



The Next Decade in Astronomy

The Unanswered Questions

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The Next Decade in Astronomy

- Recent discoveries
 - What have we learnt in the last decade?
- What's next?
 - What we don't know
 - The BIG questions
 - Tools for the next decade
- Beyond 2026

Recent Discoveries

The Demotion of Pluto

BBC NEWS **BBC NEWS CHANNEL** **News services**
Your news when you want it

Last Updated: Saturday, 30 July 2005, 15:30 GMT 16:30 UK

Astronomers detect '10th planet'

By Dr David Whitehouse
Science Editor, BBC news website

Astronomers in the United States have announced the discovery of the "10th planet" to orbit our Sun.

The largest object found in our Solar System since Neptune in 1846, it was first seen in 2003 - but important details have only now been confirmed.

Designated 2003 UB313, it is about 2,800km across - a world of rock and ice and somewhat larger than Pluto.

Scientists say it is three times as far away as Pluto, in an orbit at an angle to the orbits of the main planets.

Astronomers think that at some point in its history, Neptune probably flung the small world into its highly inclined 44-degree orbit.

A comparison of 2003 UB313 and other distant objects

It is currently 97 Earth-Sun distances away - more than twice Pluto's average distance from the Sun.

Bigger than Pluto

Its discoverers are Michael Brown of Caltech, Chad Trujillo of the Gemini Observatory in Hawaii, and David Rabinowitz of Yale University.

SEE ALSO:

- Distant object found orbiting Sun 29 Jul 05 | Science/Nature
- 'New planet' forces rethink 17 Mar 04 | Science/Nature
- Astronomers discover 'new planet' 15 Mar 04 | Science/Nature
- New world found far beyond Pluto 03 Mar 04 | Science/Nature
- Huge rock-ice body circles Sun 17 Nov 03 | Science/Nature
- Large world found near Pluto 03 Jul 01 | Sci/Tech

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- Phantom Eye 'spy plane' unveiled
- Higgs discovery rumour is denied

News feeds

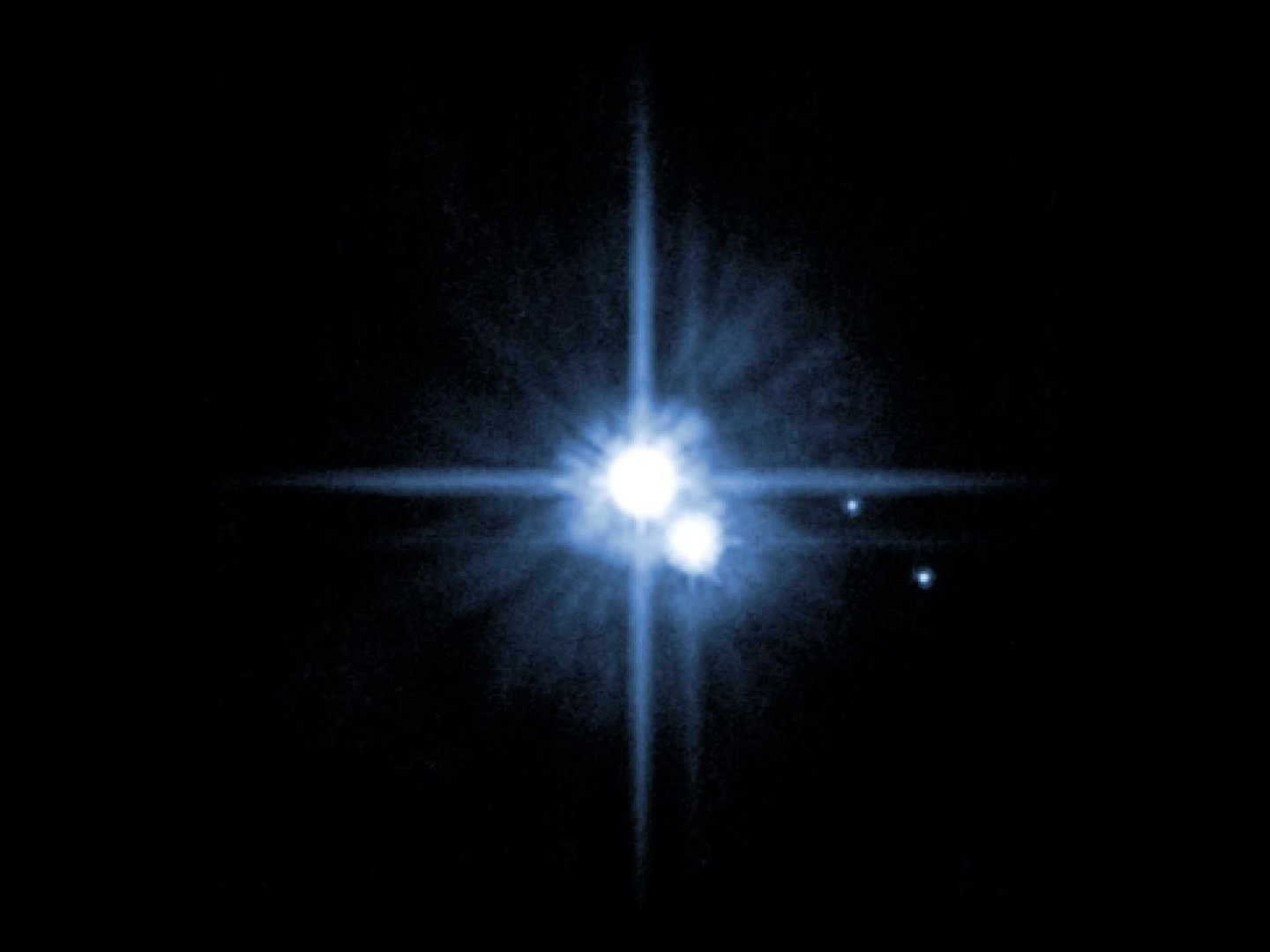


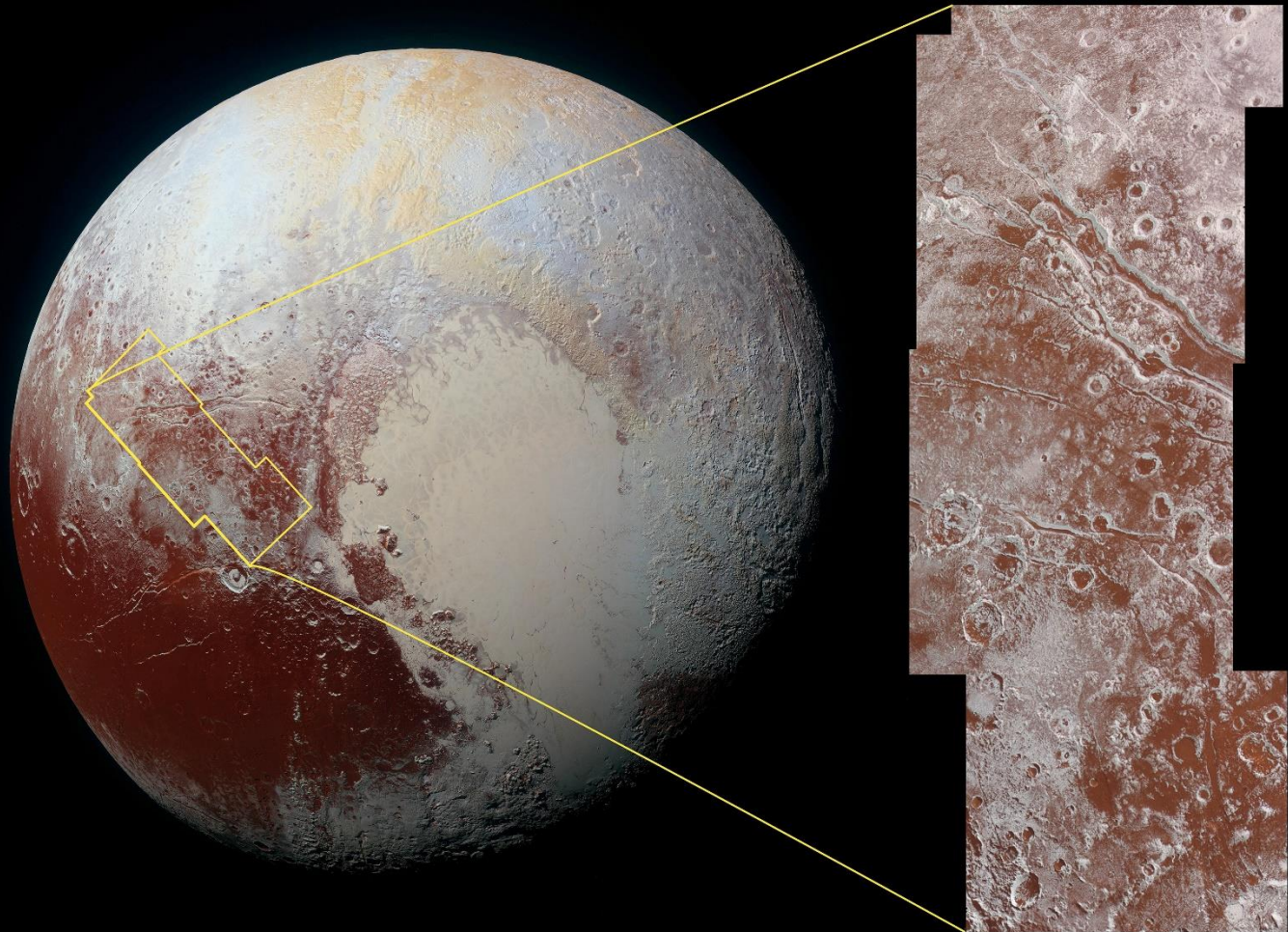
The new planet has a highly inclined orbit



The Demotion of Pluto

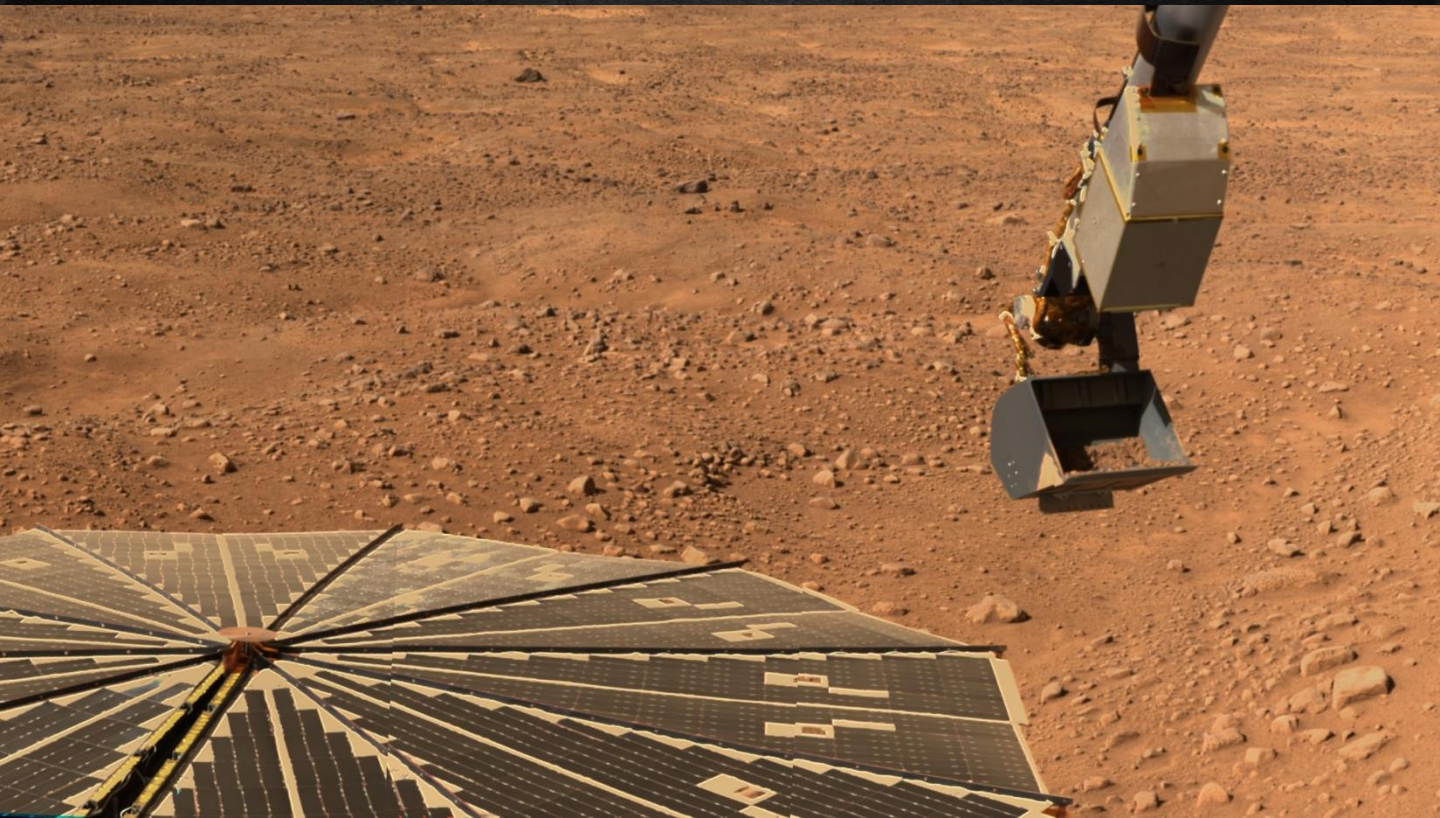






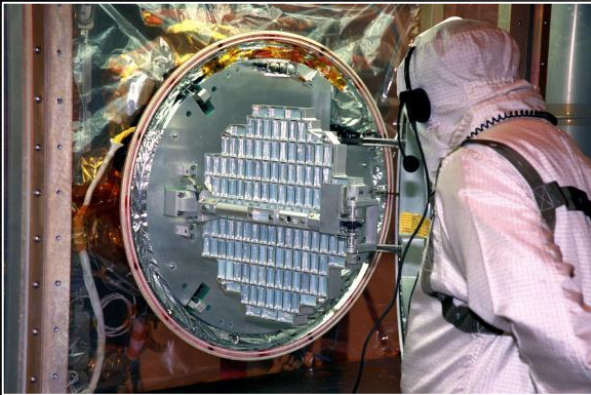


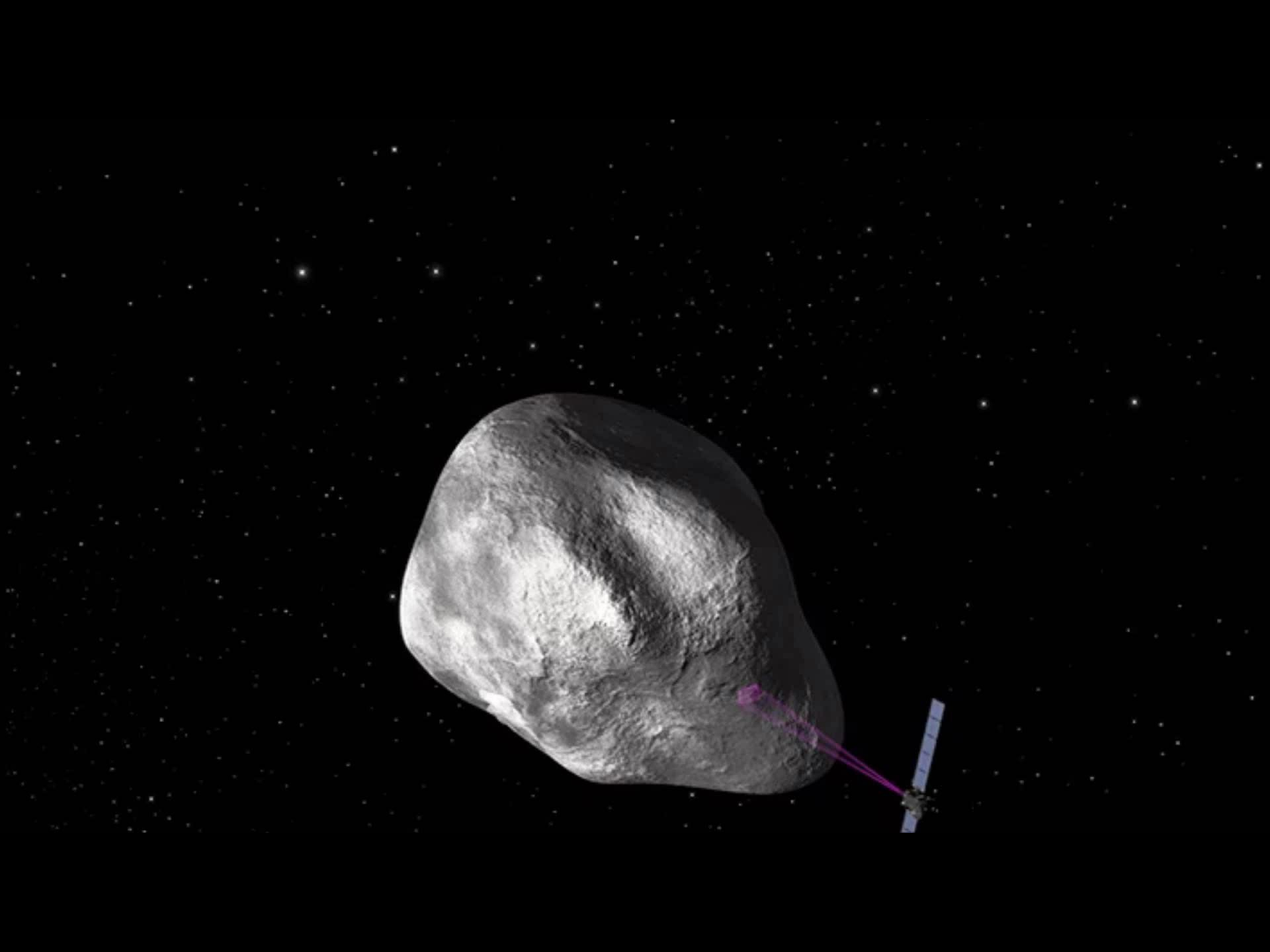
Water in the Solar System



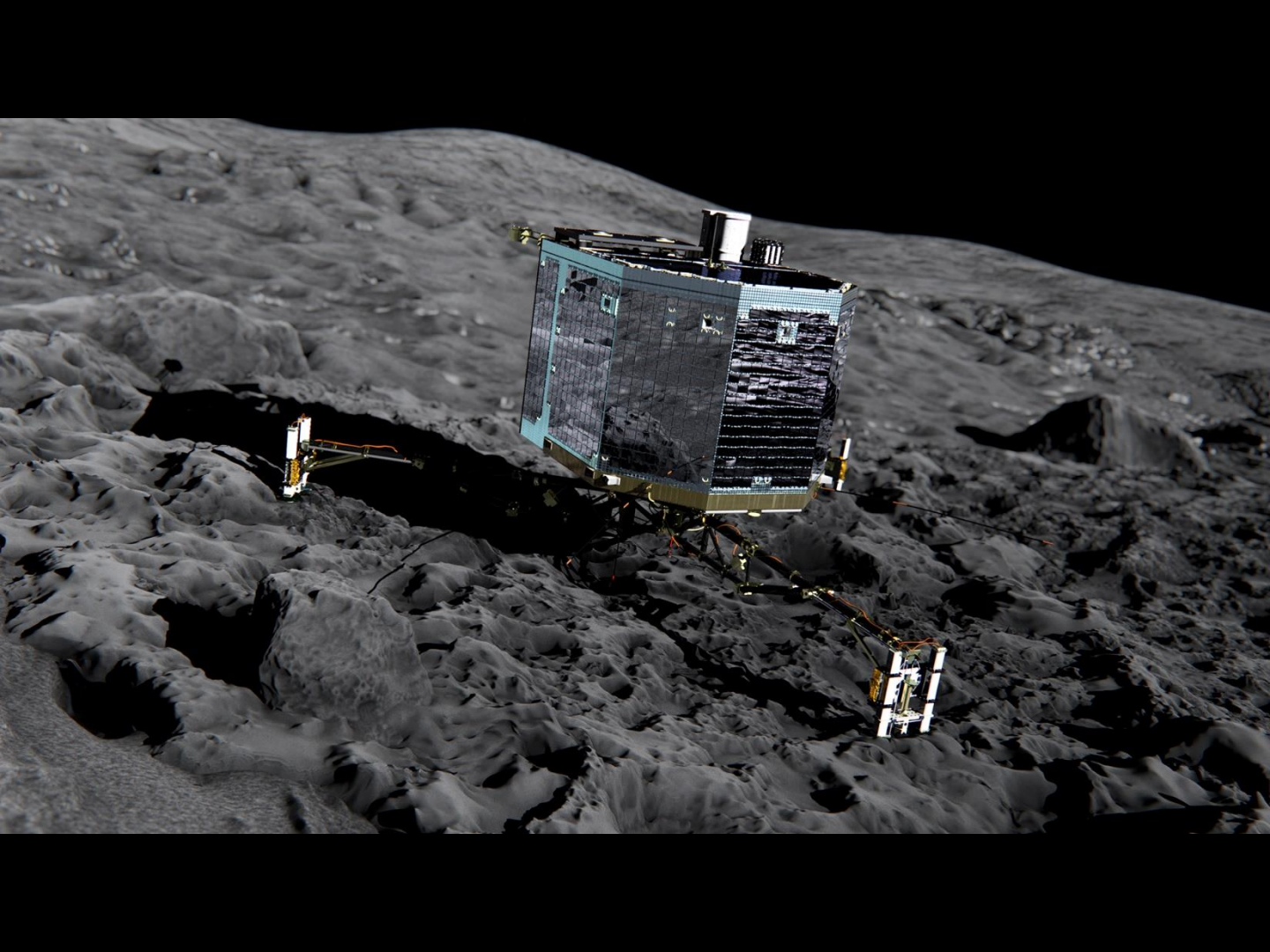
Comets

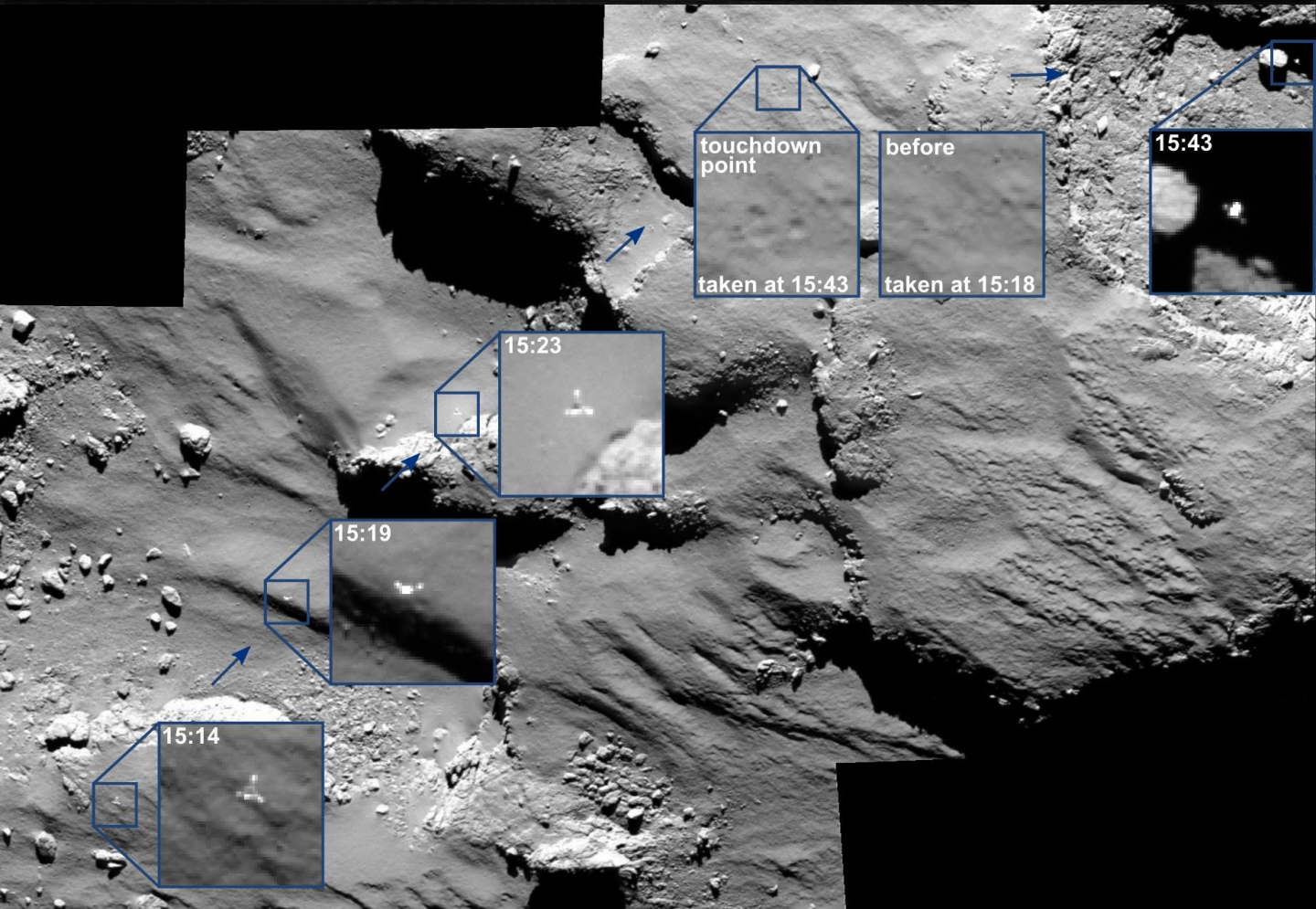
In 2004, the NASA
Stardust mission chased
after Comet Wild 2











touchdown
point

before

15:43

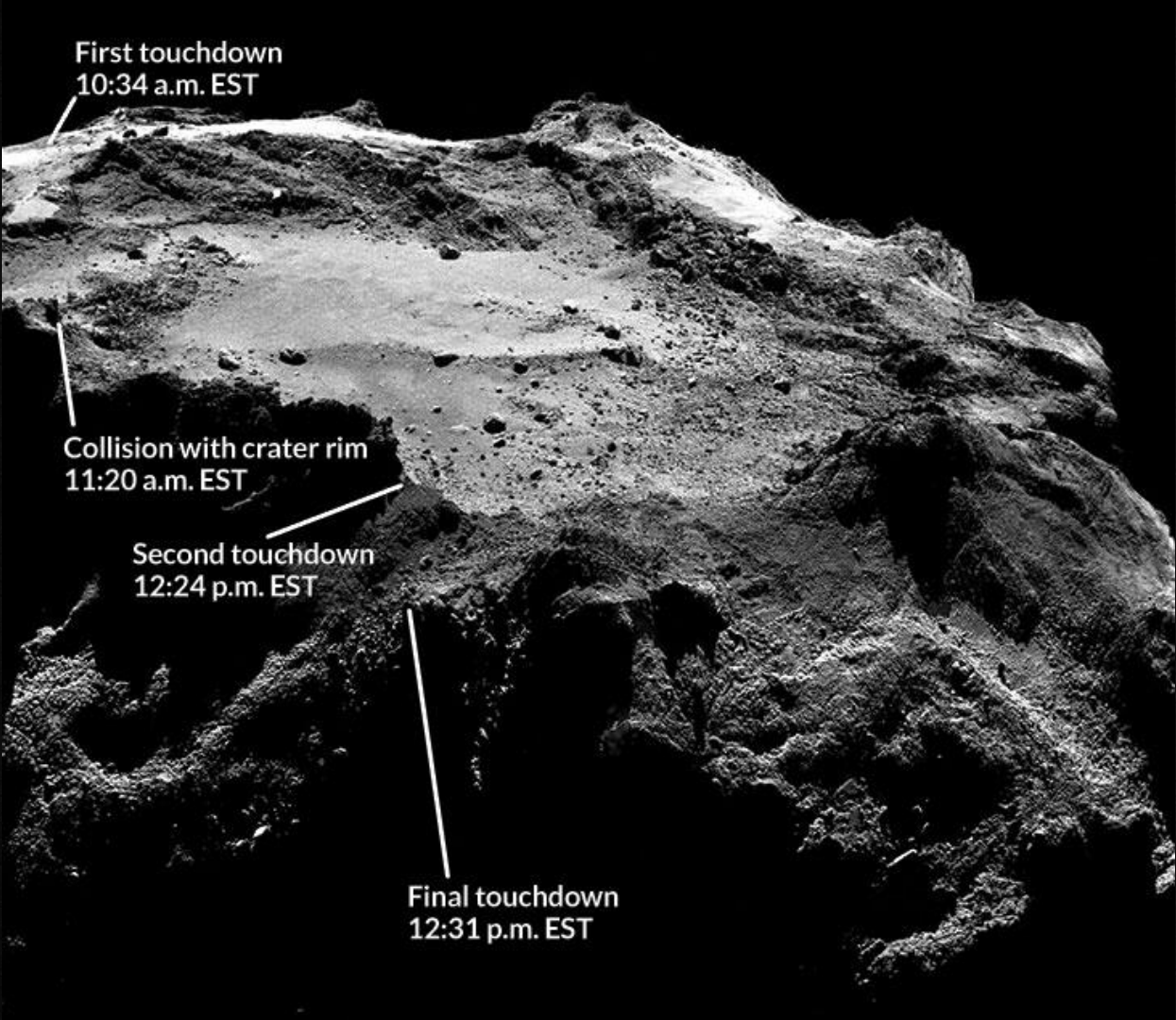
taken at 15:43

taken at 15:18

15:23

15:19

15:14



First touchdown
10:34 a.m. EST

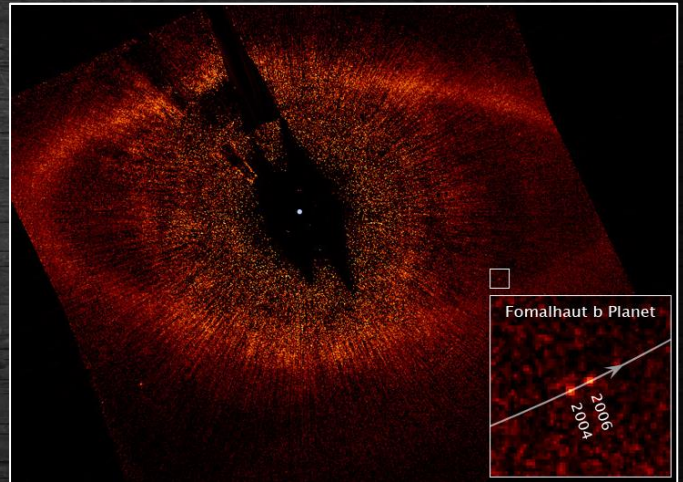
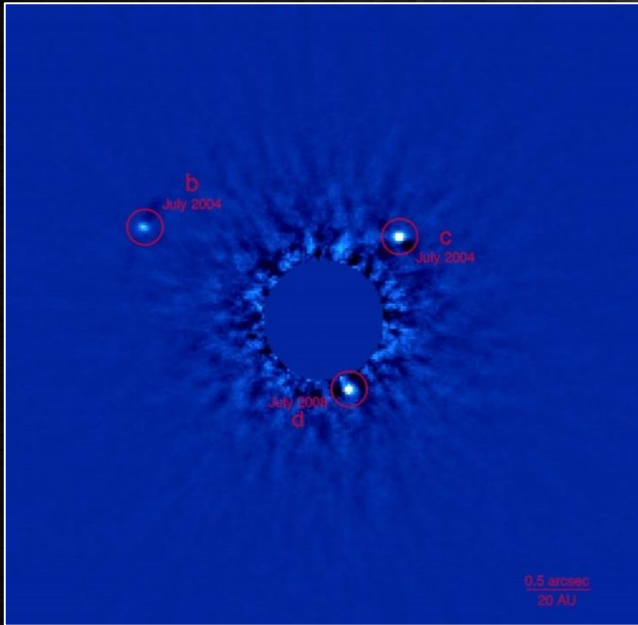
Collision with crater rim
11:20 a.m. EST

Second touchdown
12:24 p.m. EST

Final touchdown
12:31 p.m. EST



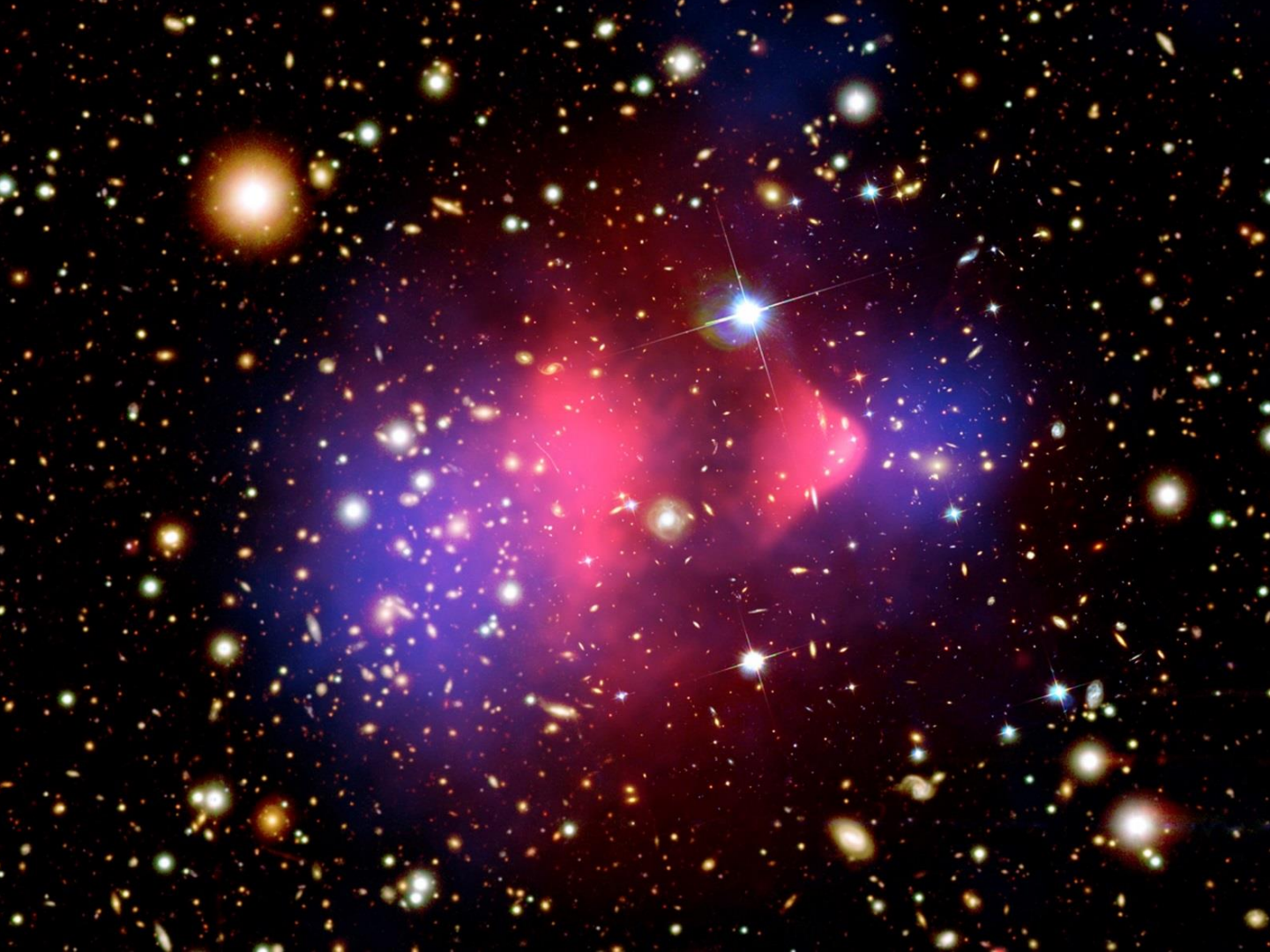
Discovery of Exoplanets



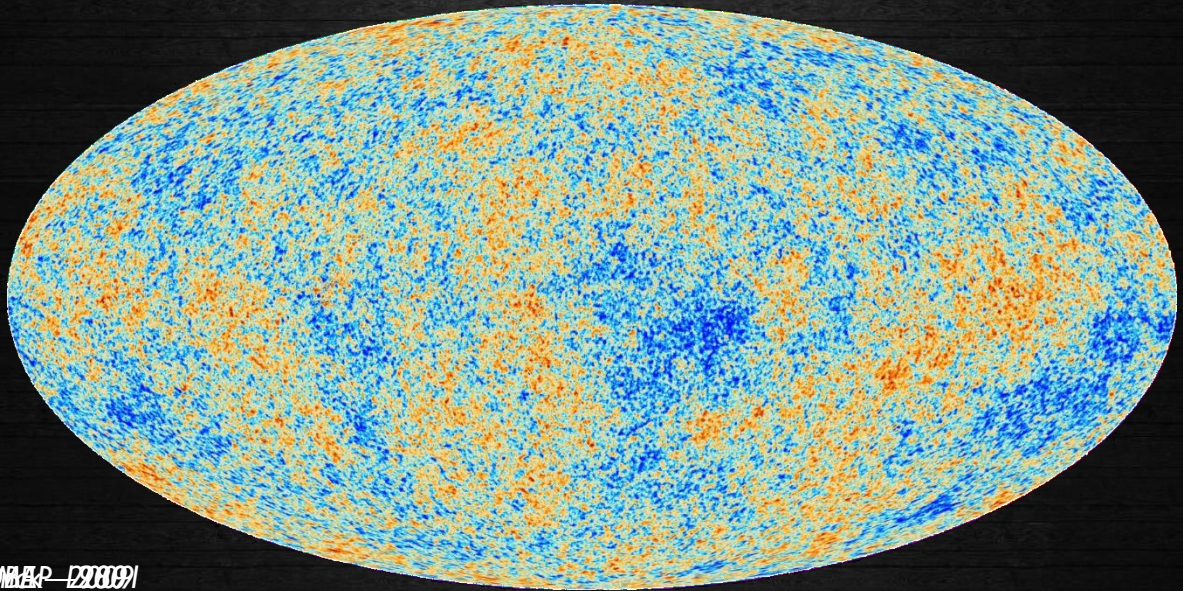
Dark Matter

- Up until 2006, we'd only seen the 'effects' of there being more mass
 - Galaxy Rotation Curves
 - Fluctuations in the Cosmic Microwave Background





The Big Bang

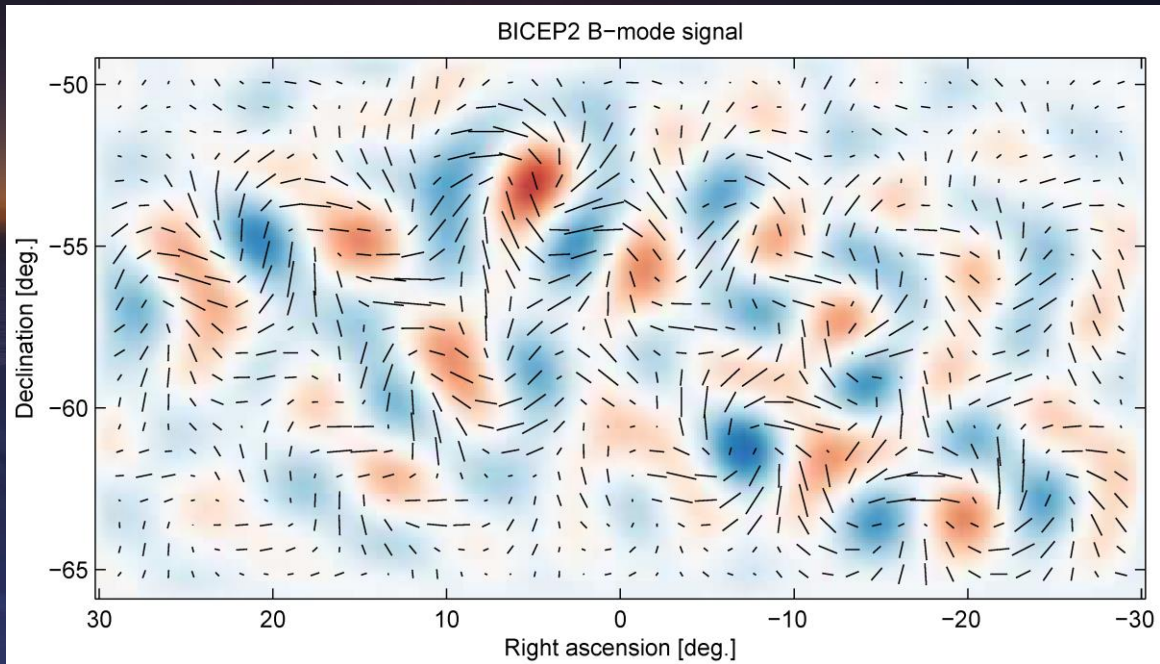


COINTEGRATED-12000091

The Big Bang

	Age of the Universe (Billion Years)	Hubble Constant ($\text{km s}^{-1} \text{Mpc}^{-1}$)	Baryons	Dark Matter	Dark Energy
WMAP	13.69	69.32	4.6%	24.0%	71.4%
Planck	13.82	67.3	4.9%	26.8%	68.3%

May Geometrically Gravitational Waves & Polarization



Maybe Gravitational Waves & Inflation

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Cosmic inflation: 'Spectacular' discovery hailed

By Jonathan Amos
Science correspondent, BBC News



STEPPEN RICHTER, HARVARD UNIVERSITY

The measurements were taken using the BICEP2 instrument at the South Pole telescope facility

Scientists say they have extraordinary new evidence to support a Big Bang Theory for the origin of the Universe.

Researchers believe they have found the signal left in the sky by the super-rapid expansion of space that must have occurred just fractions of a second after everything came into being.

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تجربي

Telescope captures view of gravitational waves


Images of the infant Universe reveal evidence for rapid inflation after the Big Bang.

Ron Cowen

17 March 2014

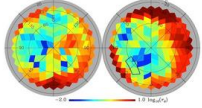
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The beginning of everything



Astronomers have peered back to nearly the dawn of time and found what seems to be the long-sought 'smoking gun' for the theory that the Universe underwent a spurt of wrenching, exponential growth called inflation during the first tiny fraction of a second of its existence.

Top Story




Full-galaxy dust map muddles search for gravitational waves

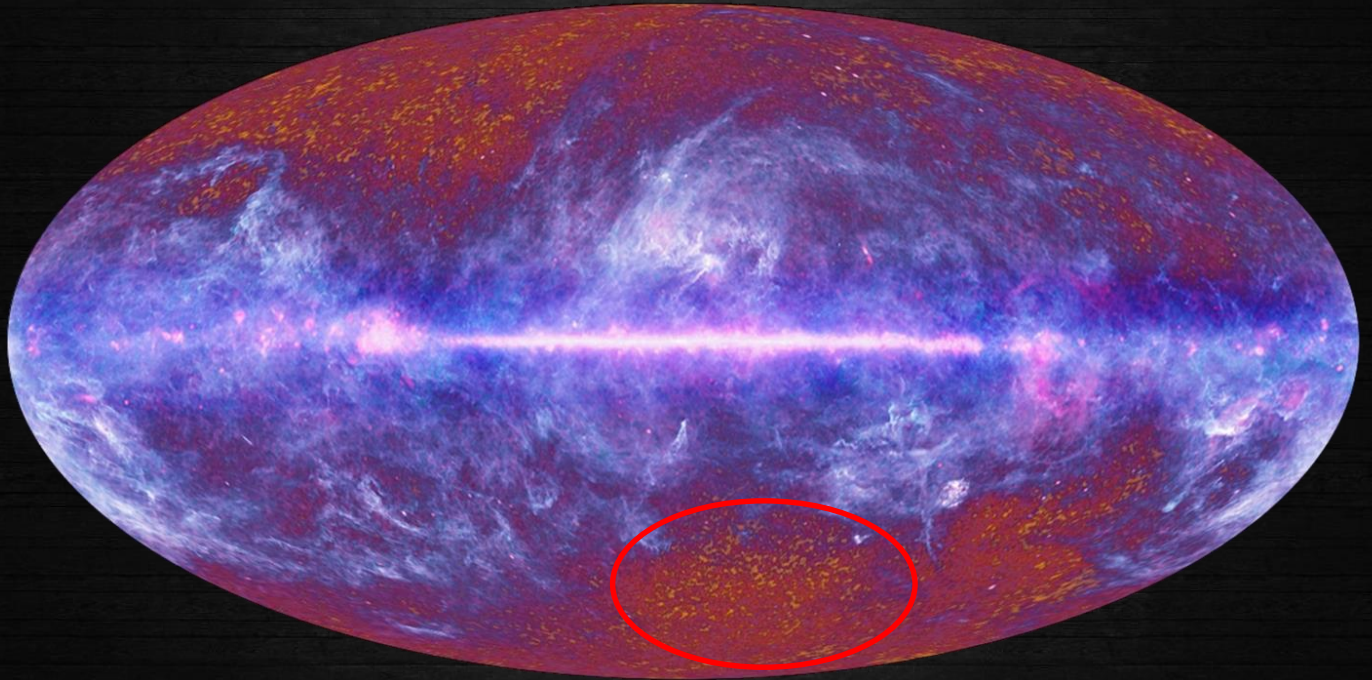
Planck probe's survey of polarized light casts further doubt on BICEP2 discovery claims and could complicate Planck's own plans.

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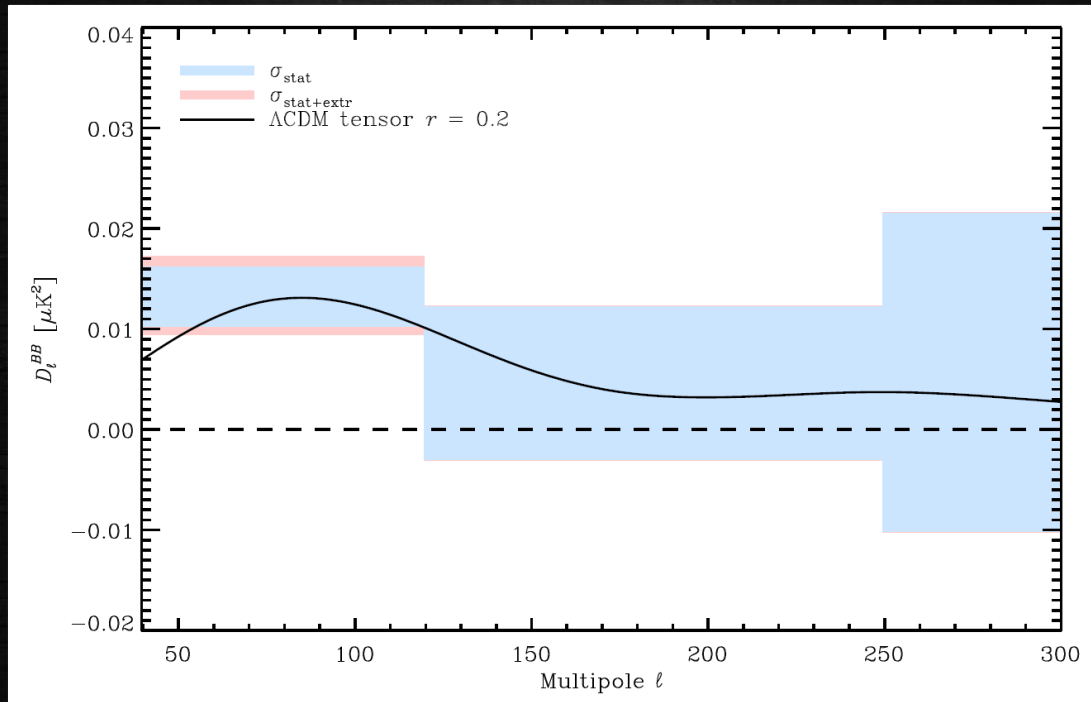
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4. UN climate summit scores high on passion <i>Nature</i> 25 September 2014			
5. Force of nature gave life its asymmetry <i>Nature</i> 25 September 2014			

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Maybe Gravitational Waves & Inflation



Maybe Gravitational Waves & Inflation





What we don't know

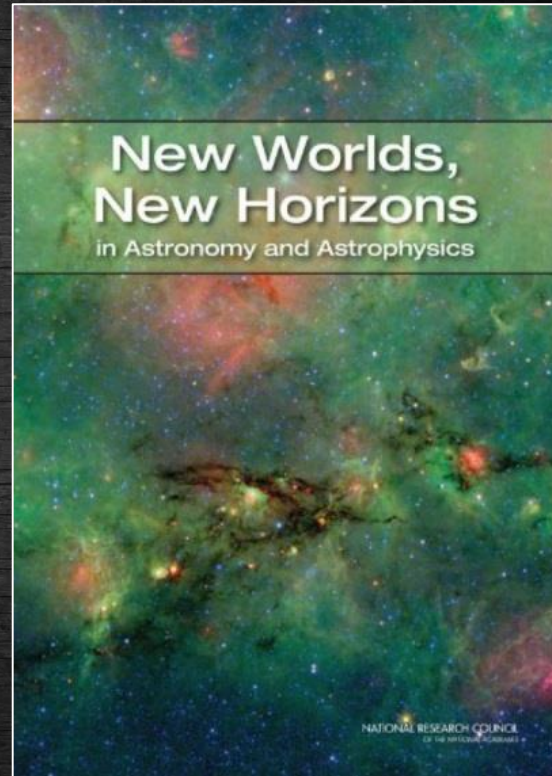
Decadal Surveys

- 1964: Ground-based Astronomy: A Ten Year Program
- 1972: Astronomy and Astrophysics for the 1970s
- 1982: Astronomy and Astrophysics for the 1980s
- 1991: The Decade of Discovery in Astronomy and Astrophysics
- 2001: Astronomy and Astrophysics in the New Millennium
- 2010: New Worlds, New Horizons in Astronomy & Astrophysics

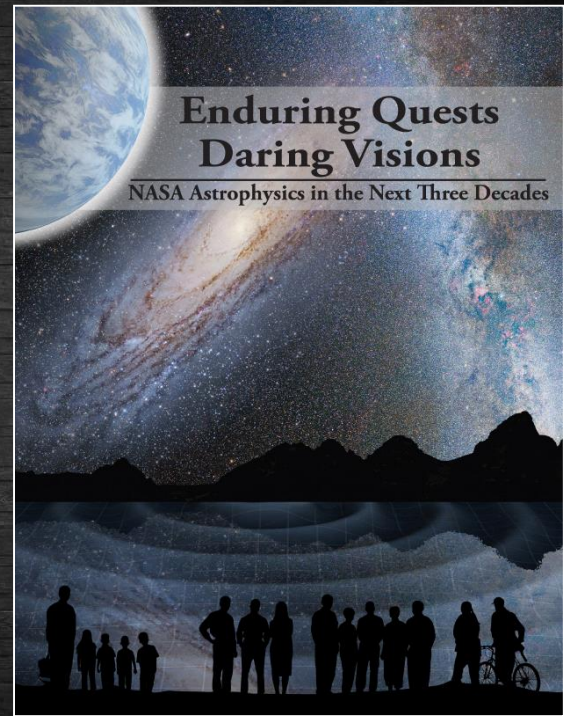
Decadal Surveys

2010:

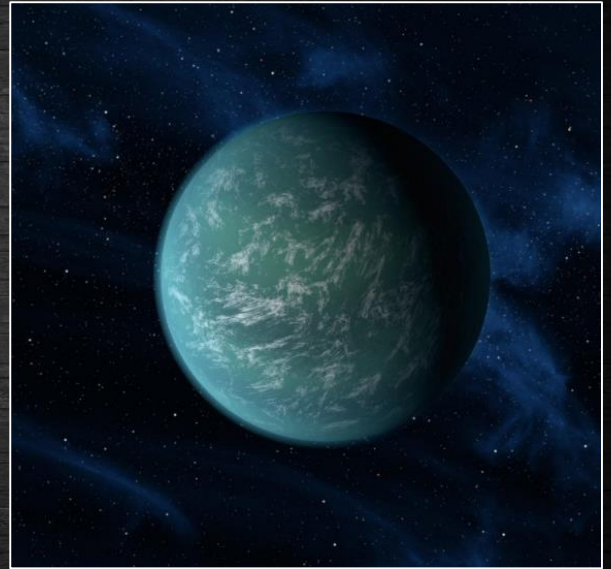
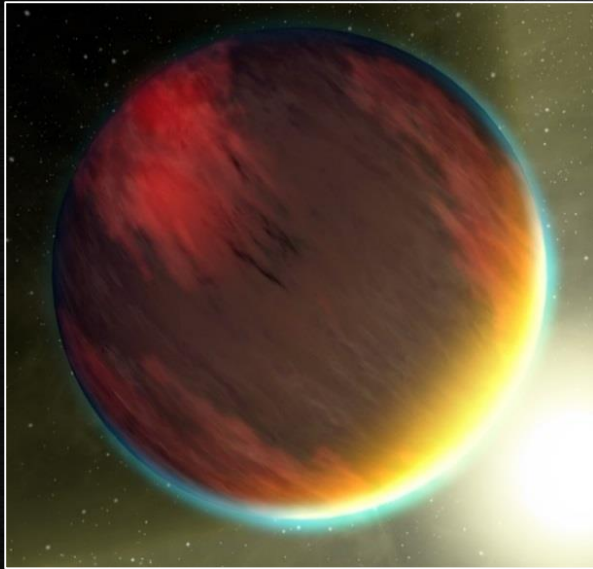
New Worlds, New
Horizons in Astronomy
and Astrophysics



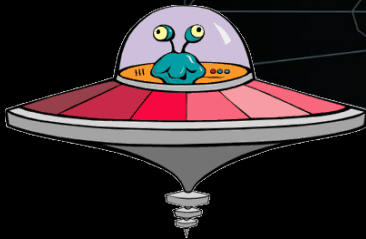
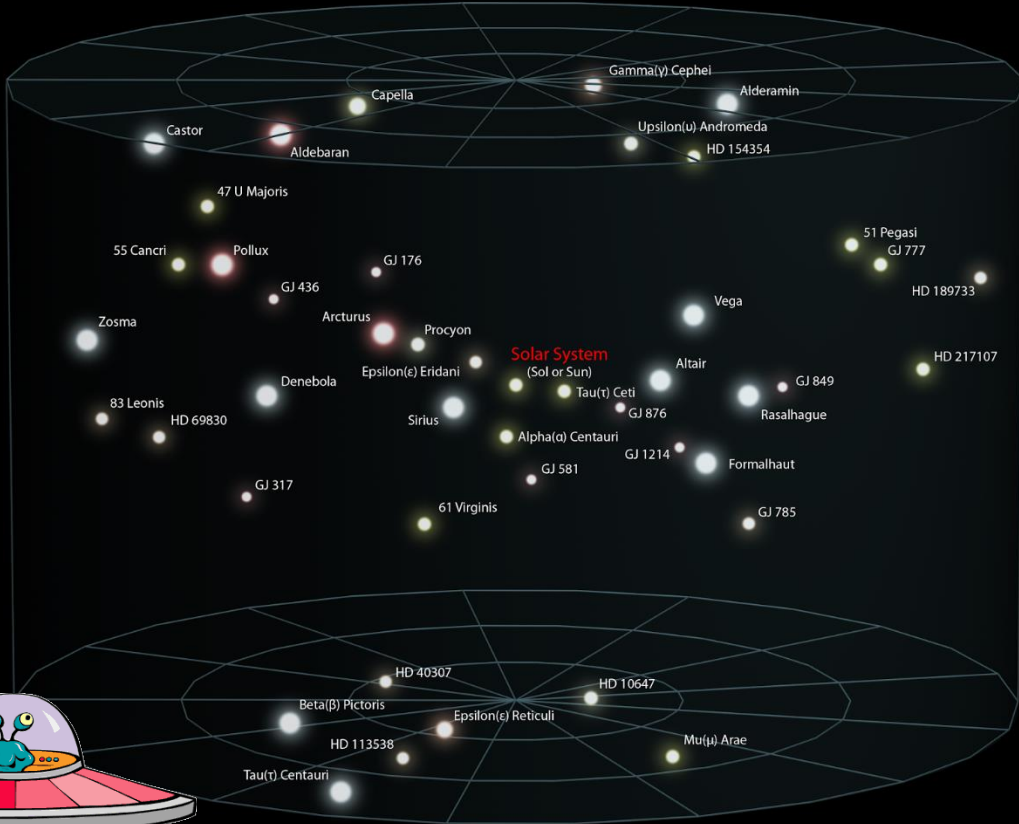
Other Roadmaps



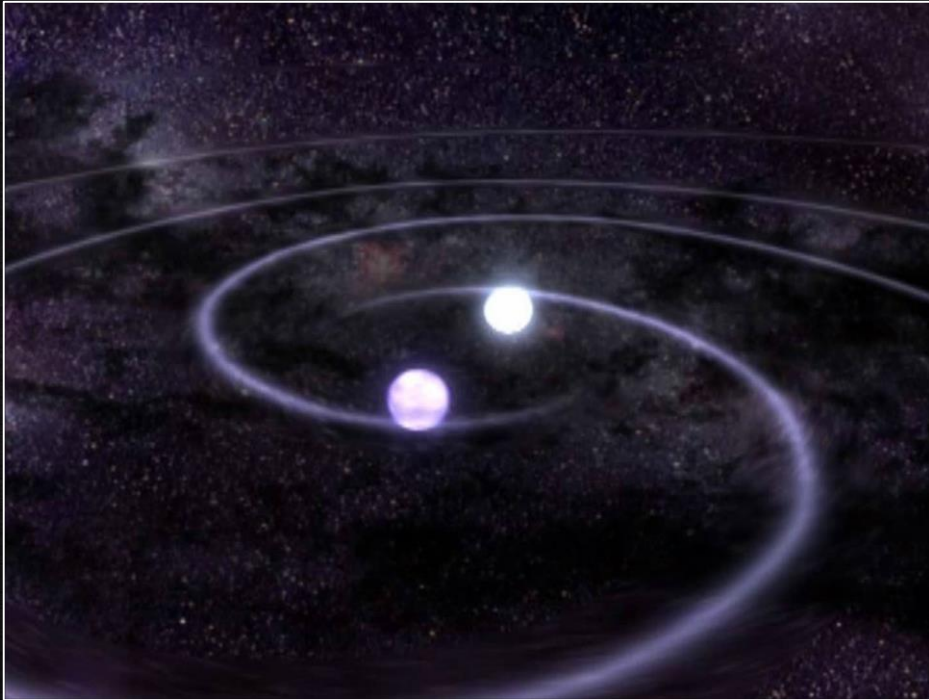
Identification and characterization of nearby habitable exoplanets



Solar Interstellar Neighborhood



Gravitational Wave Astronomy



Time-domain astronomy

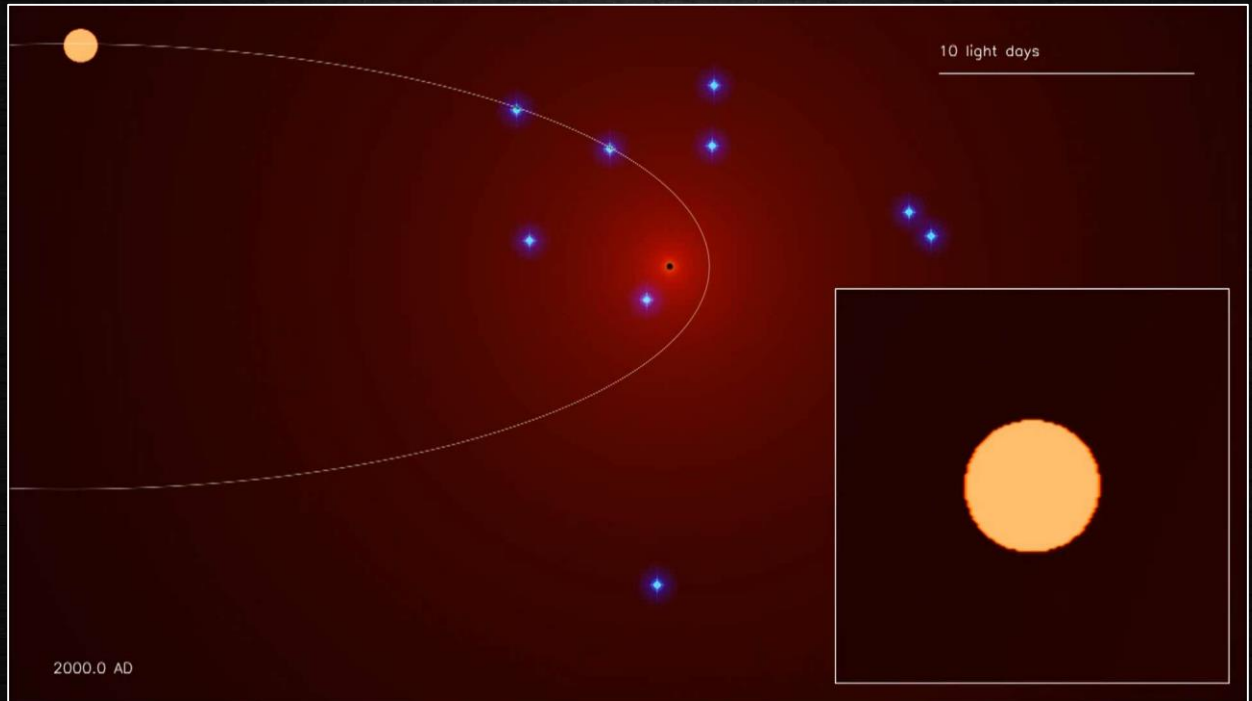


www.spacetelescope.org

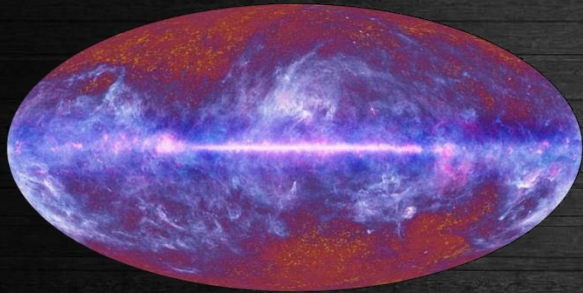
Astrometry

“Astrometry is the branch of astronomy that involves precise measurements of the positions and movements of stars and other celestial bodies.”

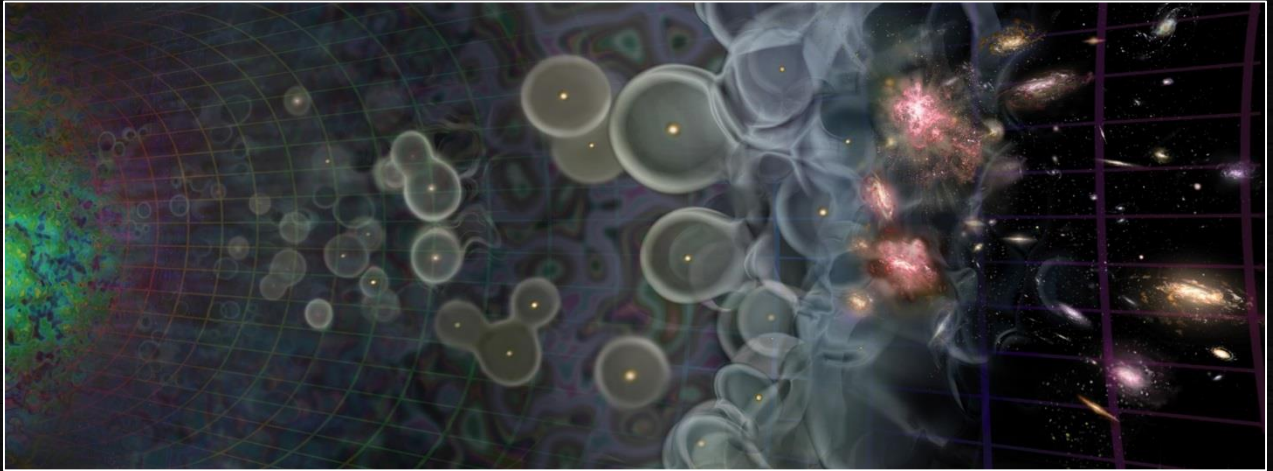
Astrometry



The epoch of reionization



The epoch of reionization



What does

DARK

mean?

The BIG Questions

- Are we alone?
 - Exoplanets
 - The search for life
- How did we get here?
 - Stars and the elements
 - Galaxies and their history
- How does our Universe work?
 - The extremes of nature



Tools for the Next Decade

Future Missions

Space Based Missions

- GAIA – Launched 2013
- LISA Pathfinder – Launched 2015
- James Webb Space Telescope (JWST) – Launches 2018
- JUNO – Jupiter – Arrives 2016
- Juice – Jupiter – Launches 2022
- New Horizons –Kuiper Belt – January 2019
- Dawn Mission – Vesta & Ceres – Arrived 2015
- InSight Lander – Mars – Launches 2016
- ExoMars – Astrobiology mission – Orbiter, stationary lander (2016 launch) and Rover (2018)
- Mars Exploration Program: 2020 Mission
- Europa Flyby Mission – 2020s
- OSIRIS-Rex – Sample from asteroid - 101955 Bennu – Launches 2016
- Solar Probe Plus – Launches 2018
- ESA Solar Orbiter – Launches 2017
- ESA BepiColombo – Mercury – Launches 2017
- ESA Euclid – Map geometry of dark universe – Launch 2020

- ESA CHEOPS – Exoplanets – Launches 2017
- Transiting Exoplanet Survey Satellite (TESS) – Launches 2017
- Athena launch - 2028

Ground Based Missions

- Upgrades to existing telescopes - Ongoing
- ALMA – From 2014
- Square Kilometer Array (SKA) – From 2019
- Extremely Large Telescopes – 2020s
 - European Extremely Large Telescope (E-ELT)
 - Thirty Meter Telescope
 - Giant Magellan Telescope



Beyond 2026

Beyond 2026

- Science missions take many years to plan, specify and develop the collaborations between scientists
- There is still however always one important factor...



Beyond 2026

- Many missions have been suggested but two were recently selected:
 - The Advanced Telescope for High-energy Astrophysics (Athena+)
 - Laser Interferometer Space Antenna (LISA)
- Also, 2016 is the year where NASA starts work on projects after the James Webb Space Telescope

“There are known knowns. These are things we know that we know. There are known unknowns. That is to say, there are things that we know we don't know. But there are also unknown unknowns. There are things we don't know we don't know.”

Donald Rumsfeld