Dark matter

Nils-Erik Bomark

April 6, 2017/CERN

Nils-Erik Bomark Dark matter Apr

Outline

- Hidden treasures of the universe
 - Intergalactic gass-clouds
 - Hidden stars and planets
 - Black holes
- Dark matter
 - Seeing dark matter
 - Wat do we know about dark matter?
 - WIMPs
- What is CERN doing about this?
 - Cosmic radiation
 - AMS-2
 - MET-searches



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Are there more things in the heavens than we can see?

Yes!



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Are there more things in the heavens than we can see?

Yes!



Coma cluster



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Coma cluster - X-ray



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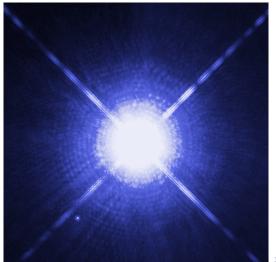
Sirius B

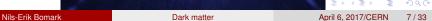


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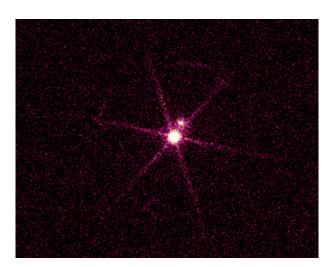
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Sirius B

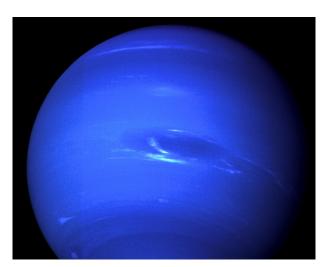




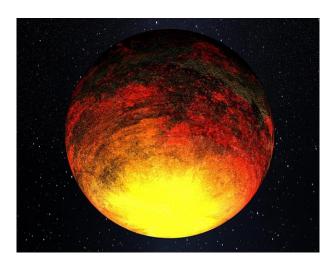
Sirius B



Neptune



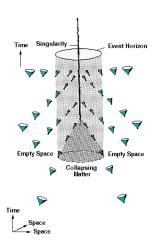
Vulcan



Rogue planets

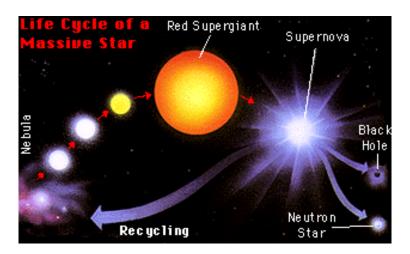


On the event horizon there is no direction "out"



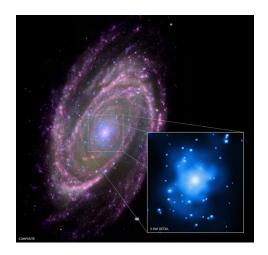
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Stellar black holes



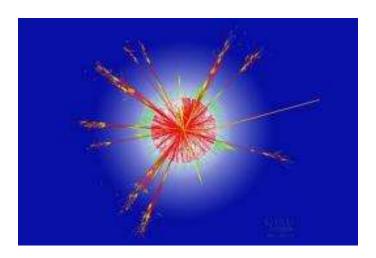
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Supermassive black holes



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Microscopic black holes



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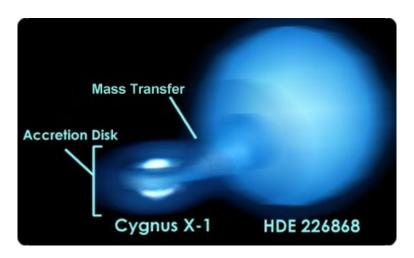
Microscopic black holes



Do they exist?

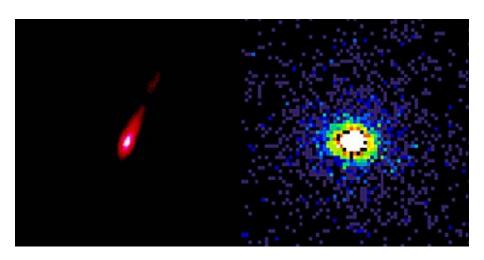


Do they exist?



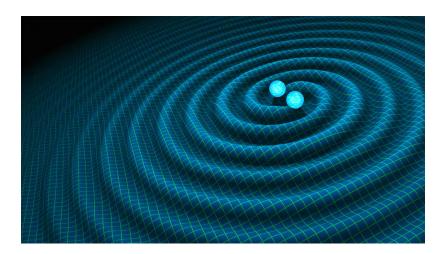
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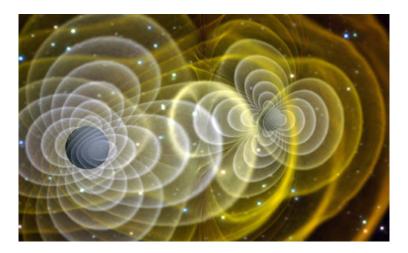
Do they exist?



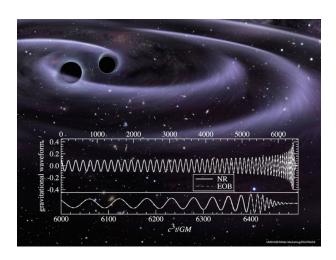
Dark matter

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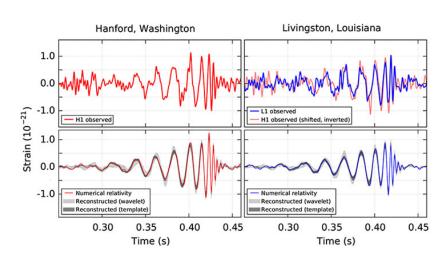




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Seeing dark matter
Wat do we know about dark matter?
WIMPs

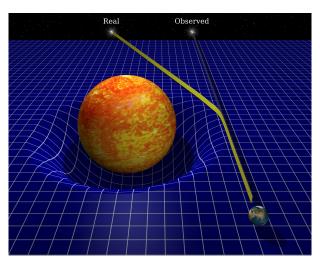
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Wat do we know about dark matter? WIMPs

Gravitational lensing

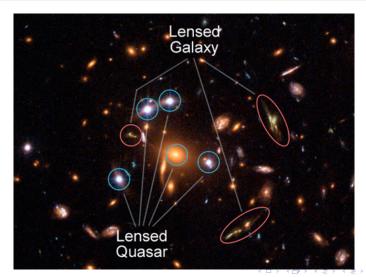


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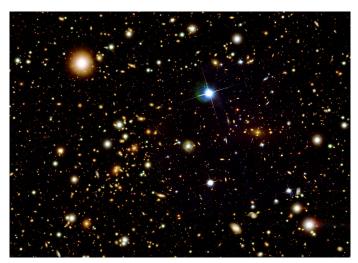
Wat do we know about dark matter? WIMPs

Gravitational lensing



Wat do we know about dark matter? WIMPs

Bullet cluster

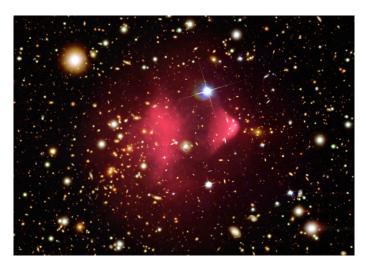


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Wat do we know about dark matter? WIMPs

Bullet cluster



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Wat do we know about dark matter? WIMPs

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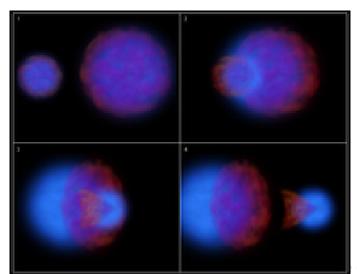
Bullet cluster



Wat do we know about dark matter? WIMPs

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Bullet cluster



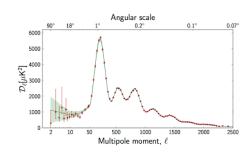
- It exists.
- It is non-baryonic.
- It has a mass less than 10⁵⁰ GeV.
- Its self-interaction is $\frac{\sigma}{m} \lesssim 1 \frac{\text{cm}^2}{\text{g}}$
- It interacts at most weakly with matter.



In conclusion: We know it is hard to detect.

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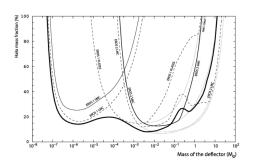


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Nils-Erik Bomark Dark matter April 6, 2017/CERN 21 / 33

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- It interacts at most



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Nils-Frik Bomark Dark matter

- It exists.
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- Its self-interaction is $\frac{\sigma}{m} \lesssim 1 \frac{\text{cm}^2}{\text{q}}$
- It interacts at most weakly with matter.

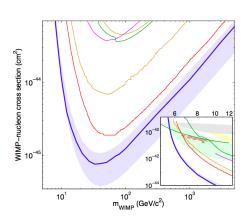


In conclusion: We know it is hard to detect.

Nils-Erik Bomark Dark matter

What do we know about dark matter?

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- It interacts at most weakly with matter.



In conclusion: We know it is hard to detect.



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What do we know about dark matter?

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- It interacts at most weakly with matter.



In conclusion: We know it is hard to detect.

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Wat do we know about dark matter? **WIMPs**

Weakly Interacting Massive Particles (WIMPs)

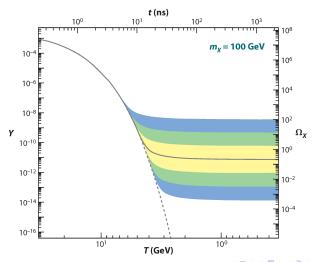
- Assume we have a particle with mass $\approx 100 \text{ GeV}$.
- It interacts with the weak force.
- Then $\langle \sigma v \rangle \approx 3 \cdot 10^{-26} \text{ cm}^3 \text{s}^{-1}$



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Weakly Interacting Massive Particles (WIMPs)



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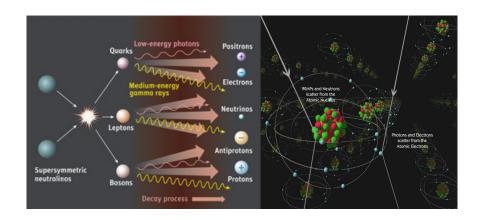
Seeing dark matter Wat do we know about dark matter? WIMPs

Weakly Interacting Massive Particles (WIMPs)

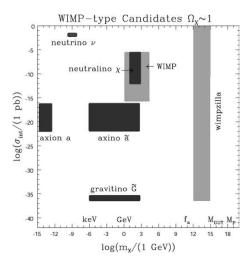
- Assume we have a particle with mass \approx 100 GeV.
- It interacts with the weak force.
- Then $\langle \sigma v \rangle \approx 3 \cdot 10^{-26} \text{ cm}^3 \text{s}^{-1}$
- WIMPs give (about) the right amount! ("the WIMP miracle")
- We expect new particles with more or less the right properties.

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WIMPs are nice — they can be detected!



Other options



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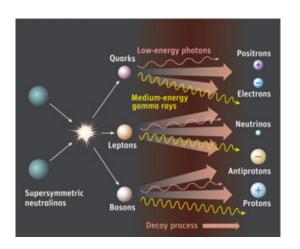
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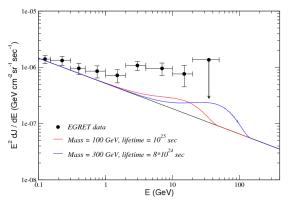
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Cosmic radiation from dark matter



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EGRET

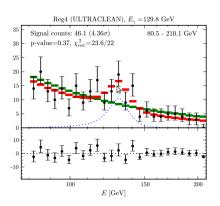


Dark matter? miscalibration.



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Fermi LAT

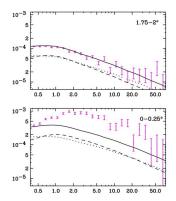


Dark Matter? don't think so.



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Fermi LAT

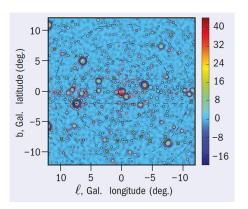


Too much γ -radiation from the galactic centre.



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Fermi LAT

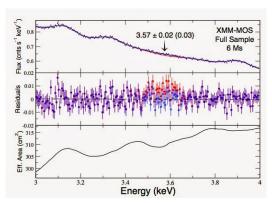


But looks like unresolved point sources.



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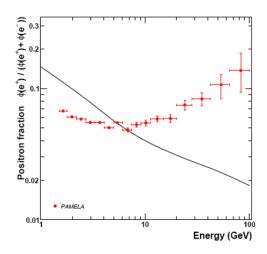
XMM-Newton



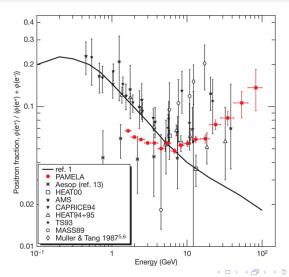
Smoking gun of dark matter?



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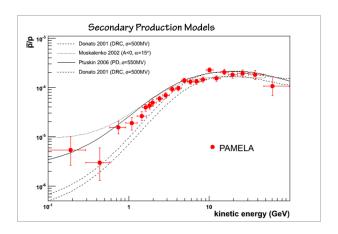


PAMELA



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PAMELA



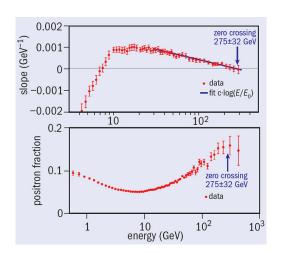


AMS-2 — particle detector in space



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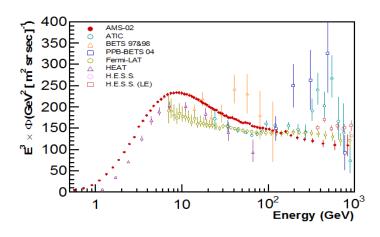
AMS-2





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AMS-2

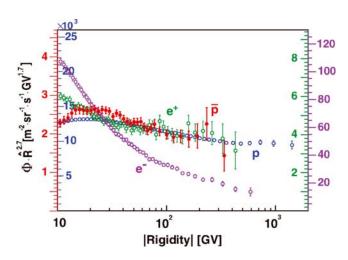




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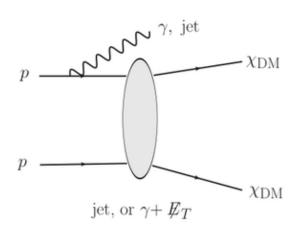
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AMS-2



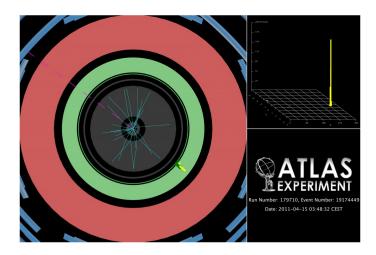
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MonoPhoton



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MonoPhoton



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