The Amazing Universe!

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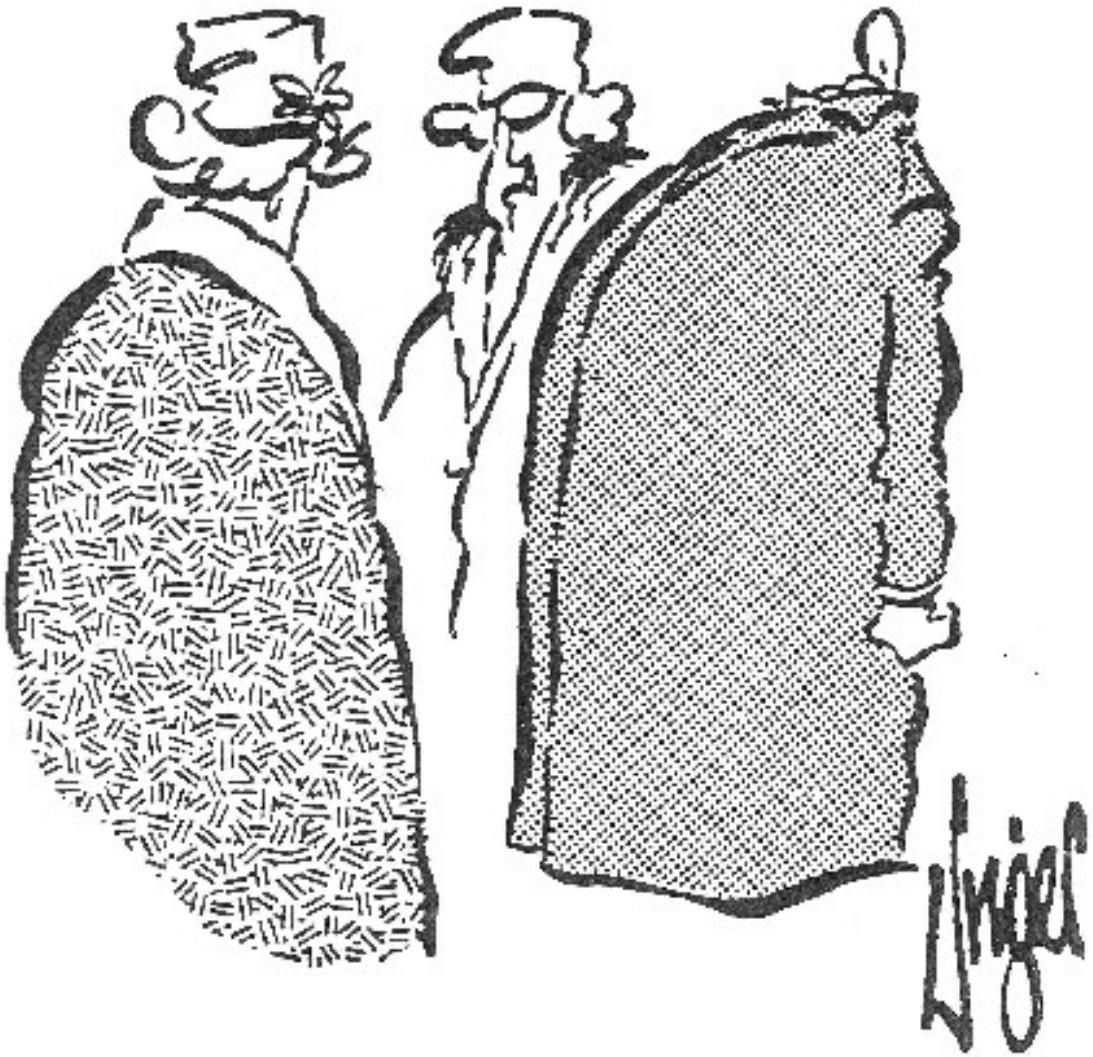


John is an astronomer."

My Colleagues in the
Dunlap Institute of Astronomy & Astrophysics

Summary

The universe, revealed by astronomy, is just as exciting as the universe of science fiction movies and video games – and it's real! And you can see it! And study it! And understand it! And you are part of it!

A Crash Course in Astronomy

Star: e.g. Sun. Produces energy by nuclear fusion

Planet: e.g. Earth. Orbits star; shines by reflected light.

Moon: e.g. Moon. Orbits planet; shines by reflected light.

Asteroid: e.g. johnpercy. Small, rocky object; orbits star

Comet: e.g. Halley's Comet. Small, icy object; orbits star

Planetary System: e.g. Solar System: all of the above.

Nebula: e.g. Orion Nebula. Cloud of unformed gas, dust

Galaxy: e.g. Milky Way: Bound family of billions of stars

Chapter 1

The Earth – The “Just Right” Planet

- Amazing because life has developed on earth for four billion years, producing millions of species, including us We are all related!

NASA

The Sun, Our Star – Giver of Life

The spotted sun, 1,400,000 km across (NASA)

- Amazing – because the sun has shone for 4.5 billion years, with a power of trillions of trillions of Watts, and will continue to do so

Art McDonald
Canadian Nobel Laureate

The Aurora – A Blast from Space

Terence Dickinson

- Amazing – because this blast of high-energy particles makes the whole atmosphere dance and glow!
- Quite frequent in Canada, under a clear, dark sky

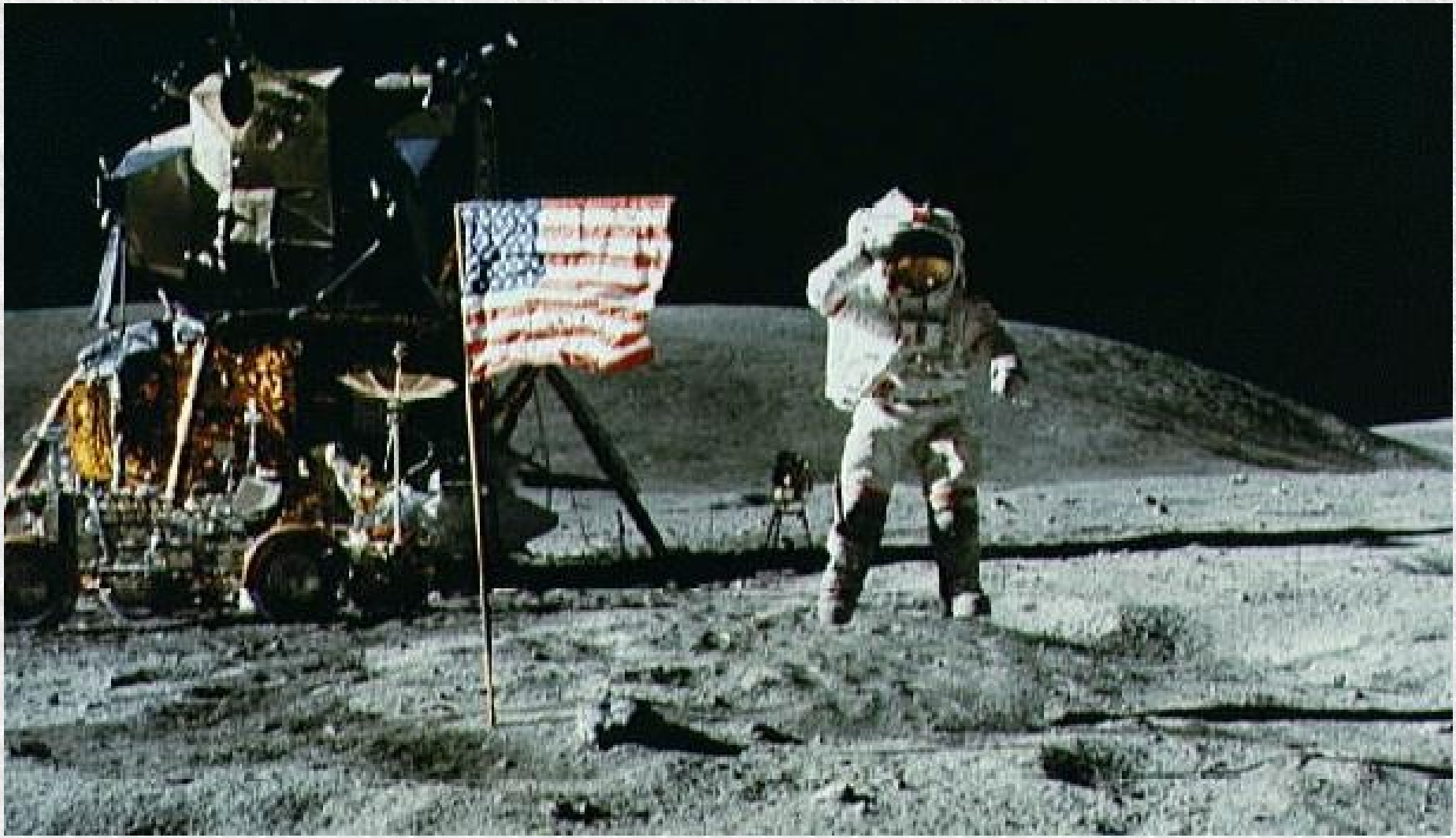
Impacts on the Moon

Mare Imbrium, an ancient lava plain

Paul Millington

- Amazing - because, with your own eye, you can see the remains of giant impact basins – craters -- from four billion years ago

Amazing! Humans have walked on the moon.

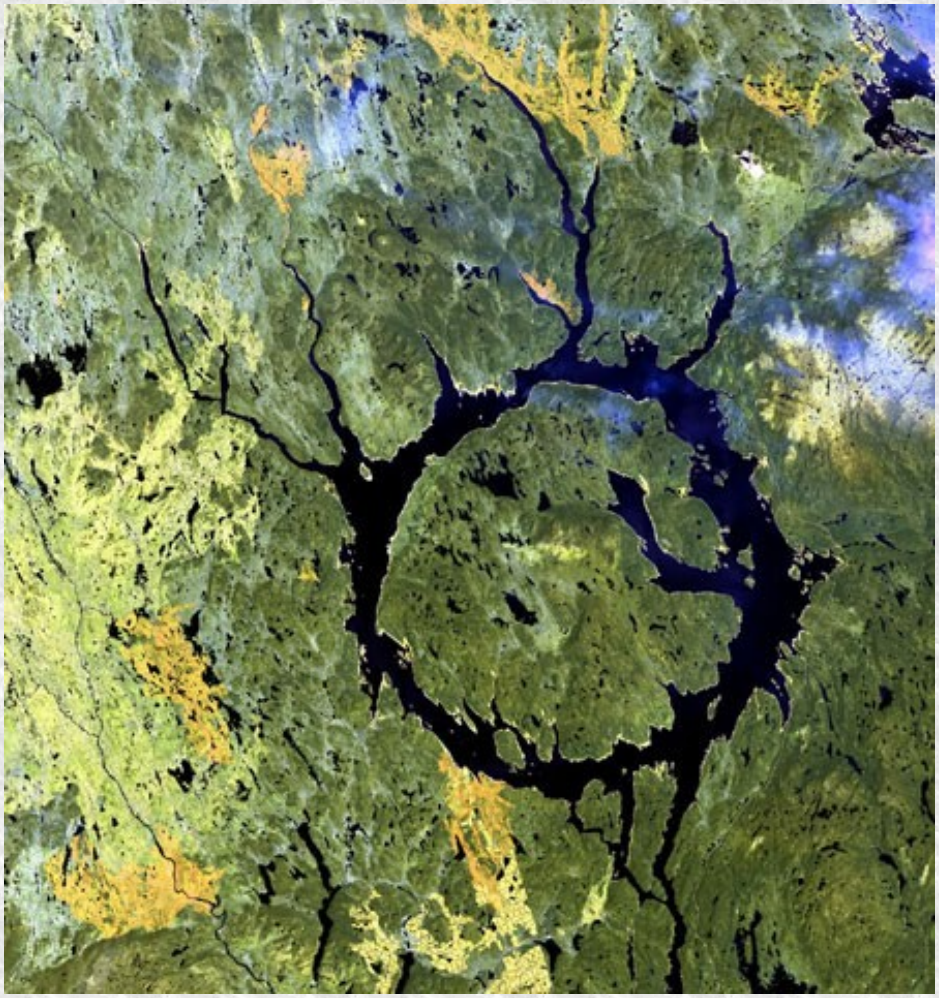


NASA

Did You Know? The magnetic properties of the moon rocks were determined at the University of Toronto Mississauga

UTM

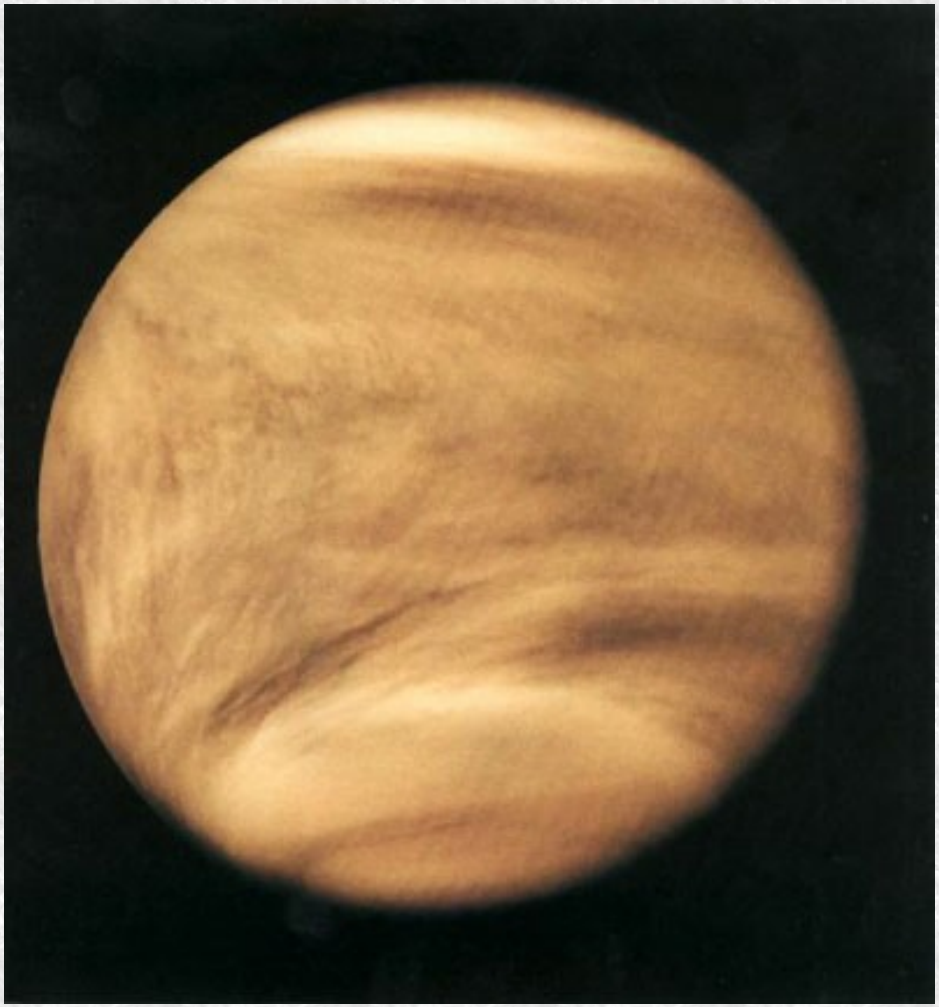
Impacts on Earth
Manicouwagan, Quebec



Satellite view of a 75-km impact crater; Canadian Space Agency

- Amazing – because these rare impacts can cause the extinction of most of the species on earth, including the dinosaurs, 65 million years ago.

Venus – Hotter than Hell!



Satellite view of Venus' upper atmosphere (NASA)

- Amazing - because, on Earth's “sister” planet, the temperature is 450C, the pressure is 100 times that on Earth, and the clouds are sulphuric acid, giving “acid rain”

Mars – Once Livable?

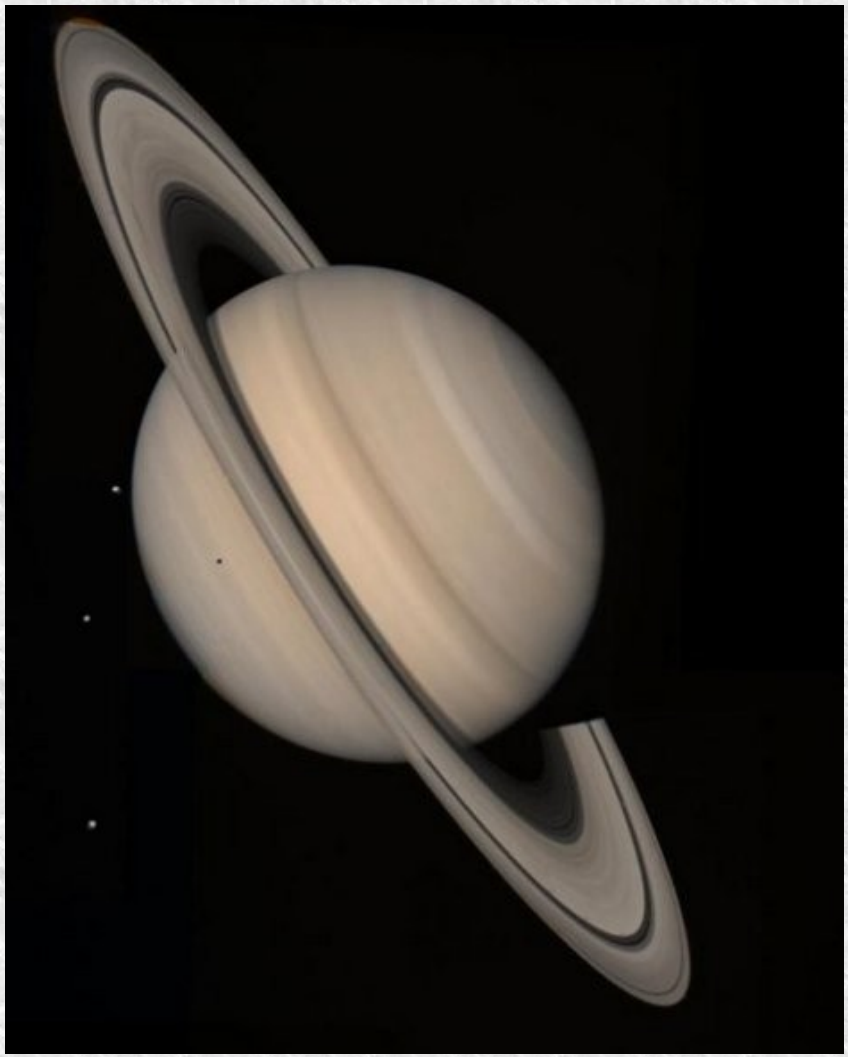
Hubble Telescope image: NASA/ESA/HST

- Amazing – because Mars was warm, wet, and habitable, four billion years ago. Now, it is cold, dry, and airless.

Amazing! Robots exploring Mars

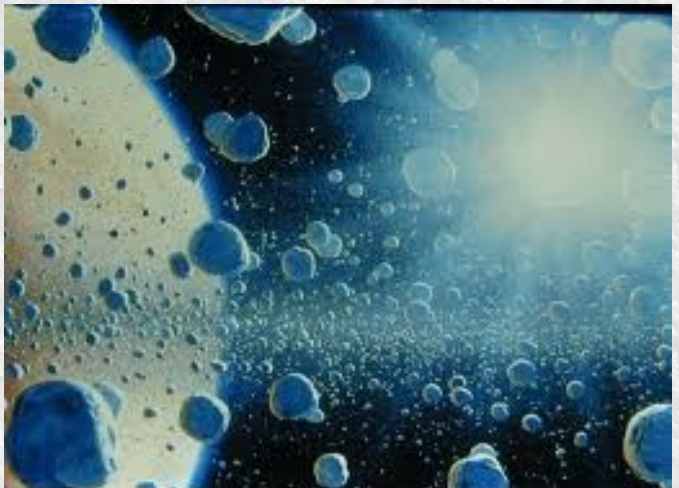
NASA

Saturn – Lord of the Rings

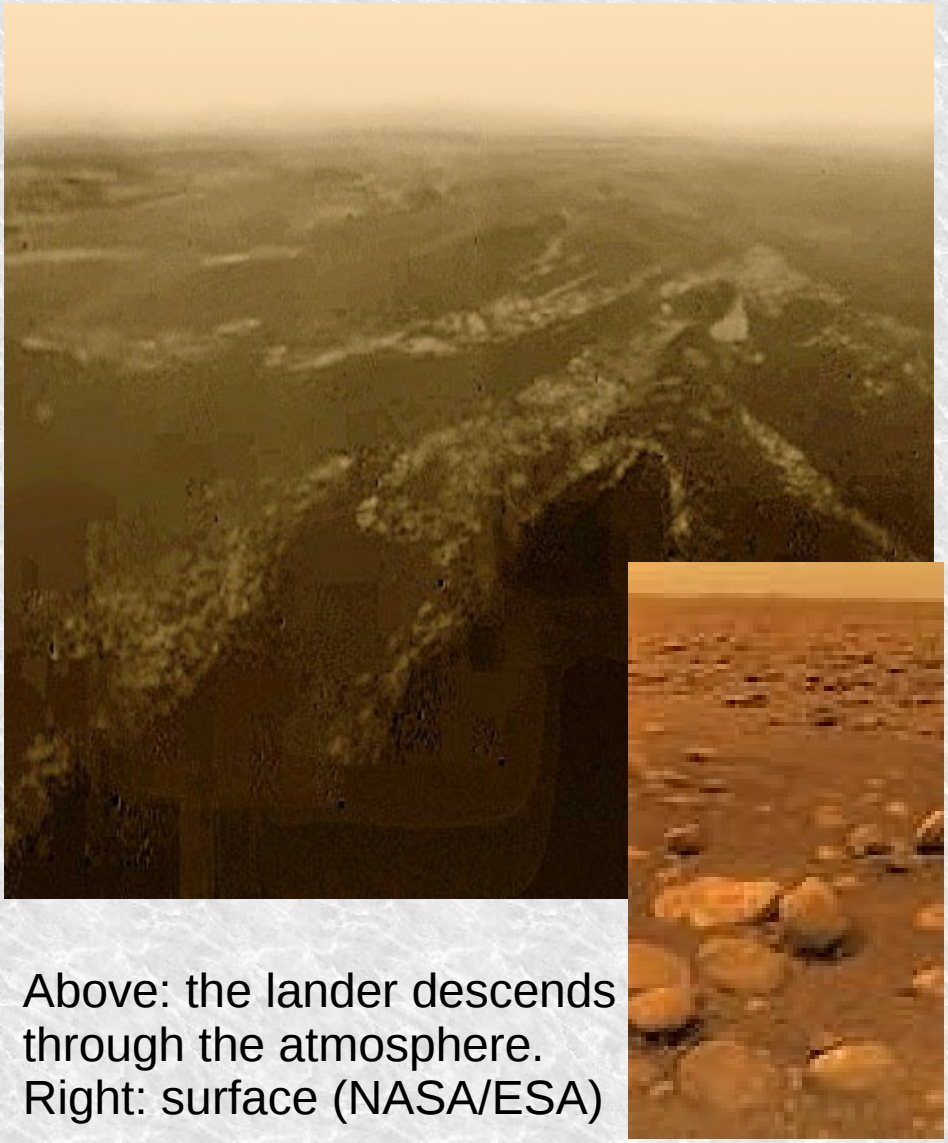


Hubble Telescope image: NASA/ESA/HST

- Amazing – because the rings are millions of chunks of ice (the same size as you are), orbiting above Saturn's equator



Titan – A Frigid Moon

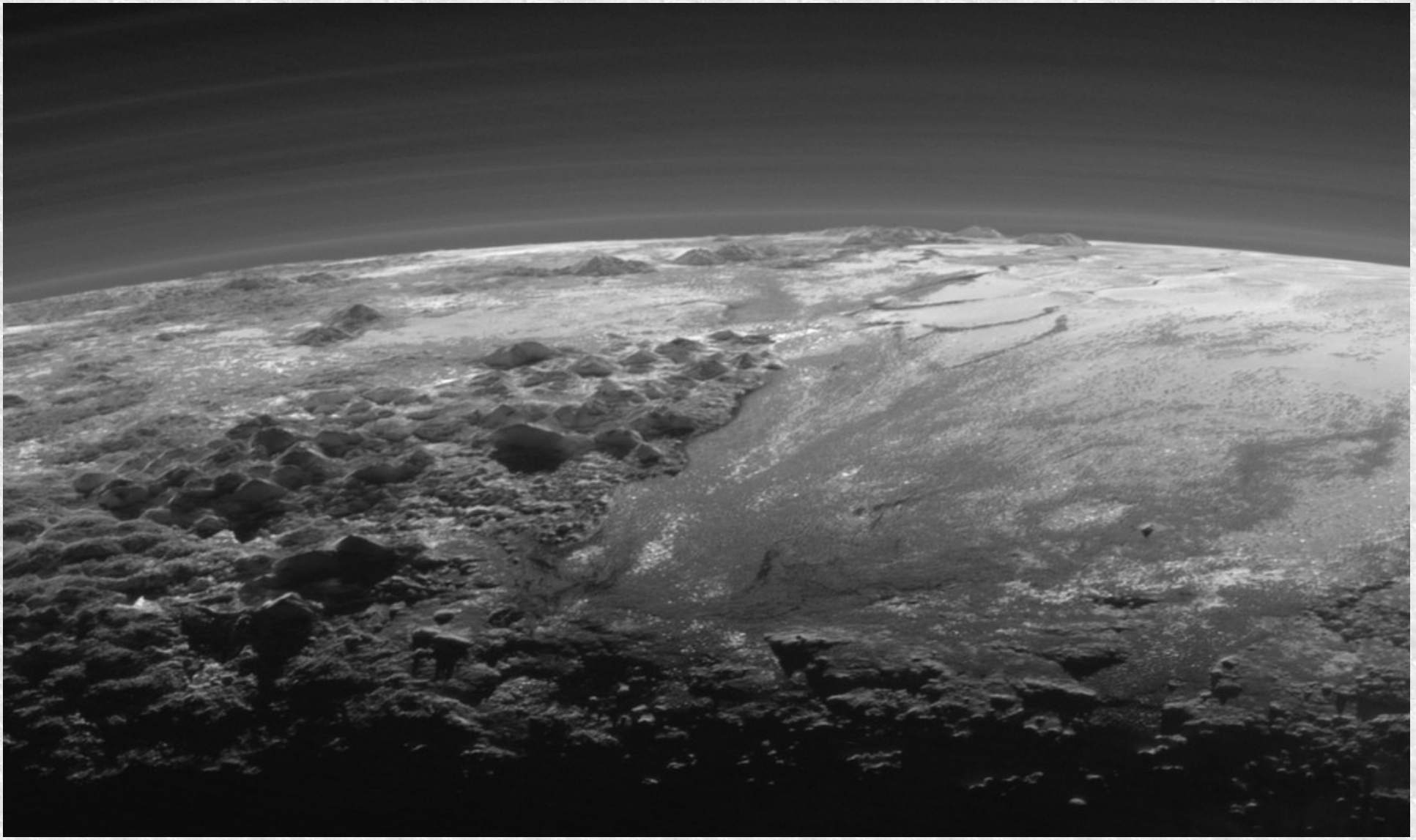


Above: the lander descends through the atmosphere. Right: surface (NASA/ESA)

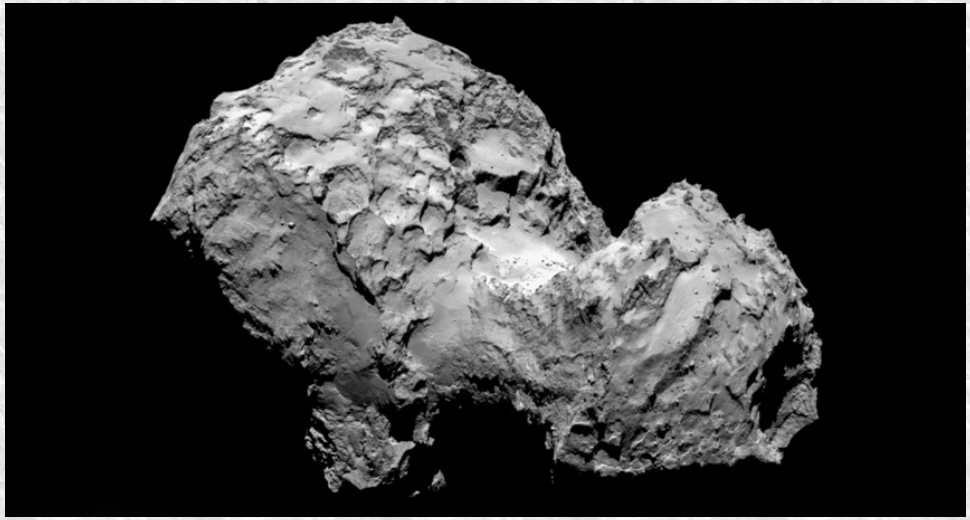
- Amazing – because this is the only moon in the solar system with a thick atmosphere. The temperature is -180C and the weather is caused by hydrocarbons!

Amazing! Fly-By of Pluto

One of hundreds of ice-worlds in the outer solar system



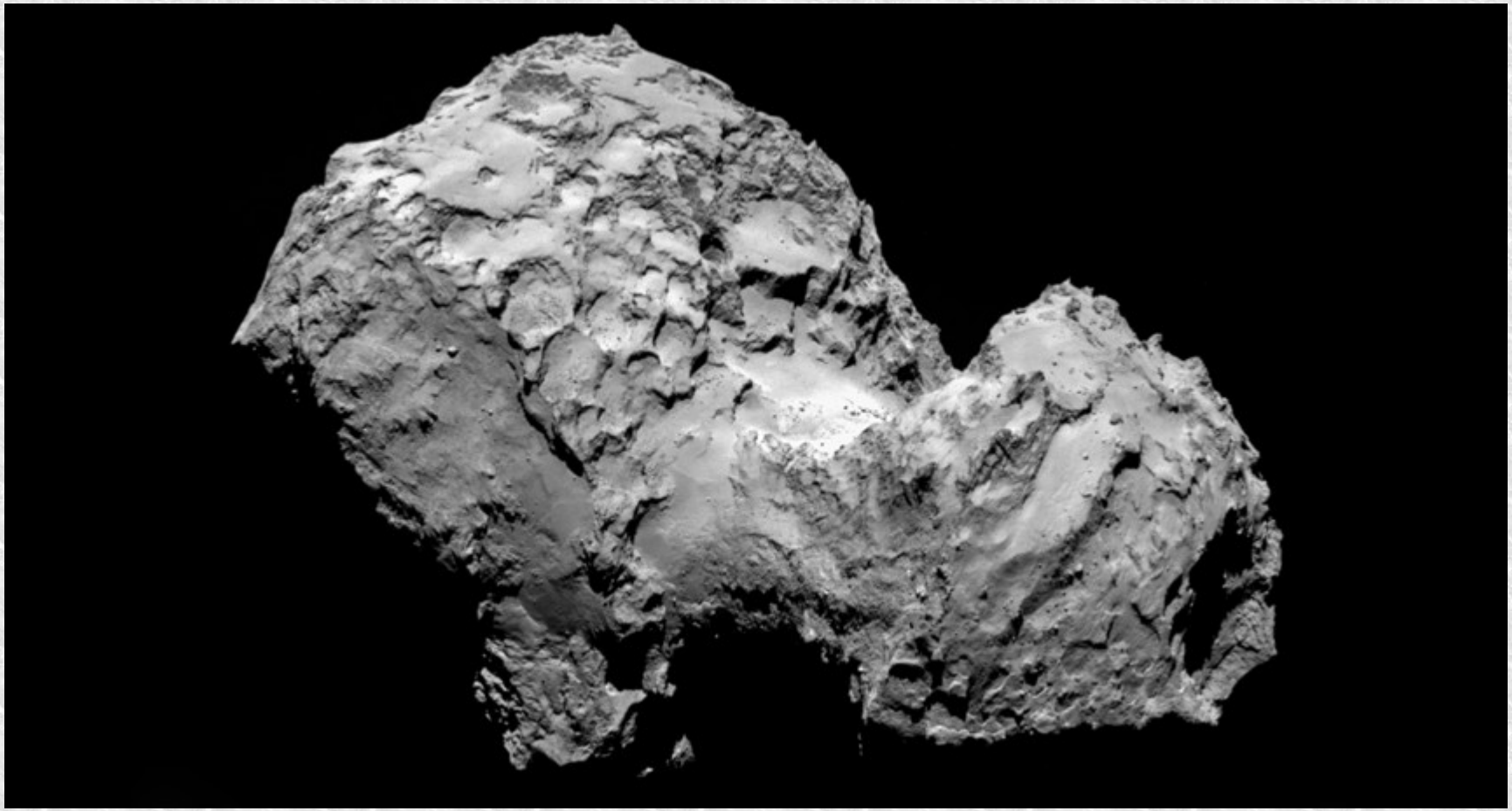
Comets! Giant Iceballs!



- Amazing – because these small (a few km) ice balls, if they approach the sun, grow tails that are tens of millions of km long!

Top: Comet Halley (NASA)
Bottom: Comet Churyumov-Gerasimenko nucleus (ESA)

Amazing! *Rosetta* travelling with a comet, and *Philae* landing on its surface – *Science* breakthrough of the year!



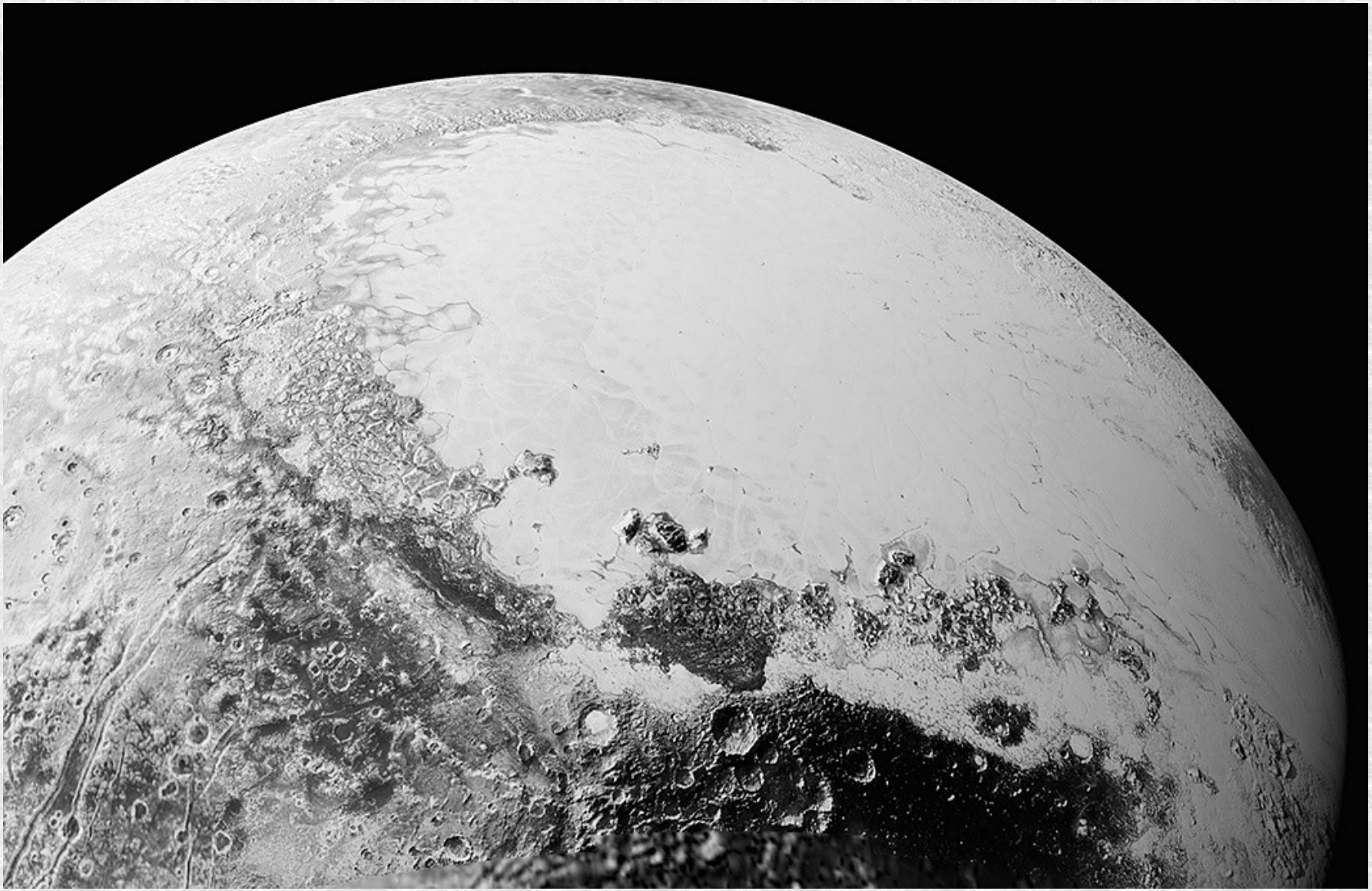
Asteroids! Giant Space Rocks!

Asteroid Gaspra (NASA)

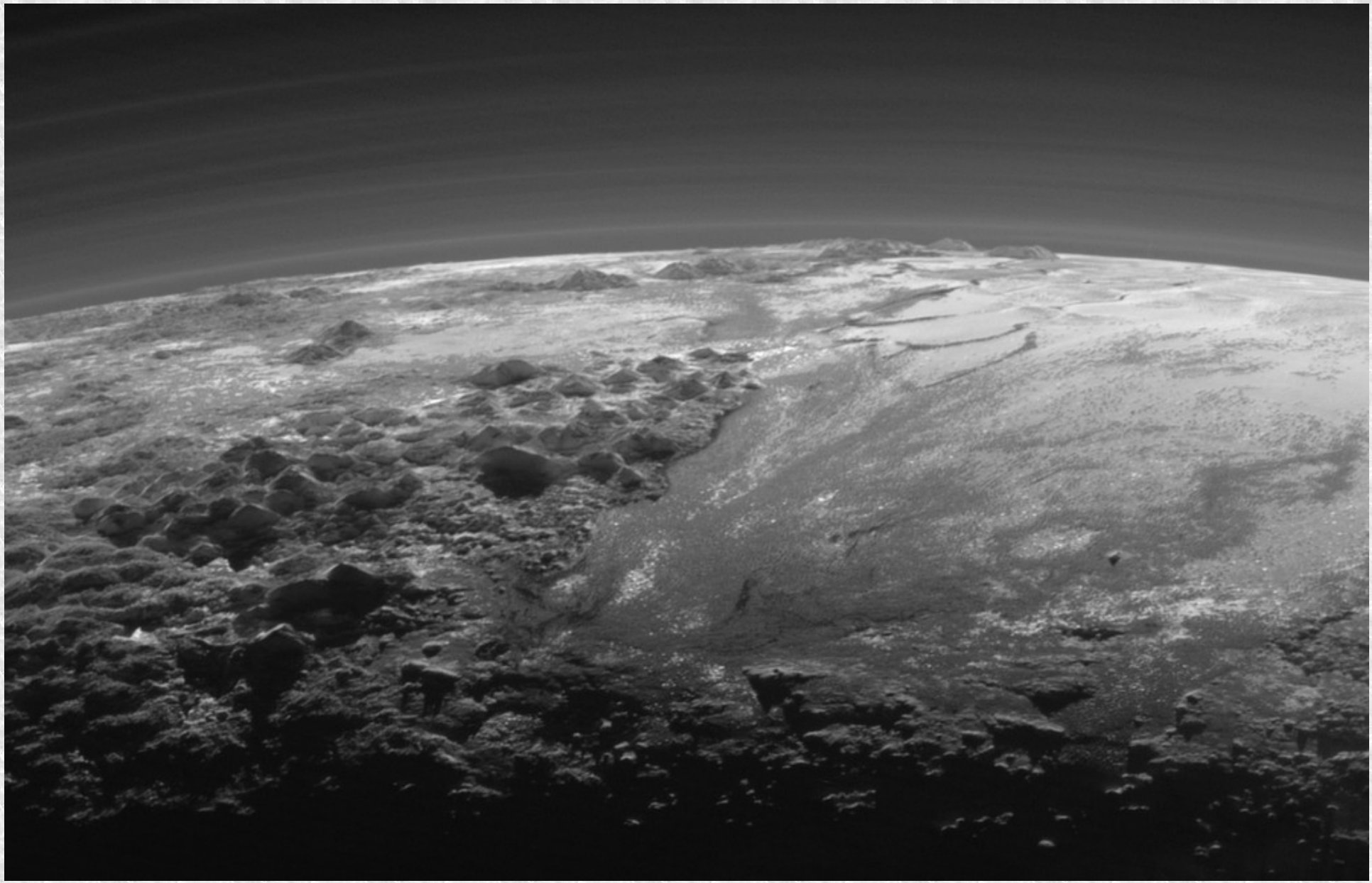
- Amazing – because these giant (up to 1000 km) rocky objects, which orbit between Mars and Jupiter, occasionally collide with Earth!

Kuiper Belt Objects

Iceballs in the outer solar system; Pluto is the first to be visited by spacecraft. Amazing image!



Amazing Pluto!



Chapter 2

Telescopes Explore the Universe

Gemini Observatory South, Chile (NRC Canada)

- Amazing – these telescopes, usually located on high mountains, gather and focus light, and tell us most of what we know about the universe.

Telescopes beyond the Visible

Atacama Large Millimetre Array, Chile; Canada is a partner.

National Research Council Canada

- Amazing – because this radio telescope produces images of radio waves, not light; there are also space telescopes for other kinds of "light".

Telescopes in Space

Hubble Space Telescope (NASA, ESA)

- Amazing, because the Hubble Space Telescope has been a “workhorse” of astronomy for two decades, providing images for research, education, and the public

BRITE – Canada's “shoebox satellites”

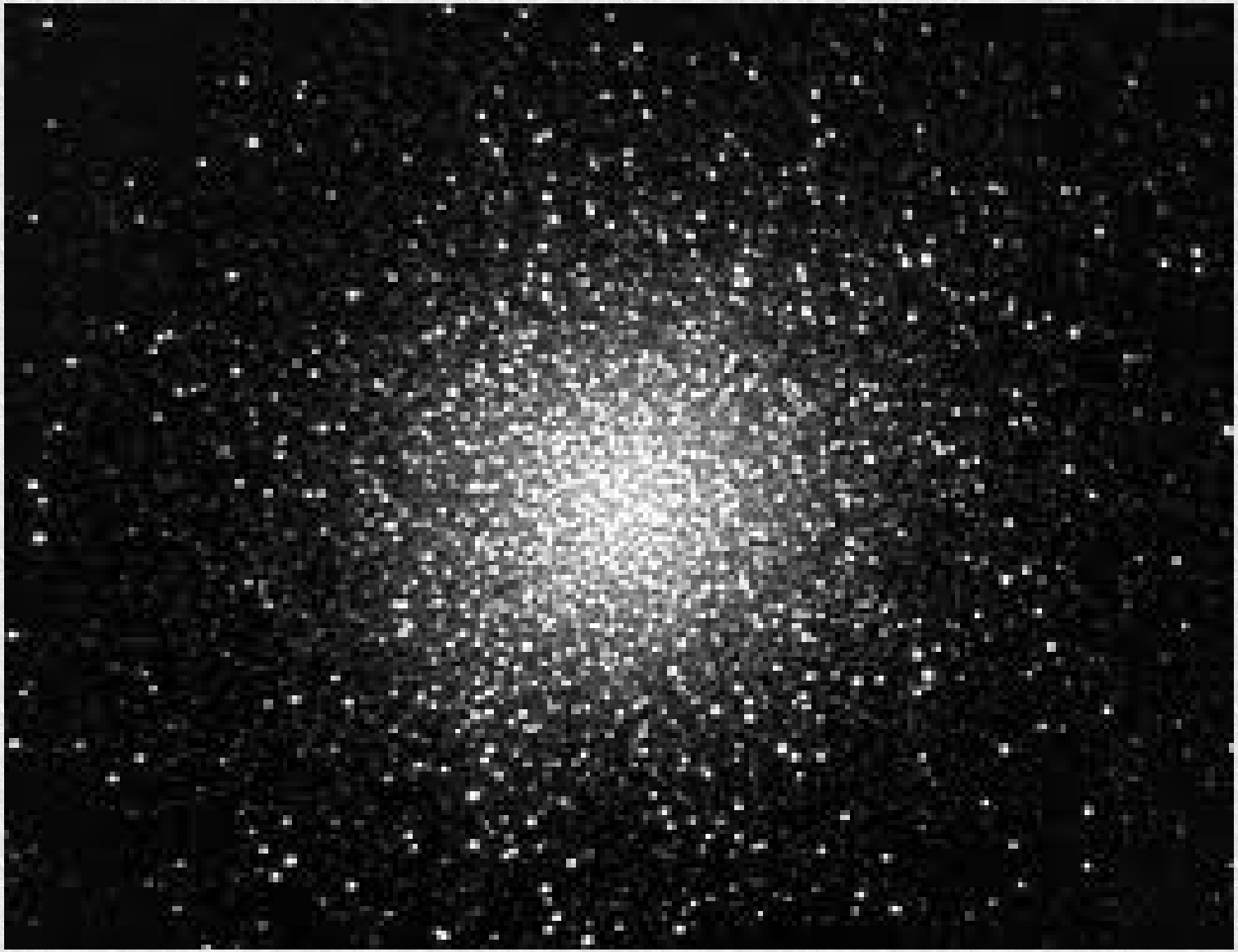
Nebulas: Birthplace of Stars and Planets

The Orion Nebula, faintly visible to the unaided eye, in the constellation Orion,

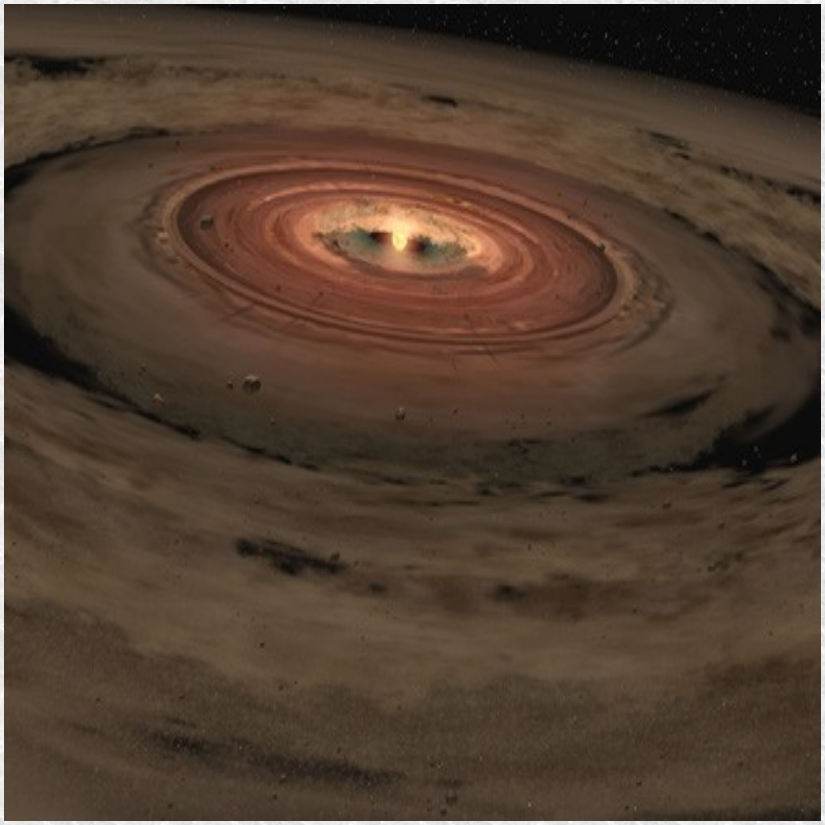
NASA/ESA/HST

- Amazing – because this dust and gas is where stars and planets are born -- from material recycled from previous generations of stars.

A Globular Mega-Cluster



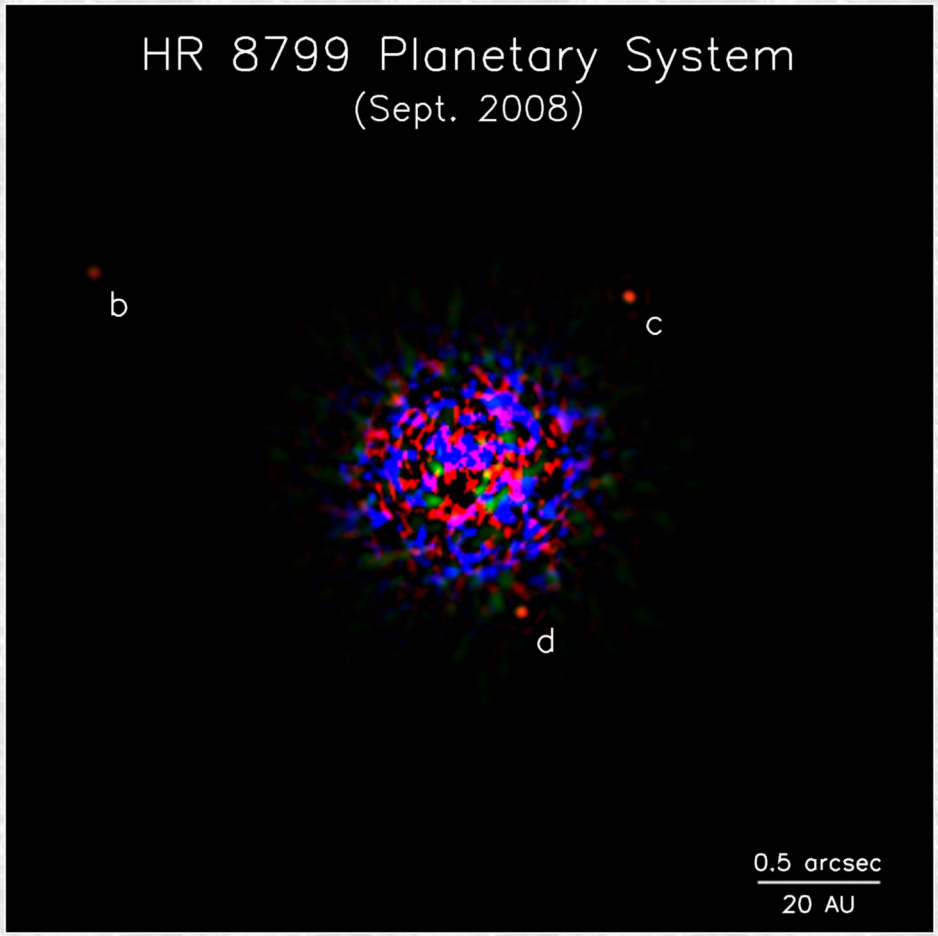
Starbirth and Planetbirth



Artist's conception of the birth of the solar system (David Darling)

- Amazing – because this forming disc, with a star in the centre, is what the solar system would have looked like, 4.5 billion years ago

Exoplanets
Planets around Other Stars

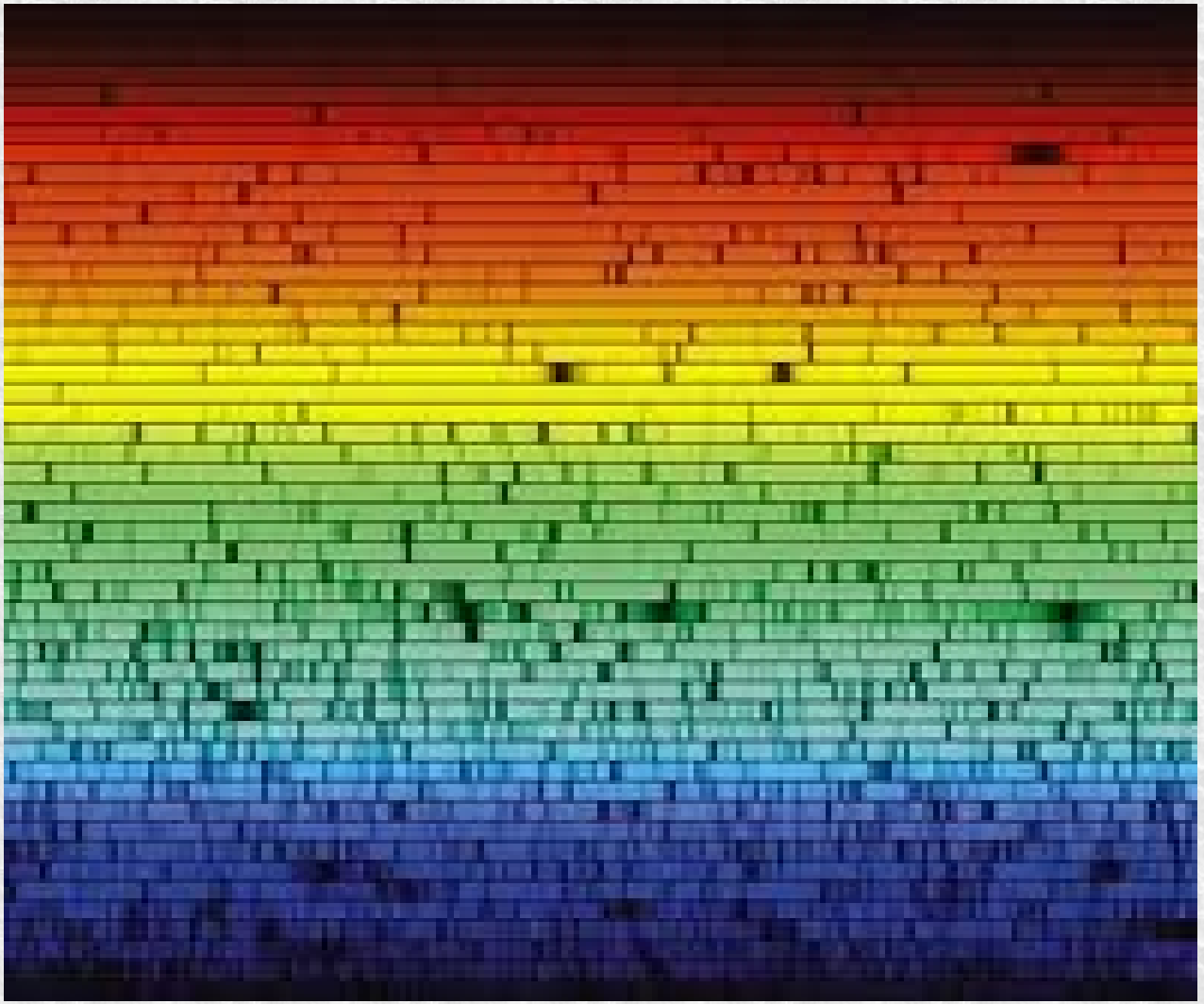


National Research Council Canada

- Amazing – because astronomers can now see planets around other stars; Canadian astronomers are leaders in this field.

Amazing: The nearest star to the sun, the red dwarf Proxima Centauri, may have an earthlike planet!

Amazing! From this beautiful spectrum, we can learn many things about the sun

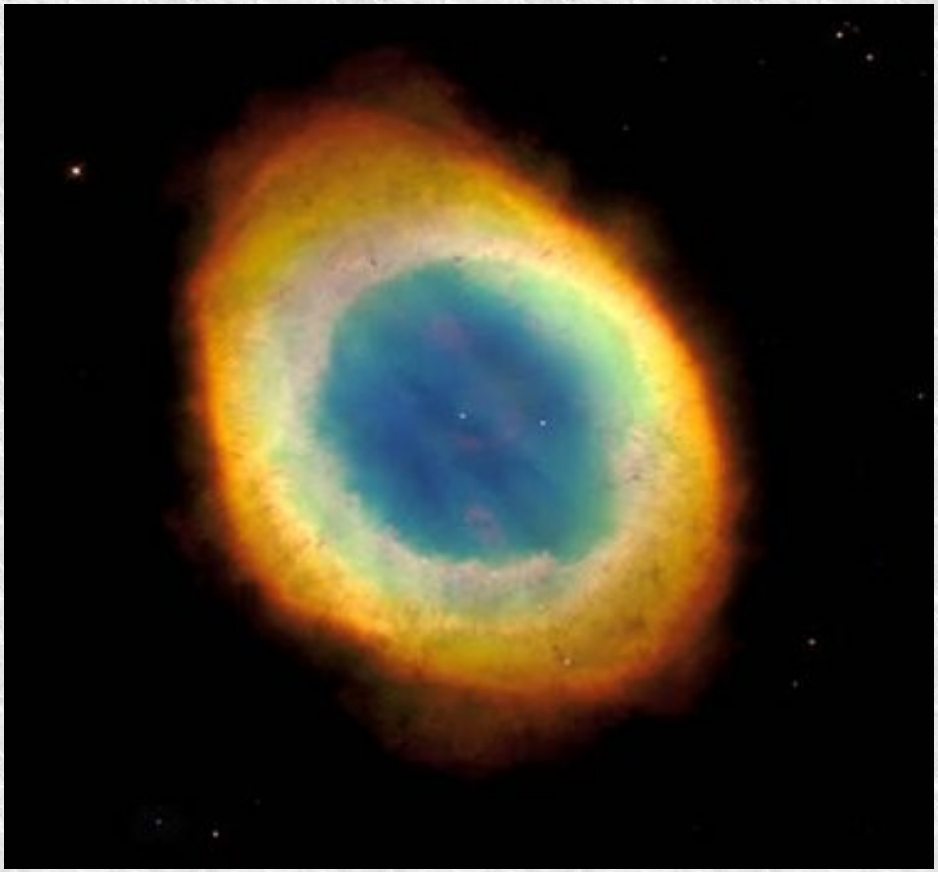


Giants and Supergiants

Artist's conception of the red giant sun, engulfing the inner solar system.

- Amazing – because there are rare stars that are a million or billion times bigger than the sun. The sun will eventually become a “red giant”

The Death of the Sun



The expanding Ring Nebula, in Lyra. The white dwarf can be seen, faintly, at the centre.

- Amazing – because this is what the sun will look like when it dies, 5 billion years from now – an expanding nebula and a white dwarf corpse.

Supernovas – Rare Exploding Stars

The Crab Nebula, in Taurus, a supernova observed in 1054 AD (NASA/ESA/HST)

- Amazing – because this rare star has exploded, spewing elements (including the elements of life) into space, from which new stars, planets, and life can form

Neutron Stars

The tiny neutron star at the core of the Crab Nebula (NASA/ESA/HST)

- Amazing - because the core of the exploding star has a density of a million tonnes per cubic cm, and spin 1000 times a second.

Black Holes!

Artist's conception of a normal star and a black hole in mutual orbit (NASA)

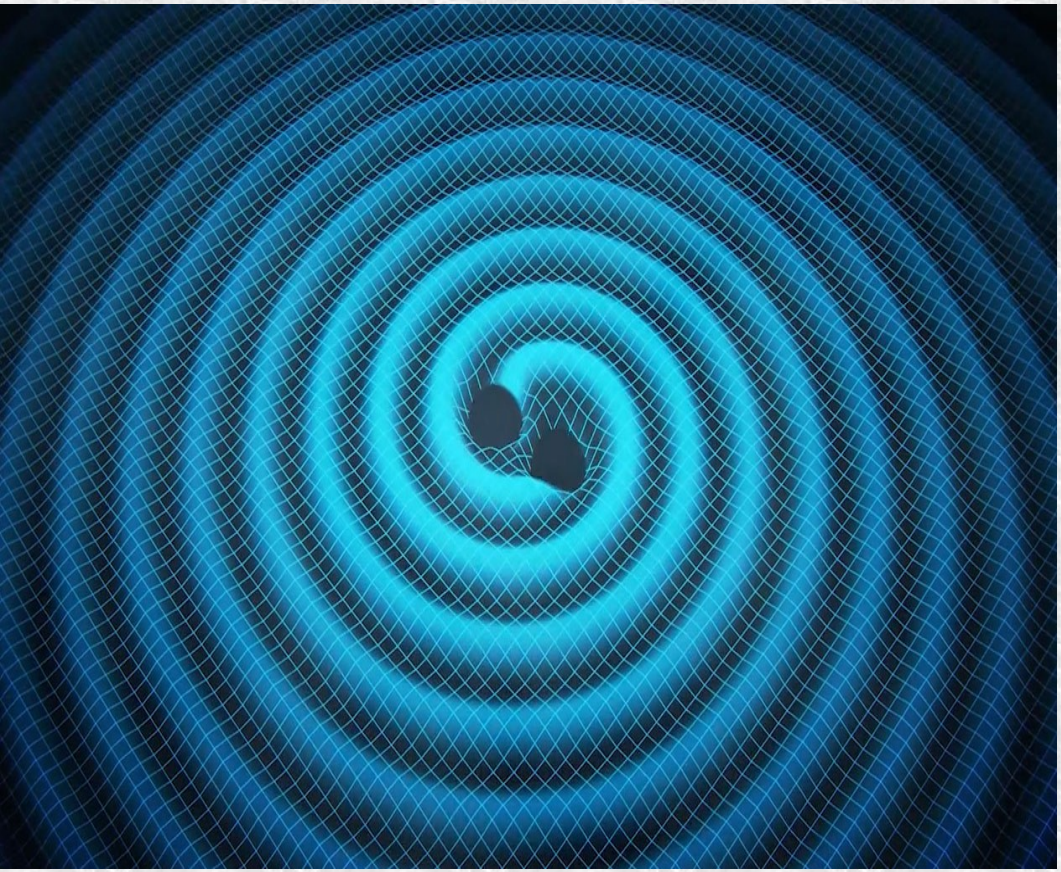
- Amazing – because a black hole, the collapsed core of a rare massive dying star, is so dense that nothing can escape, not even light.

Did You Know?

The first black hole in space was co-discovered by Professor Tom Bolton, University of Toronto

Black Holes in Mortal Embrace

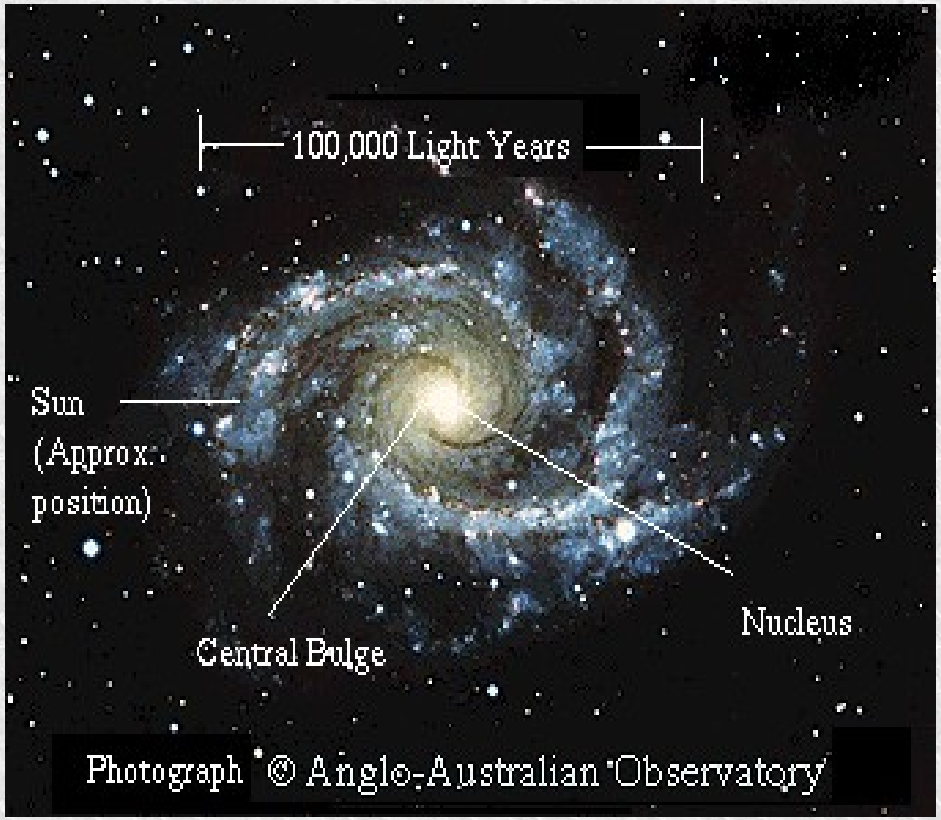
Nobel Prize in Physics 2017



- Amazing! When the black holes merge, they produce gravitational waves which can be “heard” over a billion light years away
- This may be the fate of Cygnus X-1 in the distant future

Chapter 3

Galaxies – Islands of Stars



- Amazing – because our galaxy, the Milky Way, is a family of 300 billion stars, plus gas and dust, but most of it is unknown "dark matter"!

Colliding Galaxies

NASA/ESA/HST

- Amazing - because, over billions of years, galaxies can collide, and gravitationally tear each other apart. This will happen to the Milky Way in a few billion years.

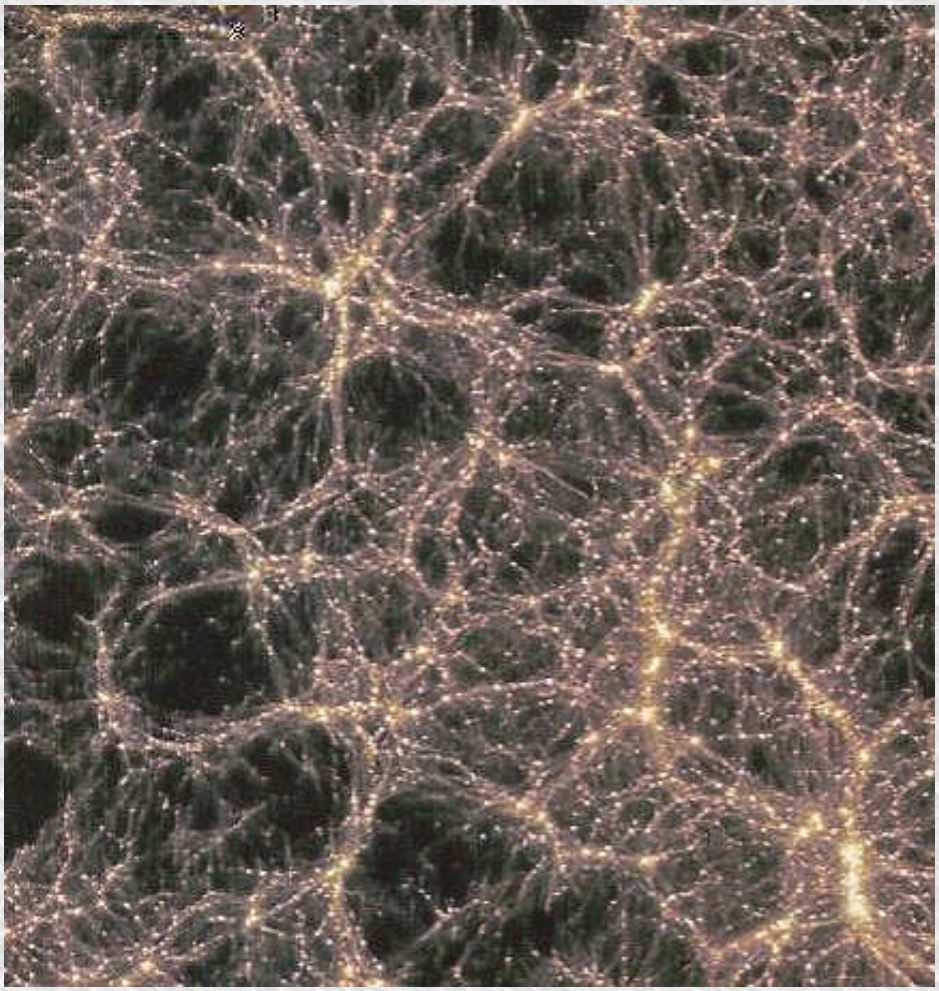
Supermassive Black Holes

Artist's conception of the supermassive black hole at the centre of the Milky Way (NASA/Dana Berry)

- Amazing – because many galaxies, including the Milky Way, have supermassive black holes at their centre, millions of times more massive than the sun.

Amazing! 90% of the matter in the universe is invisible “dark matter”

What the Universe Looks Like



Supercomputer simulation of a large portion of the universe; every dot is a galaxy (Nature Magazine)

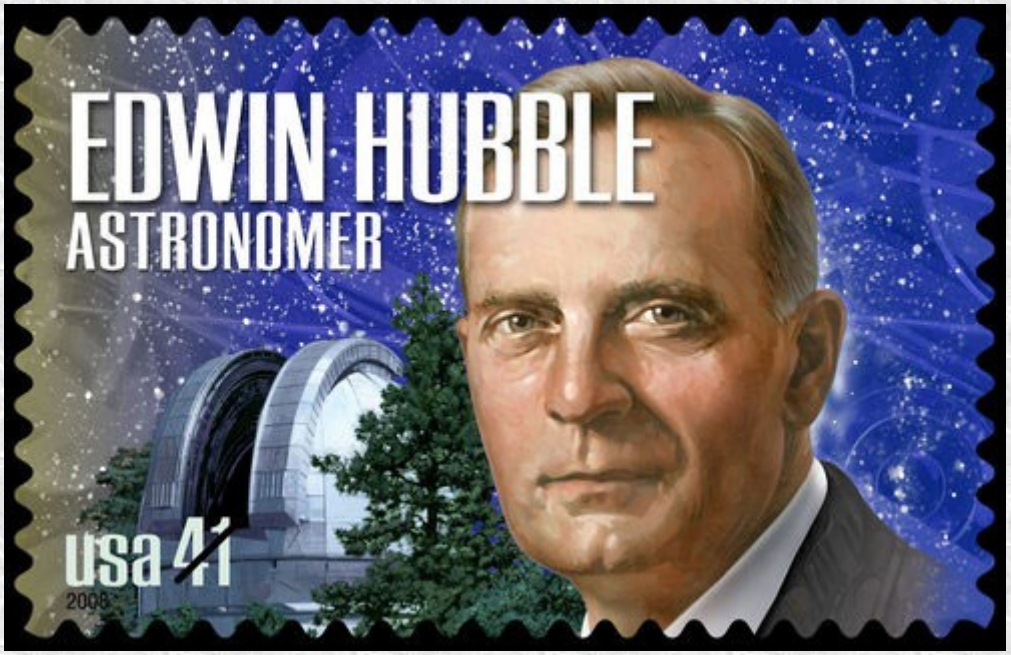
- Amazing – because astronomers have mapped the universe, and found that the billions of galaxies are arranged in filaments like this.

The Astronomical “Time Machine”

The Hubble ultra-deep field, a multi-day image of a tiny fraction of the sky (NASA/ESA/HST)

- Amazing – because the faintest galaxies are so far away that it has taken billions of years for the light to reach us; we see them as they were, billions of years ago..

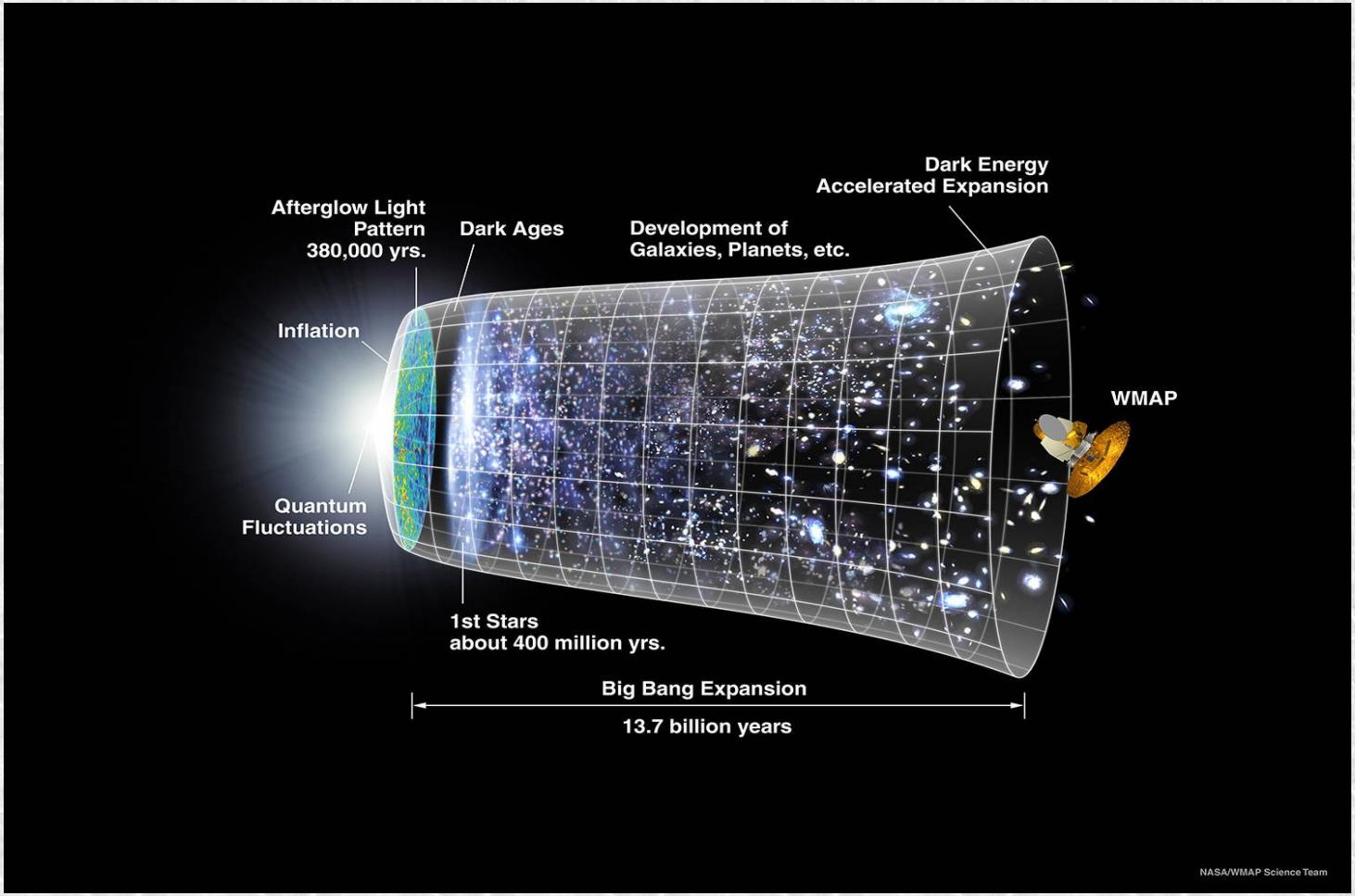
The Expanding Universe



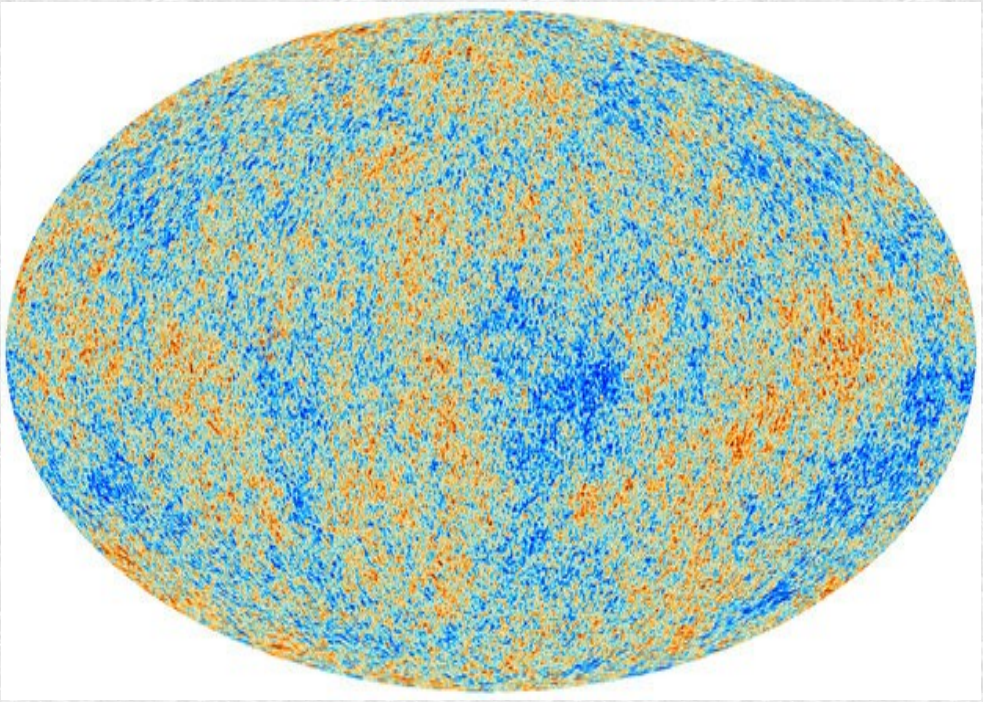
Edwin Hubble built on the work of Vesto Slipher to show that the galaxies in the universe were moving away from each other.

- Amazing – because the universe is expanding from its beginning – the Big Bang – 13.7 billion years ago ....

Amazing! Some not-yet-understood "dark energy" is causing the expansion of the universe to accelerate



Leftovers from the Universe's Birth



The cosmic microwave background radiation, imaged by the Planck satellite. The red areas are slightly warmer, the blue areas slightly cooler (ESA)

- Amazing – because we can still see the leftover radiation from the birth of the universe – the Big Bang. You can see some of it in the static on your TV set.

Chapter 4

Astrobiology

Stanley Miller who, with Harold Urey, carried out the Miller-Urey Experiment.; Image: James A. Sugar

- Amazing – because the elements of life are everywhere, and the laws of physics are universal, and atoms form naturally into the molecules of life.

Carbonaceous Chondrite

Meteorites, unaltered since the beginning of the solar system, containing naturally produced pre-biological molecules

These can form, naturally and easily!

SETI: Search for Extraterrestrial Intelligence

Artist's conception of the Allen Array of radio telescopes, designed to listen for artificial extraterrestrial signals (SETI Institute)

- Amazing - because, if there was a civilization like us, anywhere in our galaxy, we could communicate with it by radio waves, using today's technology.

THE FAR SIDE By GARY LARSON

"Mr. Osborne, may I be excused? My brain is full."

Lest you feel insignificant.....

“Astronomy is useful because it shows how small our bodies, how large our minds”

Henri Poincaré
French astronomer and mathematician

Ideas to Take Home

- Astronomers work to understand the nature, origin, and evolution of the universe, and everything in it
- We owe our existence to the cosmos: to the atoms created in stars, and the Big Bang; to the planet on which we live; and to the sun whose energy makes life possible.
- Astronomy is exciting; the night sky is beautiful
- Anyone can do astronomy as a hobby or as an amateur astronomer; “the stars belong to everyone”