Looking at the universe through very different 'eyes'

January 22 2018, by Michael J. I. Brown

The Small Magellanic Cloud galaxy here seen in infrared light, but it looks different when viewed at other wavelengths. Credit: ESA/NASA/JPL-Caltech/STScI

We are bathed in starlight. During the day we see the Sun, light reflected off the surface of the Earth and blue sunlight scattered by the air. At night we see the stars, as well as sunlight reflected off the Moon and the planets.

But there are more ways of seeing the universe. Beyond visible light

there are gamma rays, X-rays, ultraviolet light, infrared light, and radio waves. They provide us with new ways of appreciating the universe.

X-ray Moon

Have you looked at the Moon during the daytime? You will see part of the Moon bathed in sunlight and the Earth's blue sky in front of the Moon.

Now put on your X-ray specs, courtesy of the ROSAT satellite, and you will see something intriguing.

The Sun emits X-rays, so you can see the daytime side of the Moon easily enough. But the night time side of the Moon is silhouetted against the X-ray sky. The X-ray sky is *behind* the Moon!

Just what is the X-ray sky? Well, X-rays are more energetic than visible light photons, so X-rays often come from the hottest and most violent celestial objects. Much of the X-ray sky is produced by active galactic nuclei, which are powered by matter falling towards black holes.

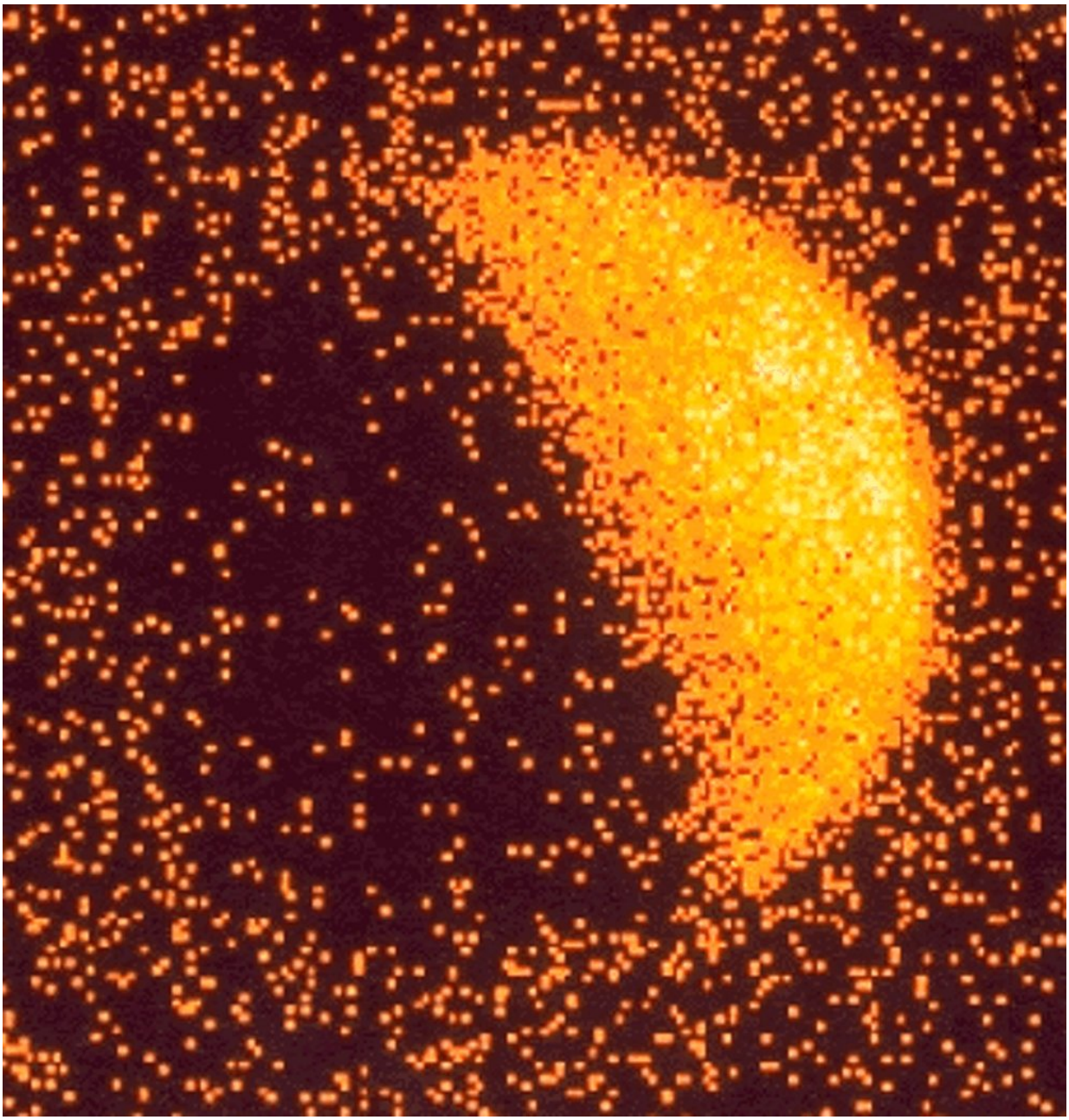
In X-rays, the Moon is silhouetted against many millions of celestial sources, powered by black holes, scattered across billions of light years of space.

Radio skies

If you're in the southern sky and away from light pollution (including the Moon), then you can see the Small Magellanic Cloud. This is a companion galaxy to our own Milky Way. With the unaided eye it looks like a diffuse cloud, but what we are actually seeing is the combined light of millions of distant stars.

Radio waves provide a very different view of the Small Magellanic Cloud. Using the Australian Square Kilometre Array Pathfinder, tuned to 1,420.4MHz, we no longer see stars but instead see atomic hydrogen gas.

The hydrogen gas is cold enough that the atoms hang onto their electrons (unlike ionised hydrogen). It can also cool further and collapse (under the force of gravity) to produce clouds of molecular hydrogen gas and eventually new stars.



The Moon seen in X-rays by ROSAT. The night side of the Moon is silhouetted against the X-ray background. Credit: DARA, ESA, MPE, NASA, J.H.M.M. Schmitt

Radio waves thus allow us to see the fuel for star formation, and the

Small Magellanic Cloud is indeed producing new stars right now.

Feeling the heat in the microwave

If the universe were infinitely large and infinitely old, then presumably every direction would eventually lead the surface of a star. This would lead to a rather bright night sky. The German astronomer Heinrich Olbers, among others, recognised this "paradox" centuries ago.

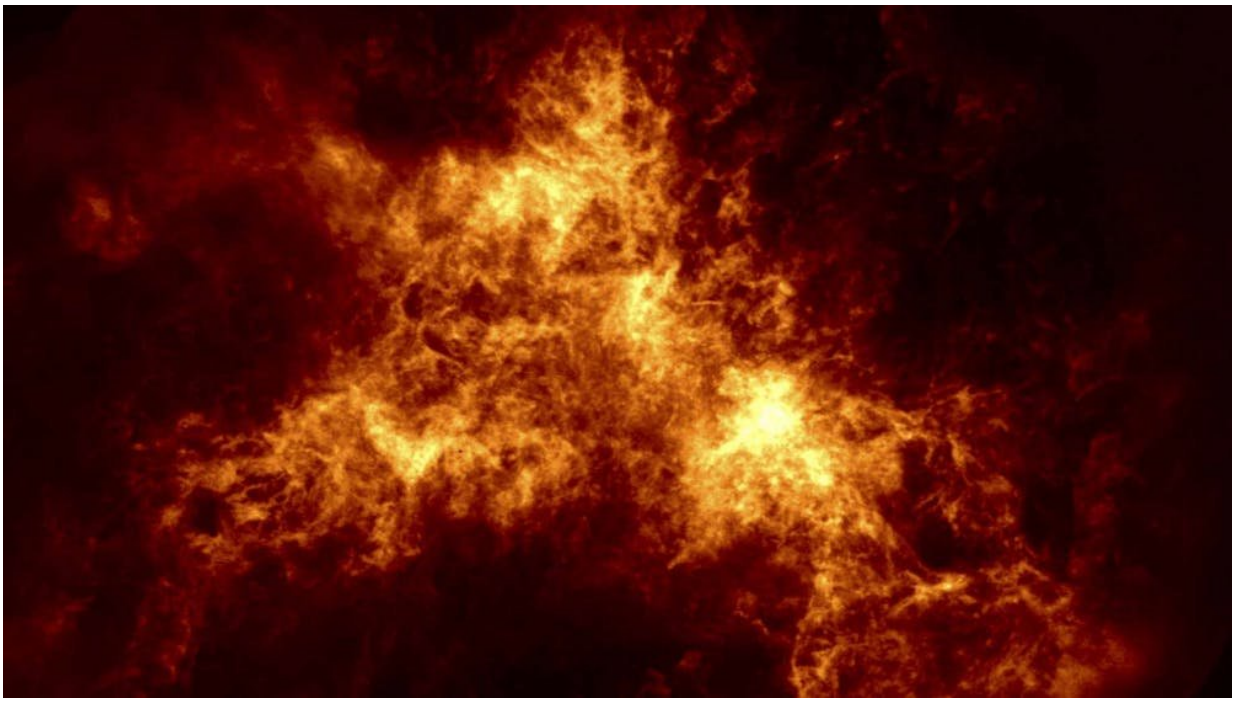
When we look up at the night sky, we can see the stars, planets and Milky Way. But most of the night sky is black, and this tells us something important.

Visible light images of the Small Magellanic Cloud are dominated by starlight. Credit: ESA/Hubble and Digitized Sky Survey/Davide De Martin

But lets take a look at the universe in microwave light. The Planck satellite reveals glowing gas and dust in the Milky Way. Beyond that, in every direction, there is light! Where does it come from?

At microwave wavelengths we can observe the afterglow of the Big Bang . This afterglow was produced 380,000 years after the Big Bang, when the universe had a temperature of roughly 2,700°C.

But the afterglow we see now doesn't look like a 2,700°C ball of gas. Instead, we see a glow equivalent to -270°C. Why? Because we live in an expanding universe. The light we observe now from the Big Bang's afterglow has been stretched from visible light into lower-energy microwave light, resulting in the colder observed temperature.



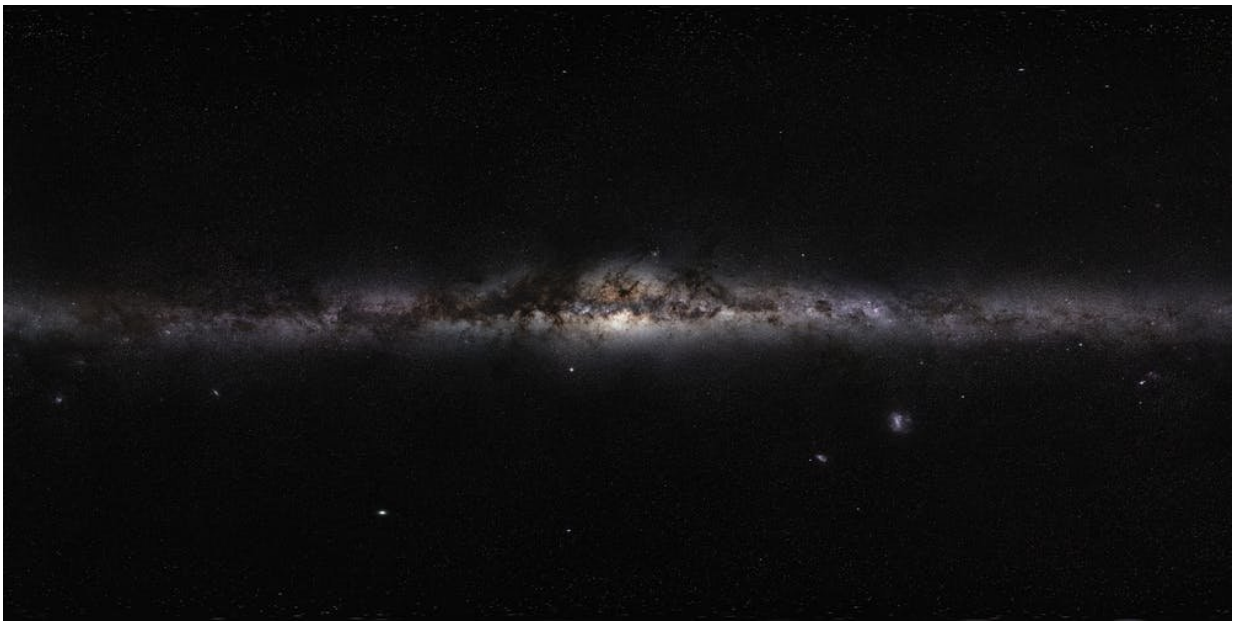
Radio waves can trace the hydrogen gas in the Small Magellanic Cloud. Credit: ANU and CSIRO

Planetary radio

Jupiter is one of the most rewarding planets to observe with a small telescope – you can see the cloud bands stretching across the giant planet. Even binoculars can reveal the four moons discovered by Galileo centuries ago.

But you get a less familiar view of Jupiter when you switch to radio waves. A radio telescope reveals the dull warm glow of the planet itself. But what really stands out are radio waves coming from *above* the planet.

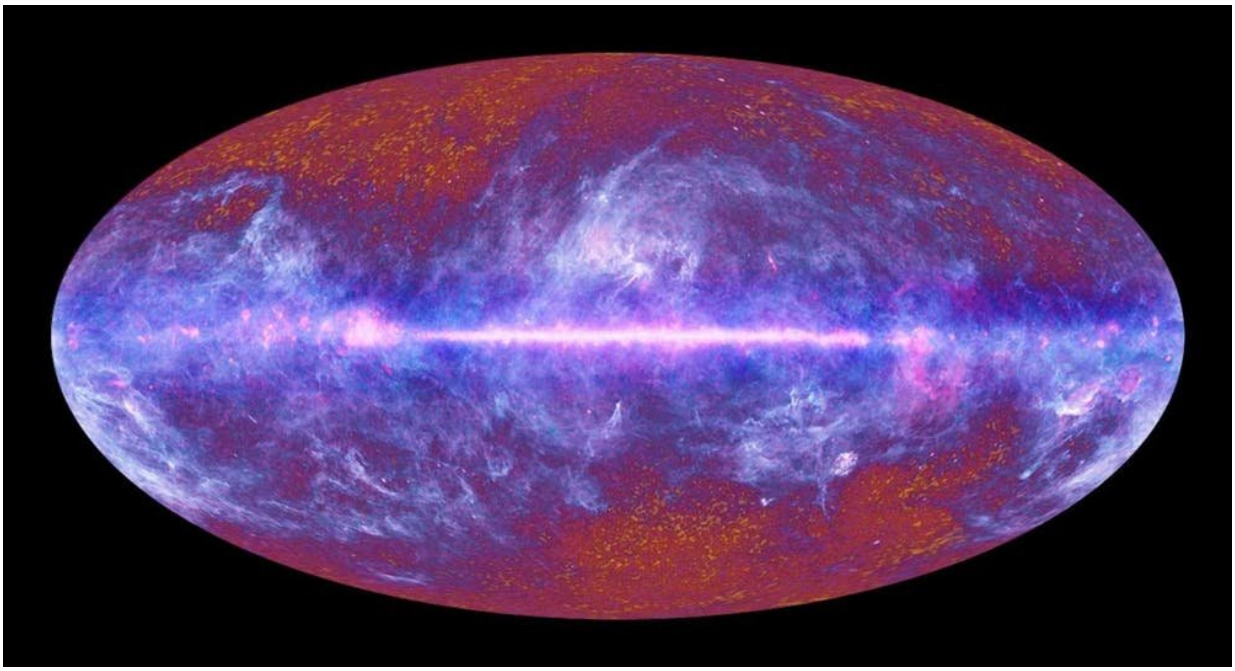
Much of the radio emission from Jupiter is produced by synchrotron and cyclotron radiation, which results from speeding electrons spiralling in a magnetic field.



A visible light image of the entire night sky is dominated by starlight from the Milky Way. ESO/S. Brunier, CC BY

On Earth we use particle accelerators to produce such radiation. But in Jupiter's powerful magnetic field it occurs naturally (and copiously).

The synchrotron produced by Jupiter is so powerful that you can detect it on Earth – not just with multimillion-dollar radio telescopes, but with equipment that can be bought for several hundred dollars. You don't need to be a professional astronomer to expand your view of the universe beyond visible light.



The microwave sky is glowing in every direction. Credit: ESA, HFI & LFI consortia

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