CelebrityLife Activities

Babylon to the Big Bang

BEYOND THE PODIUM

GUEST SPEAKER SERIES

Peter Watson
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Galaxies and Black Holes

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BEYOND THE PODIUM

Black Holes

- Invented by .....?
- Einstein
- Hawking?
- Well, actually, John Michell, rector of Thornhill Church in Yorkshire
- geologist?philosopher? astronomer? Seismologist? Polymath.
- presented his ideas to the Royal Society in London in 1783.

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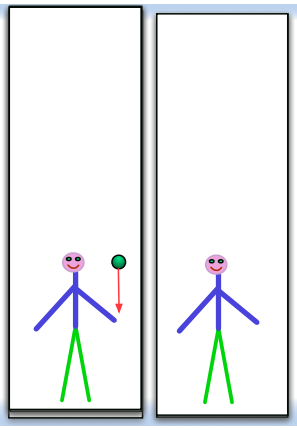

A particle will escape from the earth if it has positive energy

At the earth's surface, "escape velocity" is 11 km/s

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- Howeve ntly: what rad given escape v
- In partic he speed of
- If the ea uld be a Black
- This is t nly the black ho

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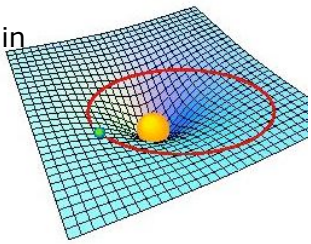
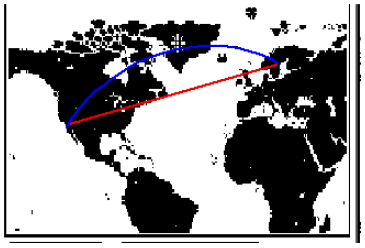
So what is a black hole like?

- It warps space (and time) round it

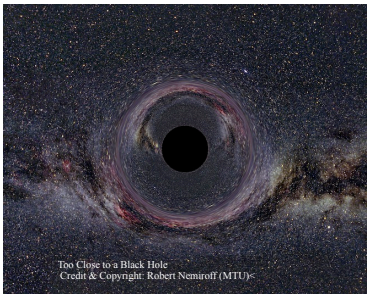
So planets are actually moving in "straight" lines in a curved space...



What is a straight line?



Did you think a laser beam was straight?



One way to see a black hole: it's black!

If we are really lucky....(or unlucky) as a gap in the sky

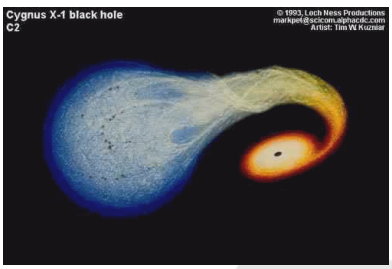
- Stuff falling in will become very hot and produce X-rays
- So want binary star, one invisible but heavy, producing lots of X-rays

Best candidate is Cygnus X-1

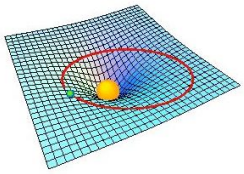
Mass of primary star ~20M_o

Mass of invisible object M~9M_o

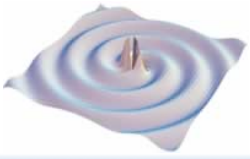
Power output in X-rays is 10,000 x total power output by sun!



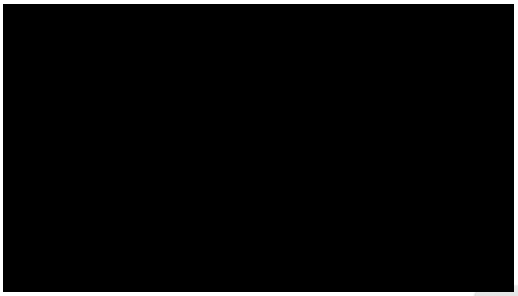
- If a BH can distort space



- Then moving BH's will produce a wave in space



- Which we might be able to pick up on earth as gravitational waves
- This is LIGO: twin detectors in Louisiana and Washington



and they found a second one!

- Which you can listen to!

When in doubt, classify!

- Messier list contains ~ 100 galaxies.
- New General Catalog ~ 10,000
- Approx. 10 billion galaxies observed (!!!).
- Approx. 2 trillion estimated
- Approx. 100000 well studied

Spiral Galaxies

Some are spread out, like NGC6946

About 10 billion stars

About 100,000 light years across

Can't see individual stars: red patches are "star nurseries"

"Hot spot" in centre

- Some are tightly wou up,like M31 (the Andromeda galaxy)

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If you are in Scotland

Go to the Crawick multiverse

Site of old open pit mine

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- Some are seen side on, like NGC4565
- Note the dust clouds

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Some have “bars” across the centre

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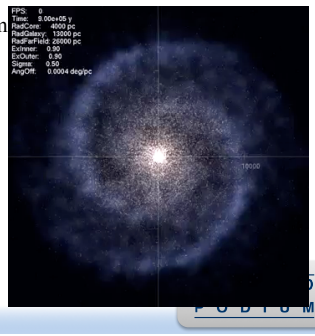
Why spirals?

Group of young stars form

go supernova and compress gas

small star remain, new group of young stars are born



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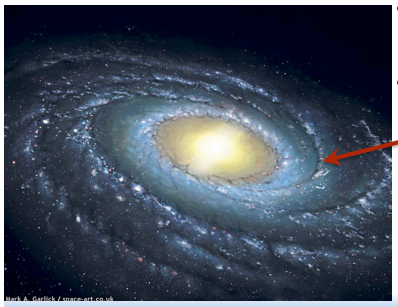
The Milky Way is hard to see, since we are inside it!



- But it looks roughly like this
- With the sun about here

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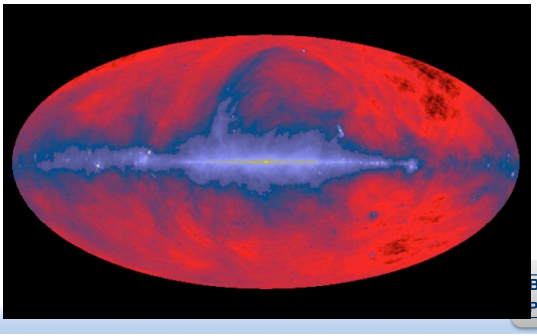
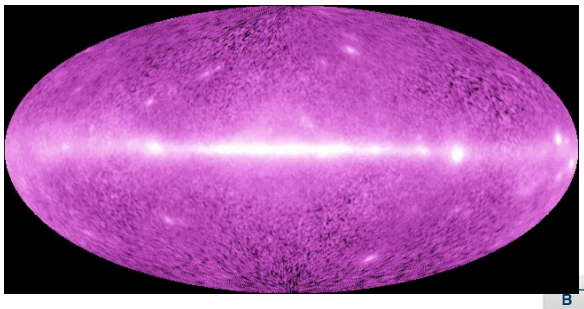
The centre of the Milky Way

This is the Milky way, showing the whole sky

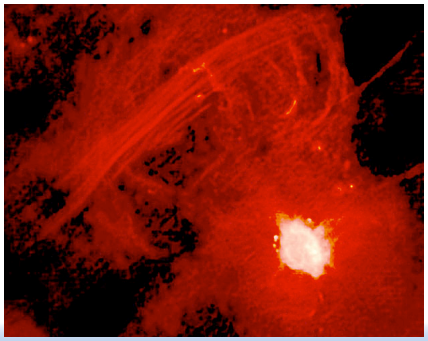
- same general structure in radio waves, but note very intense source at centre



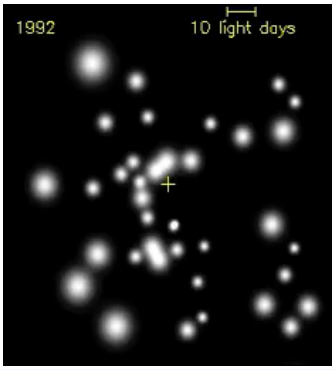
- And gamma-rays



- But we can zoom in with radio waves

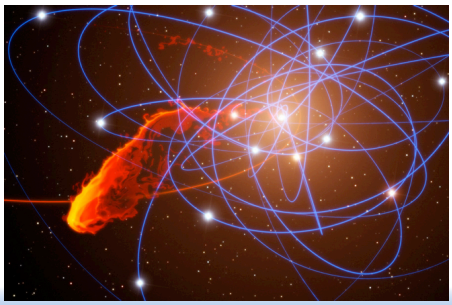


And X-rays

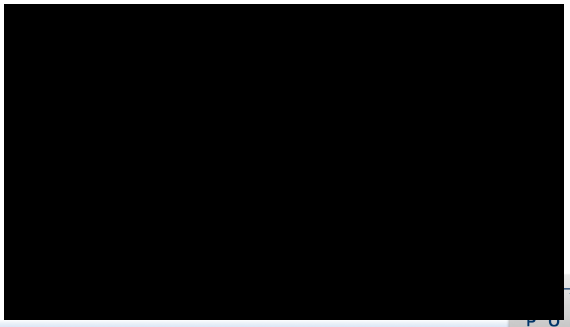


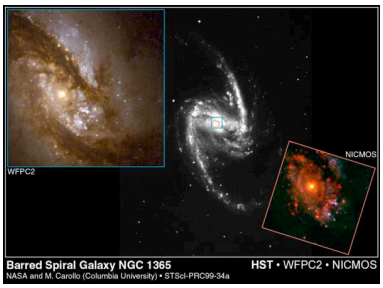
The stars there are swirling round something ~4000000 M_o

- In addition to the stars, there is a huge clump of gas feeding it



- Something like this!

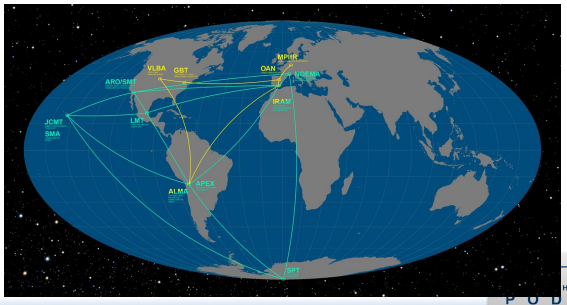


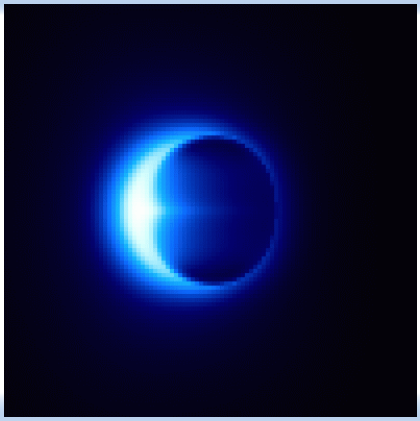


Whole picture is consistent with massive black hole (4000000 M_o) at centre

Can see this in other galaxies

The Event Horizon Telescope





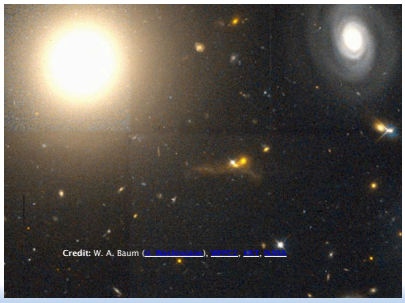
Will take the first look at a BH

Ran March 12-22 2017
Results ??????

Some galaxies have grabbed hold of other galaxies

This is M51

Elliptical galaxies are much less fun!



NGC 4881
in Coma

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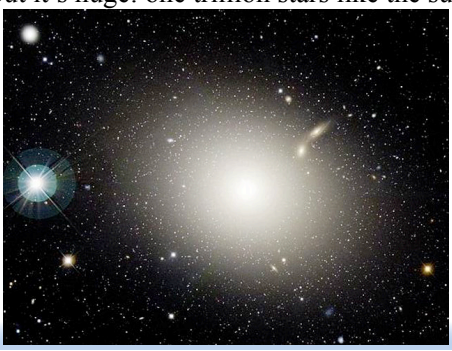
M87 looks dull
But it's huge: one trillion stars like the sun



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And it has a huge jet emerging from the black hole at its centre

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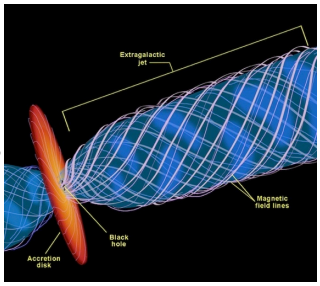
Jets

- We seem to see jets on all scales, from small new stars to giant BH's
- spinning BH produces wrapped up mag field that focusses particles



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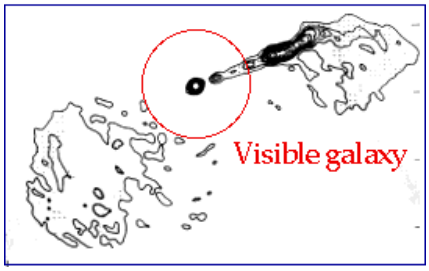
And outside



huge clouds of hot gas at the end of the jet

produces radio waves

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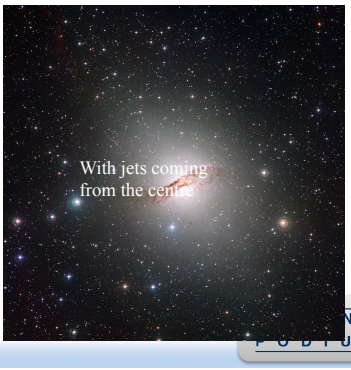
Centaurus A is a strange galaxy



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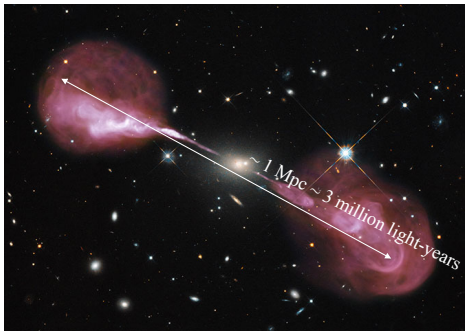
Sometimes the jets are far larger than the galaxy!

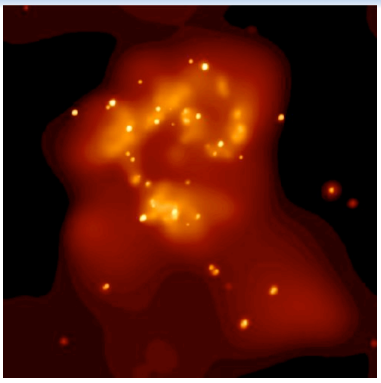


Hercules A
aka 3C348

Galaxies often come in groups

3 galaxies in Draco

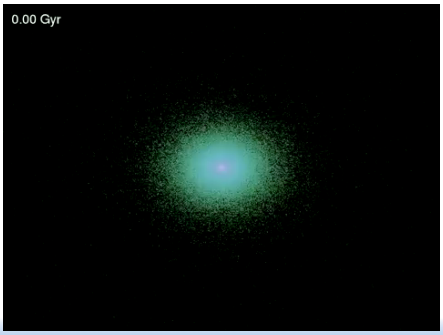
- Which means they can collide
- These are the Antennae galaxies



When galaxies collide the stars almost never do, but the clouds of gas do

X-ray picture of the antennae

- We can see how this might have happened



- And this is maybe where it is happening now:
- Two galaxies have collided and the black holes seem to be coalescing

3C75 X-rays from Chandra

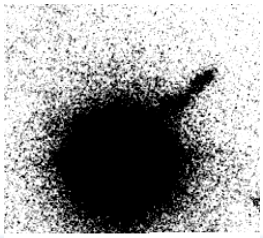
- M81 and M82 get very close every 100 million years:

- M 82 is getting ripped apart

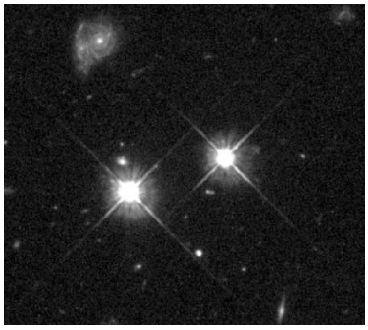
Quasars

- Bright objects were observed in early radio maps which had no obvious optical counterpart
- Several hundred seen in the 3rd Cambridge catalogue
- In 1960 a faint blue 'star' seen at location of 3C48
- Detailed studies made when another blue star found at 3C273
- *Quasi-stellar* objects…

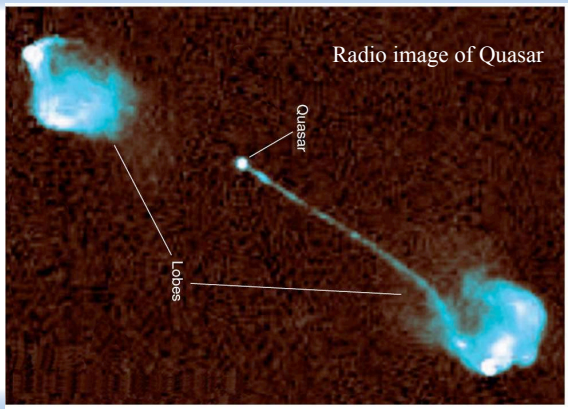
Position of 3C273 found v. accurately by lunar occultation, so could be identified with 13 mag. blue "star" with jet projecting from it



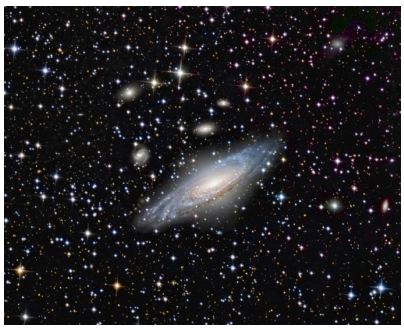
Except stars don't have jets!



This shows the problem: it shows a galaxy (maybe 2) a quasar and a star. Which is which?



- Only object we know that would work is massive hungry black hole
- Expect up to 20% of the rest energy of infalling matter gets converted to some form of radiation
- Most luminous consume 1000 stars/year



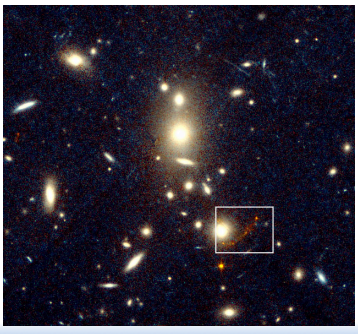
As we look out we see more and more galaxies

The Coma cluster: 10000 galaxies

Apart from one bright star, almost all the objects are galaxies

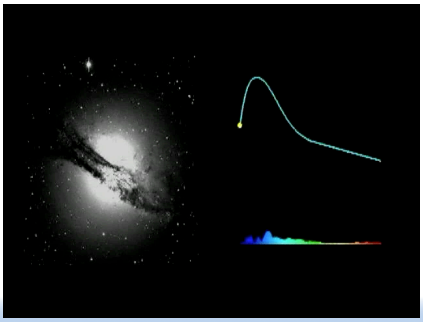
Back to Crawick • Galactic Cluster

- But there are more



And the further out we go, the more we see

- Type 1a Supernova: very rare (1/galaxy/century), very bright and they are all the same
- This is one in Centaurus A



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- The further out we go, the more we see

BEYOND THE PODIUM

- So how big is the universe?
- Could it be infinite?

•NO

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Olber's paradox: why is the sky dark at night?

If you are in the centre of a forest, what do you see?

- Trees in every direction

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If you are in a forest and you don't see trees in all directions, what is going on?

- You are close to the edge

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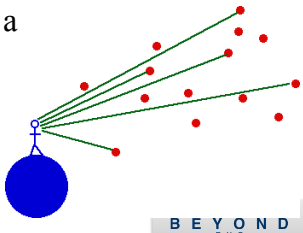
- If universe is
  1. infinite
  2. uniformly filled with stars
- Any line of sight will end on a star, as bright as the sun.
- so night sky will be bright



Except that it isn't

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Apparent Ways out

- Obviously universe is not uniform for stars
- But it is for galaxies

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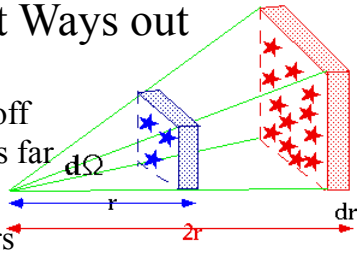
Apparent Ways out

- Light from stars falls off with distance: twice as far means 1/4 the light
- But the number of stars increases as we move out, so the effects cancel.



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Apparent Ways out

- Absorption by interstellar matter dims distant stars
- But the matter would by now be hot and radiating

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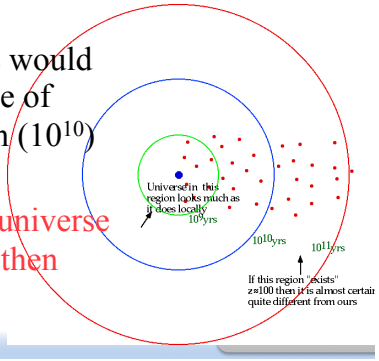
Correct Way Out

- Very distant objects would correspond to an age of more than 10 billion (10^{10}) years
- No reason why the universe should be the same then



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- So we almost **must** have a universe with a beginning

- Cannot be infinite in both space and time.
- And finally: the crucial discovery

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Doppler shift

- Universal for all waves, including sound
- Wave gets "stretched out" by motion
- Can measure how fast something is moving by looking at the light

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- e.g Virgo cluster

Credit & Copyright: Günter Kerschbaber (Gahberg Observatory)

Credit & Copyright: David Malin (AAO), AATB

- e.g Hydra cluster

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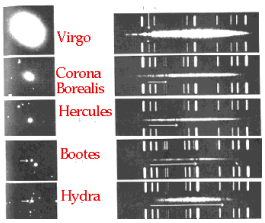
- Hubble was able to measure distances to closer clusters
- velocity increases with distance
- a galaxy at 1 Mpc is recedin from us at 70 km/s



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i.e the universe is expanding
Huh?

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