

Star Formation

Dr Sarah Jaffa

University of
Hertfordshire **UH**

School of Physics,
Astronomy and Mathematics

OVERVIEW

- 1 Basics of star formation
- 2 Why is star formation important?
- 3 Current challenges in star formation

THEORY

OBSERVATION

SIMULATION

OVERVIEW

1 Basics of star formation

Making a star

Lifetime of a star

Death of a star

2 Why is star formation important?

3 Current challenges in star formation

Star
Formation

Dr Sarah Jaffa
(U. Herts)

Overview

Basics of star
formation

Making a star

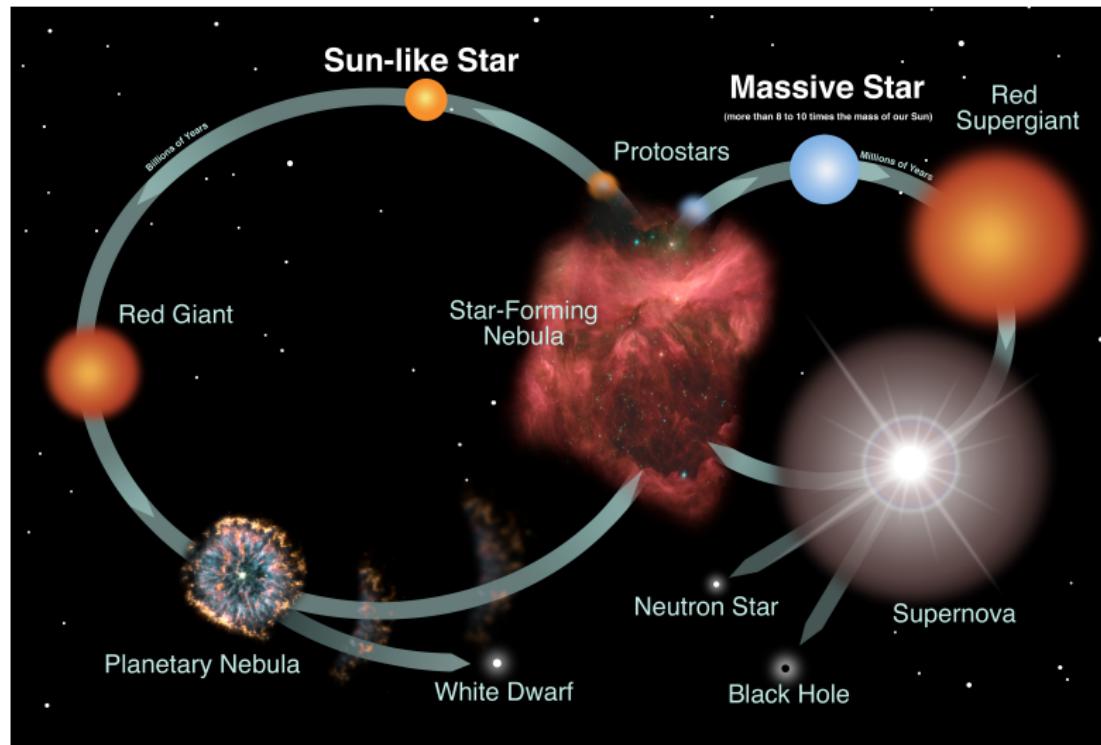
Lifetime of a star

Death of a star

Why is star
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important?

Current
challenges in
star formation

MAKING A STAR



Credit: NASA and the Night Sky Network

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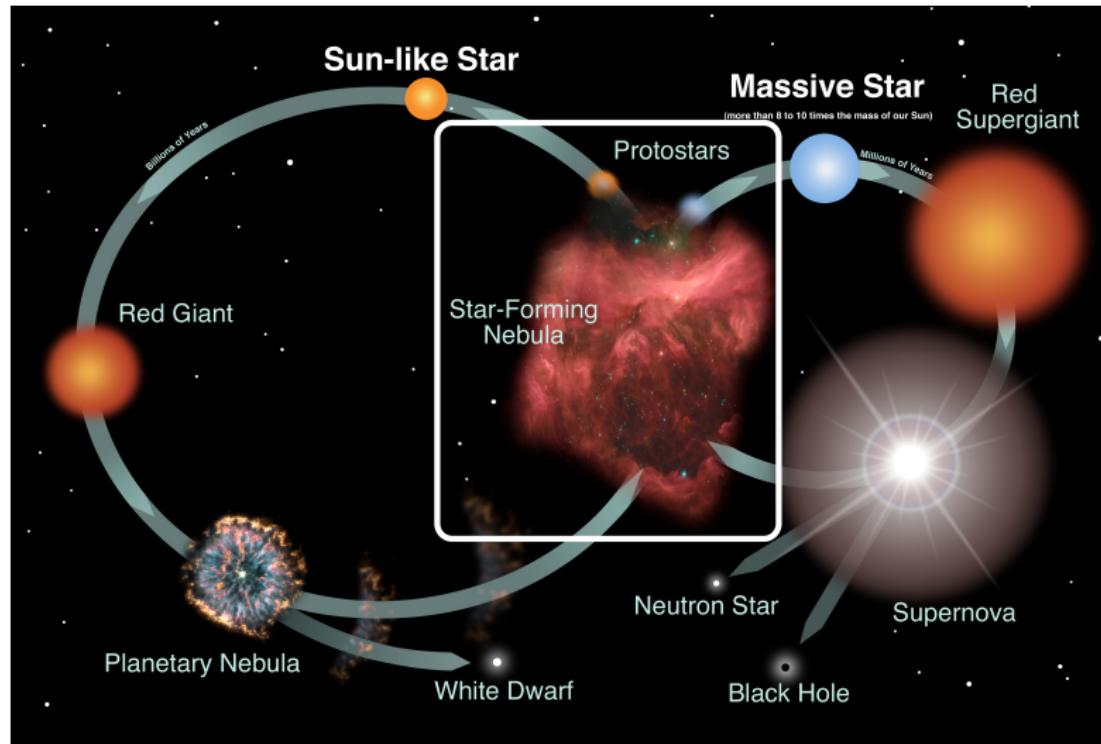
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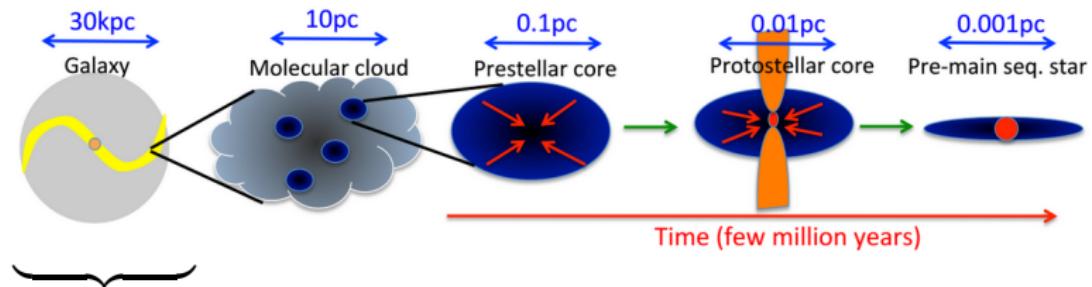


Illustration by N. Peretto, Cardiff

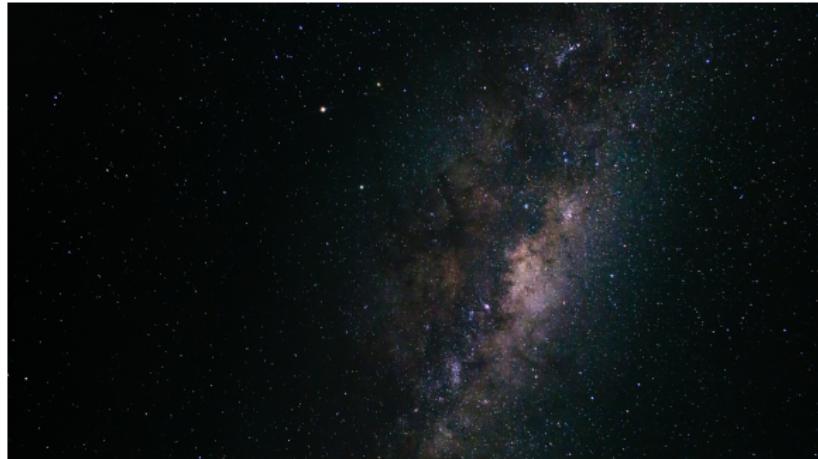


Photo by Thom Schneider on Unsplash

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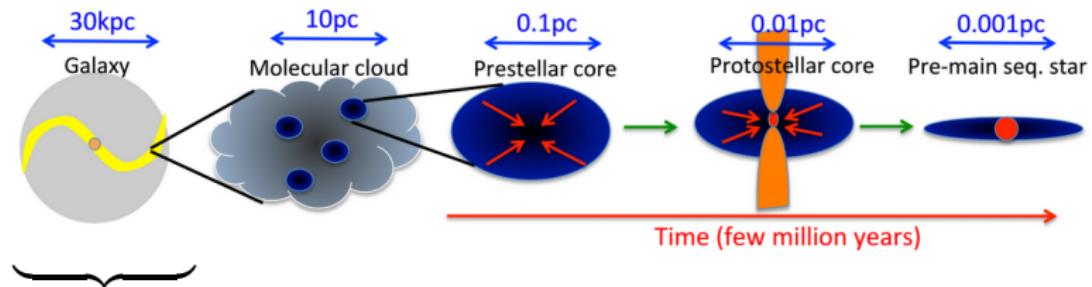


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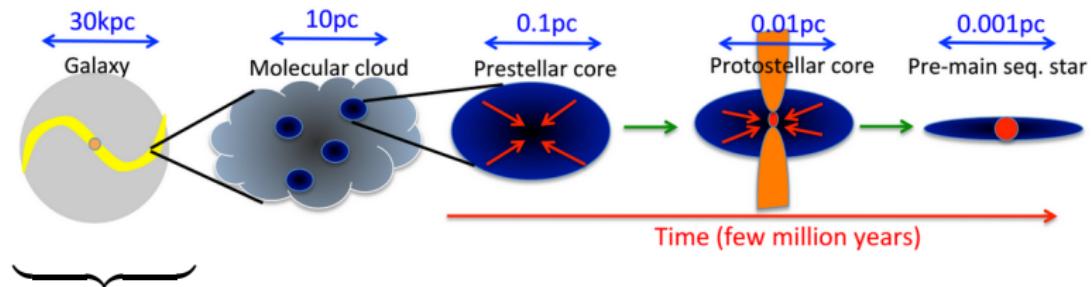


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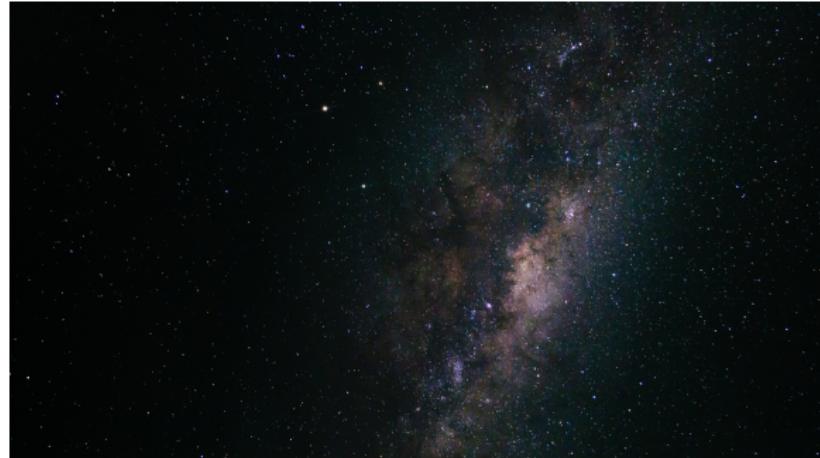


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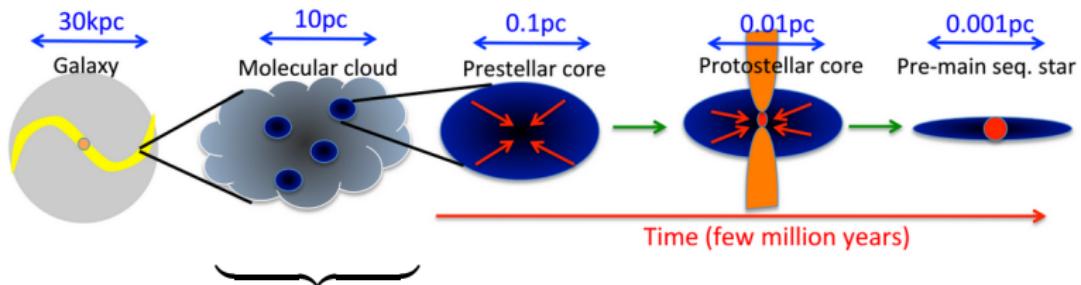


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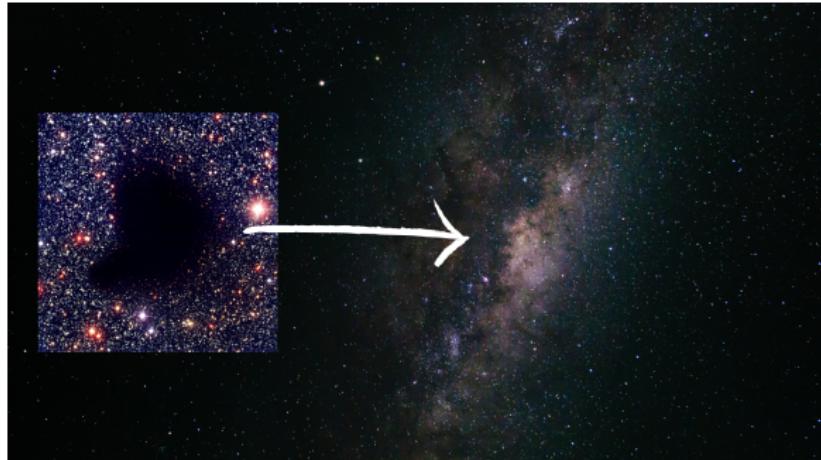


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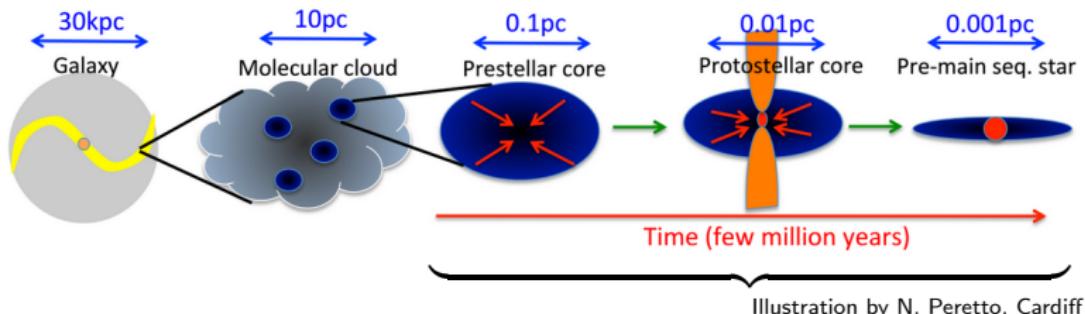


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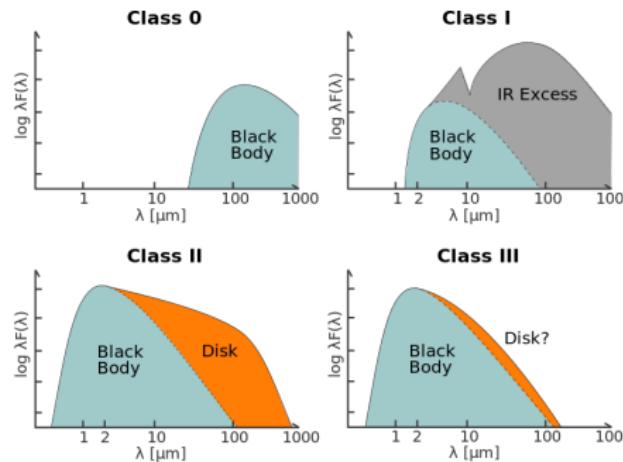


Image by M. V. Persson

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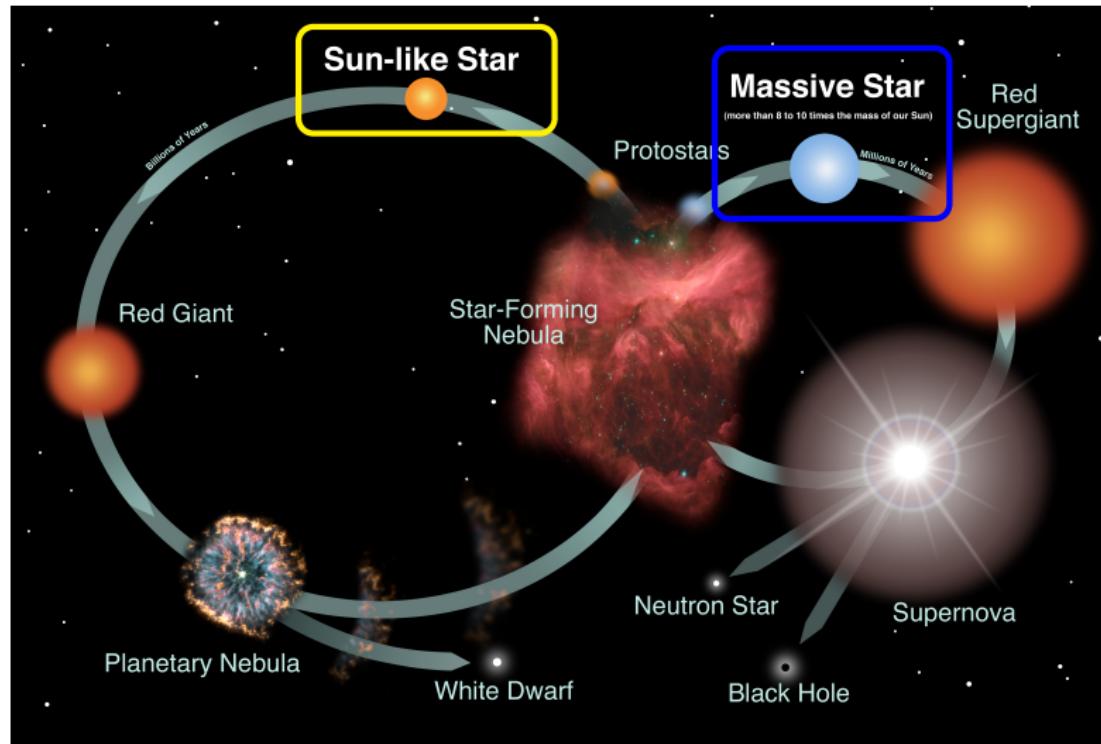
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LIFETIME OF A STAR



Credit: NASA and the Night Sky Network

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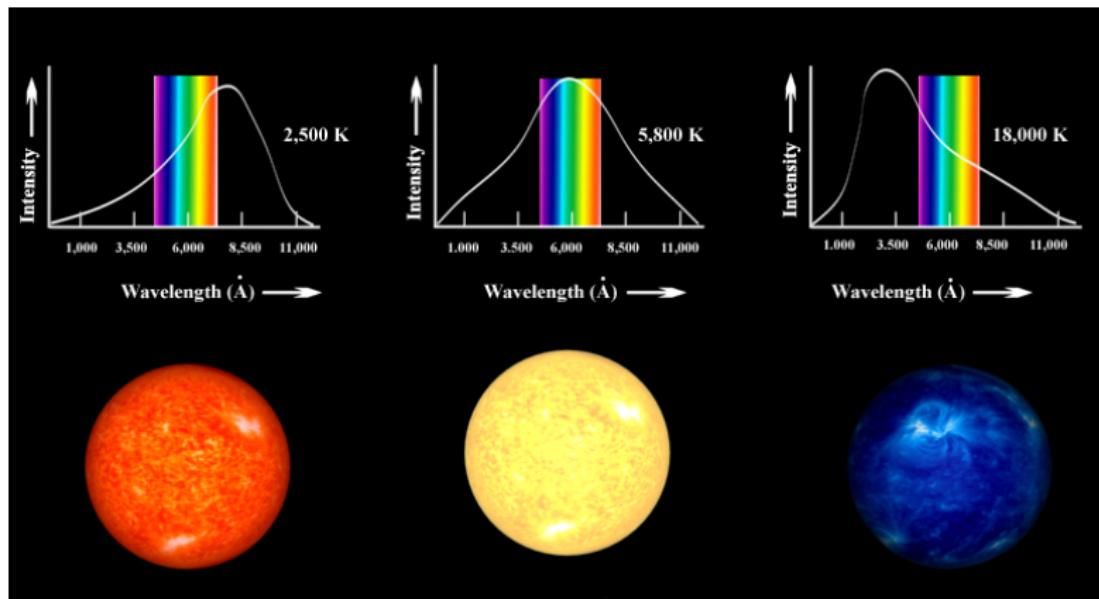
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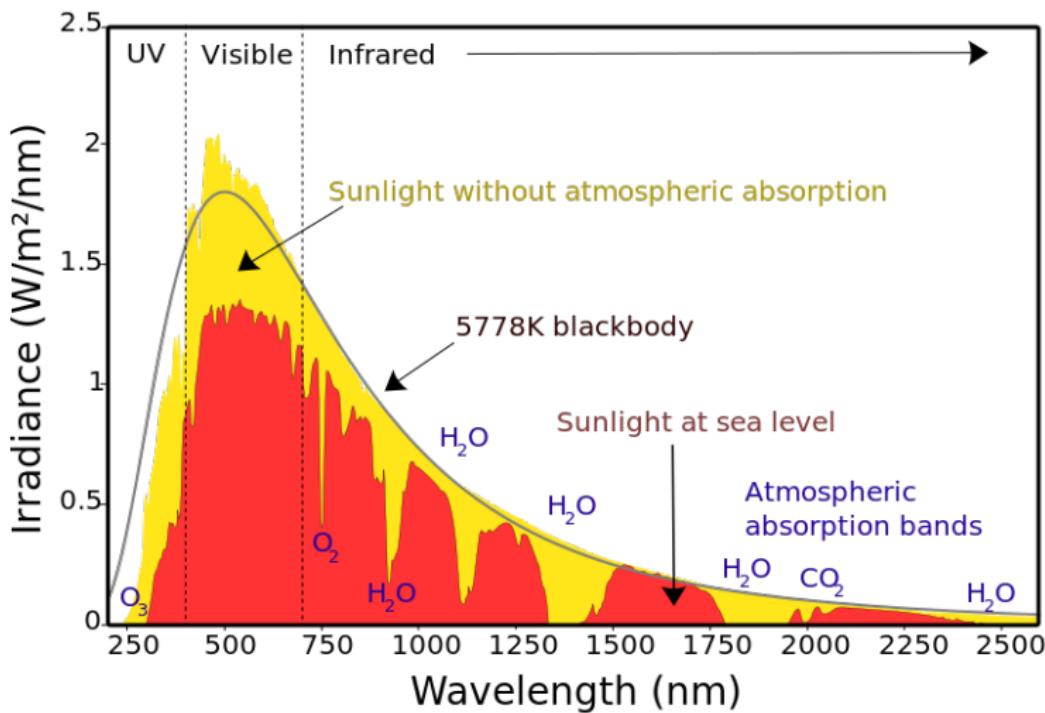
LIFETIME OF A STAR



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LIFETIME OF A STAR

Spectrum of Solar Radiation (Earth)



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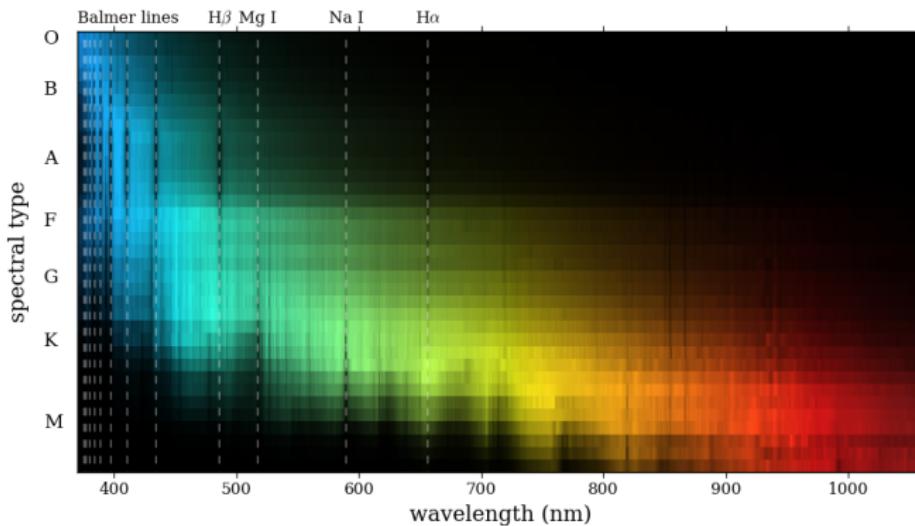
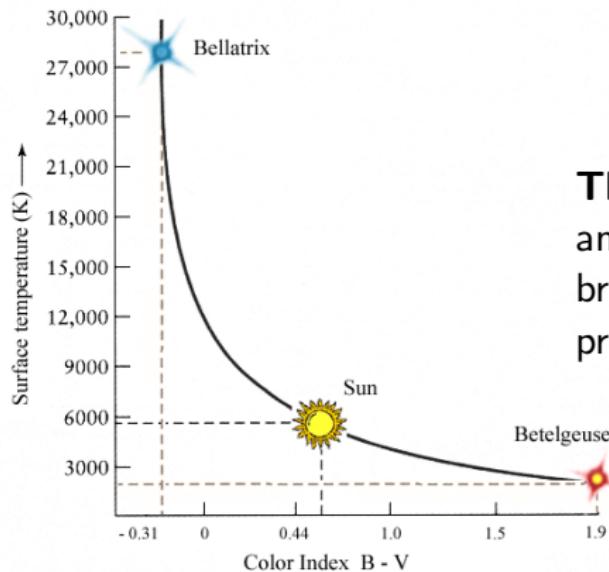


Image from WikiMedia by Warrickball

LIFETIME OF A STAR

Hertzsprung-Russell Diagram



Theory: Mass dictates radius and central pressure, so brightness and temperature are predictable.

LIFETIME OF A STAR

Hertzsprung-Russell Diagram

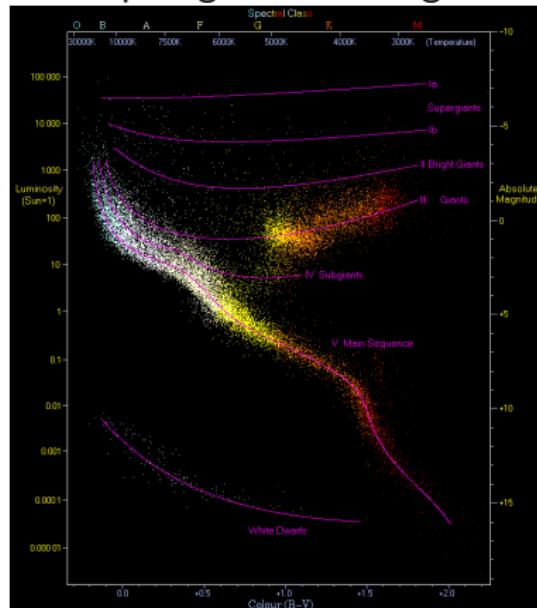


Illustration by Richard Powell WikiMedia Commons

Theory: Mass dictates radius and central pressure, so brightness and temperature are predictable.

Observation: main sequence (stable middle part of the lifecycle) stars lie on the diagonal

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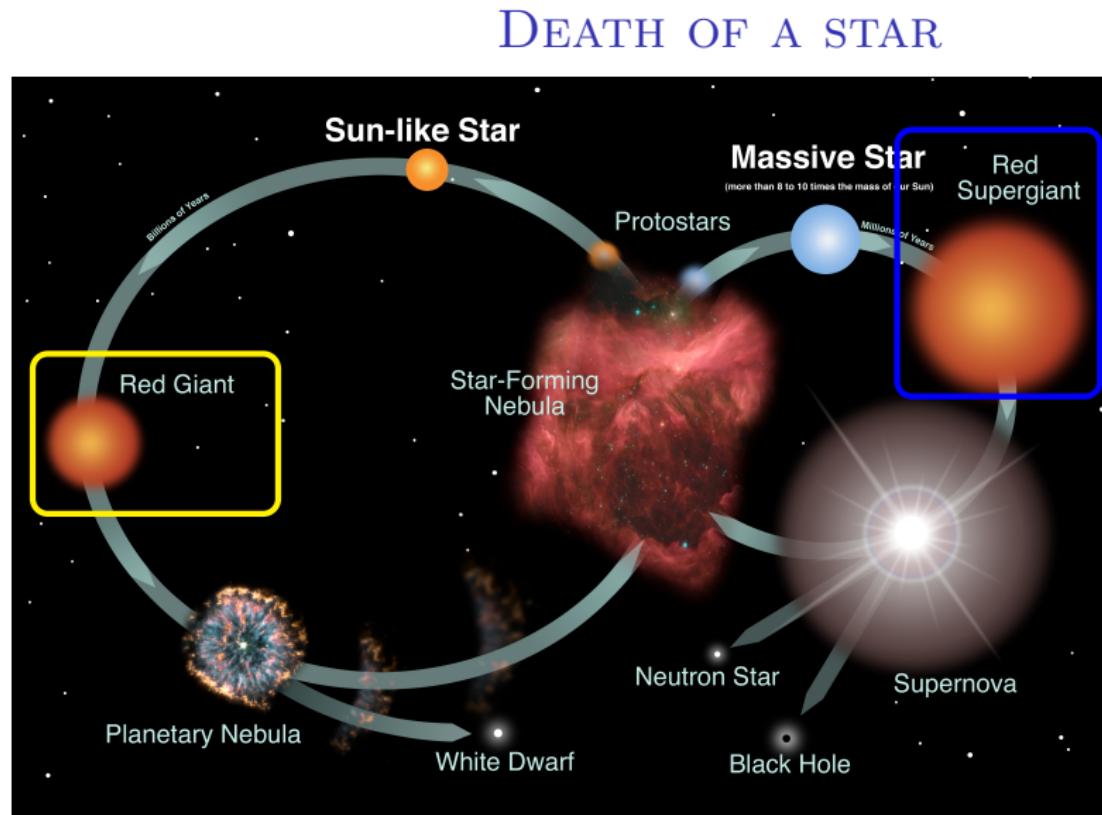
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Credit: NASA and the Night Sky Network

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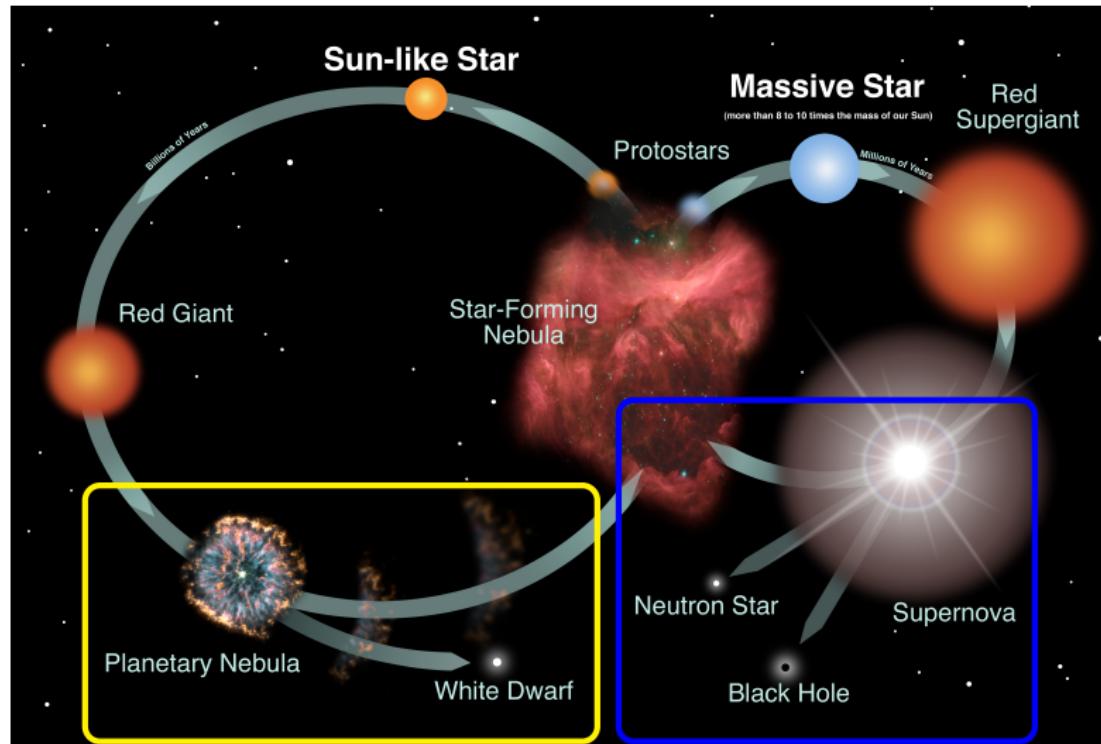
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DEATH OF A STAR



Credit: NASA and the Night Sky Network

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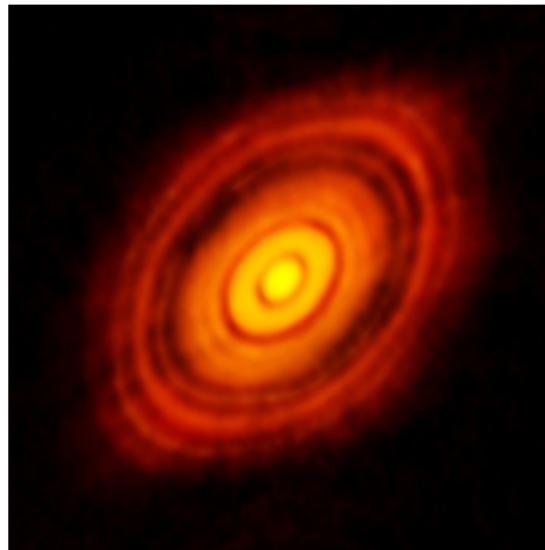
Planets and life

Galaxies

Cosmology

③ Current challenges in star formation

PLANETS AND LIFE

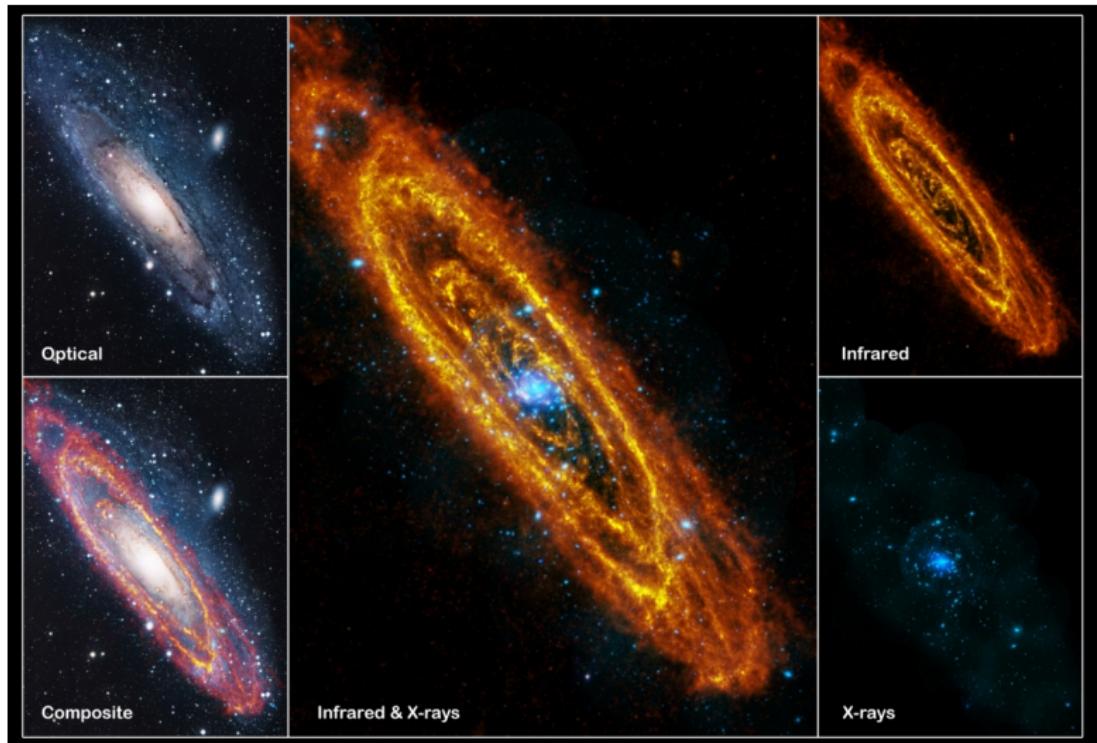


Planet formation:
How, when and where?

First observation of gaps in a
protoplanetary disc:
HL Tau, ALMA, Brogan et al.,
ApJL, 2015

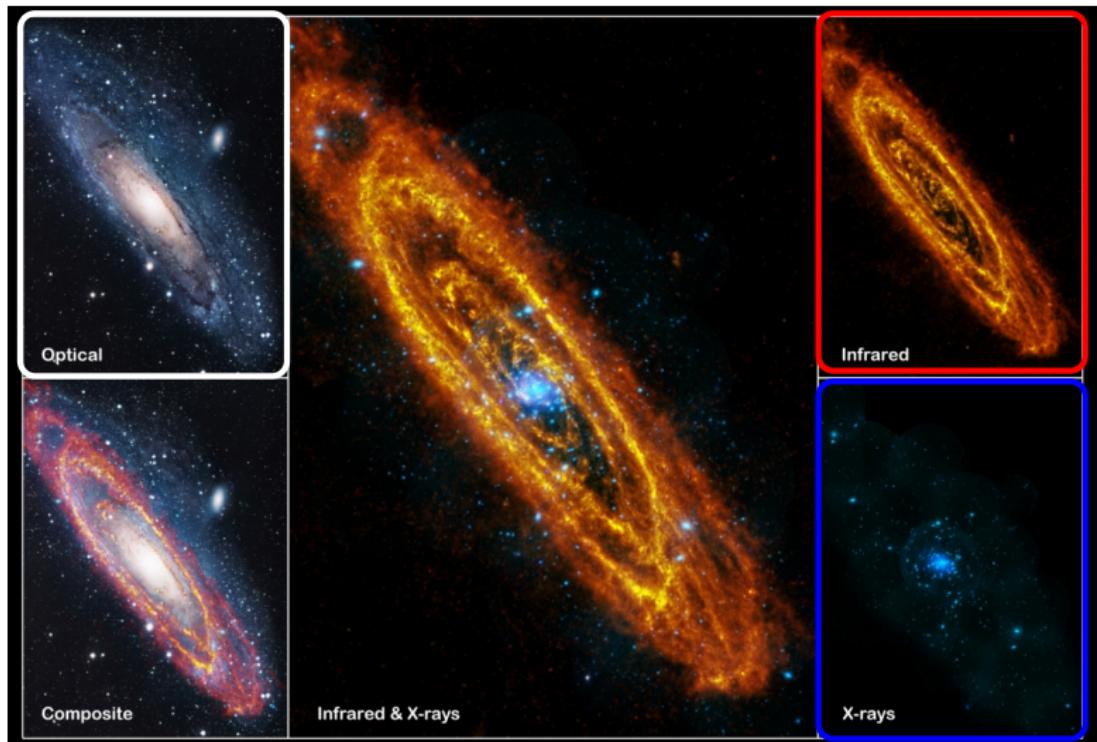
Image from ALMA (ESO/NAOJ/NRAO)

GALAXIES



Multiwavelength M31: infrared: ESA/Herschel/PACS/SPIRE/J. Fritz, U. Gent; X-ray:
ESA/XMM-Newton/EPIC/W. Pietsch, MPE; optical: R. Gendler

GALAXIES



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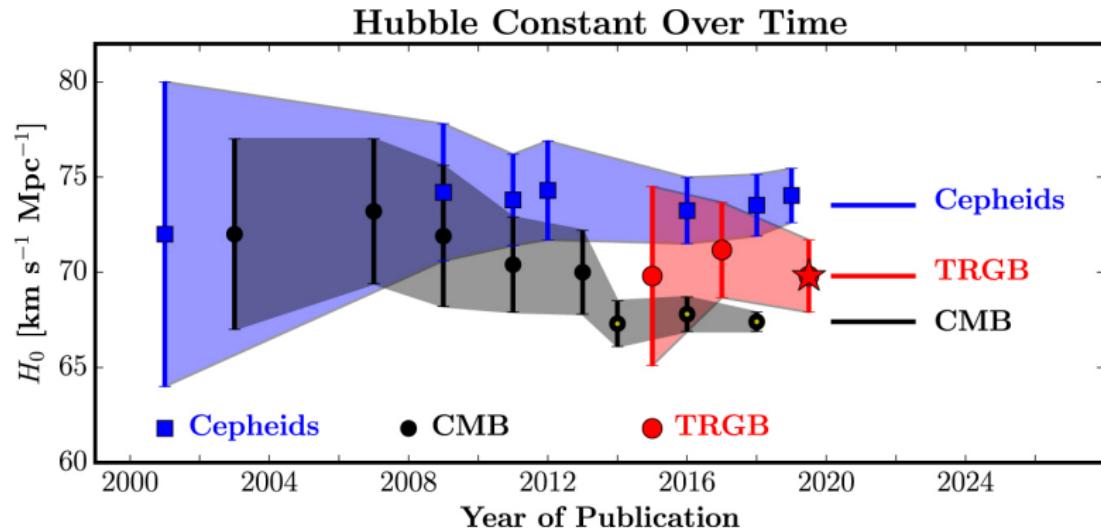
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Image from W. Freedman et al., ApJ, 2019

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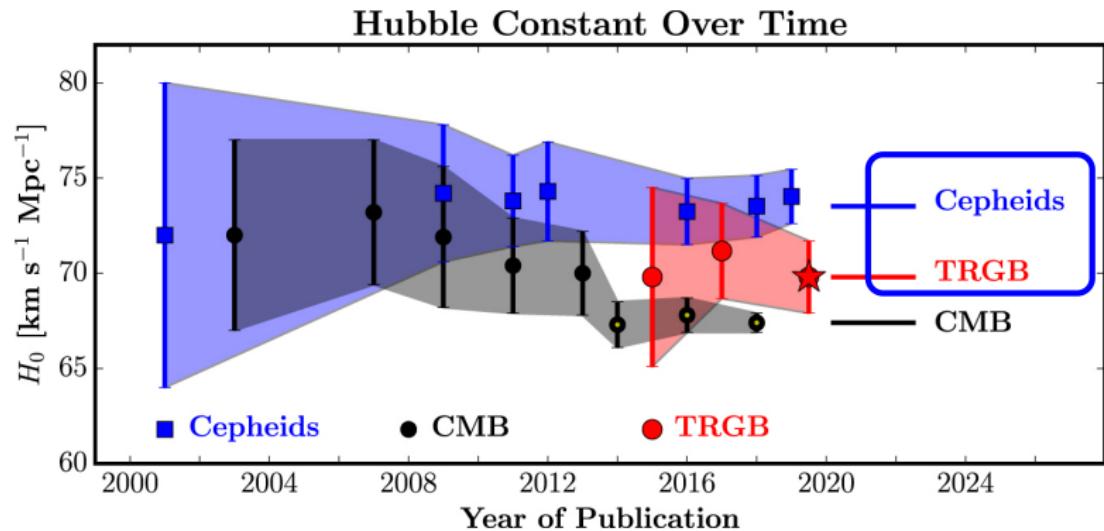
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Big questions

Big telescopes

Big data

Big issues

BIG QUESTIONS

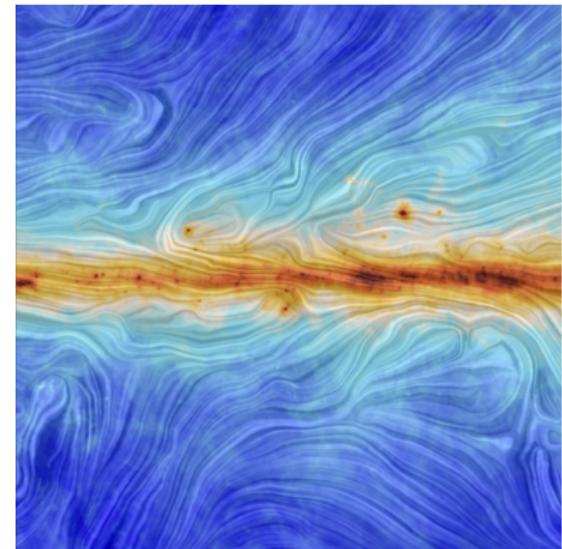
- ① Magnetic fields
- ② Structure and lifetime of clouds
- ③ Initial Mass Function and massive stars
- ④ Planets
- ⑤ Comparing simulations and observation

MAGNETIC FIELDS

Very hard to detect!

Direction: Elongated dust grains align with the magnetic field producing polarised light, but dust formation/growth theory is quite uncertain, lots of dust along the line of sight, measurements change with scale.

Strength: Zeeman splitting of $H\alpha$ line visible against very bright background sources.



ESA/Planck Collaboration/Miville-Deschénes

STRUCTURE AND LIFETIME OF CLOUDS

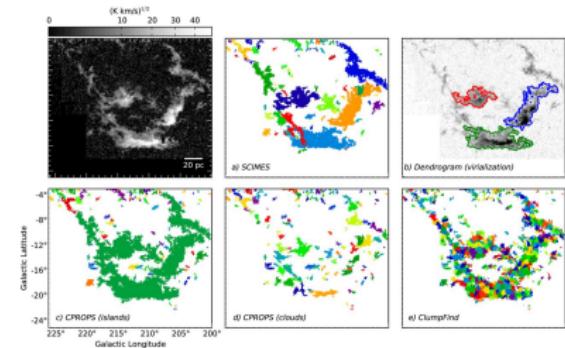
What is a cloud?

Each tracer detects different density/temperature.

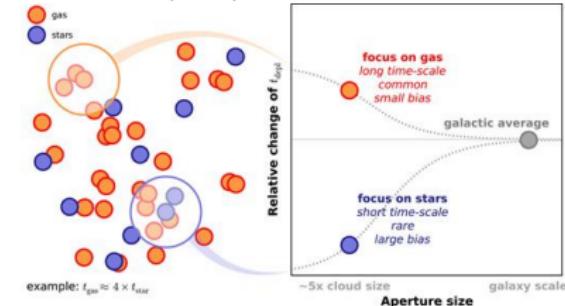
'Cloud identifying' algorithms are highly inconsistent and tuneable.

How long do they live?

What percentage is turned into stars vs. dispersed by feedback?
Are they static or dynamic?

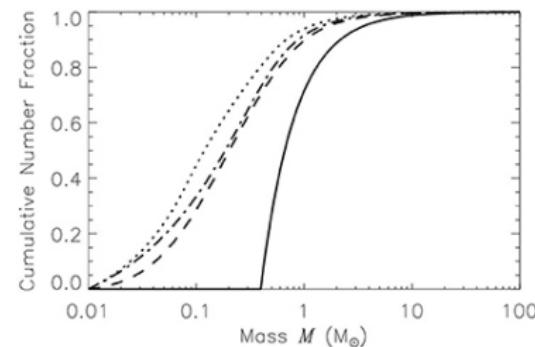
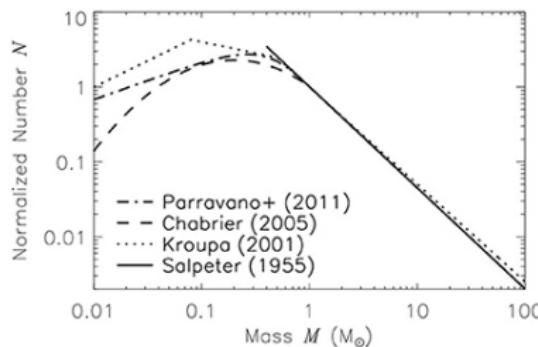


Colombo et al., 2015, MNRAS



Kruijssen et al., 2018, MNRAS

INITIAL MASS FUNCTION AND MASSIVE STARS



Krumholz et al., 2019, FrASS

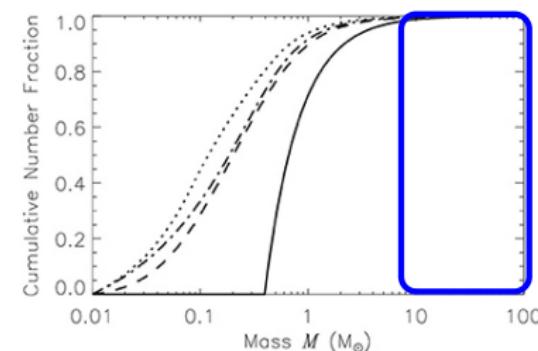
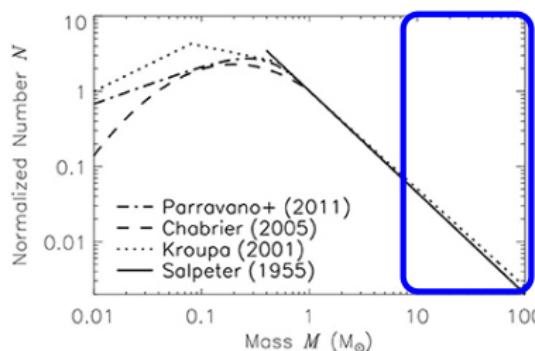
What is the mass of a star when it is born?

Observed distribution of masses in clusters is universal?

Larger stars have shorter lifespans so may not be observed at all. Smaller stars are faint and hard to observe.

Is it the same in all galaxies/clusters, or varies with environment?

INITIAL MASS FUNCTION AND MASSIVE STARS



Krumholz et al., 2019, FrASS

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At what stage of the star
formation process do planets
start to form?

How long do disks last and how
are they affected by the
forming star or others nearby?

Which type of stars are likely to
sustain life?

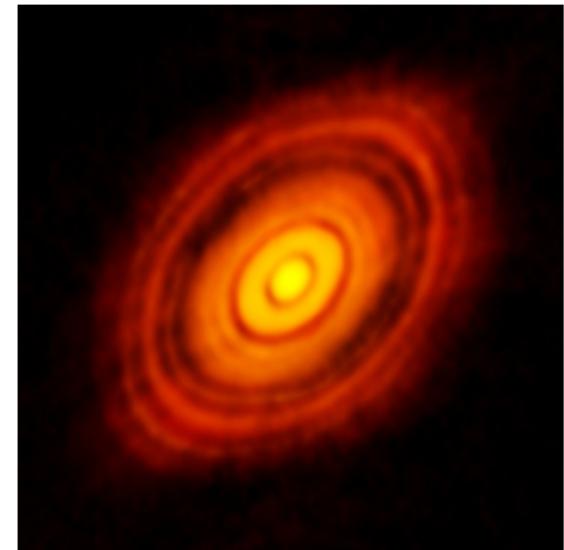
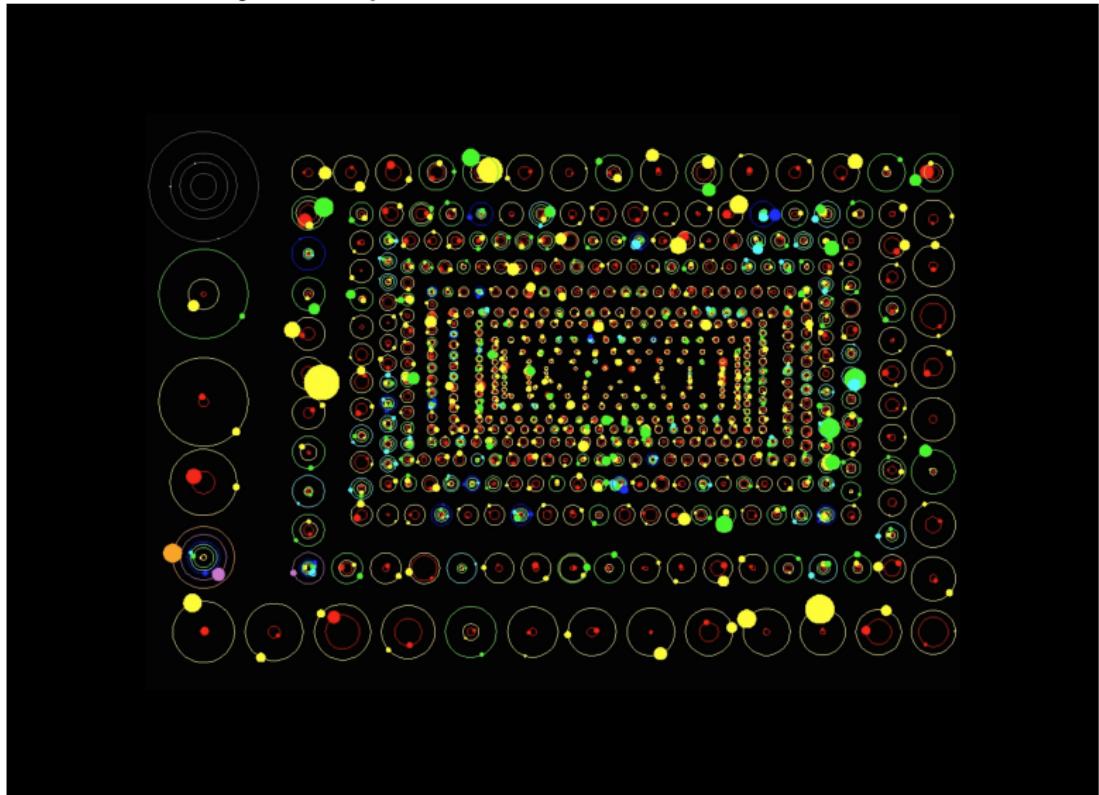


Image from ALMA (ESO/NAOJ/NRAO)

PLANETS

Image from NASA/Kepler/Dan Fabrycky

Is the Solar System special?



Star Formation

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Overview

Basics of star formation

Why is star formation important?

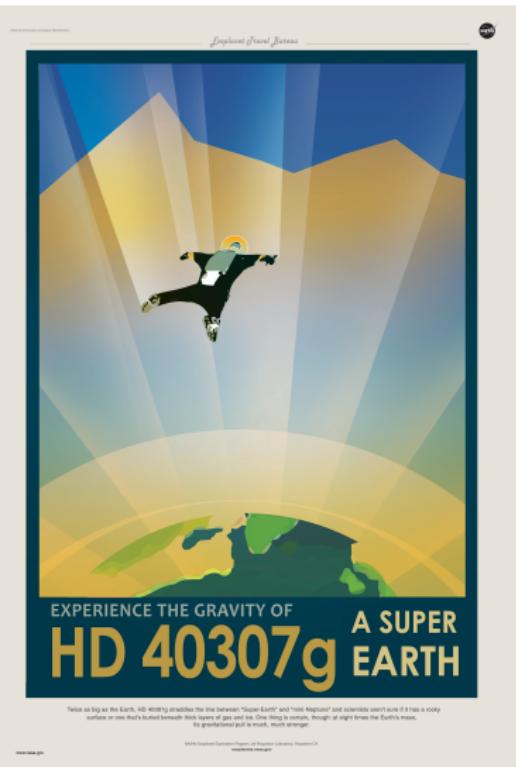
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<https://exoplanets.nasa.gov/alien-worlds/exoplanet-travel-bureau/>

COMPARING SIMULATIONS AND OBSERVATION

Simulations:



Image from Dale, 2014, MNRAS

Observations:



Image from ESA/Hi-GAL Project

COMPARING SIMULATIONS AND OBSERVATION

Simulations:

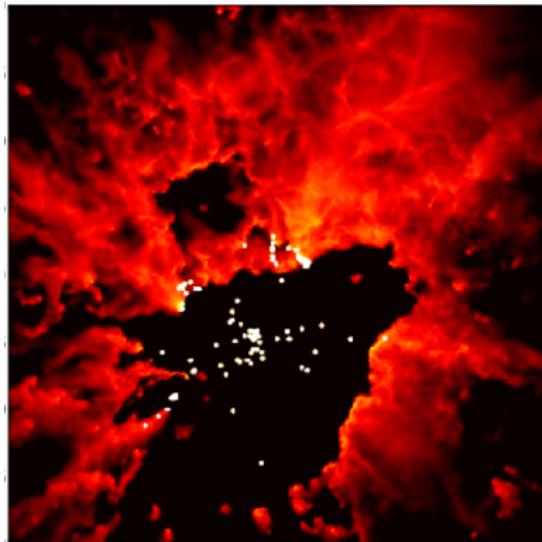


Image from Dale, 2014, MNRAS

Density

Observations:

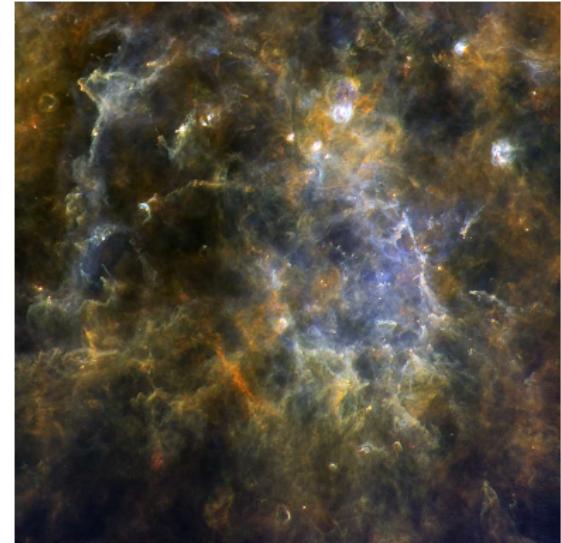


Image from ESA/Hi-GAL Project

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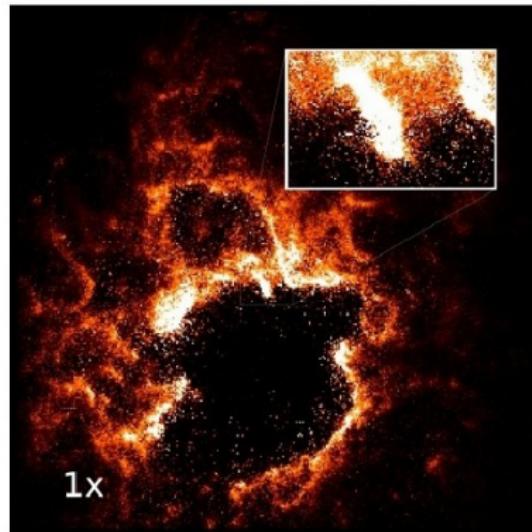


Image from Haworth et al., 2018, NewAR

Density → emission

Observations:

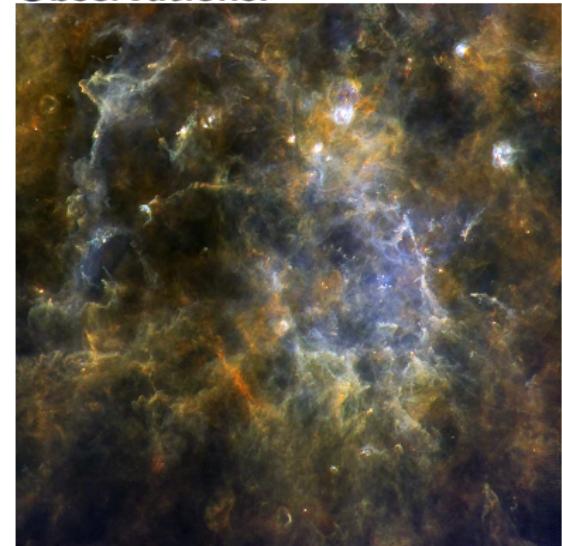


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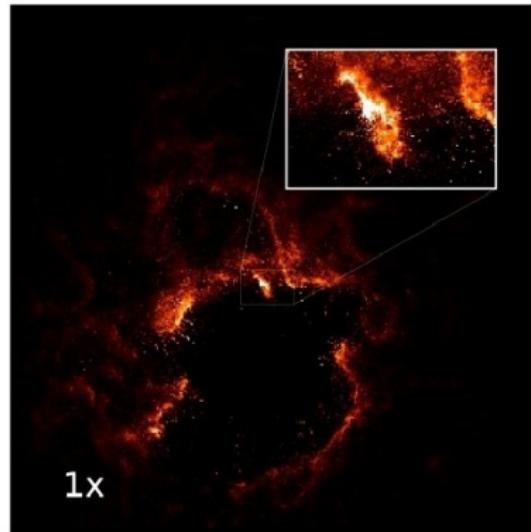


Image from Haworth et al., 2018, NewAR

Density → emission + dust

Observations:

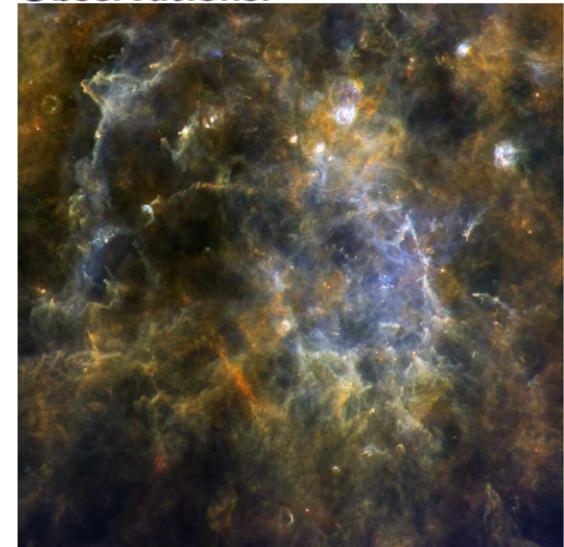


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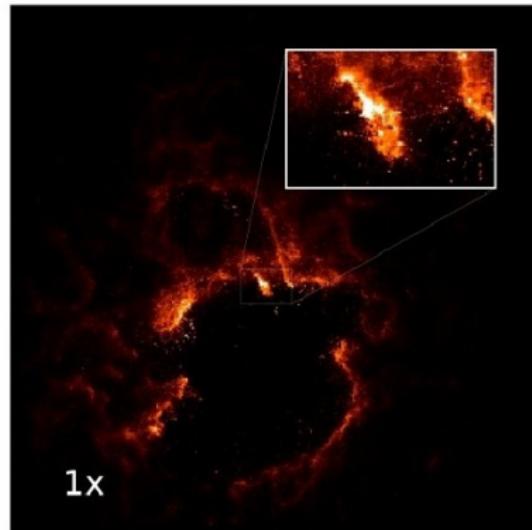


Image from Haworth et al., 2018, NewAR

Density → emission + dust + pixelation

Observations:

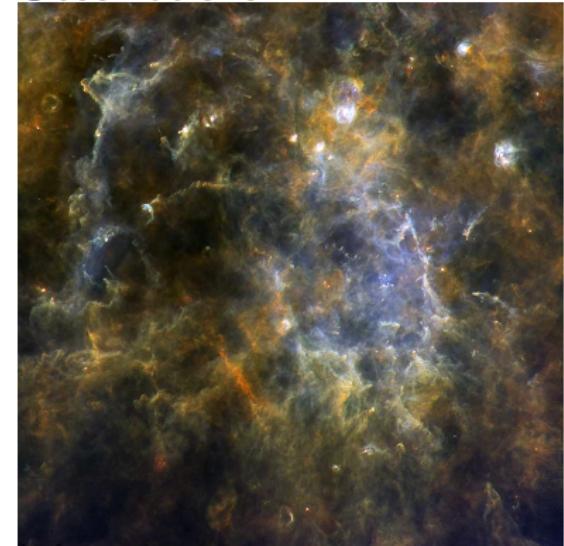


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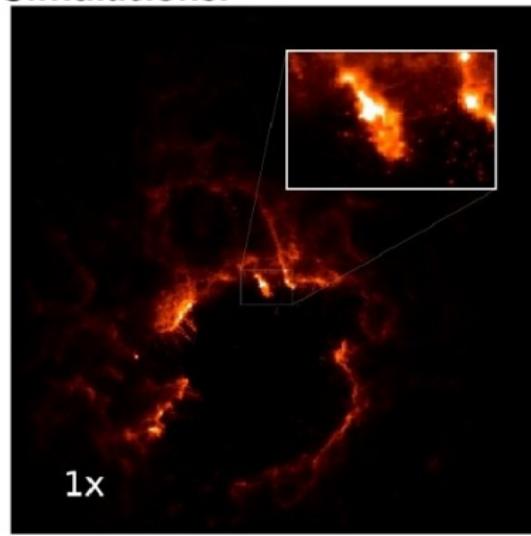


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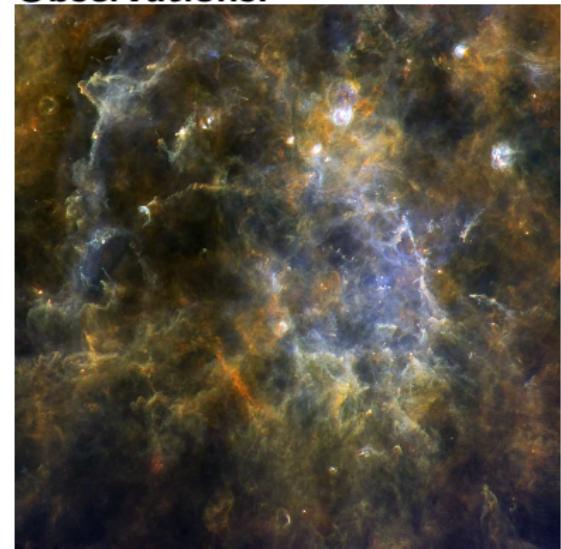


Image from ESA/Hi-GAL Project

Density → emission + dust + pixelation + point spread
function

COMPARING SIMULATIONS AND OBSERVATION

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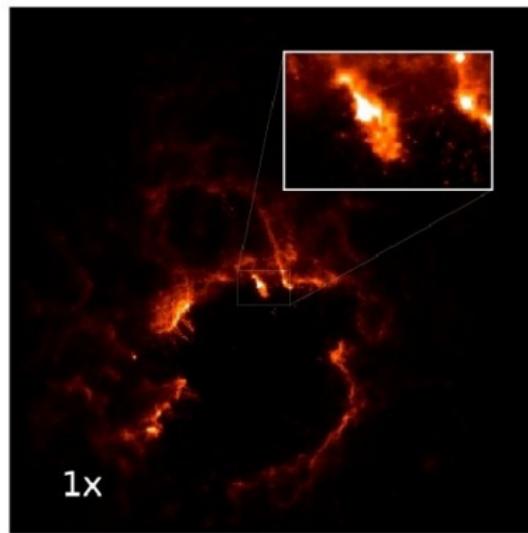


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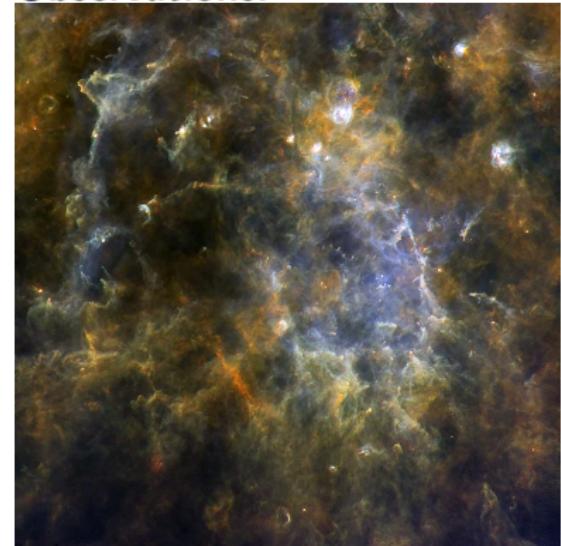


Image from ESA/Hi-GAL Project

Density → emission + dust + pixelation + point spread
function + thermal noise

COMPARING SIMULATIONS AND OBSERVATION

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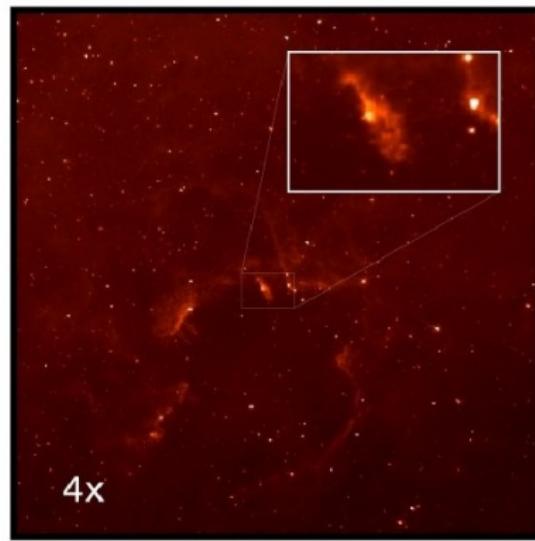


Image from Haworth et al., 2018, NewAR

Density → emission + dust + pixelation + point spread
function + thermal noise + background...

Observations:

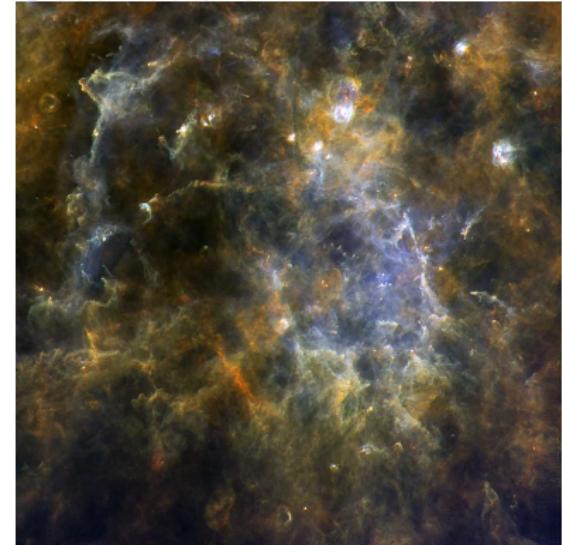
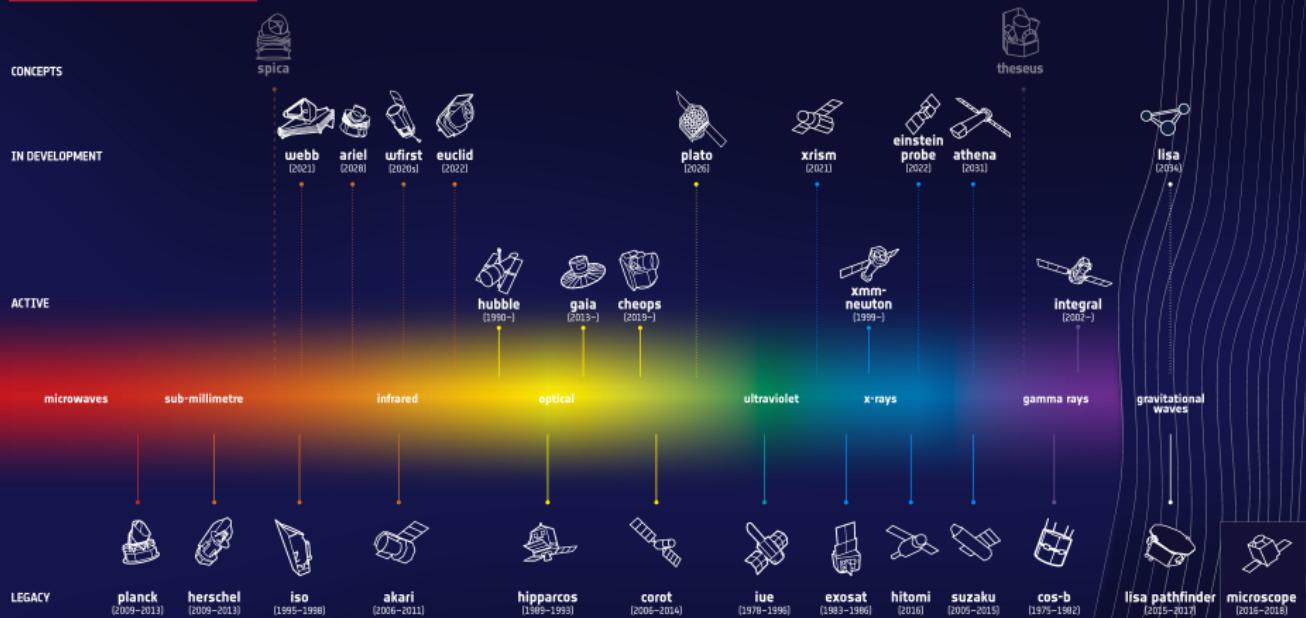


Image from ESA/Hi-GAL Project

BIG TELESCOPES



→ COSMIC OBSERVERS



BIG TELESCOPES

Better sensitivity

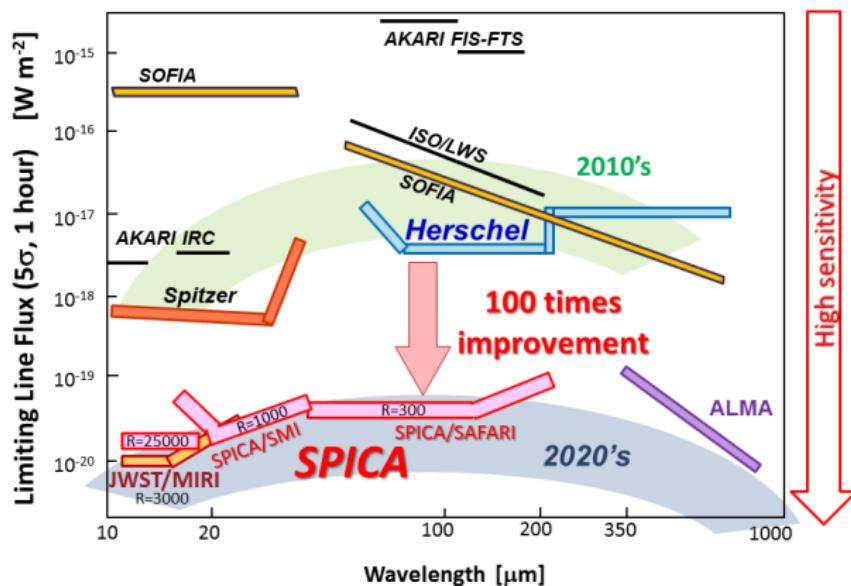


Image from JAXA/SPICA

Bigger field of view

BIG TELESCOPES

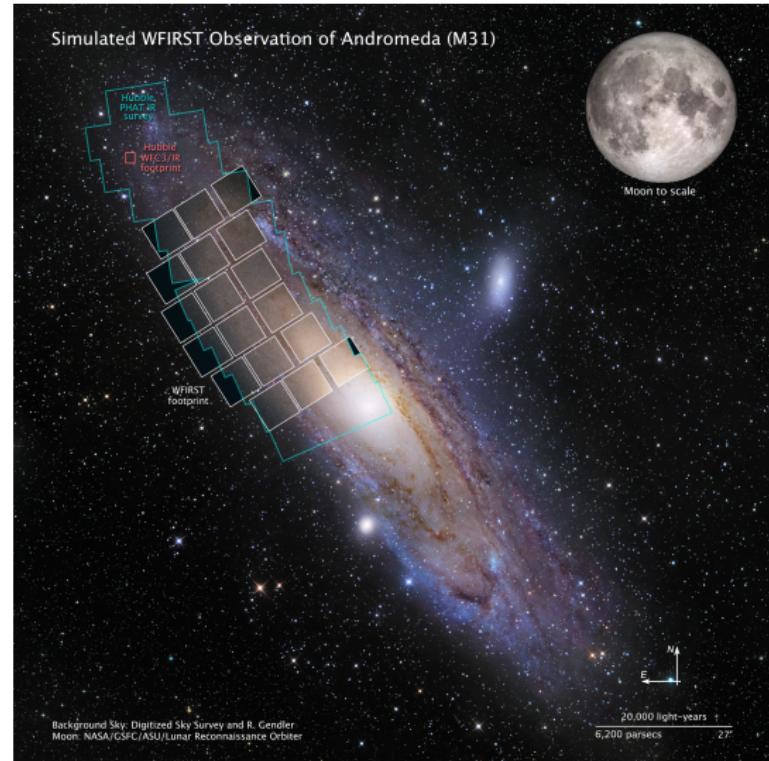


Image from NASA/WFIRST

BIG DATA

The ALMA array records a terabyte per night

Image by ESO/B. Tafreshi



First image of a black hole:
5 petabytes of data

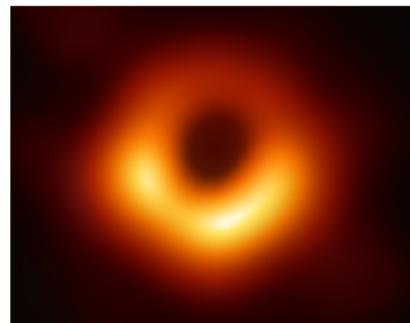


Image: EHT Collab.

Simulations can take months
or years to run

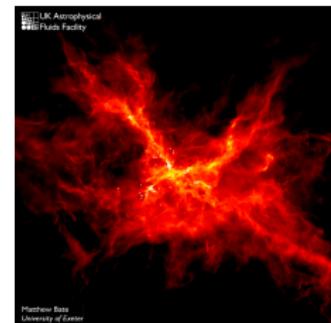


Image from Bate, 2009, MNRAS

Storing

- Every institute has their own computing facilities.
- ECRs moving jobs abandon data
- Who monitors responsible usage?

Analysing

- OPEN SOURCE CODE
- Data processing requirements - memory? GPUs?

Sharing and communicating

- Plots in papers
- Data shared on request?
- Statistical and graphical skills to effectively summarise and communicate data

BIG DATA



BIG ISSUES

- Publishing and Plan S
- Covid-19 and lockdown
- Brexit and international science
- Climate change and conferences

BLACK ASTRONOMERS MATTER

BLACK LIVES MATTER



STEPHEN
LAWRENCE
CHARITABLE
TRUST

Thank you!

Slides of this talk with full references will be available on my website:
sjaffa.github.io

Email: s.jaffa@herts.ac.uk
Twitter: @astro_biscuit

Dr Sarah Jaffa, AMInstP, FRAS
University of Hertfordshire



School of Physics,
Astronomy and Mathematics

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Image sources

Carina: http://www.esa.int/ESA_Multimedia/Images/2018/03/Chaotic_web_of_filaments_in_a_Milky_Way_stellar_nursery

Protostar SEDs: Persson, Magnus Vilhelm (2014): SEDs of the different protostellar evolutionary stages. figshare. Figure. <https://doi.org/10.6084/m9.figshare.1121574.v2>

Star lifecycle: <https://imagine.gsfc.nasa.gov/science/objects/stars1.html>

Star colours: <https://docs.kde.org/trunk5/en/extragear-edu/kstars/ai-colorandtemp.html>

Specra: By User:Warrickball, CC BY-SA 4.0,

<https://commons.wikimedia.org/w/index.php?curid=52451585>

Sun spectrum: By Nick84 - File:Solar_spectrum_ita.svg, CC BY-SA 3.0,

<https://commons.wikimedia.org/w/index.php?curid=24648395>

Kepler planets: <https://aasnova.org/2015/09/25/how-normal-is-our-solar-system/>

Multiwavelength M31: <https://sci.esa.int/web/herschel/-/48182-multiwavelength-images-of-the-andromeda-galaxy-m31>

Planck magnetic field:

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