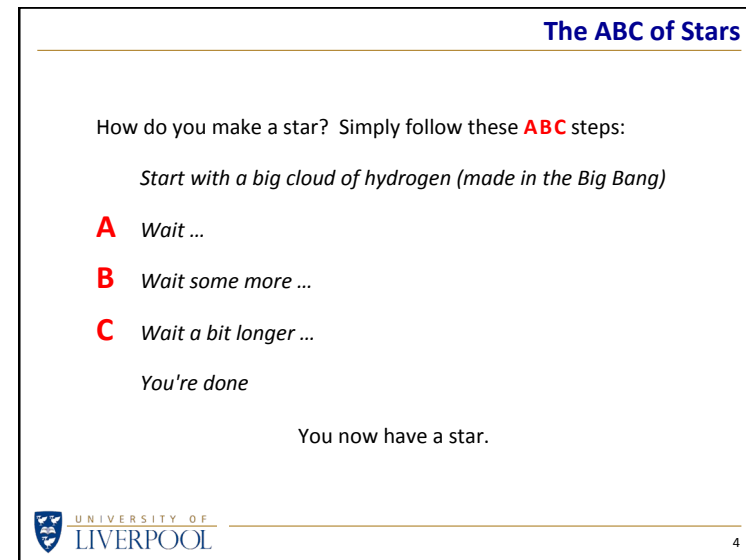
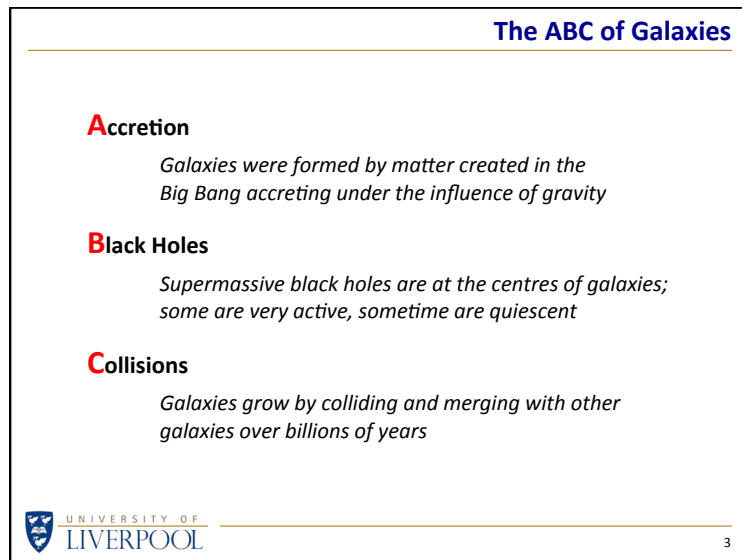
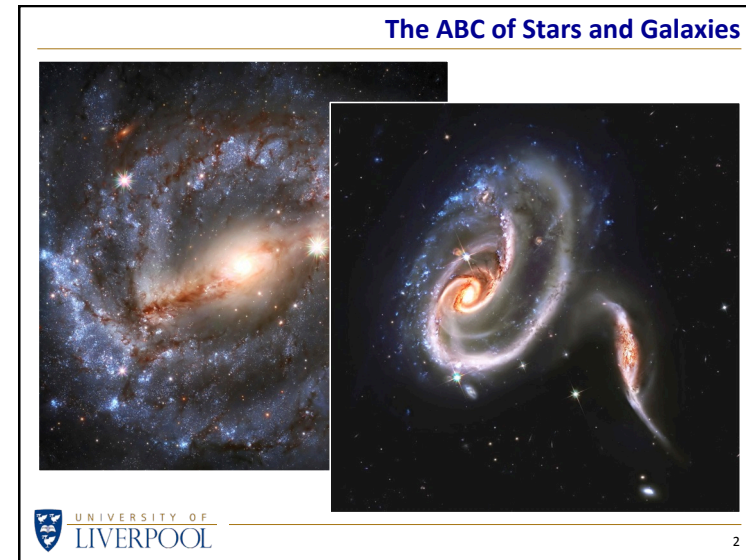
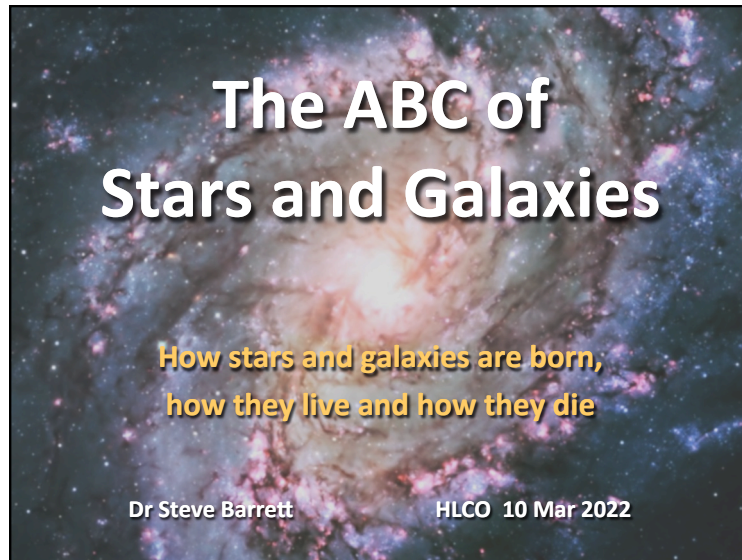


The ABC of Stars and Galaxies



The ABC of Stars and Galaxies

Simulations

Dark matter only (N-body)

Zoom (details)

Large volume (statistics)

Everything we understand about the evolution of cosmic-scale structures is the result of computer simulations.

This talk uses images and videos from the 'Illustris' simulations.

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Cosmic Web

Everything in the observable Universe once existed in a volume the size of a golf ball.

The 'dimples' were small variations in density...

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Cosmic Web

Everything in the observable Universe once existed in a volume the size of a golf ball.

The 'dimples' were small variations in density...

... that over billions of years collapsed into a cosmic web of filaments and voids.

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Computer Simulations

Simulations of galaxy formation and evolution that run from just after the Big Bang to the present day help us understand what happened.

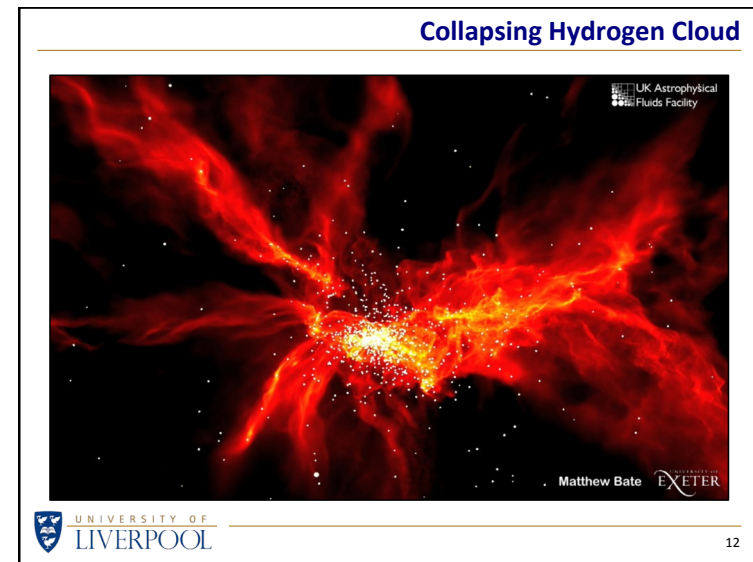
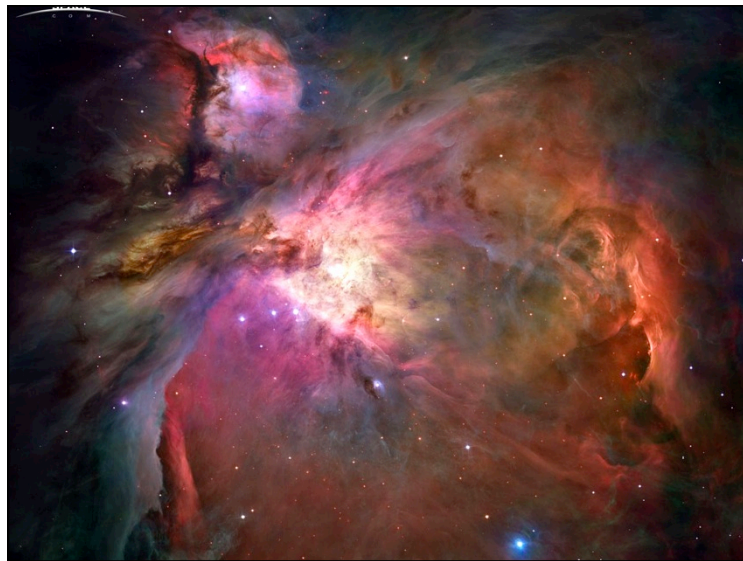
Dark matter web Black holes + supernovae Matter accretion

The simulations account for the effects of dark matter, star formation, black holes and supernovae in calculating how matter accumulates over billions of years into galaxies.

www.illustris-project.org

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The ABC of Stars and Galaxies



The ABC of Stars and Galaxies



A Question of Balance

All stars are a balance between the opposing forces of gravity and radiation pressure.

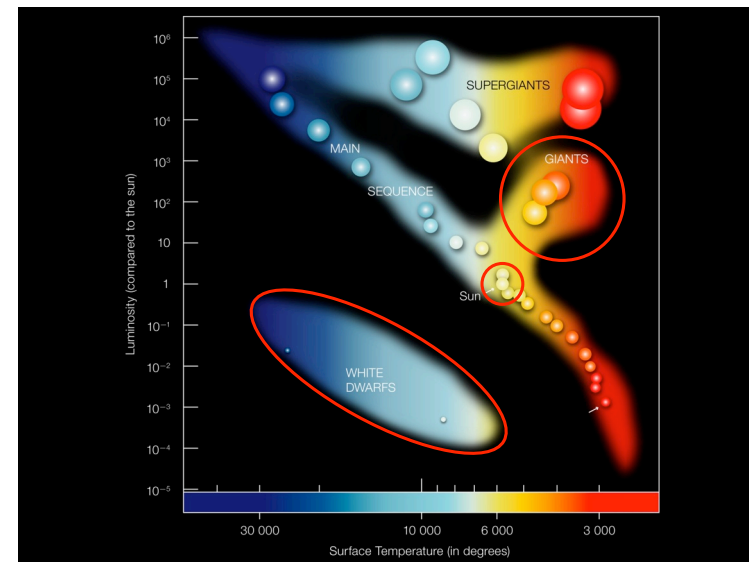
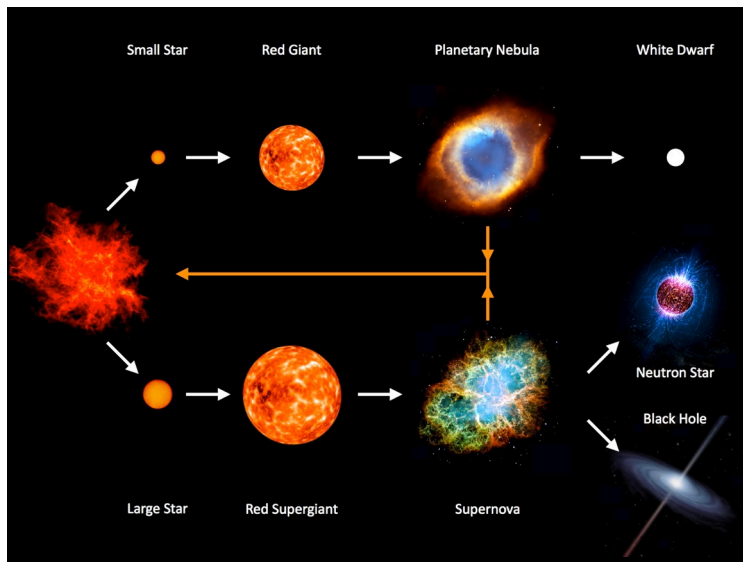
When the opposing forces are balanced, the star is stable.

When out of balance, the star must evolve.

Many aspects of star birth, life and death can be explained in terms of this balance of opposing forces.

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The ABC of Stars and Galaxies

PERIODIC TABLE of the ELEMENTS

FOUNDED BY THE INSTITUTION FOR EDUCATION, SCIENCE AND TECHNOLOGY FOR NATIONAL DAY WEEK 2010

SHUTTLEWORTH

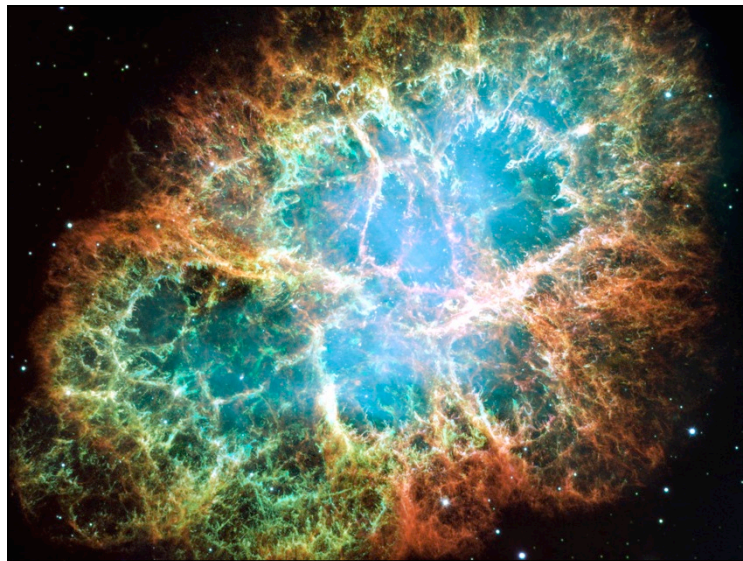
DMITRI MENDELEEV (1834 - 1907)

Planetary Nebula

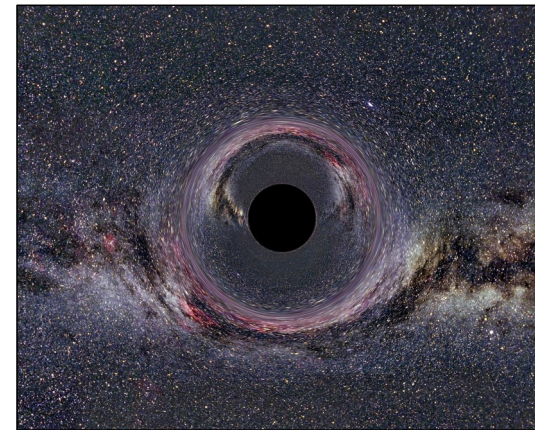


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Black Hole



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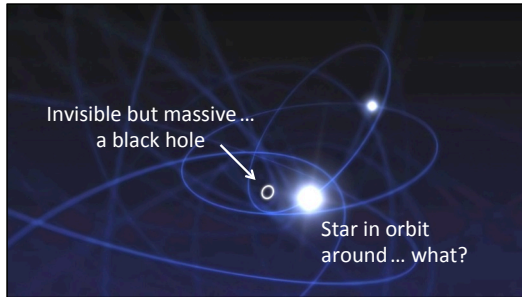
* See "Warping Space and Time"

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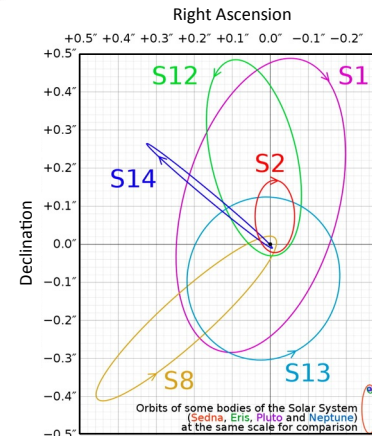
The ABC of Stars and Galaxies

At the Heart of a Galaxy

How do we know what lies at the centre of a galaxy?
 A close look at stars orbiting near the centre of the Milky Way tells us that there is something invisible but **very** massive lurking there...



Supermassive Black Hole



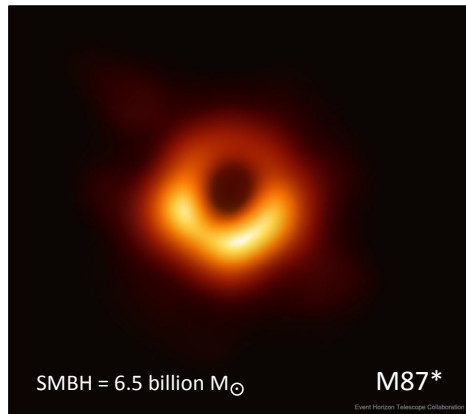
By recording star positions over more than a decade, it was calculated that the object keeping these stars in their orbits has a mass of

4 million M_{\odot}

and a size of no more than a few light-hours (\approx orbit of Pluto).

M_{\odot} = mass of our Sun

Image of SMBH in M87



SMBH = 6.5 billion M_{\odot}

M87*

Galaxy Snapshot



An image of a galaxy can give the false impression that the structure is essentially static, except for a slow rotation that can take hundreds of millions of years.


However, over its lifetime, it can evolve due to interactions with other galaxies.

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Interacting Galaxies

Some images clearly show galaxies interacting with each other ...


... but the full influence of collisions and mergers in galaxy evolution can be appreciated only through simulations.



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Galaxy Soup



1500 kly

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www.tng-project.org 26

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Accretion
Galaxies were formed by matter created in the Big Bang accreting under the influence of gravity

Black Holes
Supermassive black holes are at the centres of galaxies; some are very active, sometime are quiescent

Collisions
Galaxies grow by colliding and merging with other galaxies over billions of years

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The ABC of Stars and Galaxies

www.liverpool.ac.uk/~sdb/Talks

Dr Steve Barrett HLCO 10 Mar 2022