

# Fitzwilliam ReSearchers in Schools Programme

Astronomy, Astrophysics & Cosmology

Irene Abril Cabezas

Credits: ESO/Y. Beletsky



# A little introduction...

- Small hometown in the North of Spain
- BSc in Physics (Spain) + summer internships!
- MAST in Astrophysics
- PhD in Applied Mathematics & Theoretical Physics



La Silva



“Scientific Summer Camps”  
Spanish Foundation for Science and Technology



European Space Camp (Norway)



Summer Programme (Taiwan)

# Contents

- ❖ Higher education: Academic path
- ❖ Sneak peaks into astronomical reSearch
- ❖ Going forward

# (personal) Reasons to pursue higher education

- Science is fun!
- Role models (parents, teachers, popular culture?)
- Really curious person - continue learning
- Inertia: continue doing what I am already doing (and really enjoy)
- Excited about all the perks



Credits: Self acquired screenshot, Fair use

# A day in the (academic) life

## Collaboration Meeting



## Outreach days

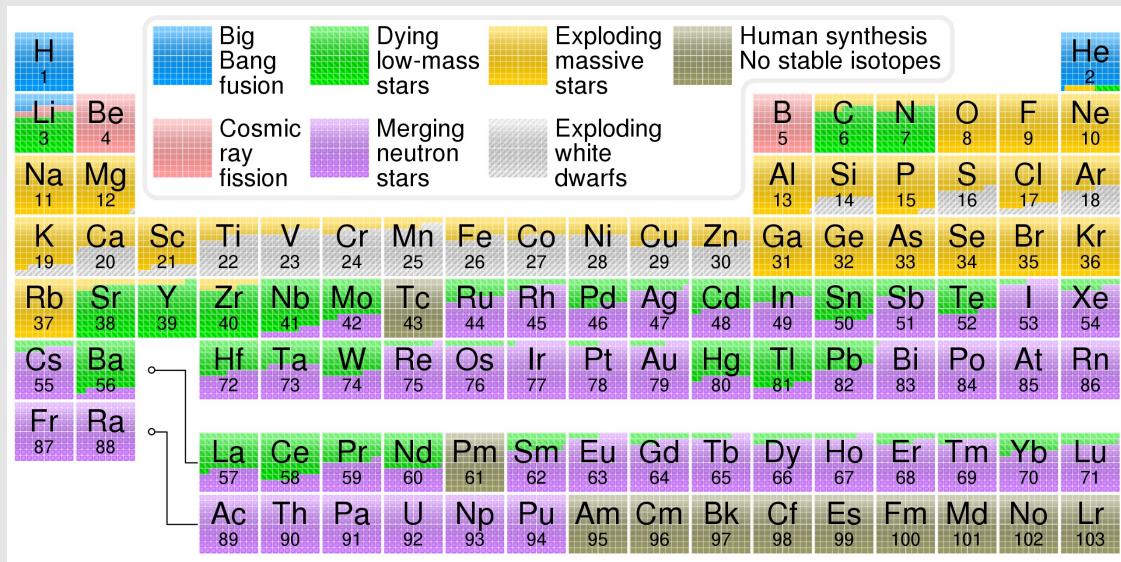


## Family visit



# We are made of stardust

## Margaret Burbidge (UK, 1911 – 2020): Founder of stellar nucleosynthesis theory



Credits: Cmqlee, CC BY-SA 3.0

Credits: Sky & Telescope

# Supermassive black-holes

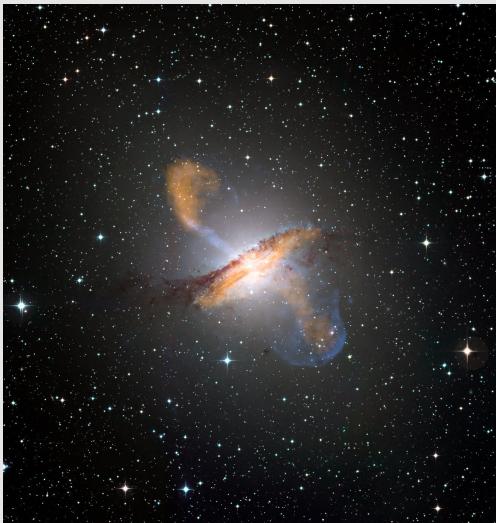
Andrea Ghez (USA, 1965-):

Evidence of its presence in our Galaxy

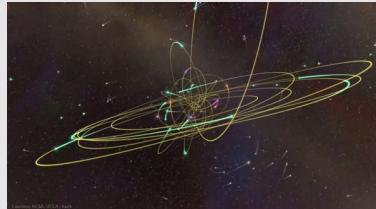
Can launch extremely powerful jets



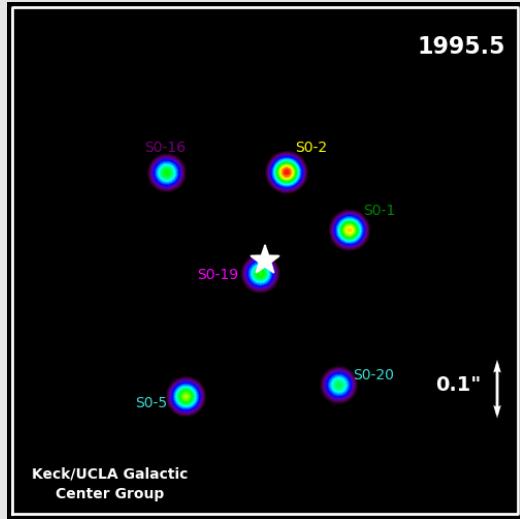
Credits: NASA/JPL-CALTECH



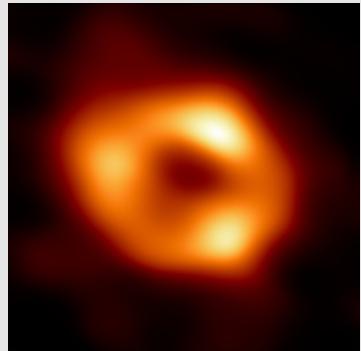
Credits: ESO/WFI, MPIfR/ESO/APEX/ A.Weiss  
et al., NASA/CXC/CfA/R.Kraft et al.



Credits: UCLA Galactic Center  
Group/W.M. Keck Observatory  
Laser Team/NCSA



Keck/UCLA Galactic  
Center Group



Credits: EHT Collaboration

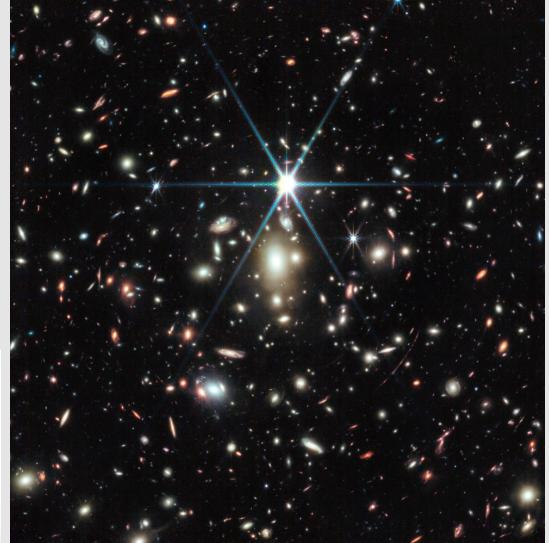


Credits: Nobel Prize Outreach / Stefan Bladh

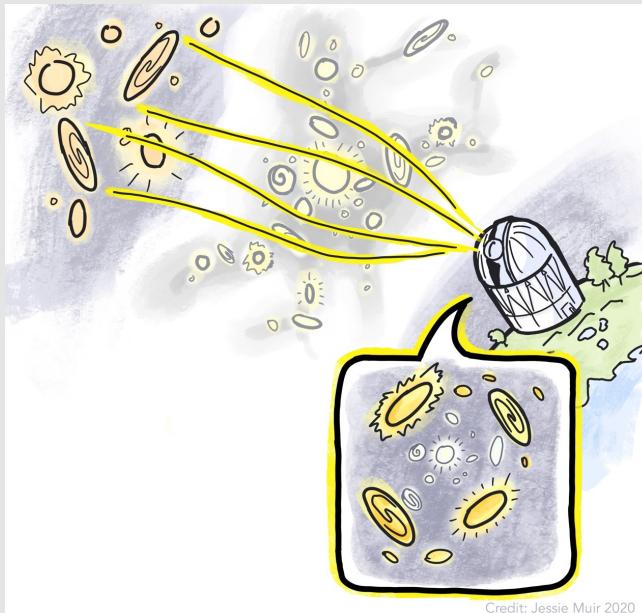
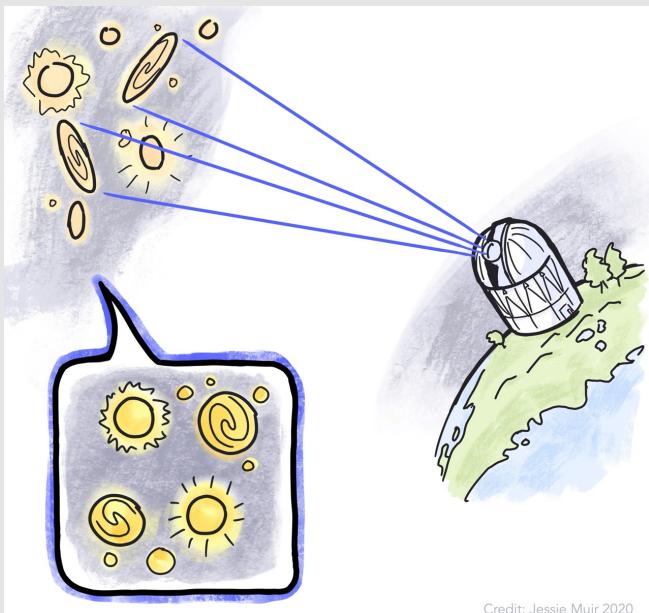
# Weak gravitational lensing

Alex Amon (Trinidad y Tobago, 1992–):  
Lead cosmic structure growth measurements

Credits: NASA, ESA, CSA



Credits: Jessie Muir



Source: Twitter

# Astronomy 101 - Table of contents

1. Astronomy is an observational science
2. Telescopes and light
3. Inverse-square law and angular resolution. The atmosphere
4. Optical telescopes. Photometry and spectroscopy
5. The electromagnetic spectra. Radio telescopes
6. Space telescopes

# Telescopes

Astrophysics is often cast as an observational science

It uses the whole electromagnetic spectrum + new windows opened in the last decade

Aims of telescopes:

1. Gather the maximum number of photons
2. Increase the detail (**angular resolution**) of astronomical observations



Galileo's telescope

James Webb Space Telescope



Credit: NASA

# Description of light

Light behaves mainly like a wave but it can also be considered to consist of tiny packages of energy called photons

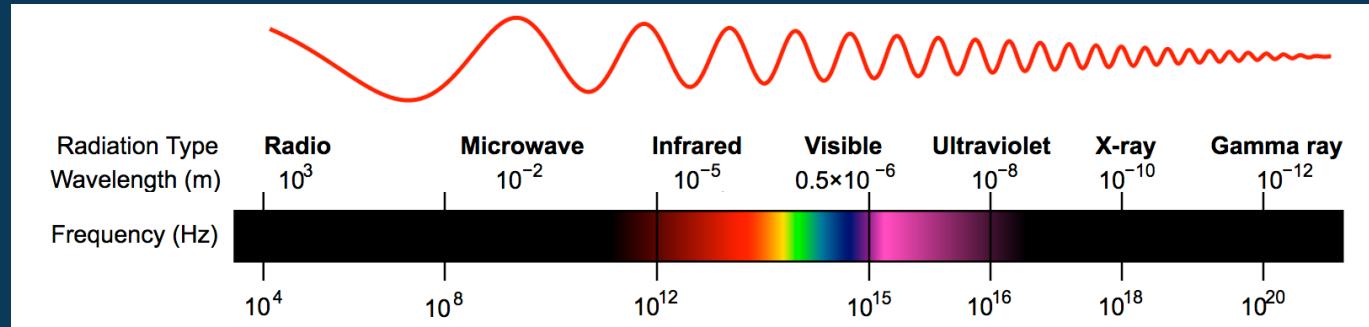
Photons carry a fixed amount of energy but have no mass

Energy of photon:  $E = h\nu$

$h$ : Planck's constant,  $h = 4 \cdot 10^{-15} \text{ eV / Hz}$ ,  $\hbar = h / 2\pi$

$\nu$  : frequency of photon,  $c = \lambda\nu = 3 \cdot 10^8 \text{ m/s}$

Credit: CC BY-SA 3.0, id=136928379



# Telescopes collecting light

Inverse-square law:

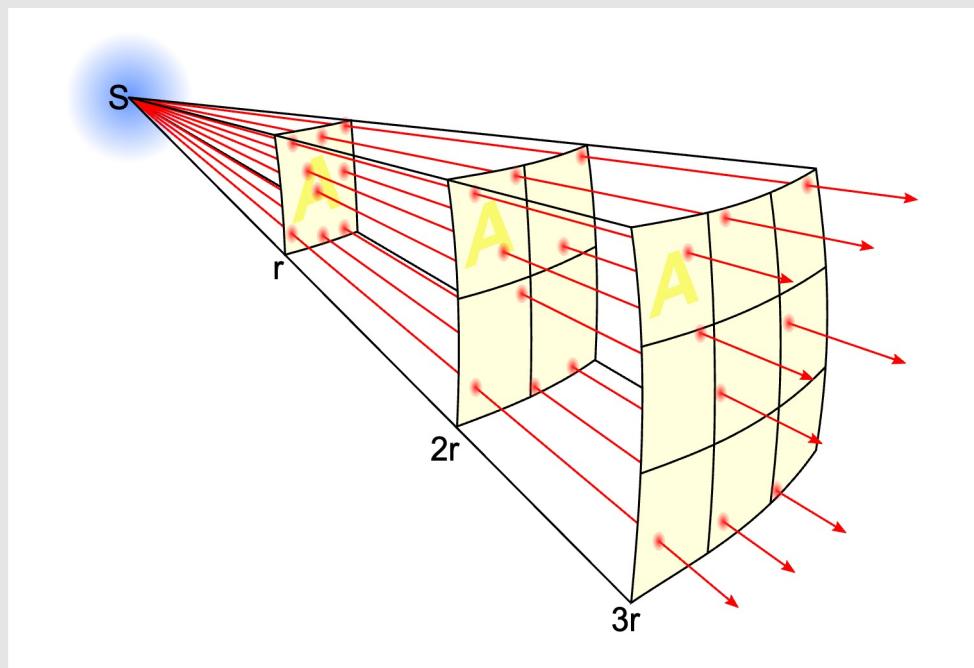
$$f = \frac{L}{4\pi d^2}$$

$f$  (W / m<sup>2</sup>): flux [energy received per unit time per unit area]

$L$  (W): luminosity [energy emitted per unit time]

$d$  (m) : distance

Credit: De Borb, CC BY-SA 3.0



# Telescopes forming images

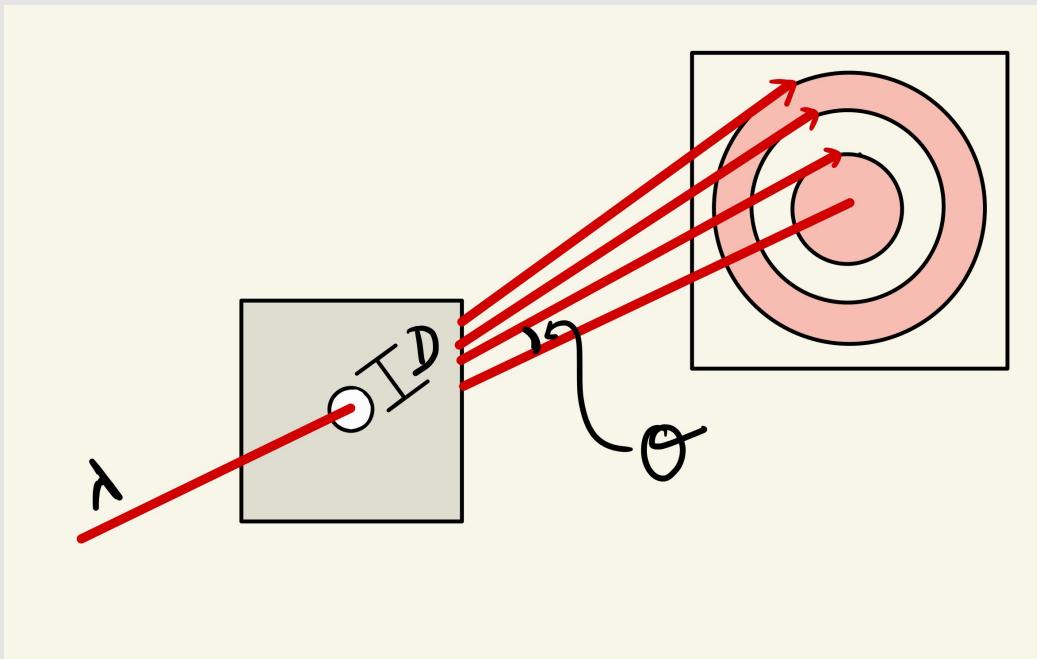
Airy disk radius:

$$\theta = 1.22 \frac{\lambda}{D}$$

$\theta$  (rad): radius containing most light

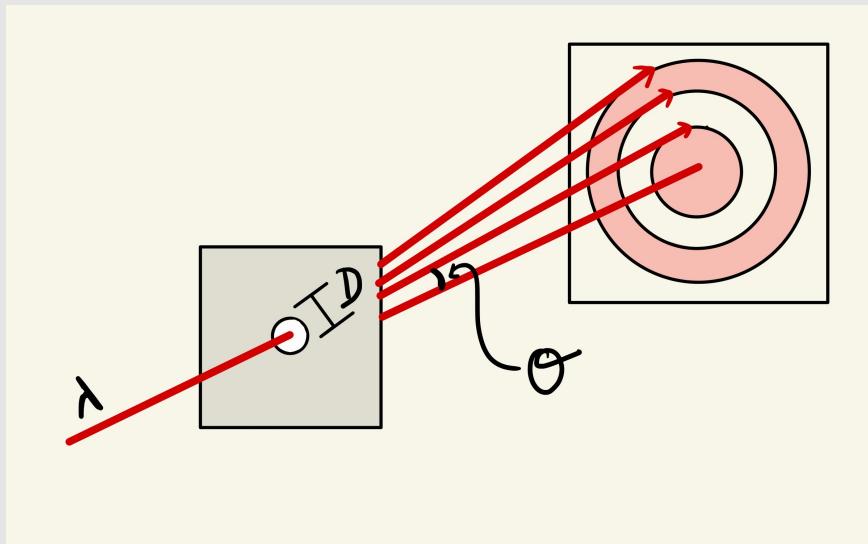
$\lambda$  (length): wavelength of light

$D$  (length) : diameter of aperture

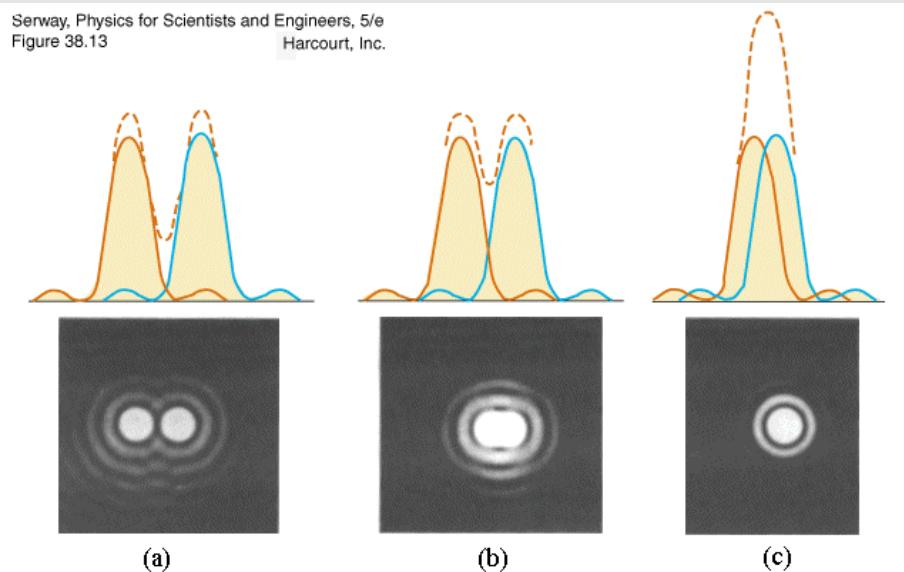


# Telescopes forming images - angular resolution

Airy disk radius:  $\theta = 1.22 \frac{\lambda}{D}$



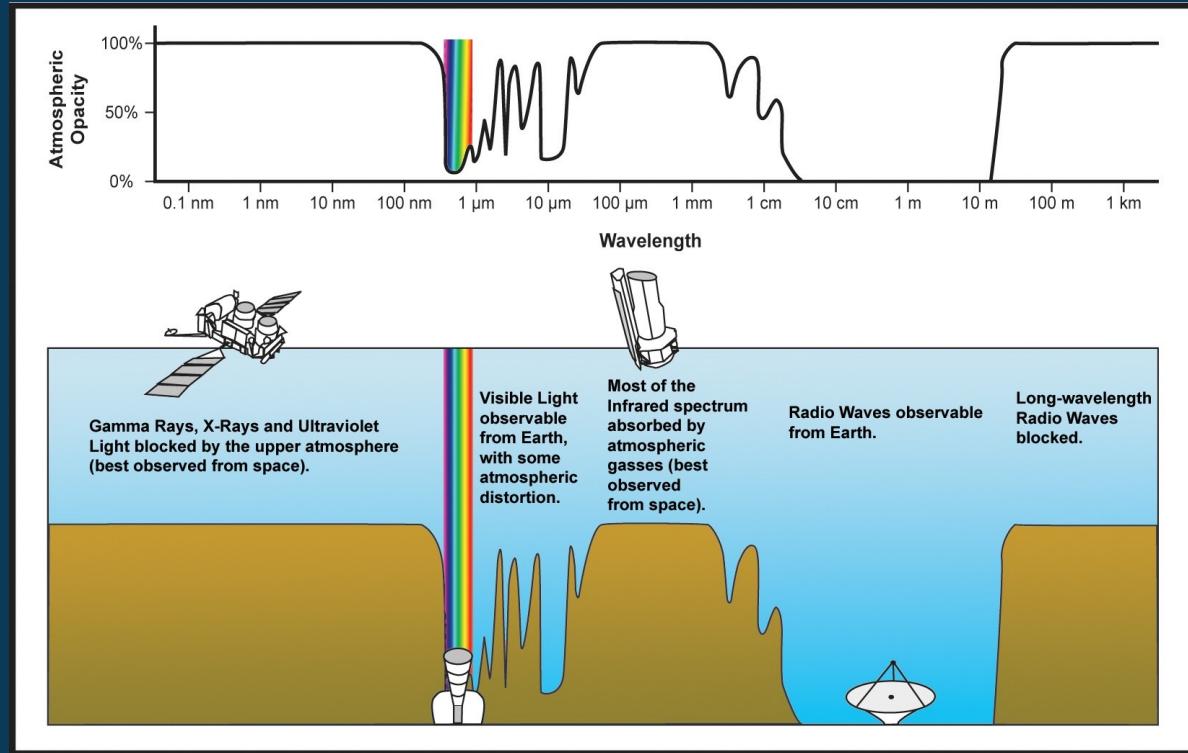
Serway, Physics for Scientists and Engineers, 5/e  
Figure 38.13  
Harcourt, Inc.



# AtmoSphere

Earth's atmosphere is opaque to radiation across most of the electromagnetic spectrum

- ✓ Visible wavelength
- ✓ Radio wavelengths
- ✓ Some infrared light



# Optical BIG telescopes

Gran Telescopio de Canarias - 10.4m in La Palma (Canary Islands, Spain)



Credit: Daniel López/IAC

Credit: Daniel López/IAC



# Optical BIG telescopes

Keck Observatory – Two 10-meter telescopes



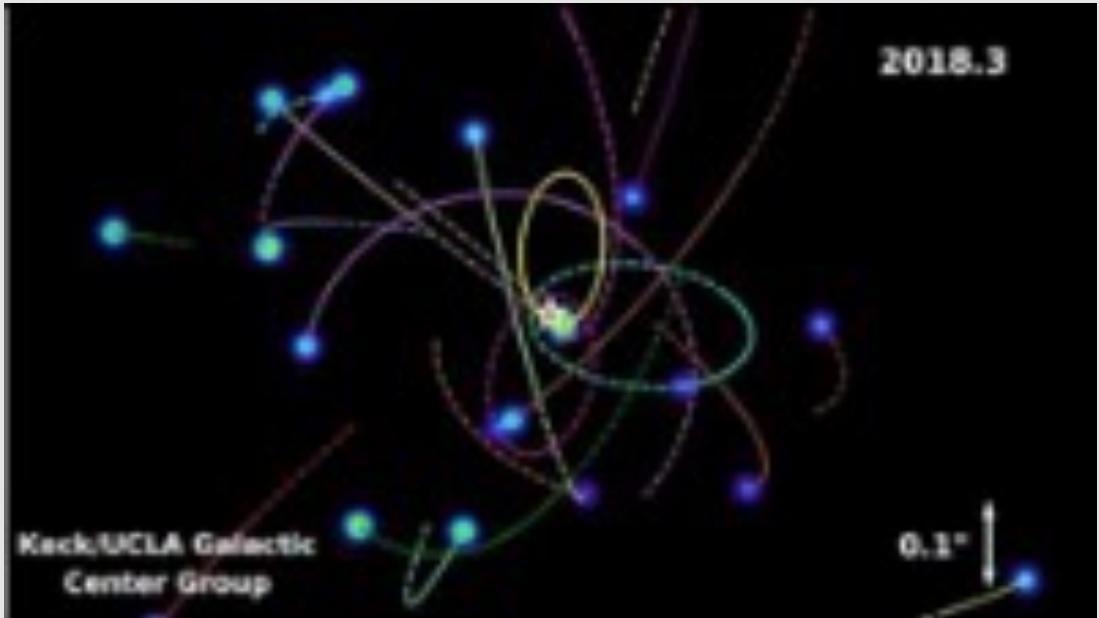
Courtesy W. M. Keck Observatory



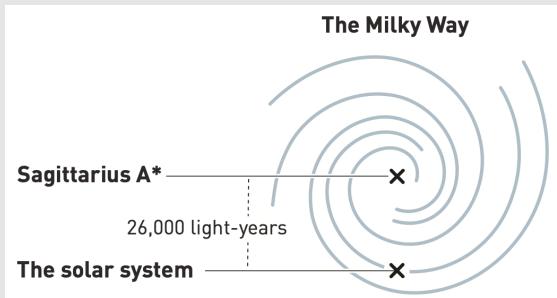
Courtesy W. M. Keck Observatory

# Nobel Prize in Physics 2020

Stars orbiting super massive black hole - Keck UCLA  
Galactic Center Group



<https://youtu.be/rxJgebvqzXA>



Credit: Johan Jarnestad/The Royal Swedish Academy of Sciences

Andrea Ghez



Credit: Nobel Prize Outreach/  
Stefan Bladh

# Hawaii' Mauna Kea is Sacred for Native Hawaiians

Thirty Meter Telescope (TMT) construction protests in 2019



Credit: Pu'uhonua o Pu'uhuluhulu Maunakea

12 observatories are already present in the summit

## The Fight for Mauna Kea Is a Fight Against Colonial Science

*The protests by Native Hawaiians against the Thirty Meter Telescope are a cry for respect for indigenous autonomy.*

KEOLU FOX and CHANDA PRESCOD-WEINSTEIN

SHARE ▾

# Optical GIANT telescopes



Credit: G. Hüdepohl ([atacamaphoto.com](http://atacamaphoto.com))/ESO

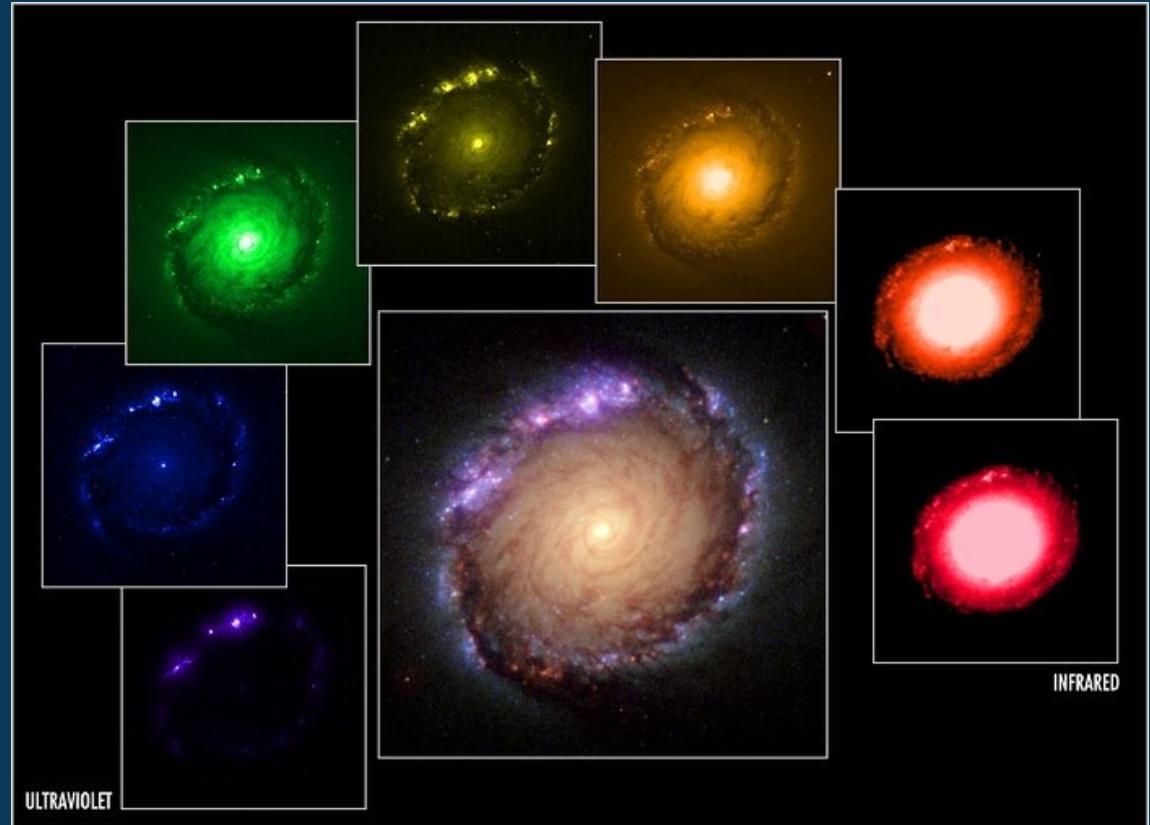


Credit: G. Hüdepohl ([atacamaphoto.com](http://atacamaphoto.com))/ESO

# Photometry

Celestial bodies emit light at a variety of wavelengths, anywhere from gamma rays to radio waves

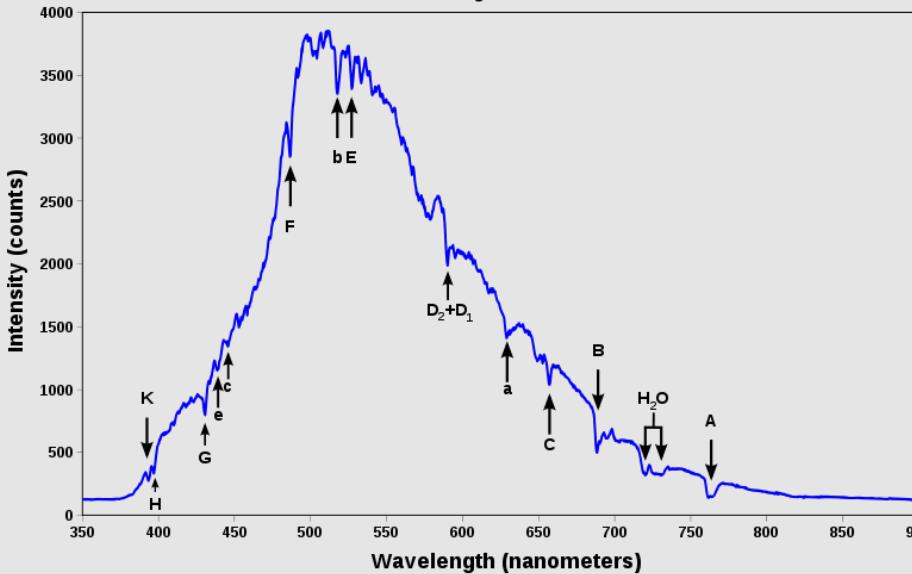
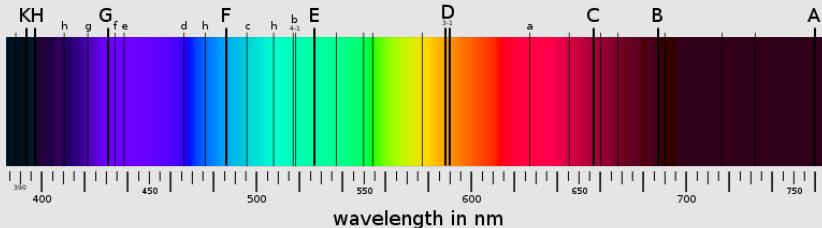
Photometry gathers light and passes it through specialized photometric optical bandpass filters



Credit: NASA, ESA, Dan Maoz (Tel-Aviv University, Israel, and Columbia University, USA)

# SpectroSCOPY

## Optical spectrum of the Sun



Credit: Eric Bajart CC BY-SA 4.0

Credit: Apic/Getty Images



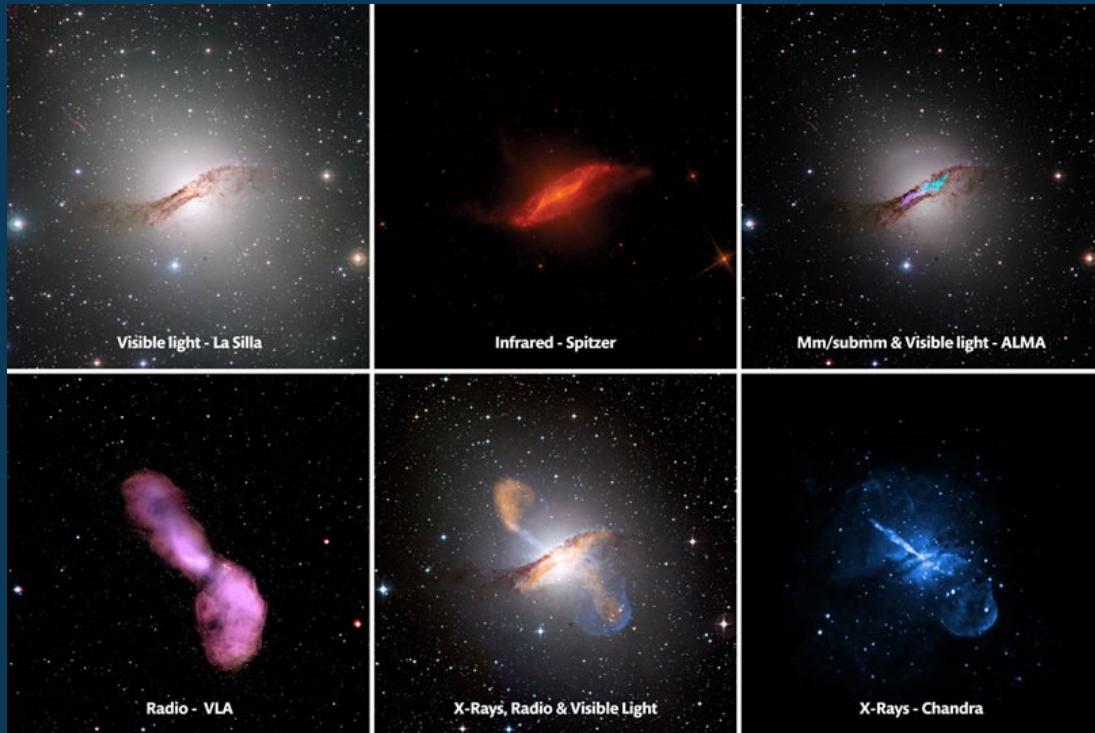
Spectroscopy is high-resolution photometry

From the absorption/emission lines we obtain physical parameters of astronomical system (temperature, element abundances...)

# Multi-frequency obServations

A complete description of astronomical objects can only be obtained with observations across the whole electromagnetic range

Credit: Atacama Large Millimeter/Submillimeter Array



Centaurus A is an elliptical & active galaxy, 13 million light-years away from us. Its dusty core is apparent in visible light, but its jets are best viewed in X-ray and radio light.

# Radio telescopes

Radio waves are accessible from Earth's surface

Low angular resolution...  $\theta = 1.22 \frac{\lambda}{D}$

$$\lambda = 21cm, \theta = 10'$$

Jodrell Bank Observatory – 76m  
(Manchester)



Credit: Phil Noble/PA

FIRAS - 500m (Guizhou, China)

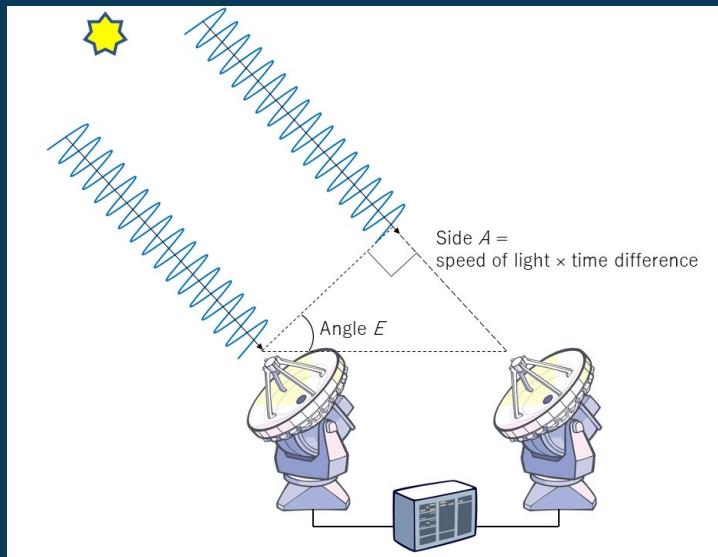


Credit: Lu Xu/Xinhua/Getty Images

# Interferometry

$$\theta = 1.22 \frac{\lambda}{D}$$

Achieve higher resolution with antenna array (resolution given by longest baseline)



Credit: ALMA (ESO/NAOJ/NRAO)

ALMA - 66 high-precision antennas

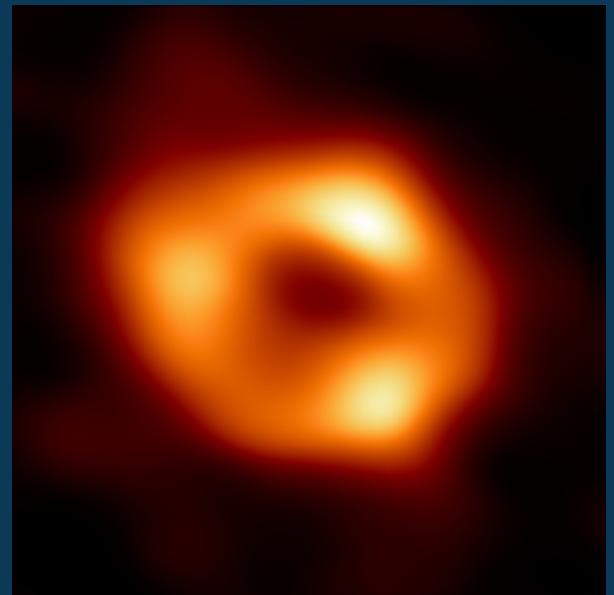


Credit: ESO/C. Malin ([christophmalin.com](http://christophmalin.com))

# Interferometry

$$\theta = 1.22 \frac{\lambda}{D}$$

PICTURE OF OUR OWN SUPER MASSIVE BLACK HOLE!?



Credit: EHT Collaboration

[https://www.youtube.com/watch?v=hMsNd1W\\_lmE](https://www.youtube.com/watch?v=hMsNd1W_lmE)

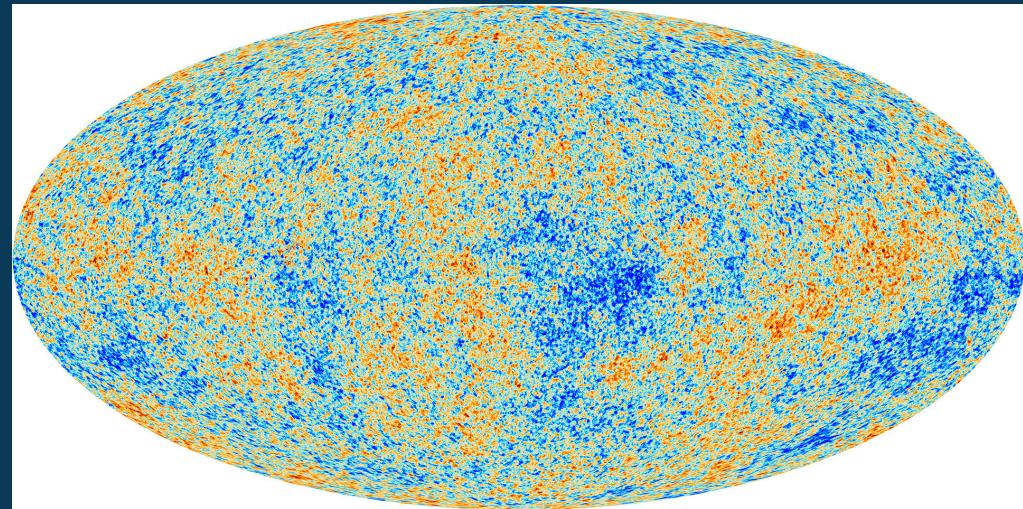
# Space telescopes

Grand-design spiral galaxy M51 with Webb (stellar nursery)



Credit: ESA/Webb, NASA & CSA, A. Adamo  
(Stockholm University) and the FEAST JWST team

Planck telescope measures the cosmic microwave background radiation (picture of baby Universe)



Credit: ESA/Planck

# Going forward



Higher education: Academic path

Loads of fun!



Astronomy & Astrophysics

BIG telescopes for BIG science



This is only the beginning!

Own story shaped by own curiosity and interests

Thank you!