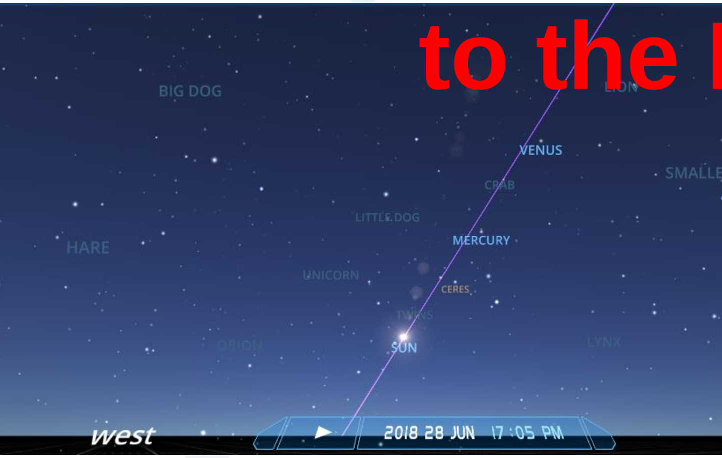
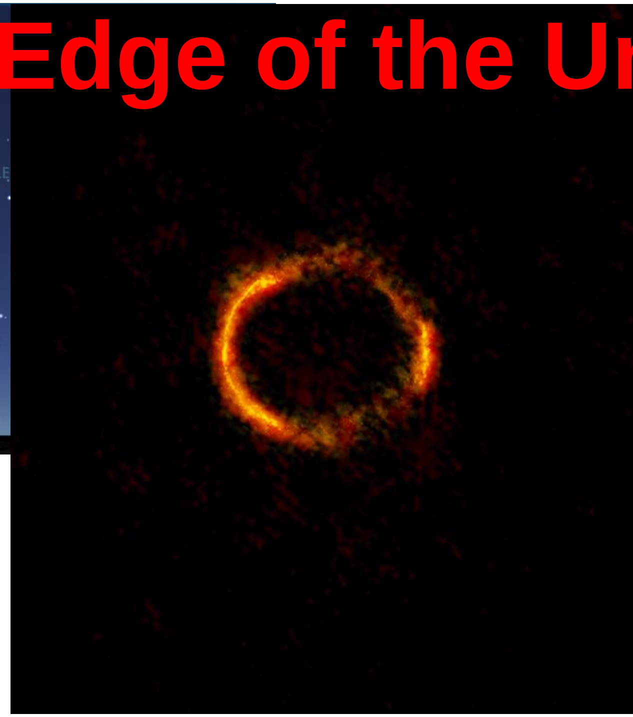
An Astrophysics Journey from the Kalahari to the Edge of the Universe





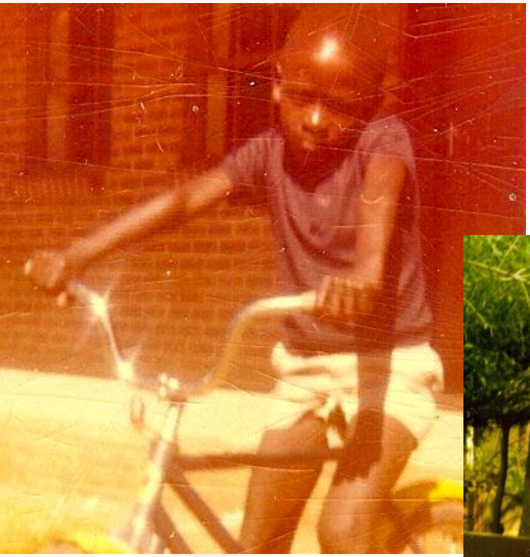
talk by Lerothodi Lapula Leeuw
of the University of South Africa

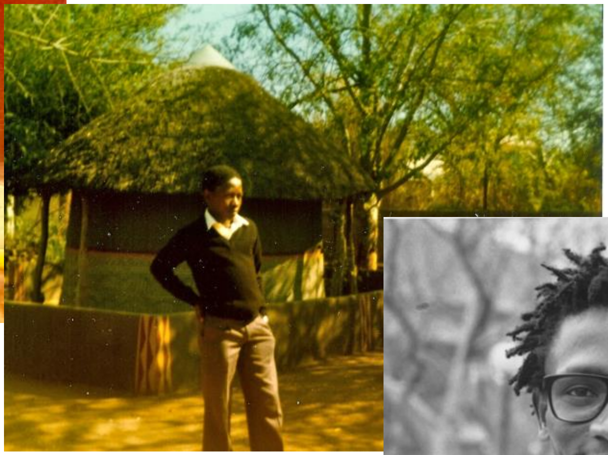
African Conference of Physics 2018 in Namibia

Itinerary of the Journey

- The Journey’s Beginning
- Our Place in the Solar System
- Selected Nearby Submm-bright Galaxies
- Selected Distant Submm-bright Galaxies in Gravitationally Lensed and Un-lensed Systems
- ACP 2018

From the Kalahari to MIT





Journey into Astrophysics

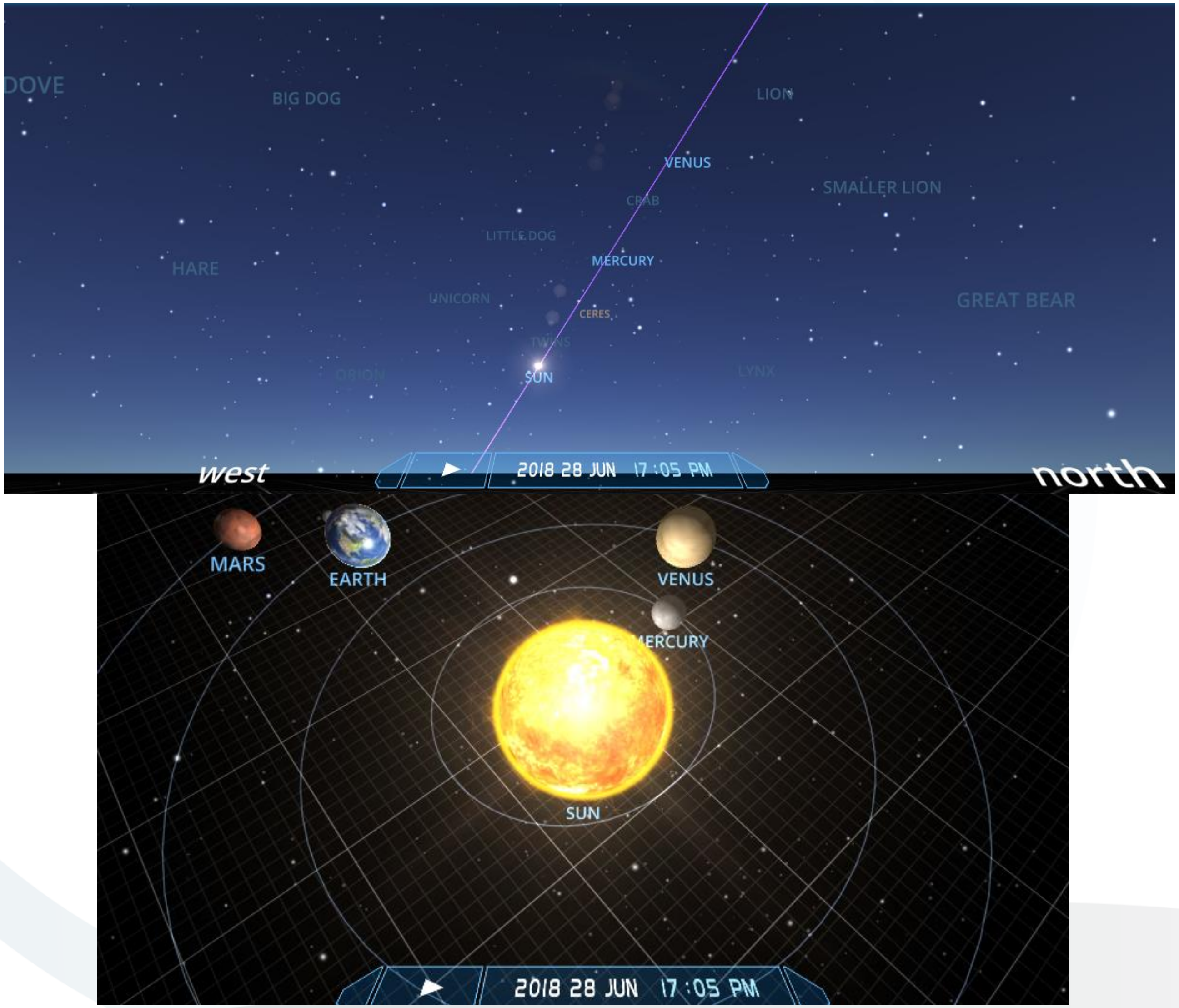
- Venus, the morning star
- Occultation of Saturn’s Rings and Cataclysmic Variables
- Mira Variables
- Active Submm-bright Galaxies
- Selected Distant Submm-bright Galaxies in Gravitationally Lensed and Un-lensed Systems
- Astroparticle Physics Forum

Why planets and the solar system

- Planets easily observable by eye to all
- They follow deep physical laws of Newton, Kepler, ...
- Their orbital plan and tracks linked to the formation of the solar system, including earth
- Their study has been at the centre of major human imagination and scientific exploration over time
- In the submm wavebands, selected planets are primary flux calibrators

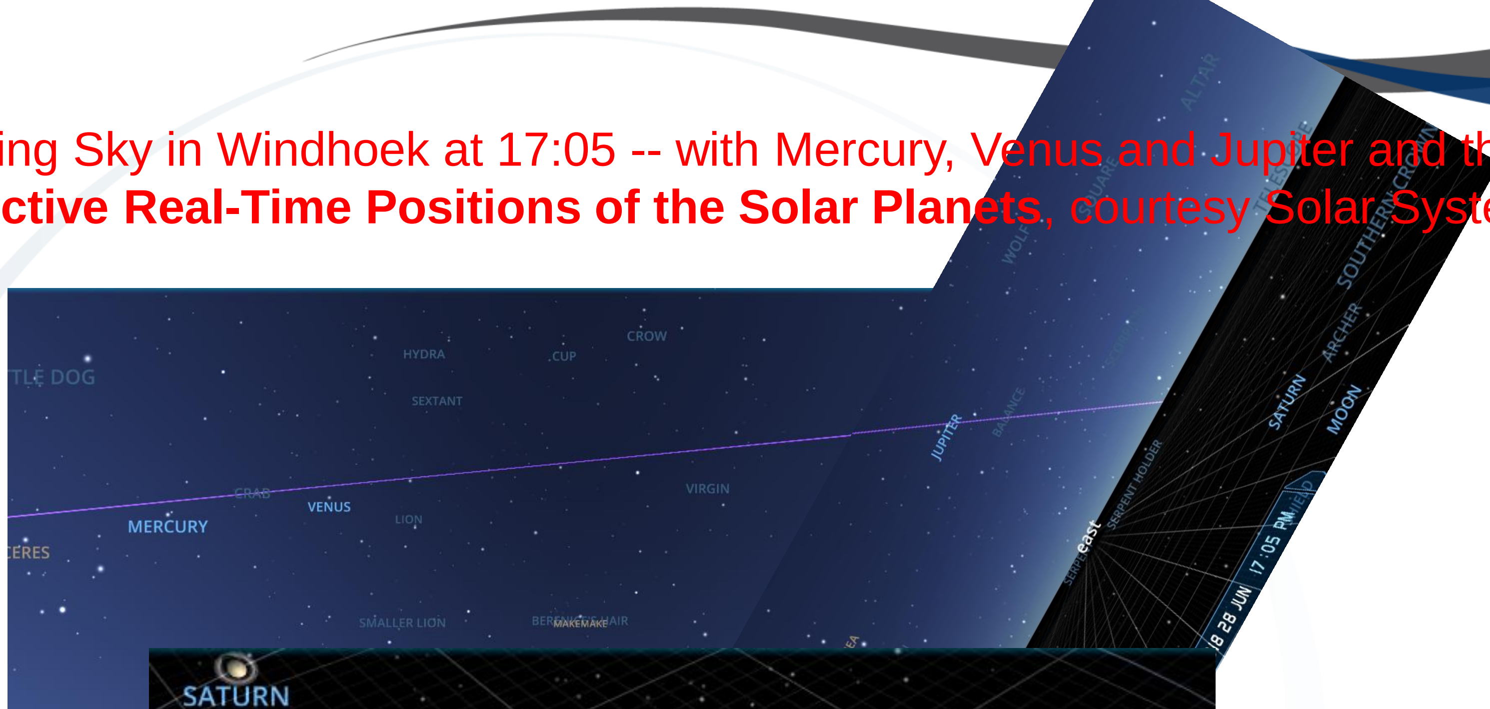
Early Evening Sky in Windhoek Now at 17:05 -- with Mercury and Venus, near the Sun, courtesy Solar System Scope

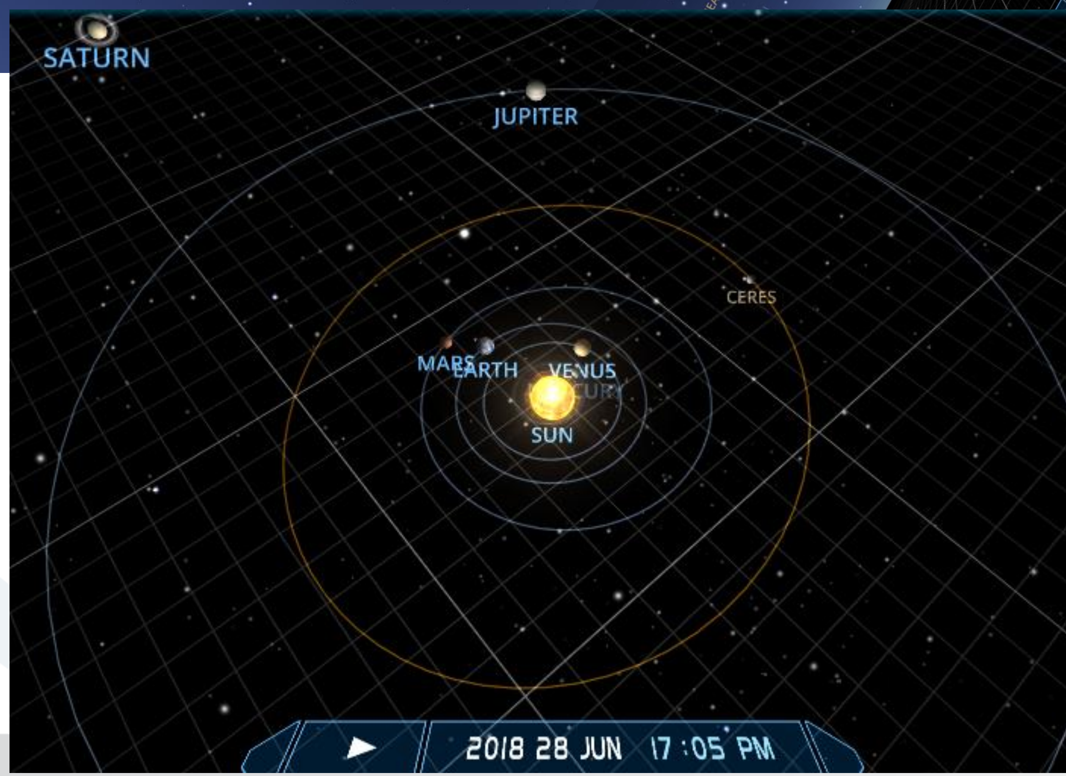
Top: Early Evening Sky in Windhoek Now at 17:05 -- with Mercury and Venus, near the Sun; and **Bottom: Respective Real-Time Positions of the Solar Planets**, courtesy Solar System Scope



Top: Early Evening Sky in Windhoek at 17:05 -- with Mercury, Venus and Jupiter and the Ecliptic

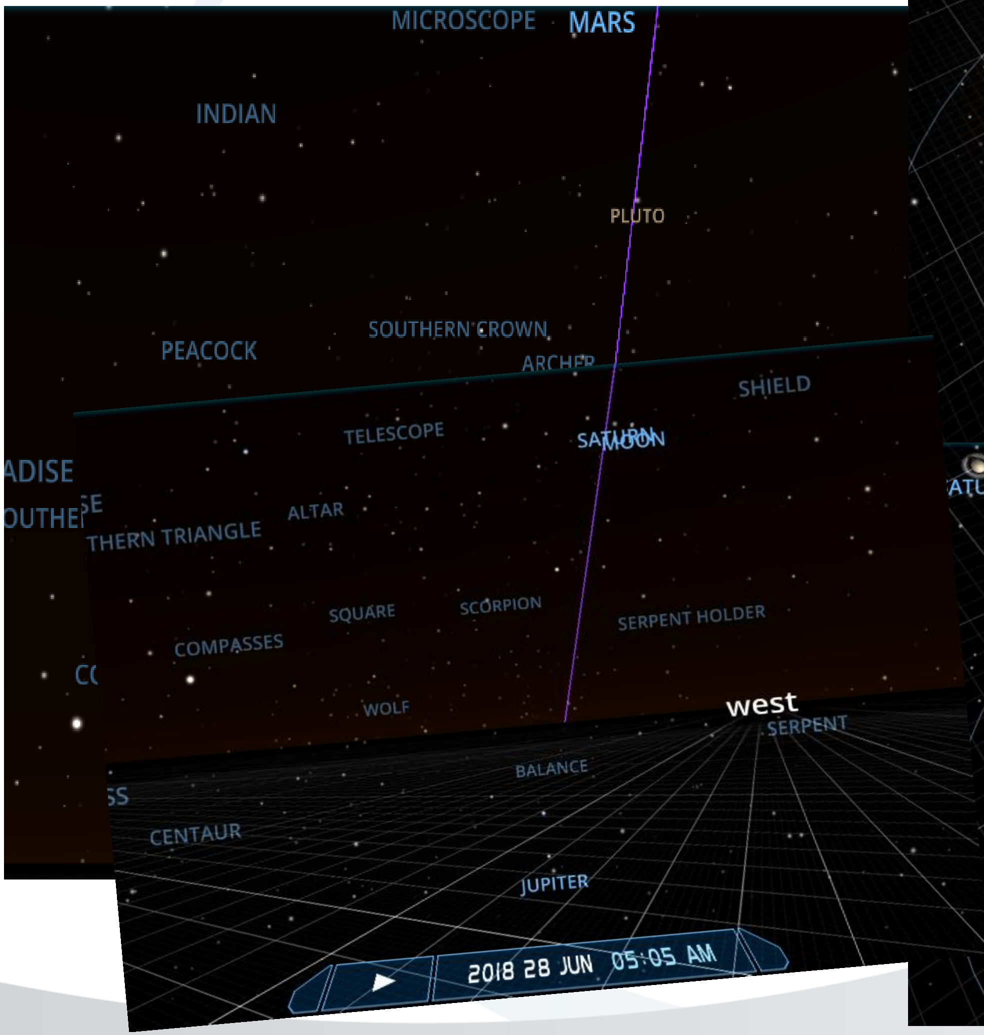
Bottom: Respective Real-Time Positions of the Solar Planets, courtesy Solar System Scope

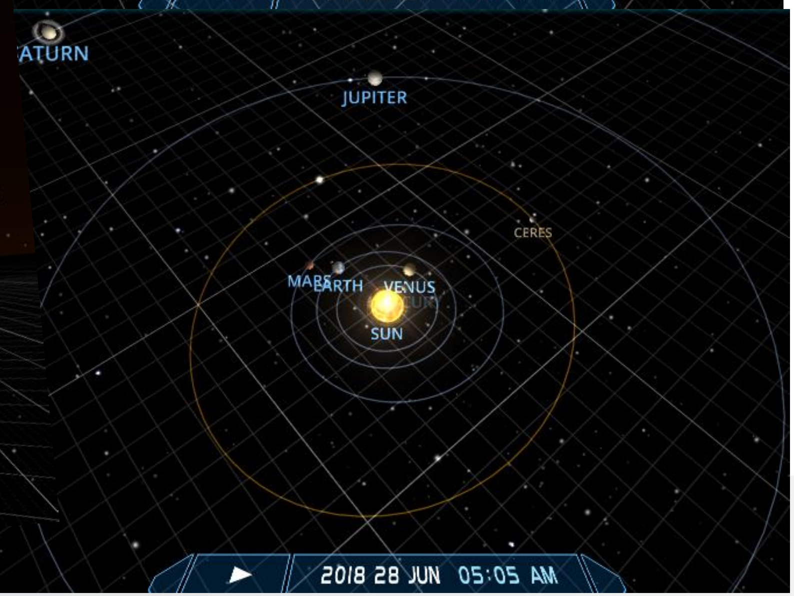




Left: Early Morning Sky in Windhoek at 05:05 – with the Moon near Saturn & Mars following.

Right Respective Real-Time Positions of the Solar Planets, courtesy Solar System Scope





Recap -- Why planets and the solar system

- Planets easily observable by eye to all
- They follow deep physical laws of Newton, Kepler, ...
- Their orbital plan and tracks linked to the formation of the solar system, including earth
- Their study has been at the centre of major human imagination and scientific exploration over time
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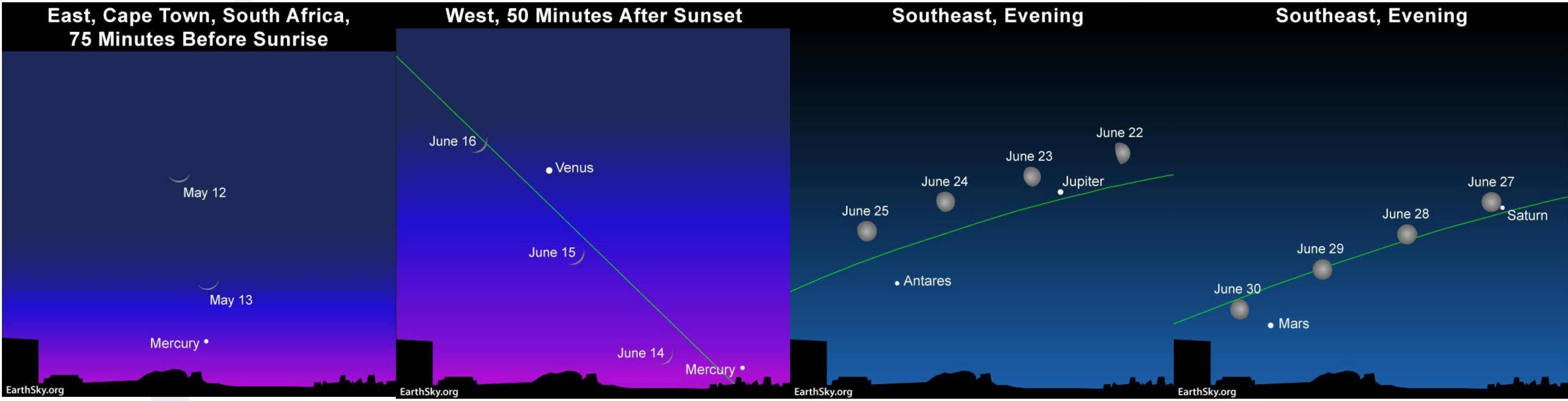
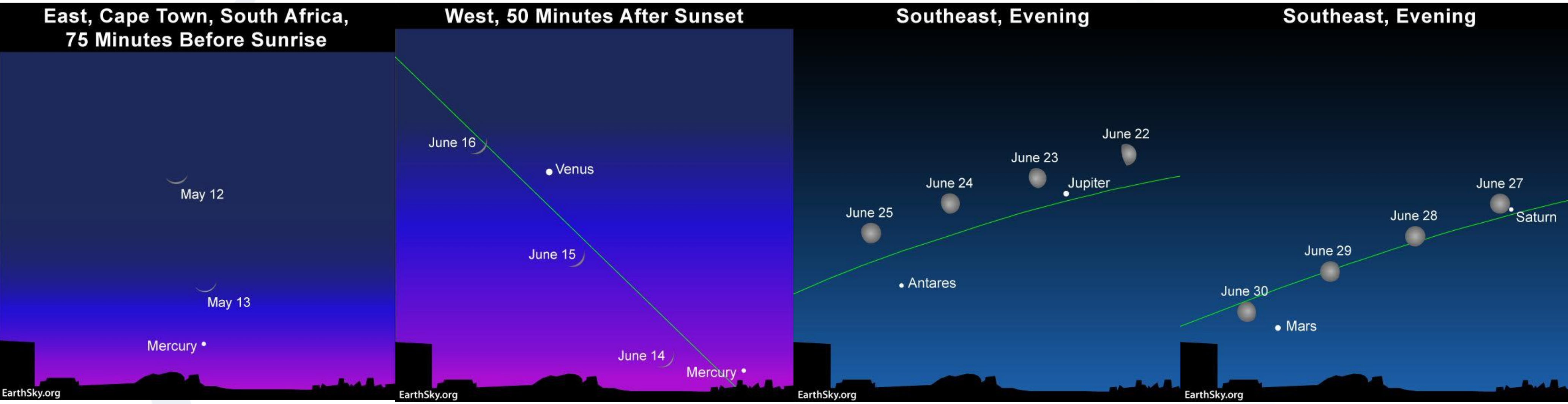
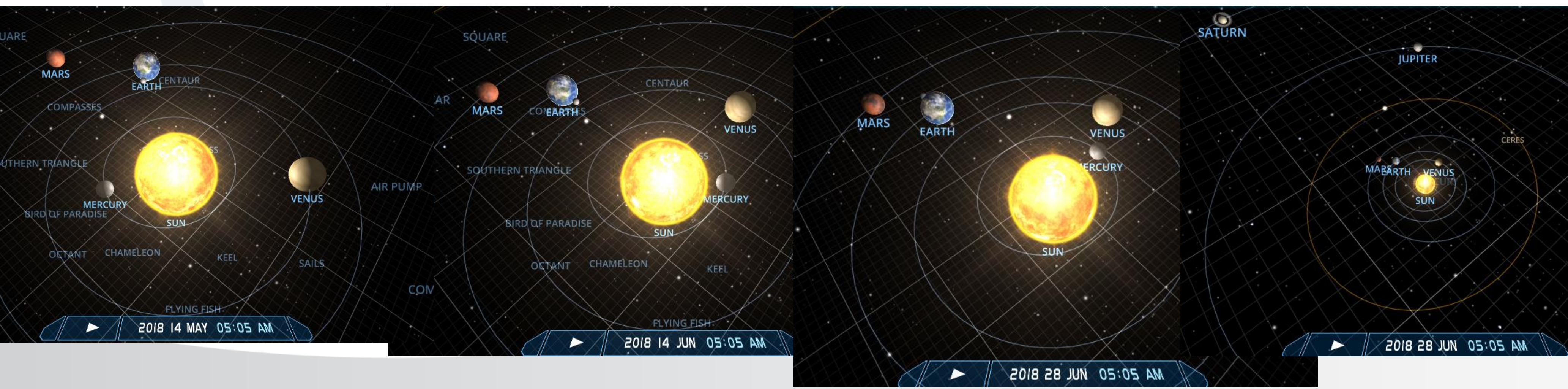
The Moon and its phases along the Planets on the Ecliptic in May/June 2018, courtesy EarthSky.

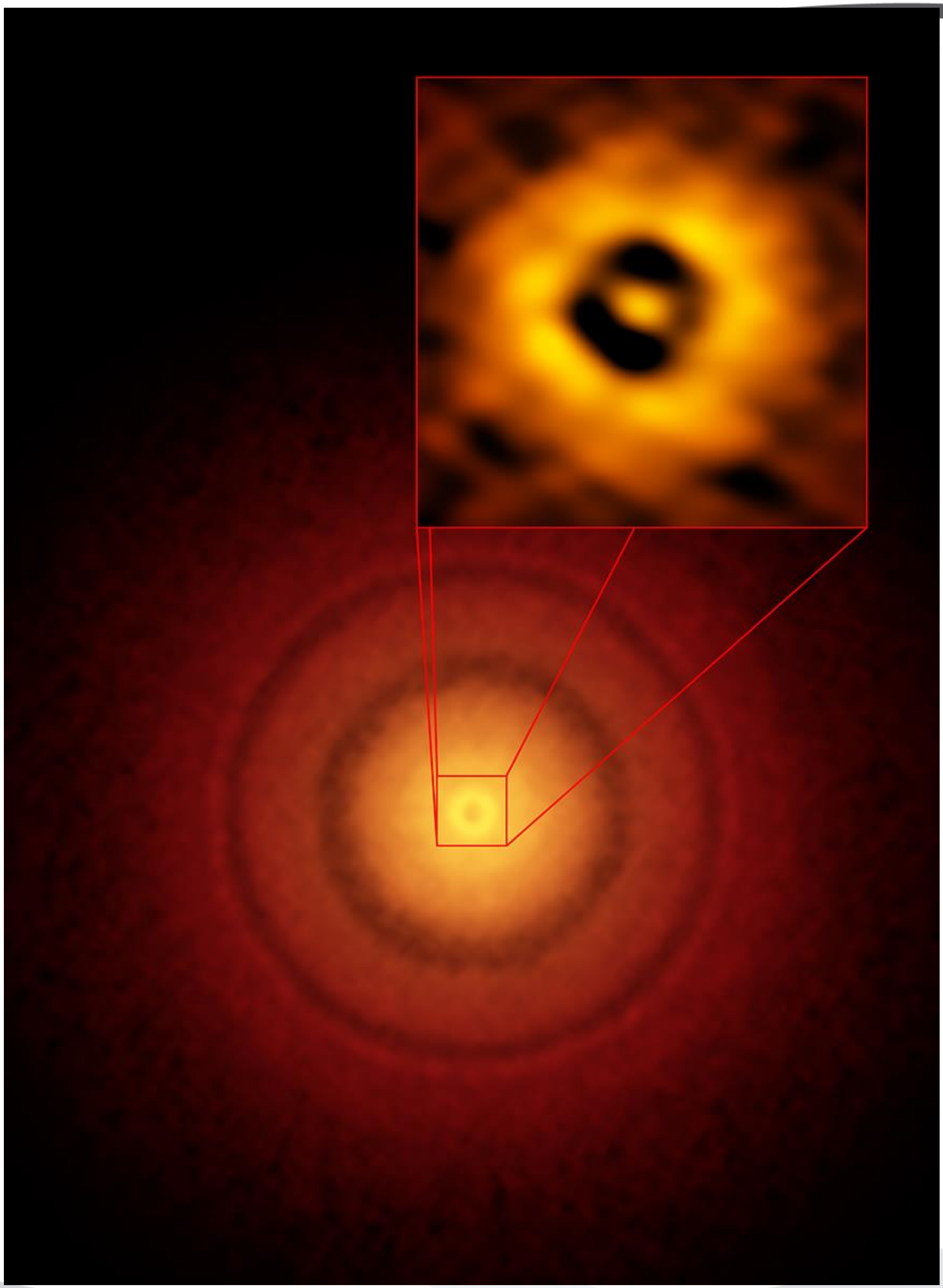


Top: The Moon & its phases with Planets, on along the Ecliptic in May/June 2018, courtesy EarthSky.

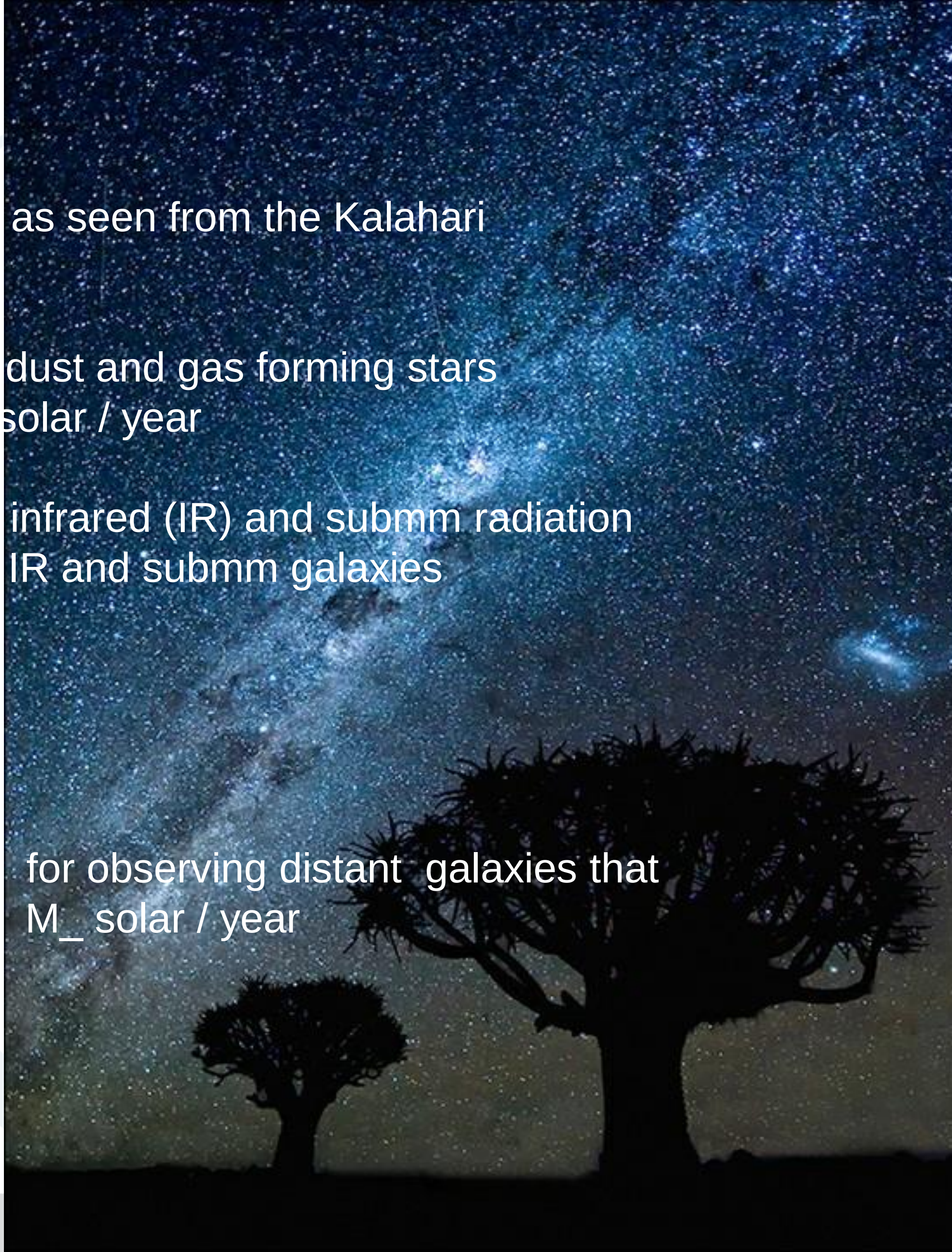
Bottom: Respective Real-Time Positions of the Planets in May/June 2018, courtesy Solar System Scope







Submm Image of a Proto-planetary Disk
Around TW Hydrae, courtesy ALMA 2016

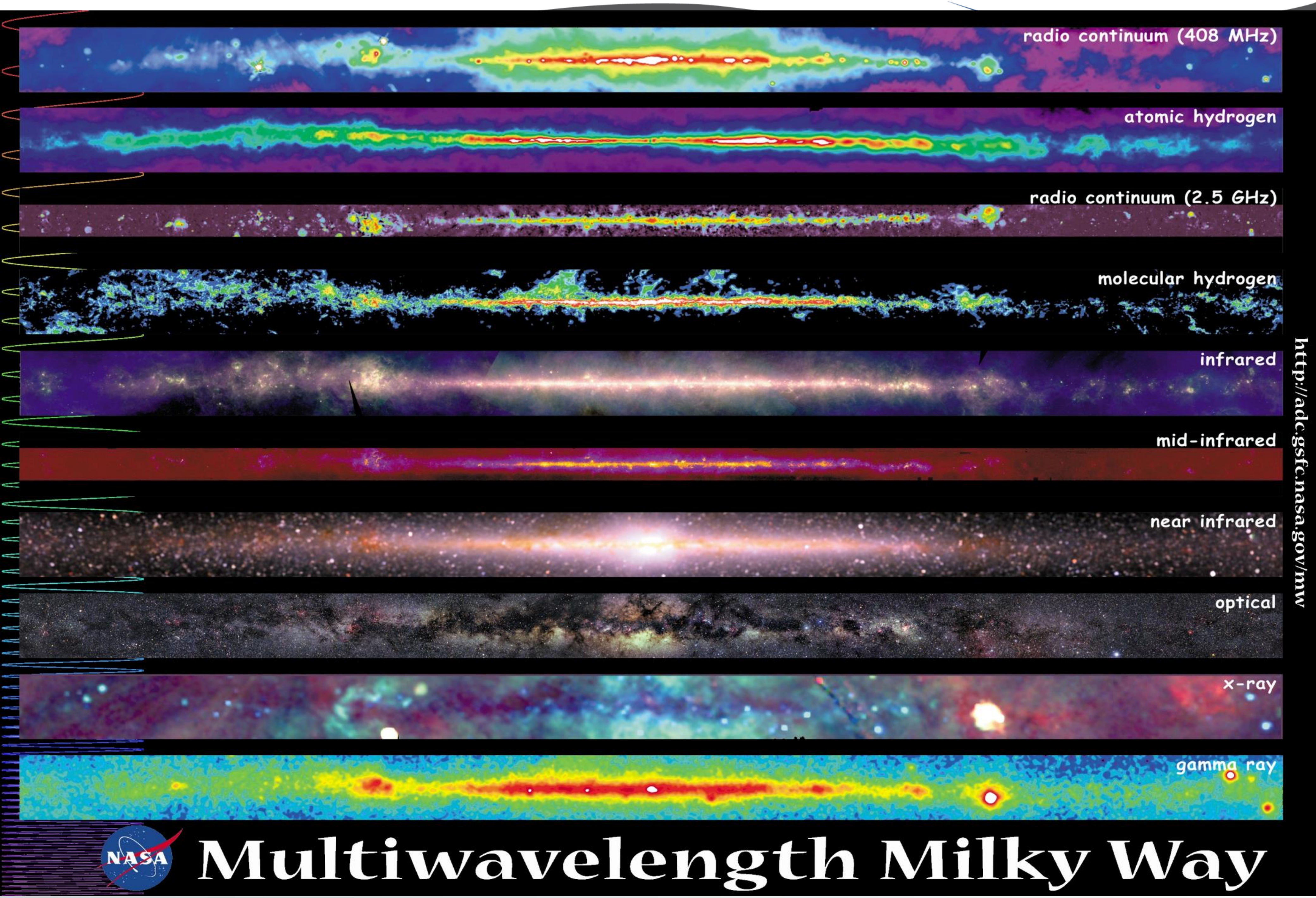


Molagodimo,
the Milky Way as seen from the Kalahari
in the optical.

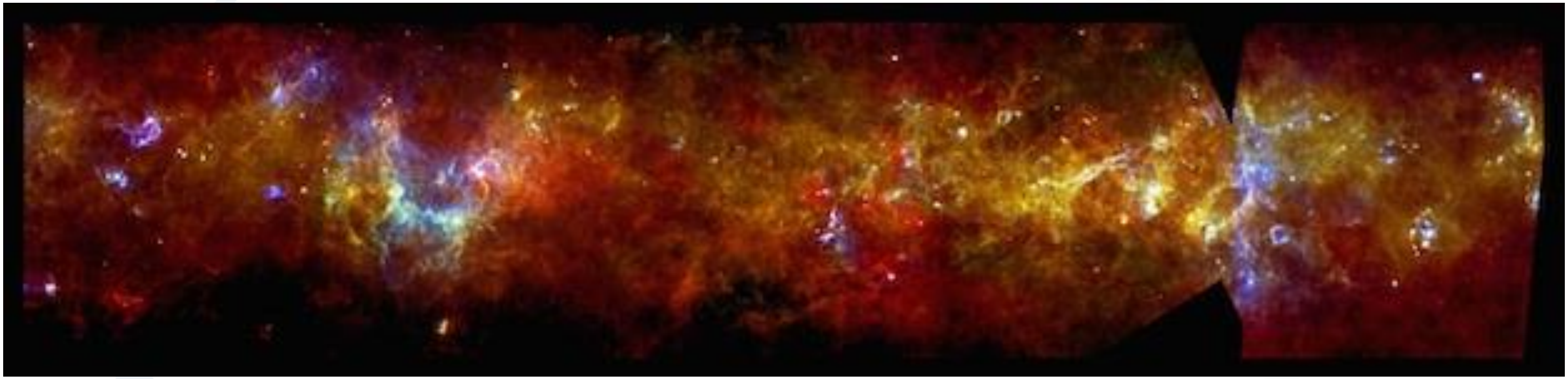
Dark patches of dust and gas forming stars
At 0.5 to 10 M _solar / year

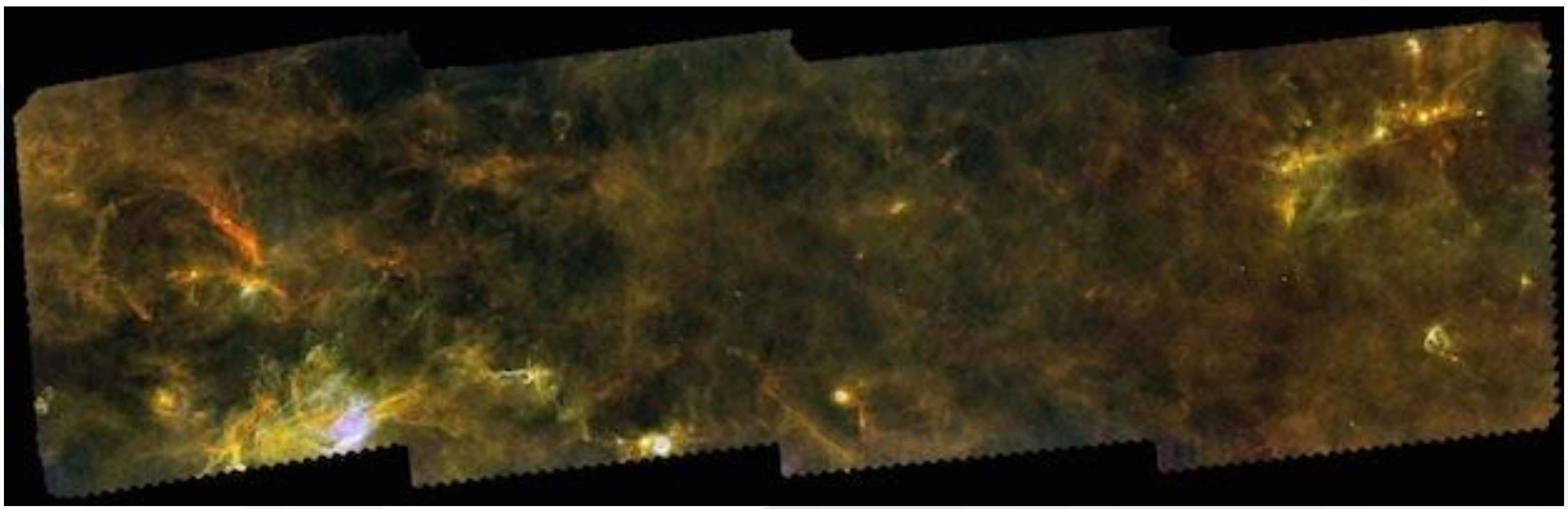
The dust emits infrared (IR) and submm radiation
seen by in the IR and submm galaxies

Distant Submm-Bright Galaxies (Milky Way Progenitors)
Exploiting lenses for observing distant galaxies that
have up to ~1000 M_ solar / year


radio continuum (408 MHz)
atomic hydrogen
radio continuum (2.5 GHz)
molecular hydrogen
infrared
mid-infrared
near infrared
optical
x-ray
gamma ray
http://adc.gsfc.nasa.gov/mw
NASA
Multiwavelength Milky Way

Filamentary Structure of **Star-formation seen in Emission** in the Galactic Plane and Outer Edges of the **Milky Way**, e.g. respectively Molinari et al. (top) & Schisano et al. (bottom)



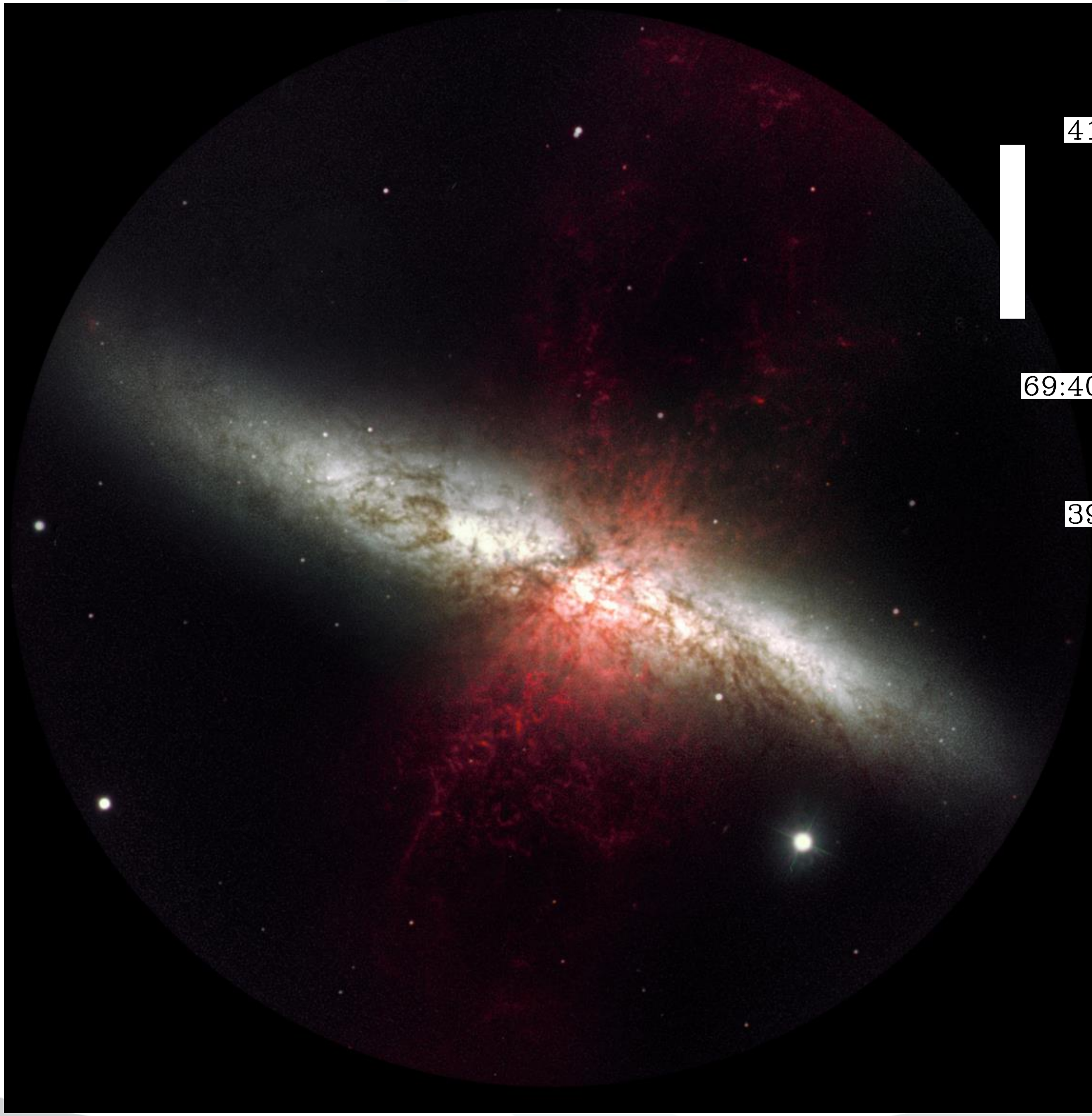


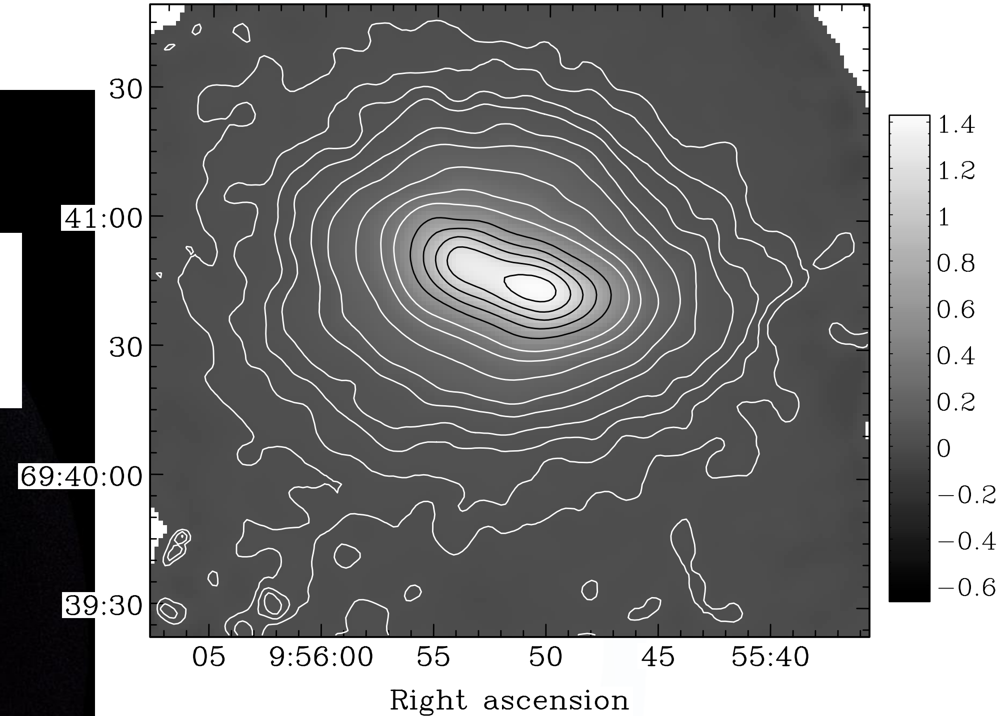
ESA/NASA Herschel Observatory Hi-Gal Project

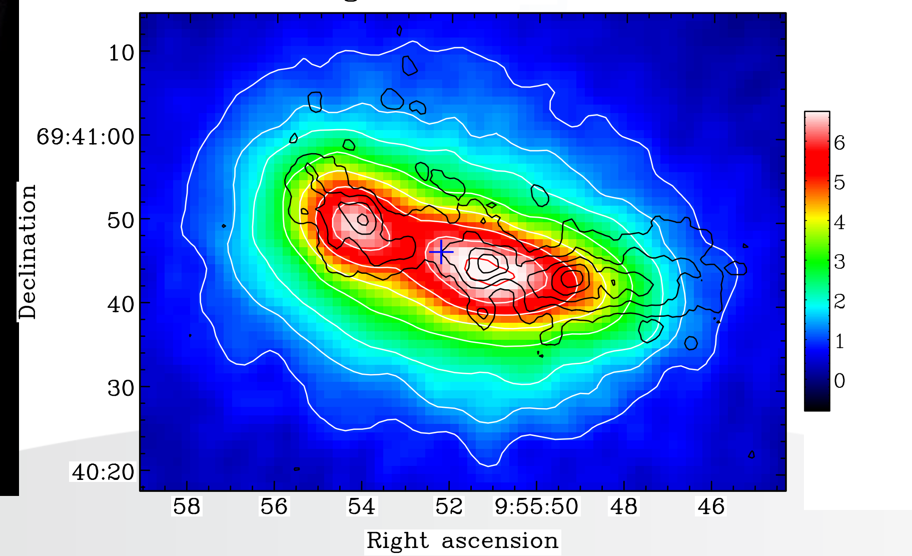
G67: Filamentary Structure of Star-formation seen in of the Milky Way

ESA/NASA Herschel Observatory Hi-Gal Project, e.g. Molinari et al.

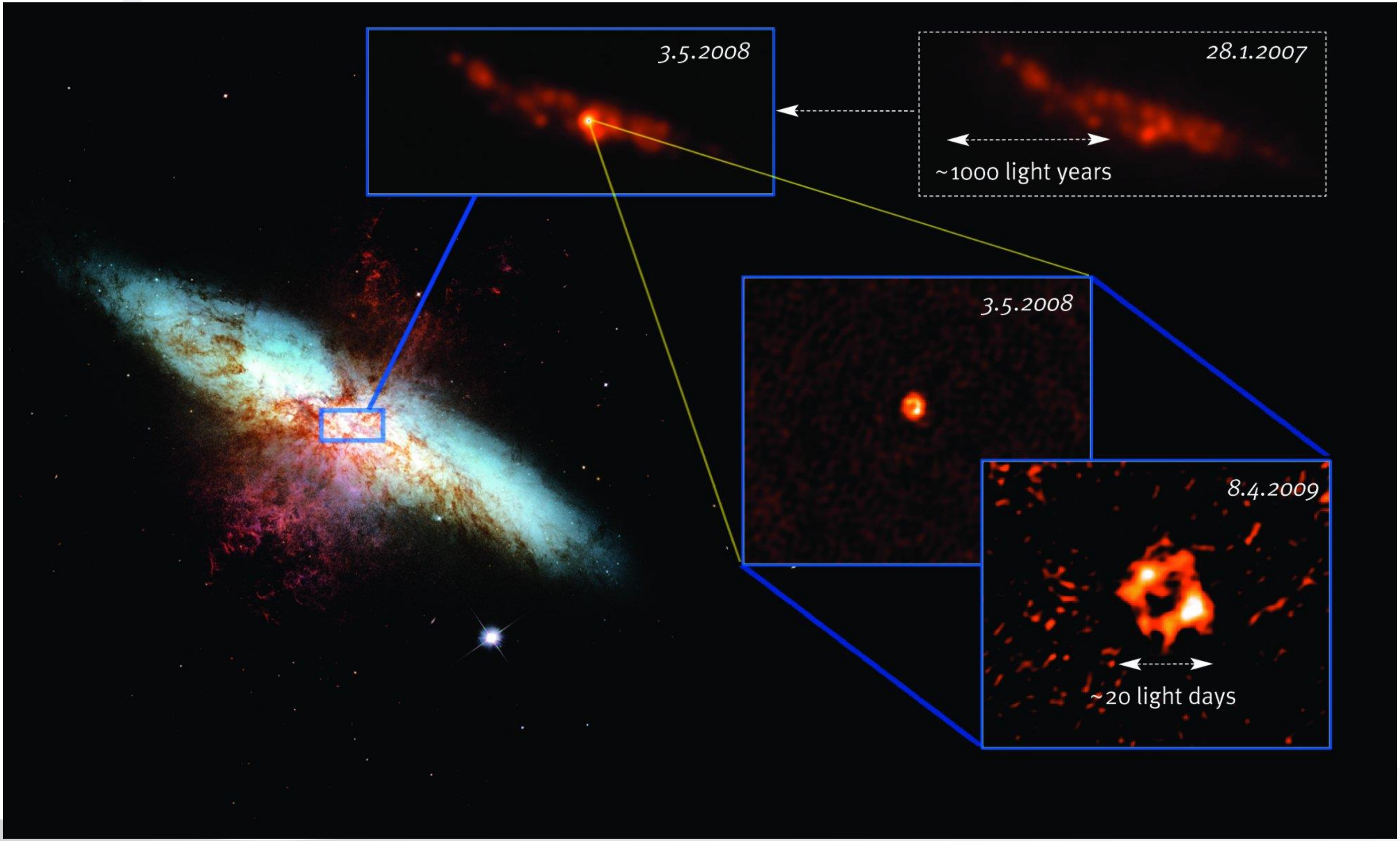
Core and Outflows of **M82** in optical (NASA/ESA) and submm (Leeuw et al.)



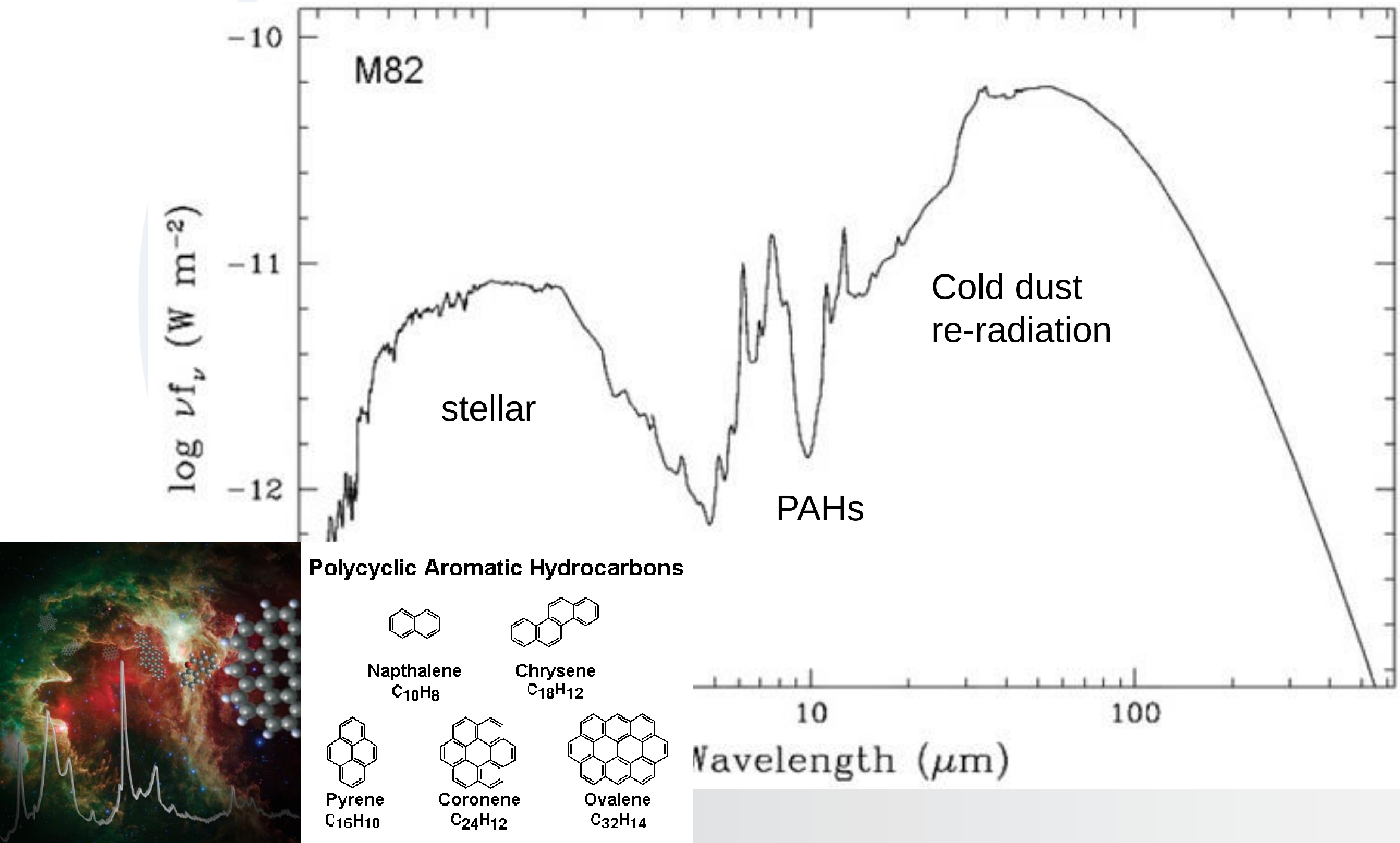




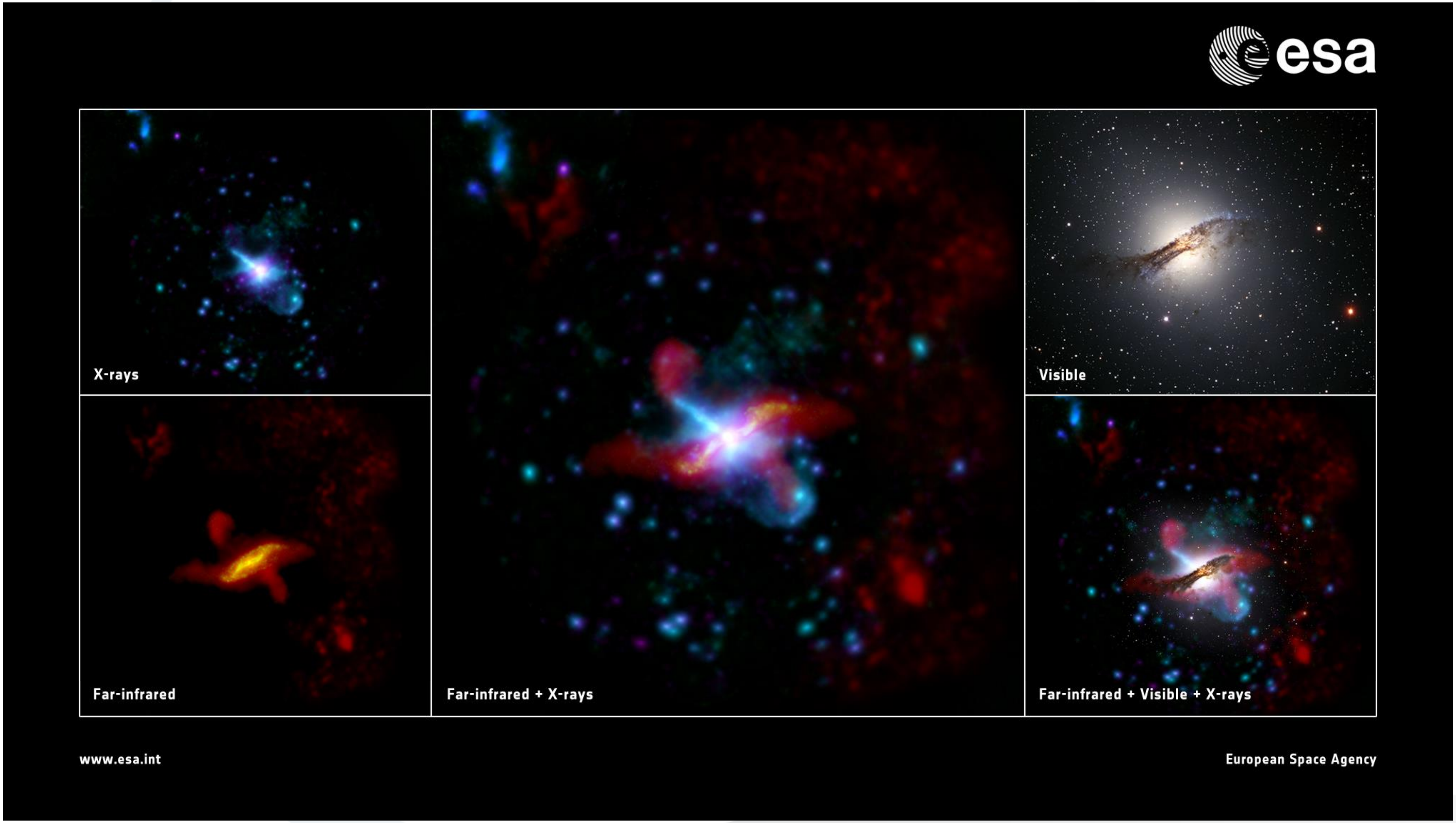
On-going **Supernovae** Imaged in the Starburst and **Model-Submm Galaxy M82**
Image credit ESA/NASA, A. Brunthaler



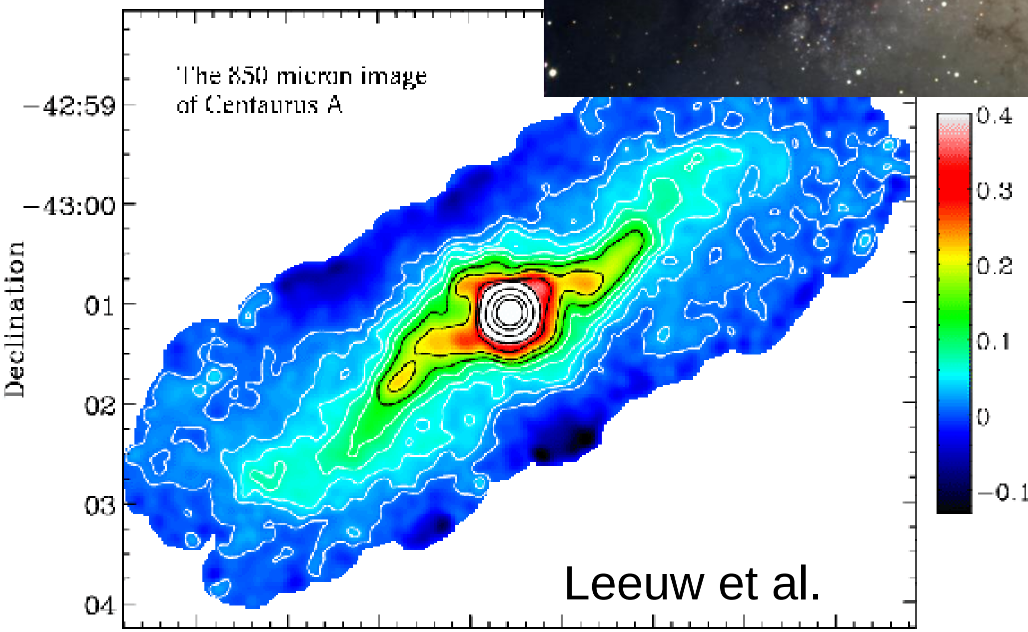
Panaromic SED of M82, the archetypal submm-SED, cf. Leitherer et al

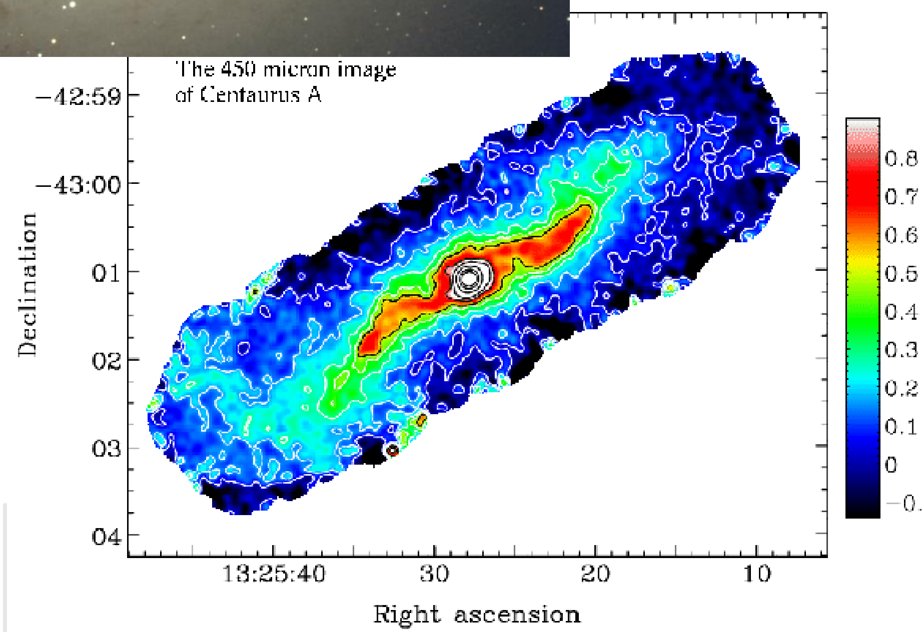


Multi-wavelength View of Centaurus A

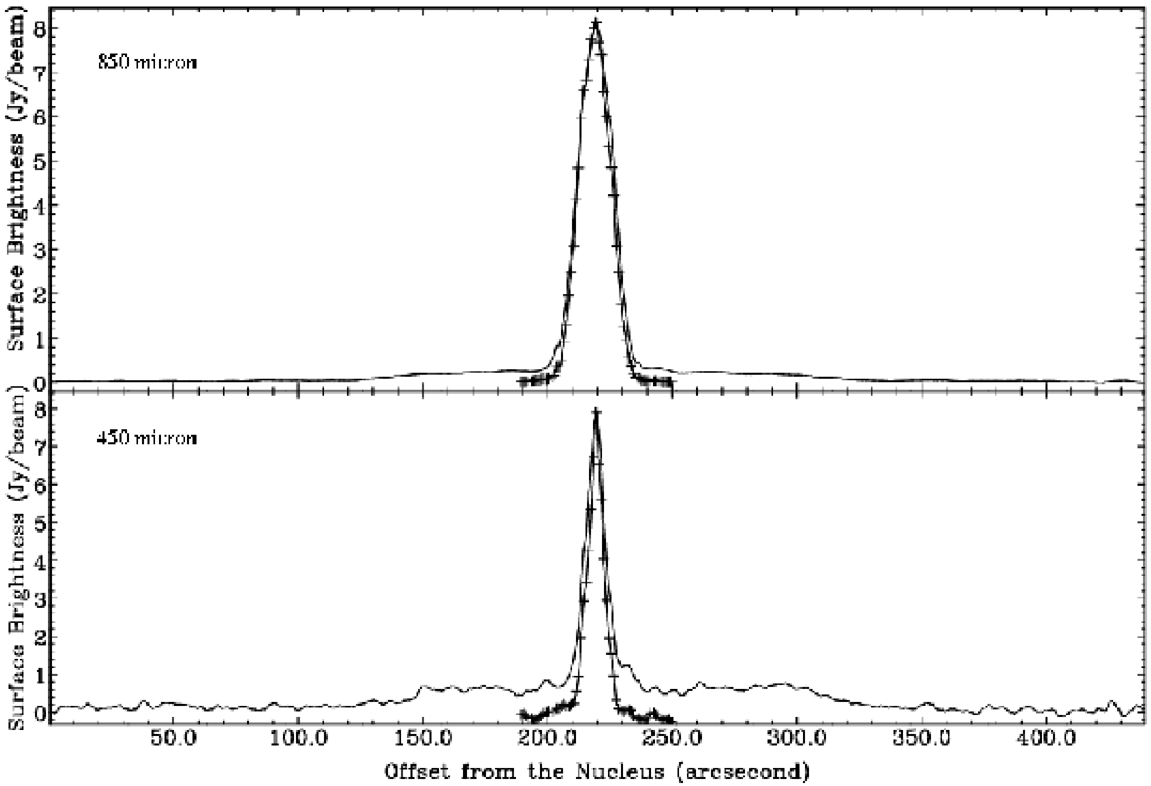


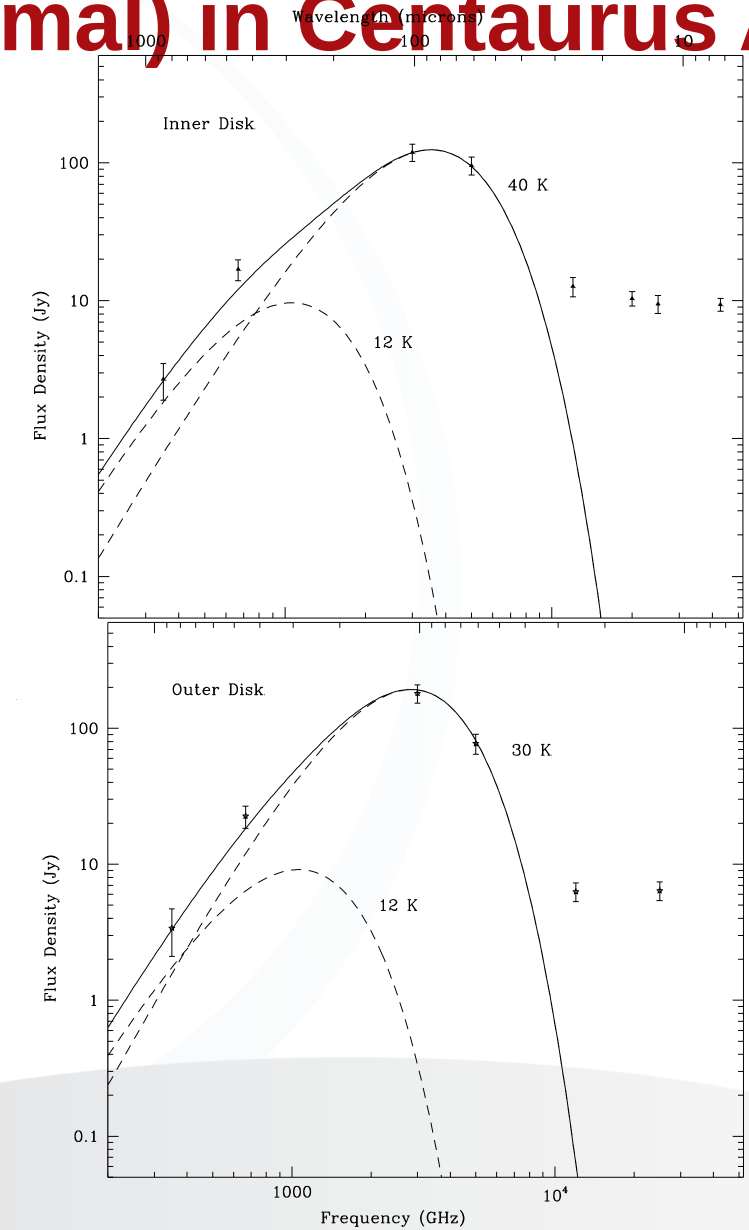
Centaurus A in optical and submm





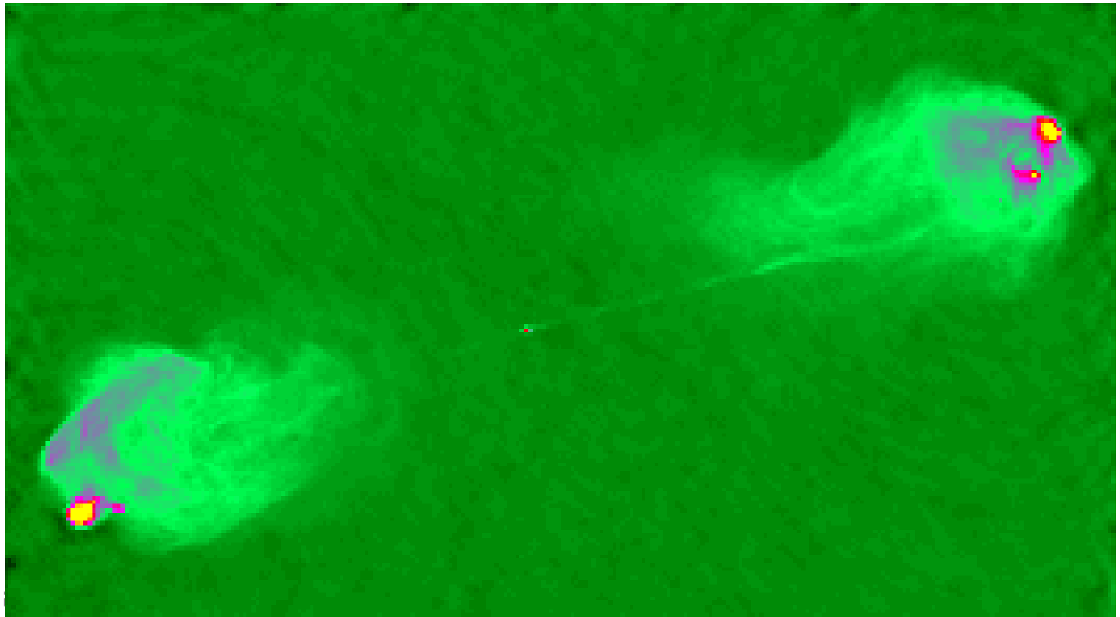
The 850 and 450um emission of the core (non-thermal) and dust lanes (thermal) in Centaurus A

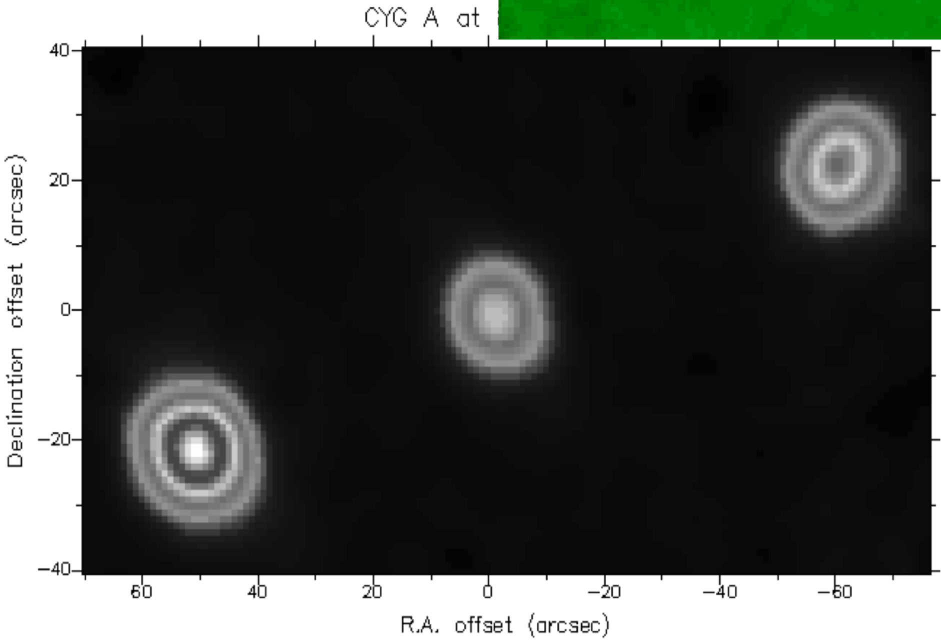


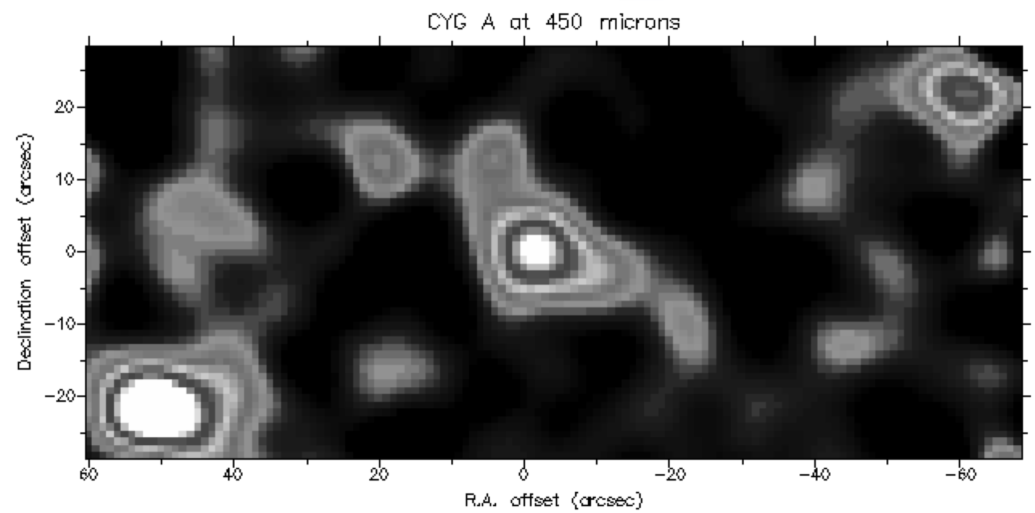


Leeuw et al.

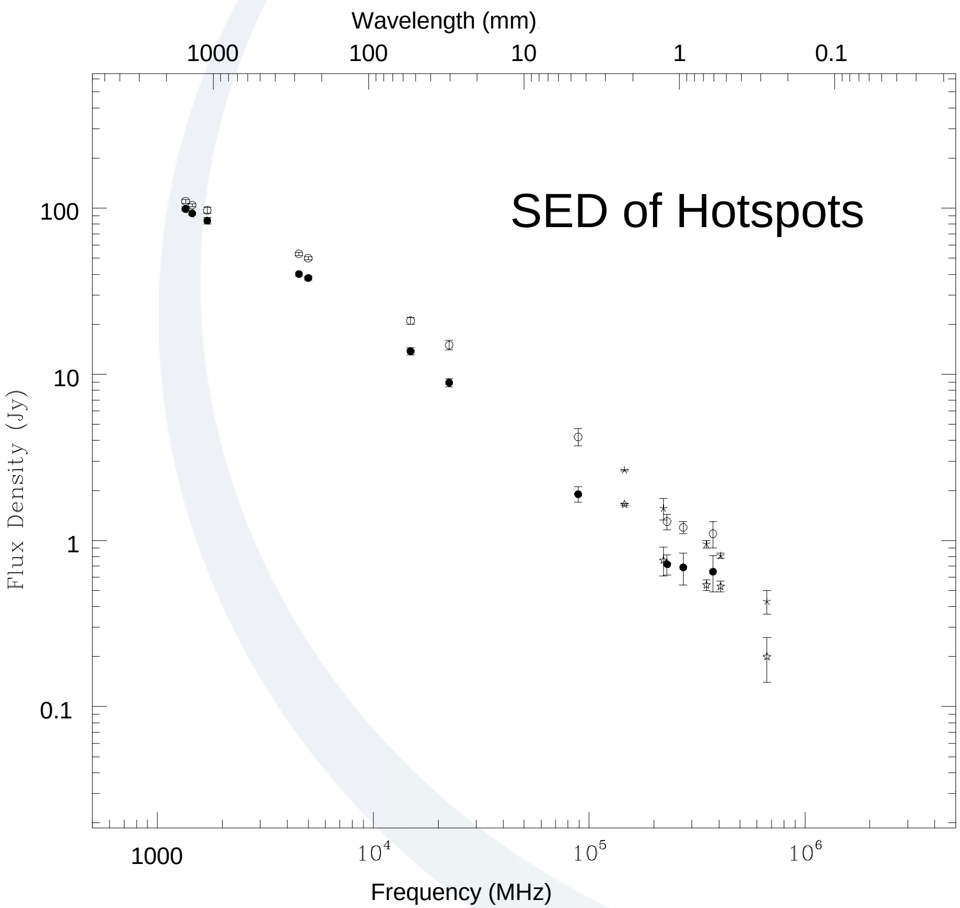
Cygnus A in Radio and 850 and 450um emission

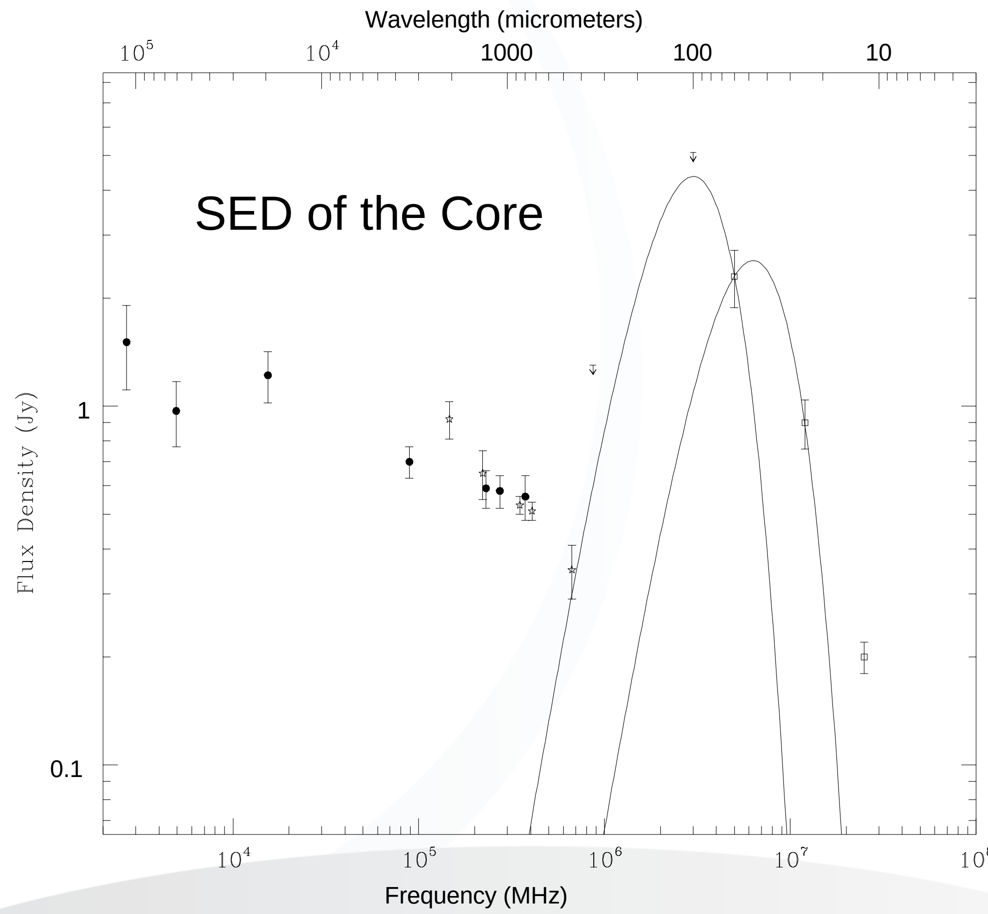






Spectral Energy Distributions of Synchrotron Emission in the Hotspots and Thermal and Synchrotron Emission in the Core of **Cygnus A**





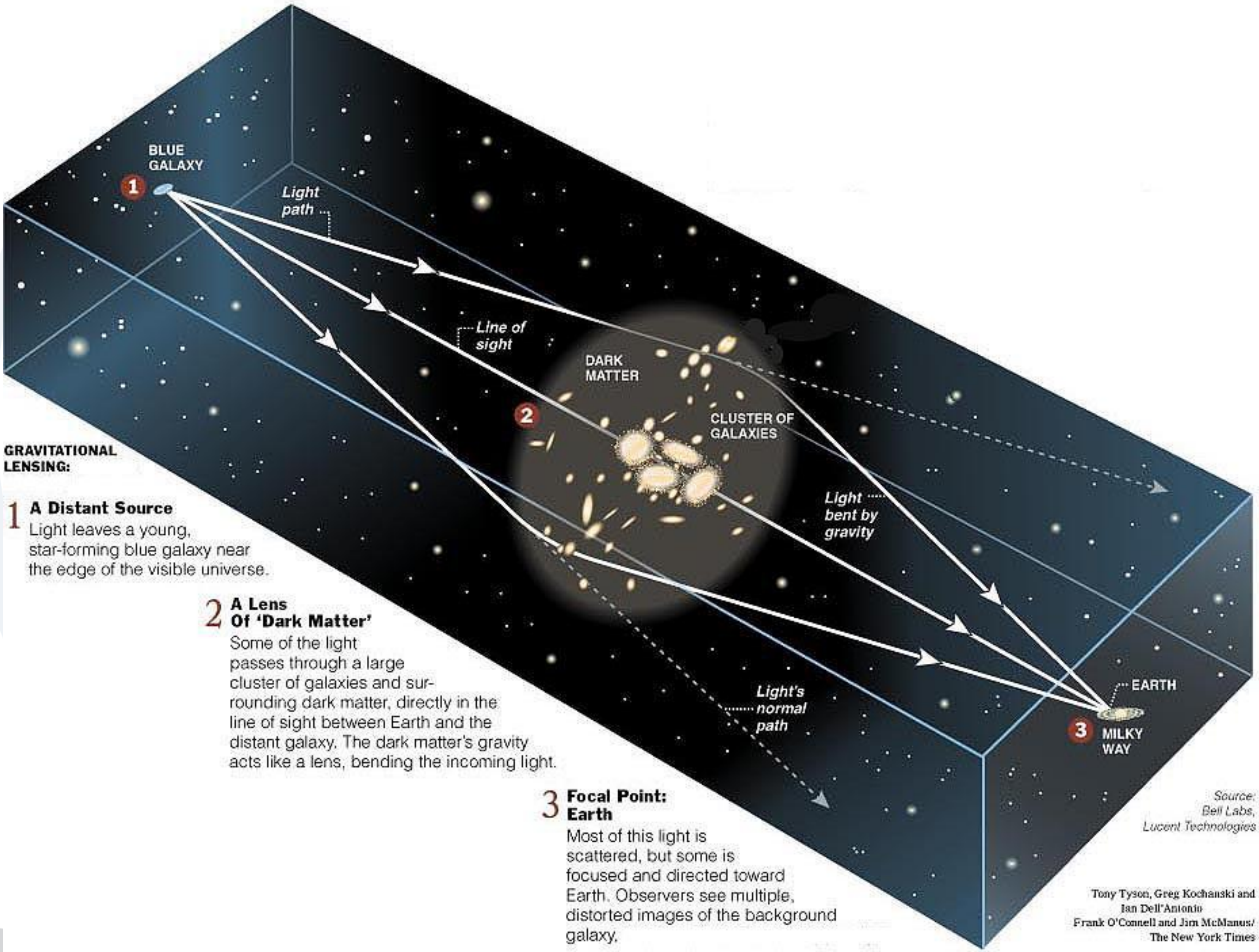
Leeuw et al.

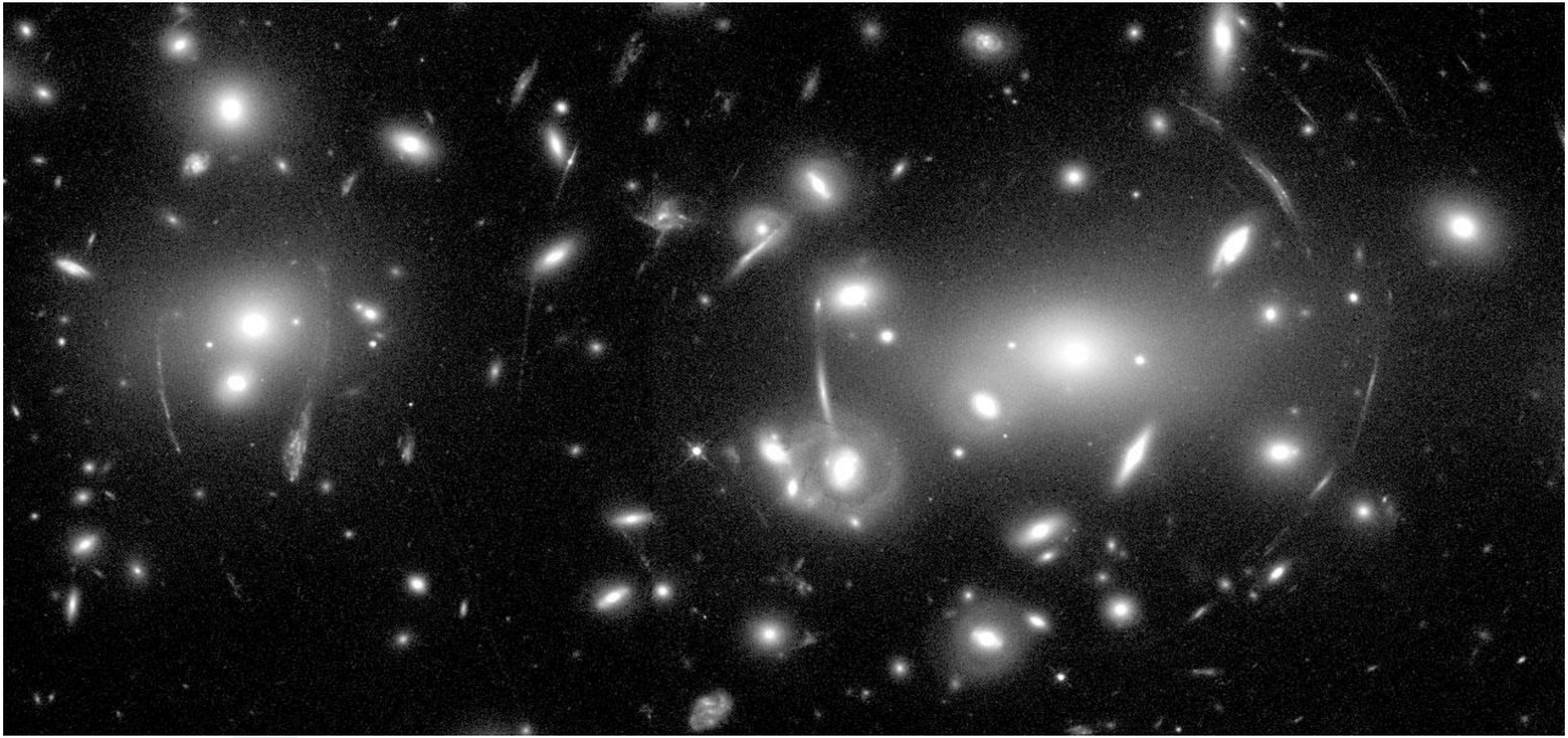
Gravitationally Lensed Systems Discovered in the Herschel Observatory

in collaboration with the H-ATLAS team

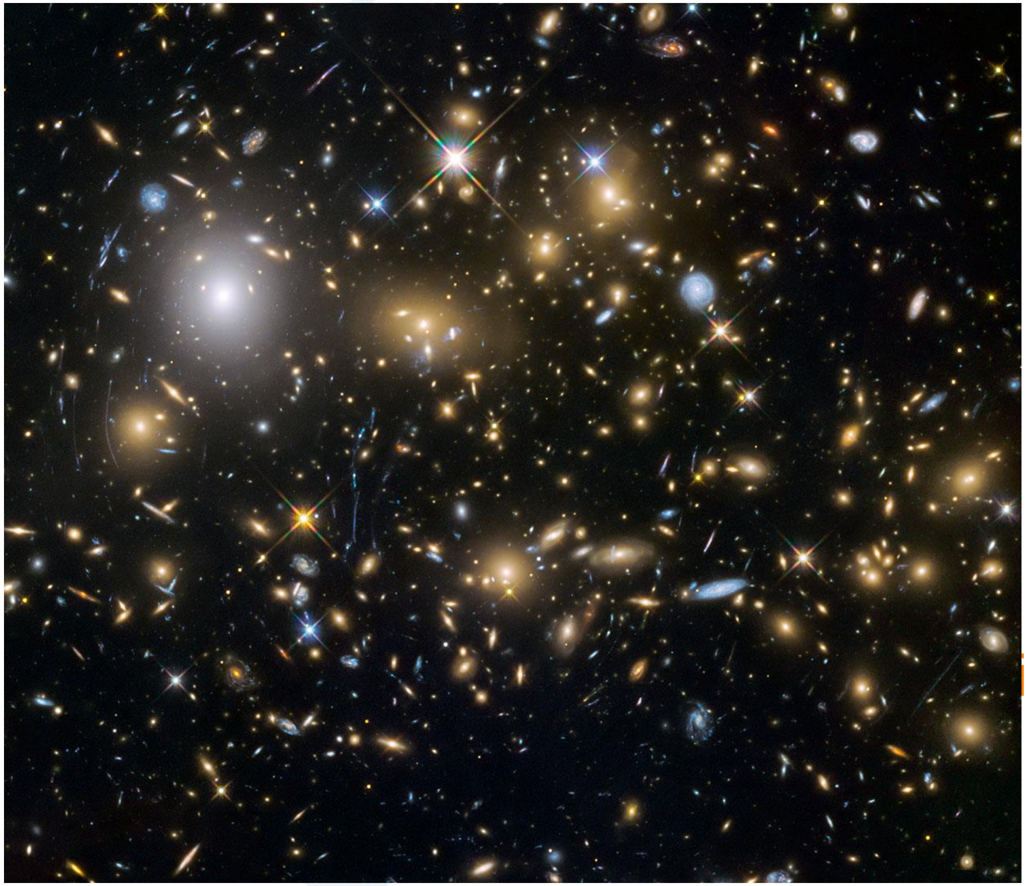
ASTROPHYSICAL TERAHERTZ LARGE AREA SURVEY

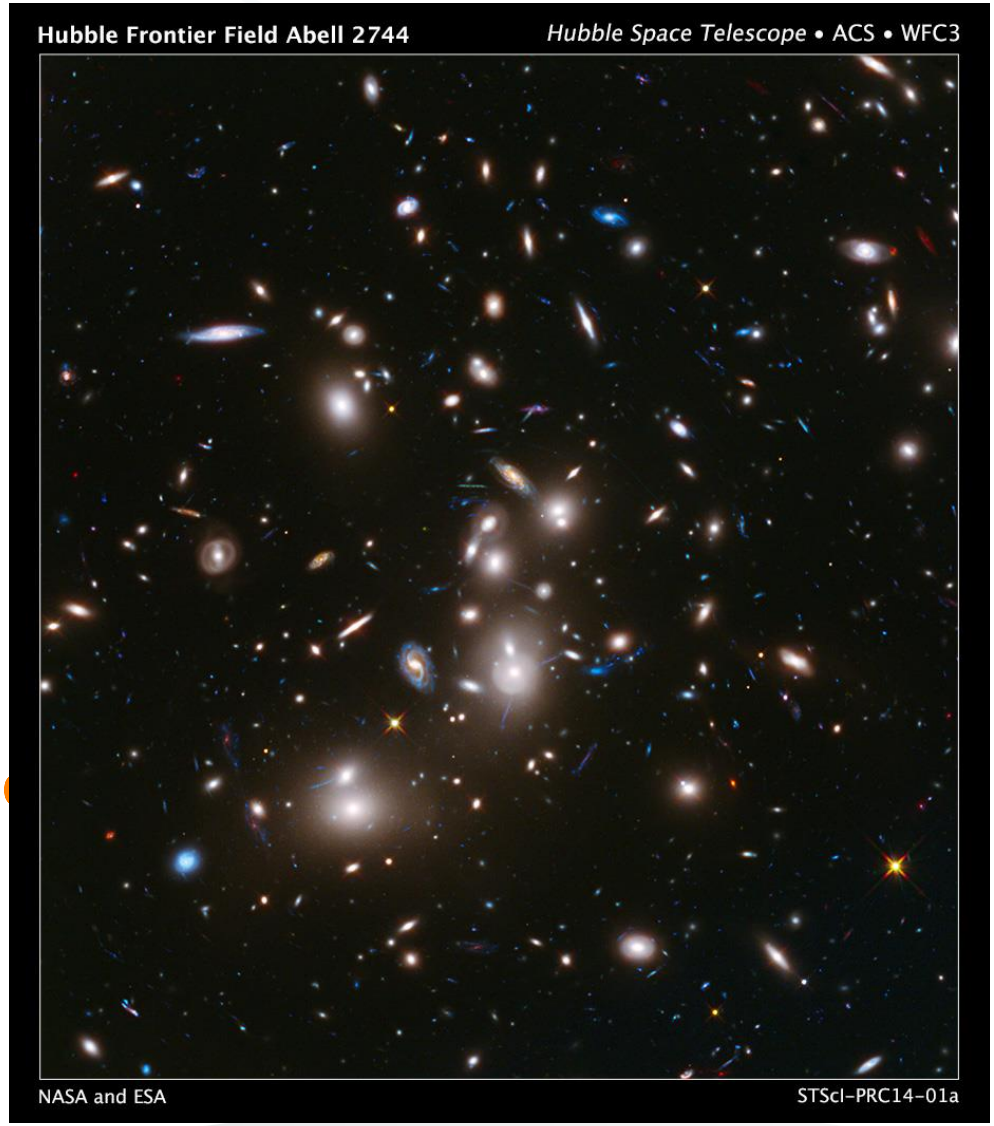
(http://www.h-atlas.org/)


GRAVITATIONAL LENSING:
1 A Distant Source
Light leaves a young, star-forming blue galaxy near the edge of the visible universe.
2 A Lens Of 'Dark Matter'
Some of the light passes through a large cluster of galaxies and surrounding dark matter, directly in the line of sight between Earth and the distant galaxy. The dark matter's gravity acts like a lens, bending the incoming light.
3 Focal Point: Earth
Most of this light is scattered, but some is focused and directed toward Earth. Observers see multiple, distorted images of the background galaxy.
BLUE GALAXY
1
Light path
Line of sight
DARK MATTER
2
CLUSTER OF GALAXIES
Light bent by gravity
Light's normal path
EARTH
3
MILKY WAY
Source: Bell Labs, Lucent Technologies
Tony Tyson, Greg Kochanski and Ian Dell'Antonio
Frank O'Connell and Jim McManus/
The New York Times



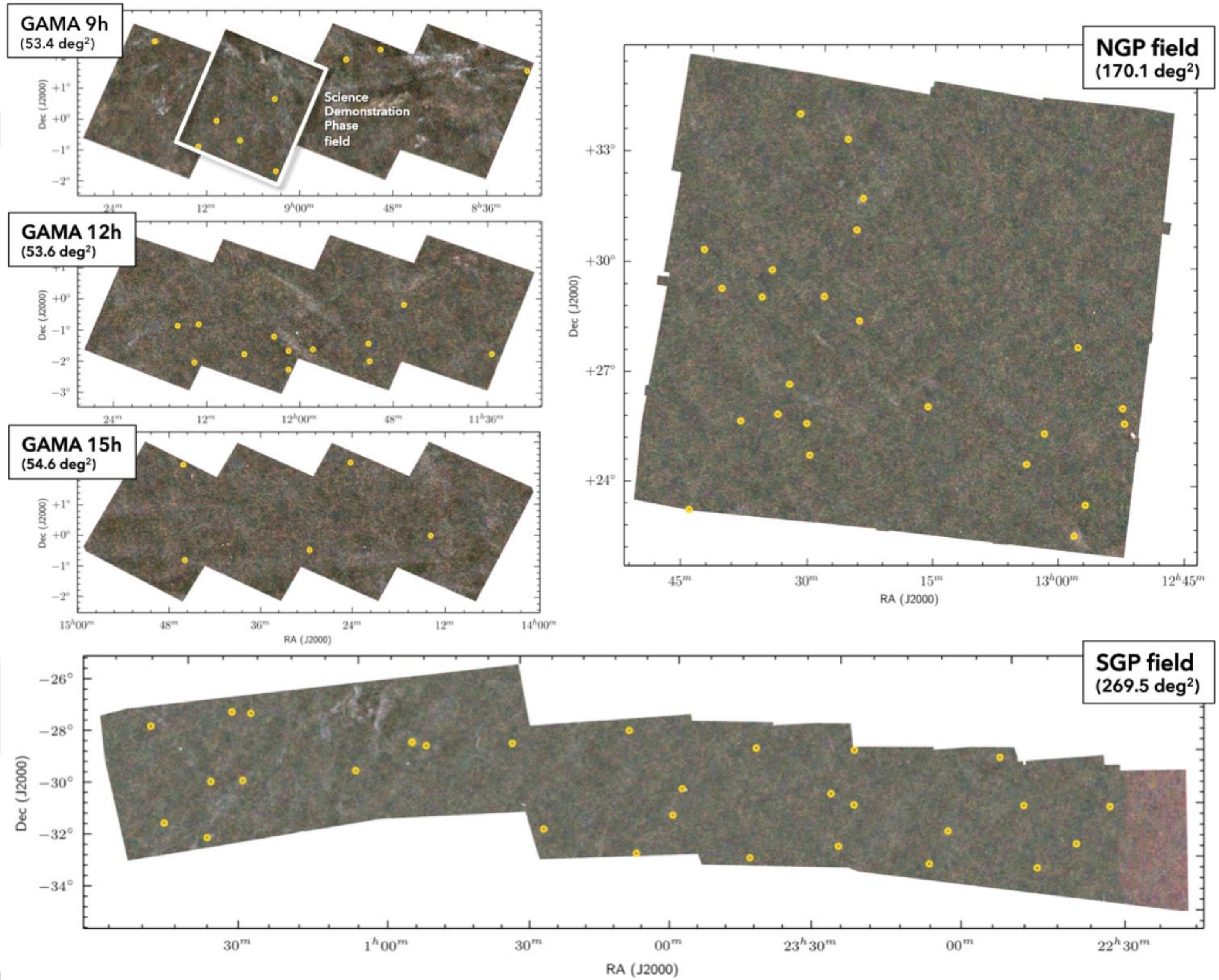
Hubble Space Telescope Image of Abell 2218

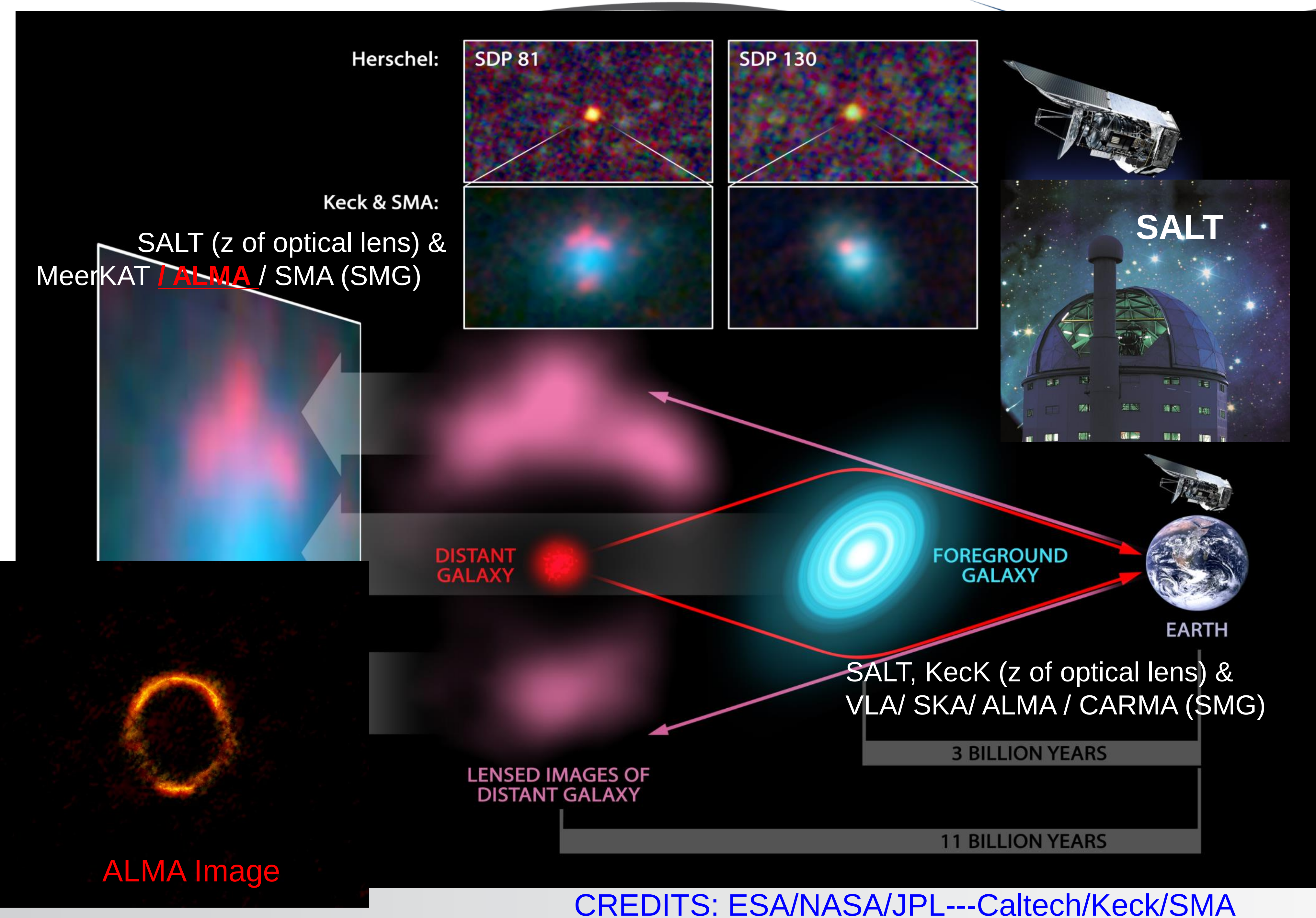




Hubble Space Telescope ACS Frontier Field Image
Gravitational Lensing Study

Herschel-ATLAS 80 Lensed Candidates, 20 confirmed, with F500um > 100mJy, Negrello et al.





CREDITS: ESA/NASA/JPL---Caltech/Keck/SMA

Discovery paves way for easier ride back in time

KANINA FOSS

START at the Big Bang – the beginning of the universe. Now begin to move forward. One million years, two million years… 2.7 billion years, a young galaxy emits light into the void… 4.5 billion years. In another galaxy – the Milky Way – the Earth forms.

At 13.7 billion years, humans fire a telescope called Herschel into space. Images come back dotted with peculiarly bright points. Excitement stirs.

Other telescopes are called upon to verify, and produce hits. Excitement builds. More telescopes, more hits.

The team of scientists – including a South African – are stunned. They realise they've made a groundbreaking discovery: a better way of going back in time.

The bright points are light that has travelled billions of years to reach the Earth. It was emitted by galaxies when they were very young – a mere 2.7 billion years old, for example.

Usually, light that has travelled this far can't be seen easily. But a phenomenon called gravitational lenses enables Herschel to pick it up.

Enter Einstein. He showed that light could be bent by gravity. The effect is very small and only noticeable when light passes objects with a very large mass, such as a galaxy containing hundreds of billions of stars.

When light from a distant galaxy passes a closer galaxy, it gets bent so that the image of the distant galaxy is magnified, as if by a cosmic zoom lens.

Many of these lenses have been identified, but it has been a difficult and time-consuming procedure, involving searching through tons of data. Most methods have a very poor success rate, with less than one in 10 candidates found to be real.

Launched in May 2009, the powerful European Space Agency's Herschel Space Observatory can pick up submillimetre light. This is light with wavelengths shorter than radio wavelengths, and longer than optical wavelengths (which can be seen by the eye).

Last November, when the Herschel-Atlas scientists received their first image from the project and saw the peculiar bright points, they quickly eliminated a few options.

Option one: active galactic nuclei (a compact mass in a galaxy containing a black hole). These emit submillimetre light at submillimetre wavelengths, but they are also strong emitters at radio wavelengths, and there was no radio light being emitted by the bright points.

Option two: nearby galaxies that are forming a lot of stars or those that have spiral formations, like the Milky Way. These emit submillimetre light, but the bright points had no signs of forming lots of star and were not in spiral formations.

Next, they used optical telescopes to measure the distance of the bright points from the Earth. For one of the points, the optical distance was 3 billion light-years, ie the light from that point had taken 3 billion years to reach the Earth.

But when the distance was measured using detections of molecular gas, it was 11 billion years – evidence of two separate galaxies: the galaxy responsible for bending the light, and the galaxy being magnified.

Herschel was showing them gravitational lenses.

Lead researcher Dr Mattia Negrello, from the UK's Open University, said: "Many of the brightest sources of light seen by Herschel are being magnified by lenses, which means we no longer have to rely on the rather inefficient methods of finding lenses which are used at visible and radio wavelengths."

The implications are staggering.

According to local team member Dr Lerothodi Leeuw, from the University of Johannesburg and the Search for Extra-Terrestrial Intelligence (SETI) Institute, "the lenses magnify galaxies at quite a distance, which we'd otherwise not be able to see easily. They can help us understand how galaxies are formed, because what we're seeing happened when the universe was a third of its current age."

For South Africa, the discovery means a new range of uses for its new, large ground-based telescopes, the MeerKAT radio array and the SA Large Telescope, which can be called upon to verify Herschel's findings and study them in more detail.

"We're seeing where we came from… Our sun is just one star and an average one among billions of stars. It's humbling, but to be humbled doesn't mean to be lost, or to be lesser. It's still very exciting that we have the brains and tools to study these things," Leeuw says.

Galaxies magnified by 'new' lenses

EXCITED: South Africa's Dr Lerothodi Leeuw was on the team who found a new way to study the universe's history.

PICTURE: ITUMELENG ENGLISH

NC doctor part of team 'going back in time'

KANINA FOSS
SPECIAL CORRESPONDENT

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Usually, light that has travelled this far can't be seen easily. But a phenomenon called gravitational lenses enables Herschel to pick it up.

Enter Einstein. In school, we are taught that light travels in straight lines. But Einstein showed that light could be bent by gravity. The effect is very small, and only noticeable when light passes objects with a very large mass, such as a galaxy containing hundreds of billions of stars.

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The scientists sat back with a collective head scratch.

Next, they used optical telescopes to measure the distance of the bright points from the Earth. For one of the points, the optical distance was three billion light-years, ie the light from that point had taken three billion years to reach the Earth.

But when the distance was measured using detections of molecular gas, it was 11-billion years. This proved that, in fact, two separate galaxies were being looked at – the galaxy responsible for bending the light, and the galaxy being magnified.

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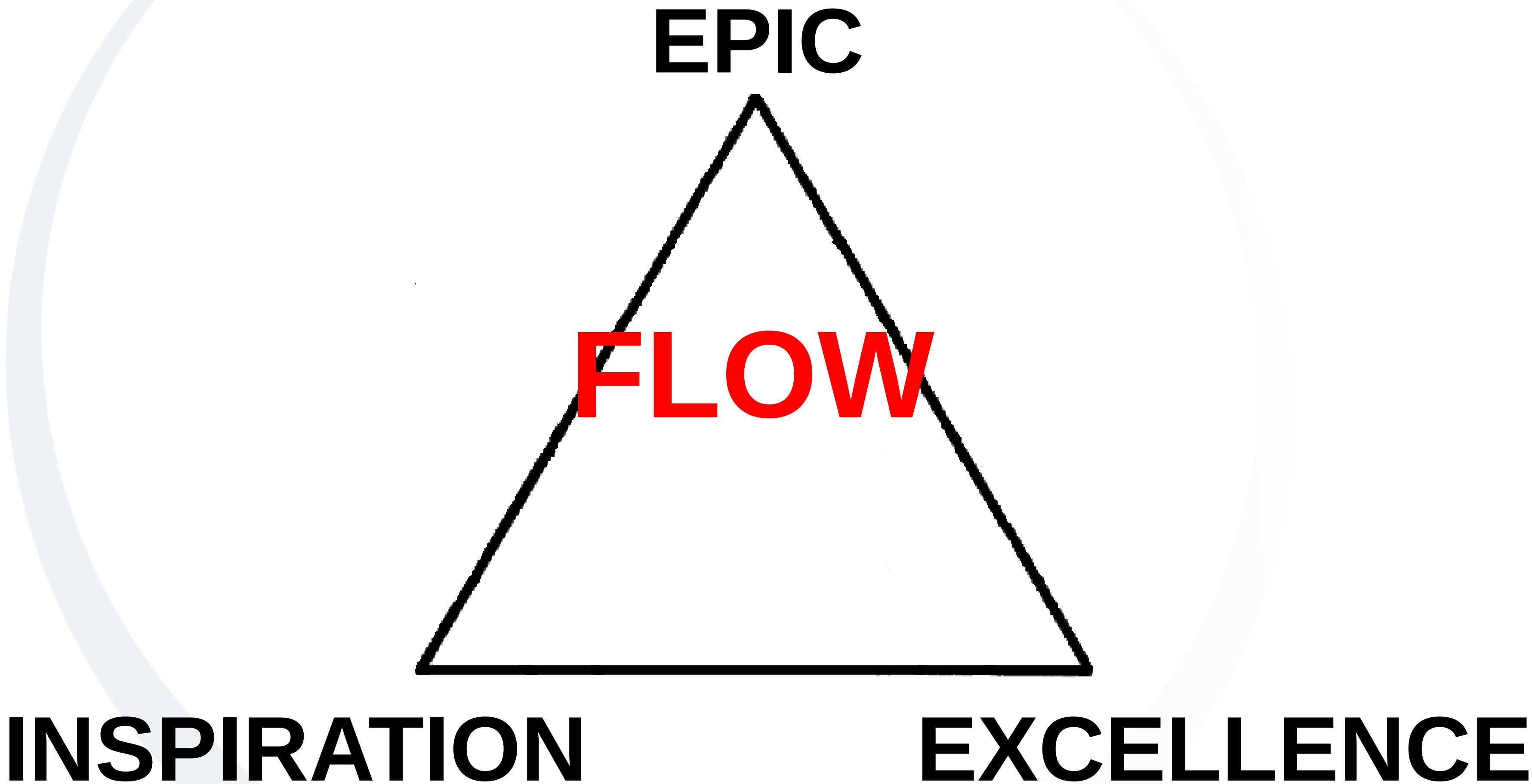
BACK IN TIME: Dr Lerothodi Leeuw, a University of Johannesburg physicist, working on Herschel-ATLAS. He grew up in Pampierstad in the Northern Cape.

Gravitational lenses can also be caused by dark matter, which makes up 80 percent of the mass of matter in the Universe. Identifying the location and amount of the dark matter will help scientists study it.

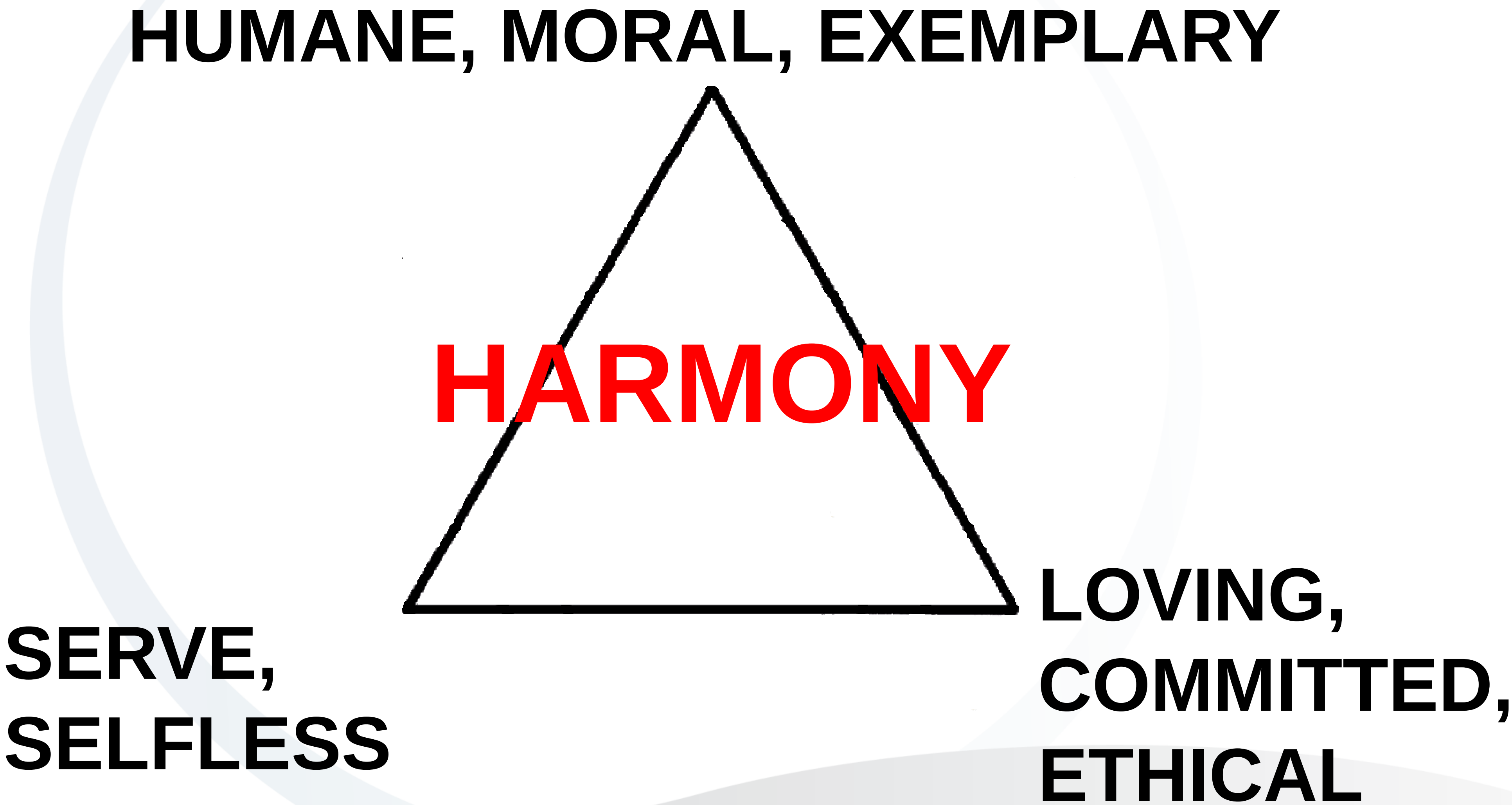
For South Africa, the discovery means a new range of uses for its new, large ground-based telescopes, the MeerKAT radio array and the South African Large Telescope, which can be called upon to verify Herschel's findings and study them in more detail.

"We're seeing where we came from as these small beings. Our own Sun is just one star and an average one among billions of stars. It's humbling, but to be humbled doesn't mean to be lost, or to be lesser. It's still very exciting that we have the brains and tools to study these things," Louw said.

PHILOSOPHY FOR SELF



PHILOSOPHY FOR SELF IN SOCIETY



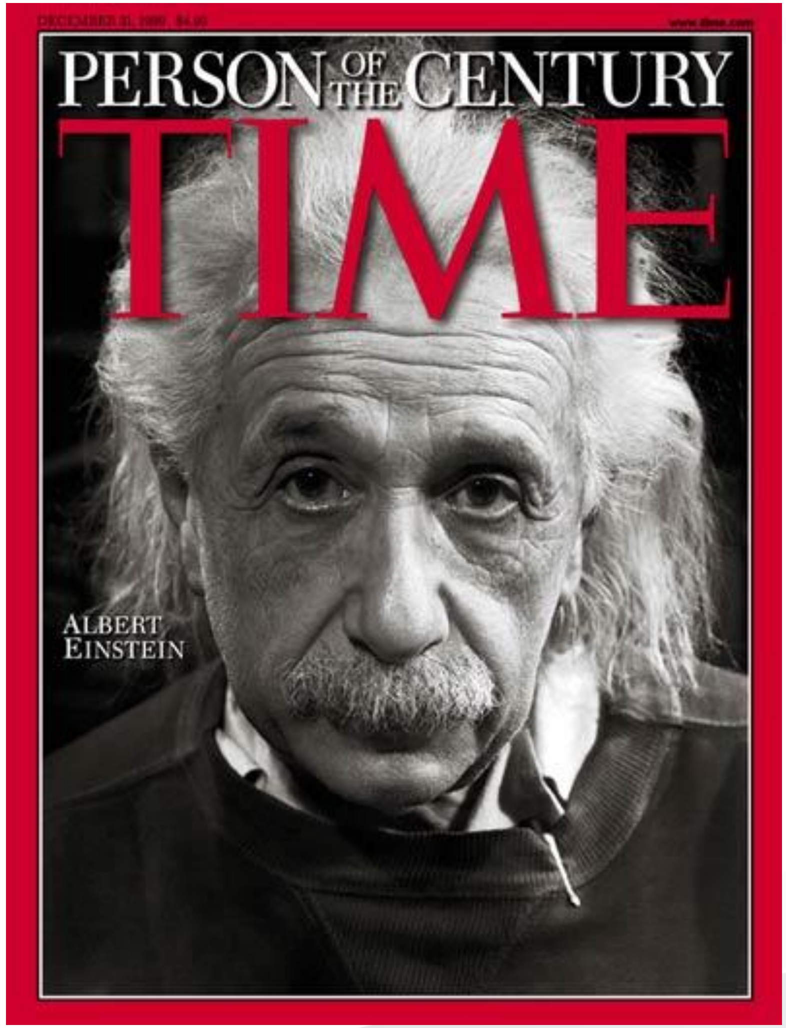
PHILOSOPHY FOR **SELF** IN **SOCIETY**

EPIC /
HUMANE, MORAL, EXEMPLARY

INSPIRATION /
SERVE,
SELFLESS

EXCELLENCE / LOVING
COMMITTED, ETHICAL

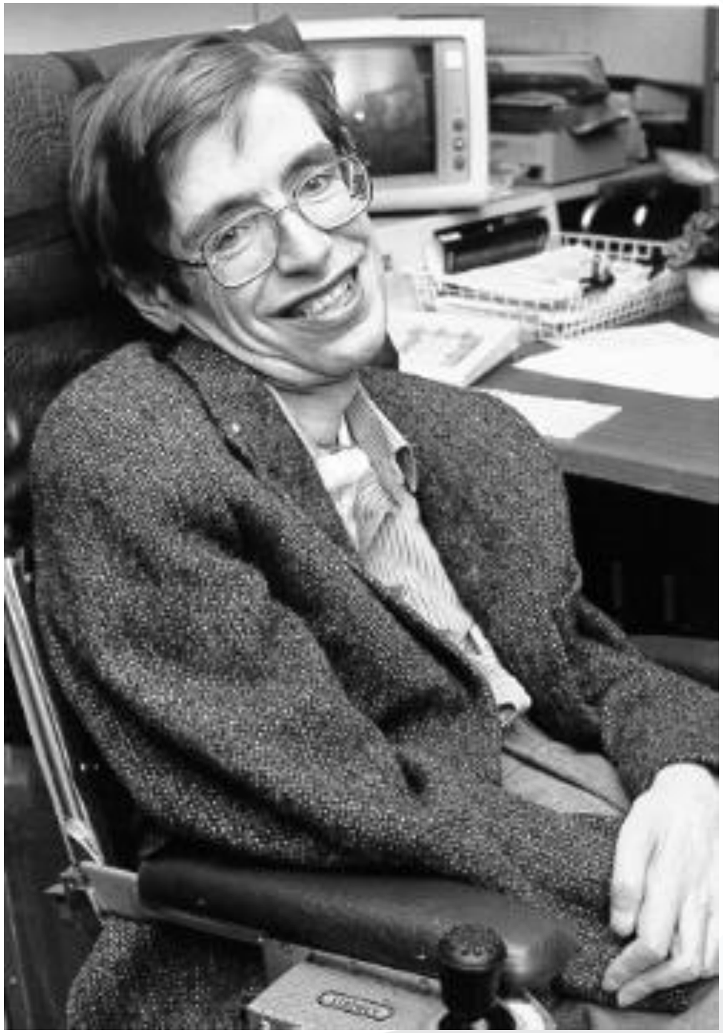
He was **the pre-eminent scientist in a century dominated by science**.
The touchstones of the era--the Bomb, the Big Bang, quantum physics and electronics--all bear his imprint.



“The Temple of Science”

“The Principles of Research”

Prof Stephen Hawking 1948 2018 -- Focus on what we can do



Professional and Civic Astrophysics Life

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