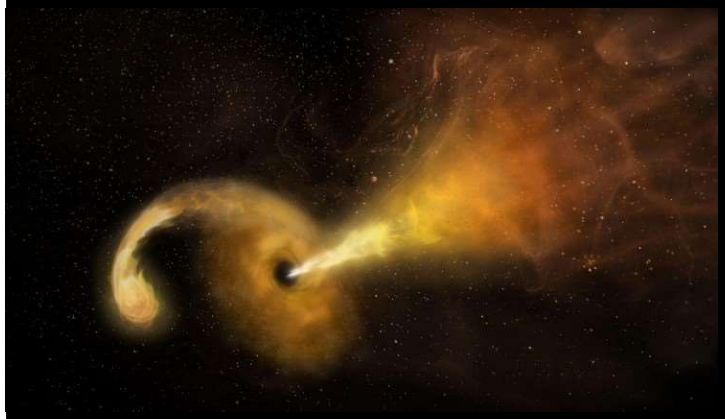
- Ordinary: predict their existence & then observe them
- SMBH: observed them first, working on the theory for how they came to be

Super Massive Black Hole Creation



- Signus X-1: 15 times as massive as our Sun
- SMBH in ctr of MW: 4 million times
- Andromeda: 100 million times
- Other SMBH: 10-20 billion times
- How can you make a SMBH that big?
  Unlikely to have come from a collasped star ……

- Method 1: gas eventually gets sucked in & BH continues to grow



Method 2: rip apart a star in only a few months or years

- In 2015 Chander X-ray telescope discovers an object which has been emitting X-rays for 10 years
- Emitting in 2011, 2008 & July 2005 but not in Apr 2005
- A super nova could show nothing in one month & then massive x-ray emissions 3 months later but not continuously for the next 10 years

Black holes that are not feeding
are silent & invisible
Black Holes devouring a star will
blast out massive amounts of x-rays

Has a Black Hole started to devour something big?
- A star that has wandered to close?
- Massive tidal disruption & rip the star apart in only a few years.

- All well and good but we still have a problem …..

- QUASARS among the oldest known objects in the universe (13BY old)
- Existed near the beginning of the universe
- Not enough time to achieve the size we see now by simply eating stars

So how did they form?

We don’t really know !

Direct collapse of massive gas clouds during the early formation of a galaxy
(tornados & hurricanes)

Stellar black hole consumes enormous amounts of material over millions of years, growing to supermassive black hole ?

Clusters of stellar black holes form and eventually merge into a supermassive black hole?

What is the role of Super Massive Black Holes?

- Are they just random or are they connected to the very structure of the Universe?
- They don't live in isolation –
  they live in the center of galaxies
- The bigger the galaxy the bigger the Black Hole

So which comes first?

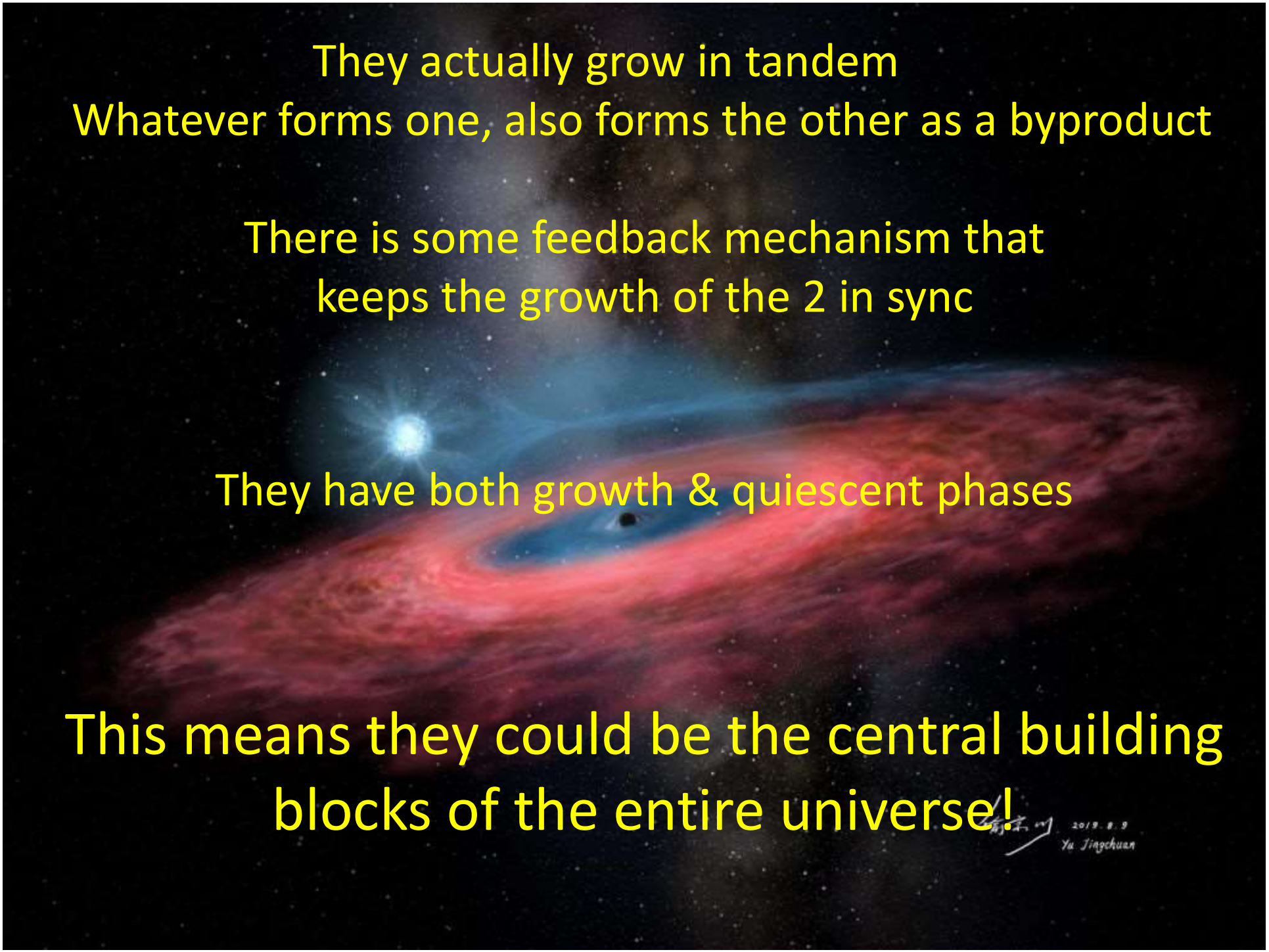
Galaxy or Super Massive Black Hole?

They actually grow in tandem
Whatever forms one, also forms the other as a byproduct

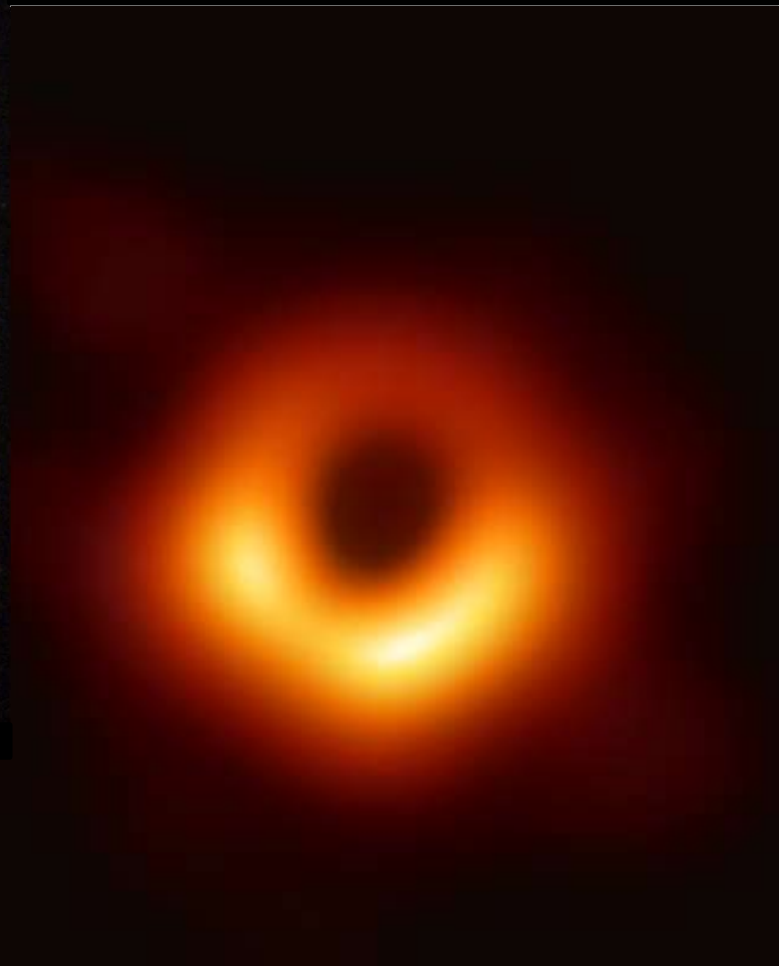
There is some feedback mechanism that
keeps the growth of the 2 in sync

They have both growth & quiescent phases

This means they could be the central building blocks of the entire universe!



Super Massive Black Hole at the center of the M87 galaxy



We've now come full circle on Einstein's theory of general relativity:

When objects move they create ripples in space/time: gravity waves

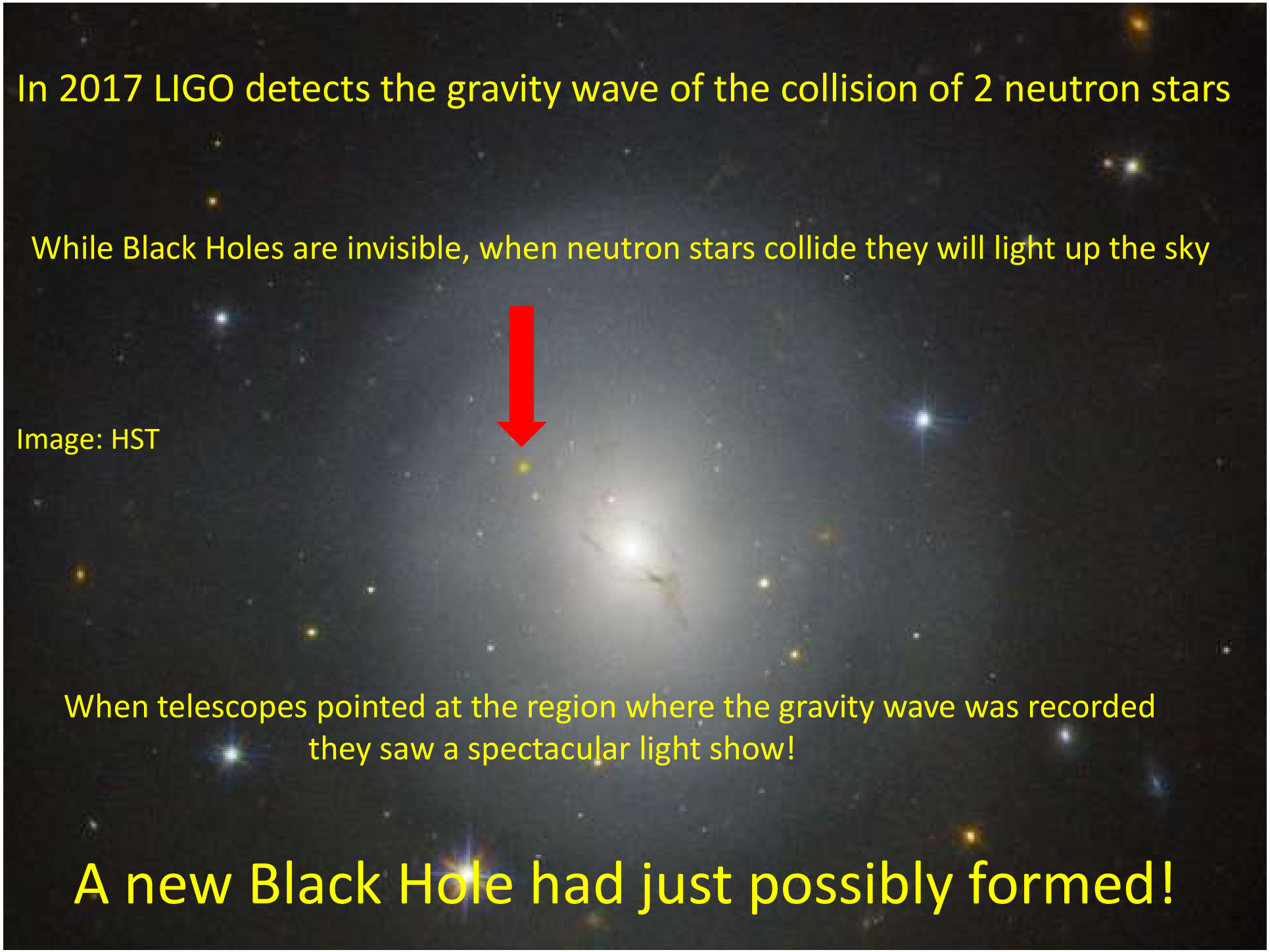
Detecting these gravity waves will not only prove his theory
but also how SMBHs grow

1970: astro physisct Ray Weise builds a device called a laser interferometer (LIGO)
to attempt to detect gravity waves

It takes 45 years to detect the 1st gravity wave (2015) of 2 BHs that collided

Since then LIGO has detected
several more collisions – common occurrence?

Image: HST


In 2017 LIGO detects the gravity wave of the collision of 2 neutron stars
While Black Holes are invisible, when neutron stars collide they will light up the sky
Image: HST
When telescopes pointed at the region where the gravity wave was recorded
they saw a spectacular light show!
A new Black Hole had just possibly formed!

What will eventually happen ?

Will Black Holes absorb all matter in the universe trillions of years from now?

Will the universe eventually become just empty space?

Could the Big Bang have been the start of our Universe from a previous Universe?
(all matter sucked into a Super Massive Black Hole & then exploded into the Big Bang to create our Universe?)

No one knows but whatever is in store for our Universe but you can expect it to be spectacular!


Questions?
Photo by Ron Brecher

UPCOMING LECTURES ON THIS CRUISE:

CAN WE REALLY BE THE ONLY INTELLIGENT LIFE IN THE UNIVERSE?

SO YOU WANNA BE AN ASTRONAUT?

SO YOU WANNA BE A MEMBER OF THE FIRST MARS COLONY?