Dark Matter Theory.

GRK20144 lecture series

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Universität Freiburg
19-21 April 2017

HELMHOLTZ ASSOCIATION

DESY

Practicalities

- I'm currently a fellow (i.e. postdoctoral researcher) in the Theory Group at DESY Hamburg, working on
  - Astroparticle physics
  - Physics beyond the Standard Model
  - Phenomenology of dark matter
- These slides and (hand-written) lecture notes will be available at
  - http://www.desy.de/~fkahlhoe/teaching.html
- Questions?
  - Just send me an email: felix.kahlhoefer@desy.de
  - ...or stop by in room 604 after the lectures

Outline

1. Evidence for Dark Matter
2. Explanations for Dark Matter
3. Dark matter in the early Universe
    1. A brief introduction to cosmology
    2. Thermal freeze-out
    3. Misalignment mechanism
4. Phenomenology of WIMPs
    1. Case study: Scalar singlet dark matter
    2. Model-independent approaches

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Astrophysics: Today

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Cosmology: Tomorrow

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    2. Model-independent approaches

Particle physics: Friday

Literature

- TASI lecture notes by Mariangela Lisanti:
  - https://arxiv.org/pdf/1603.03797.pdf
- SI2015 lecture notes by Matthew Reece:
  - http://indico.ihep.ac.cn/event/4878/material/2/0.pdf (incomplete)
- Review “Particle Dark Matter: Evidence, Candidates and Constraints” by Gianfranco Bertone, Dan Hooper and Joseph Silk:
  - https://arxiv.org/pdf/hep-ph/0404175.pdf

Galactic rotation curves

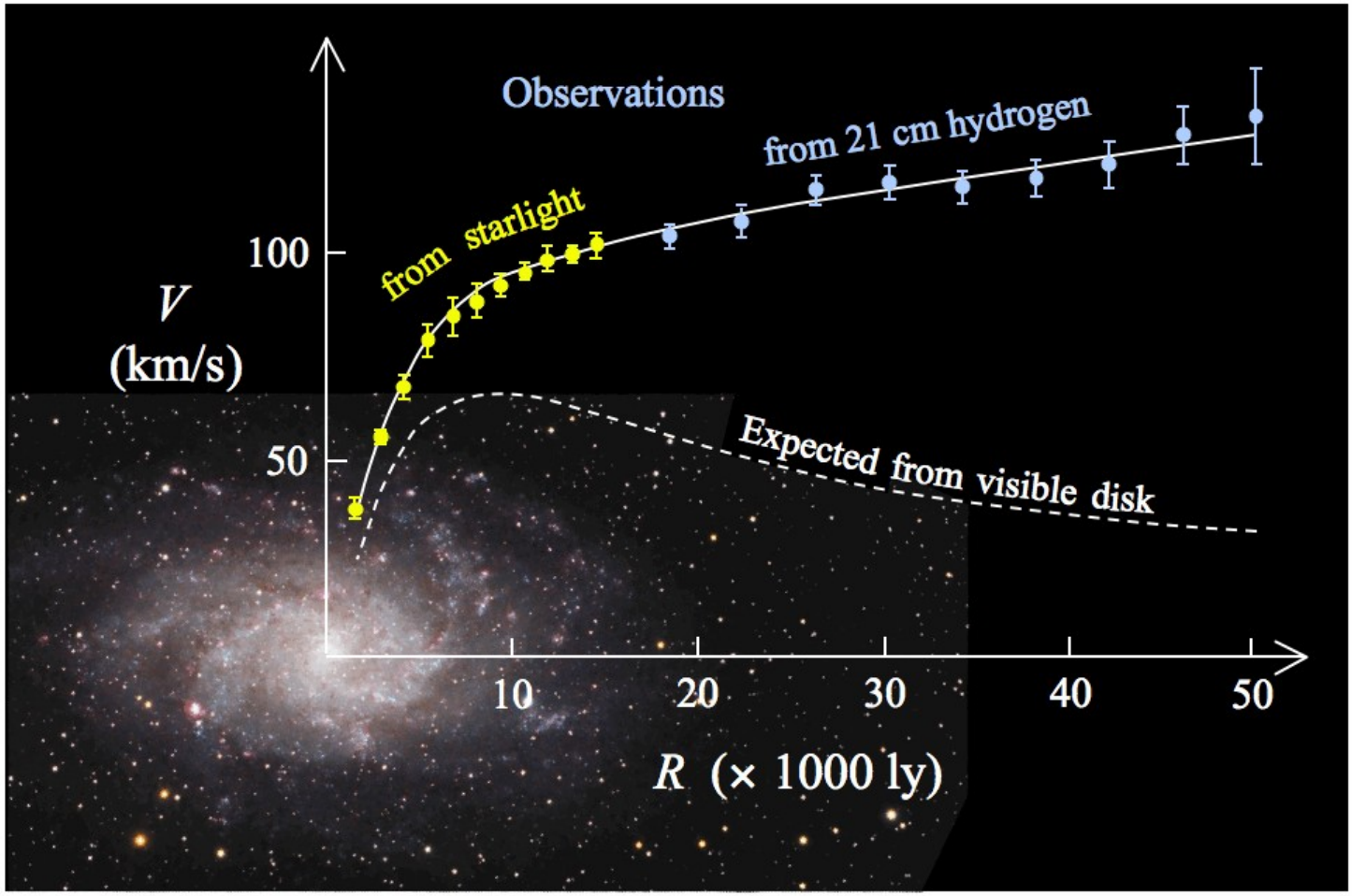
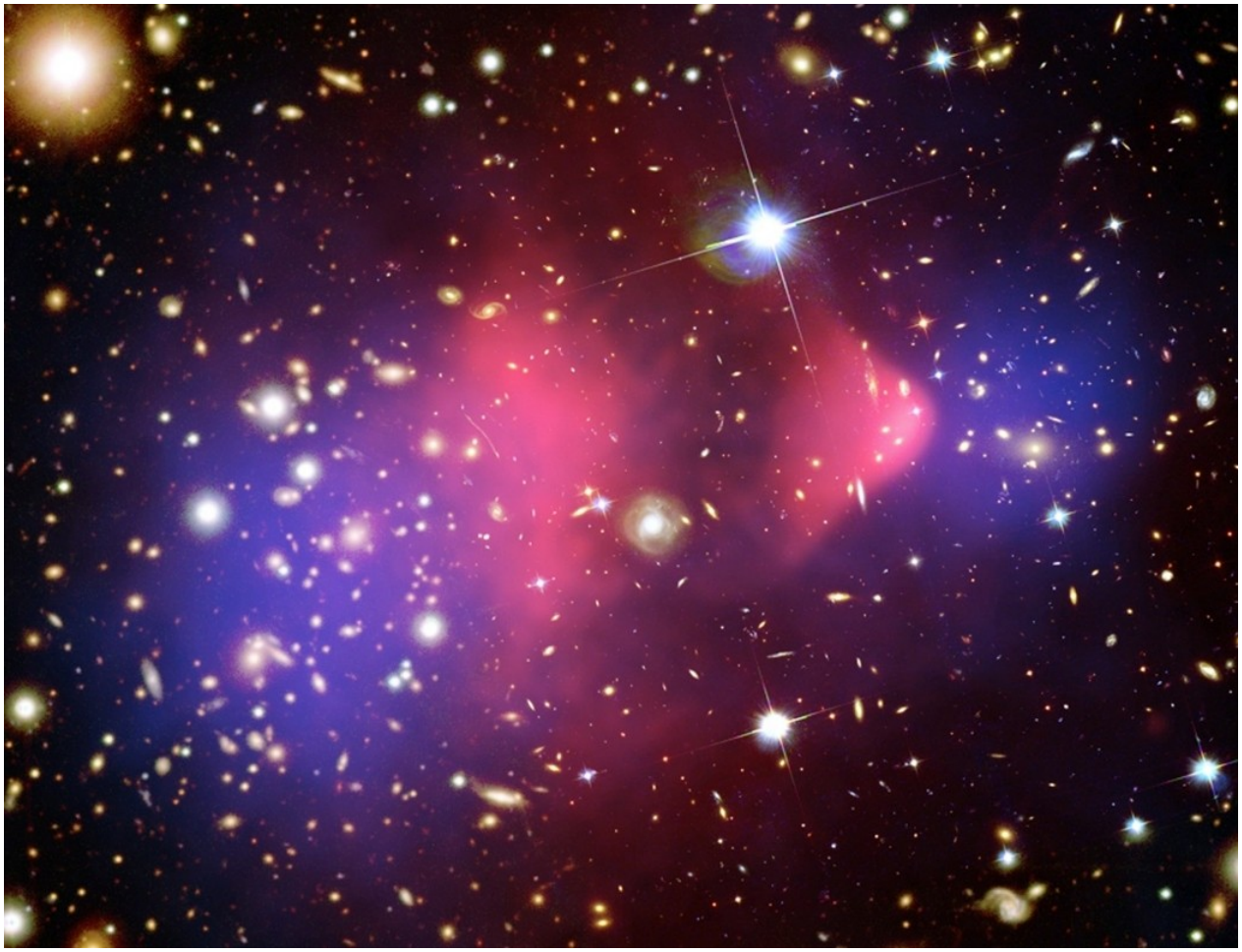
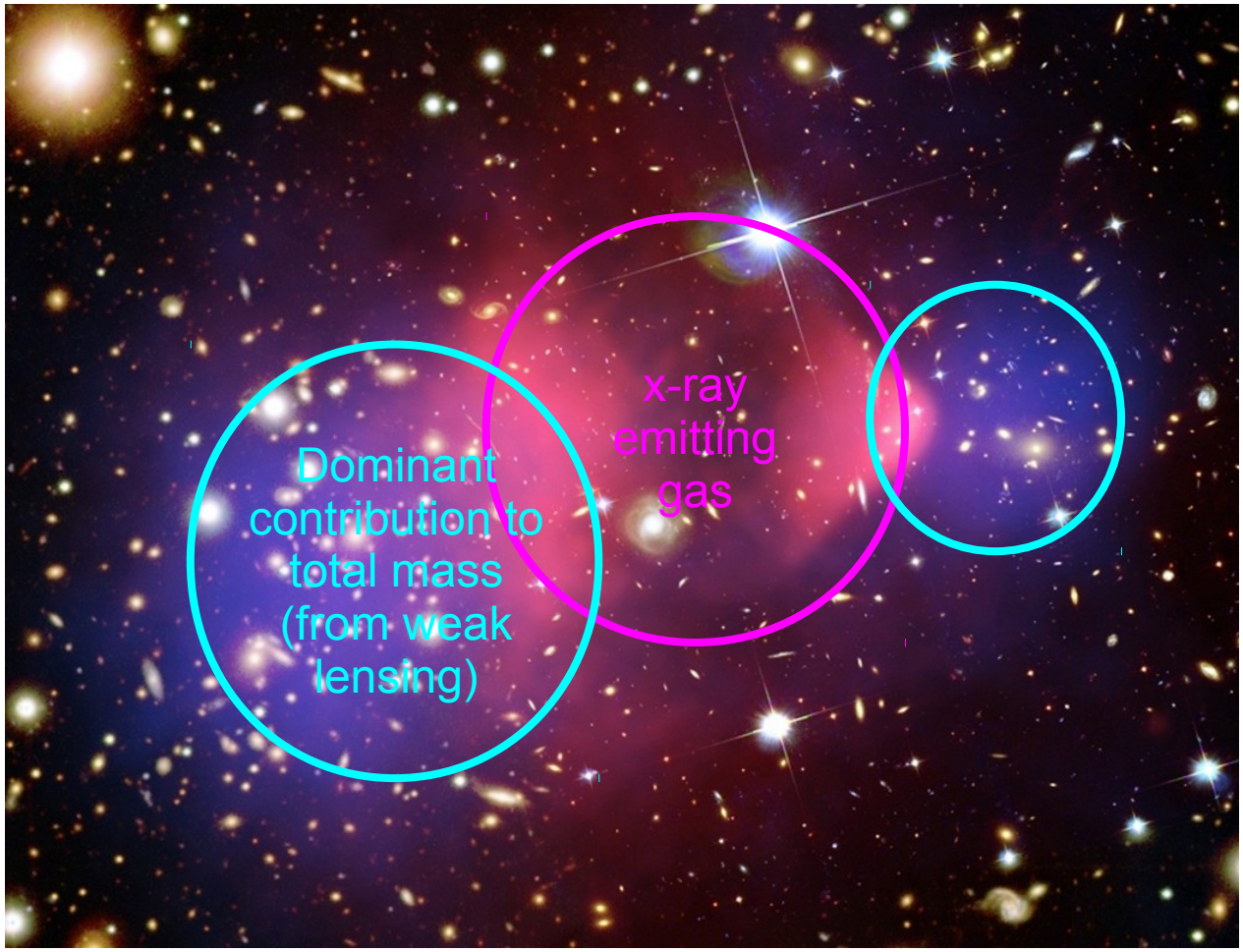


Image from Wikipedia, data from Corbelli, E. & Salucci, P. (2000), MNRAS 311 (2): 441–447

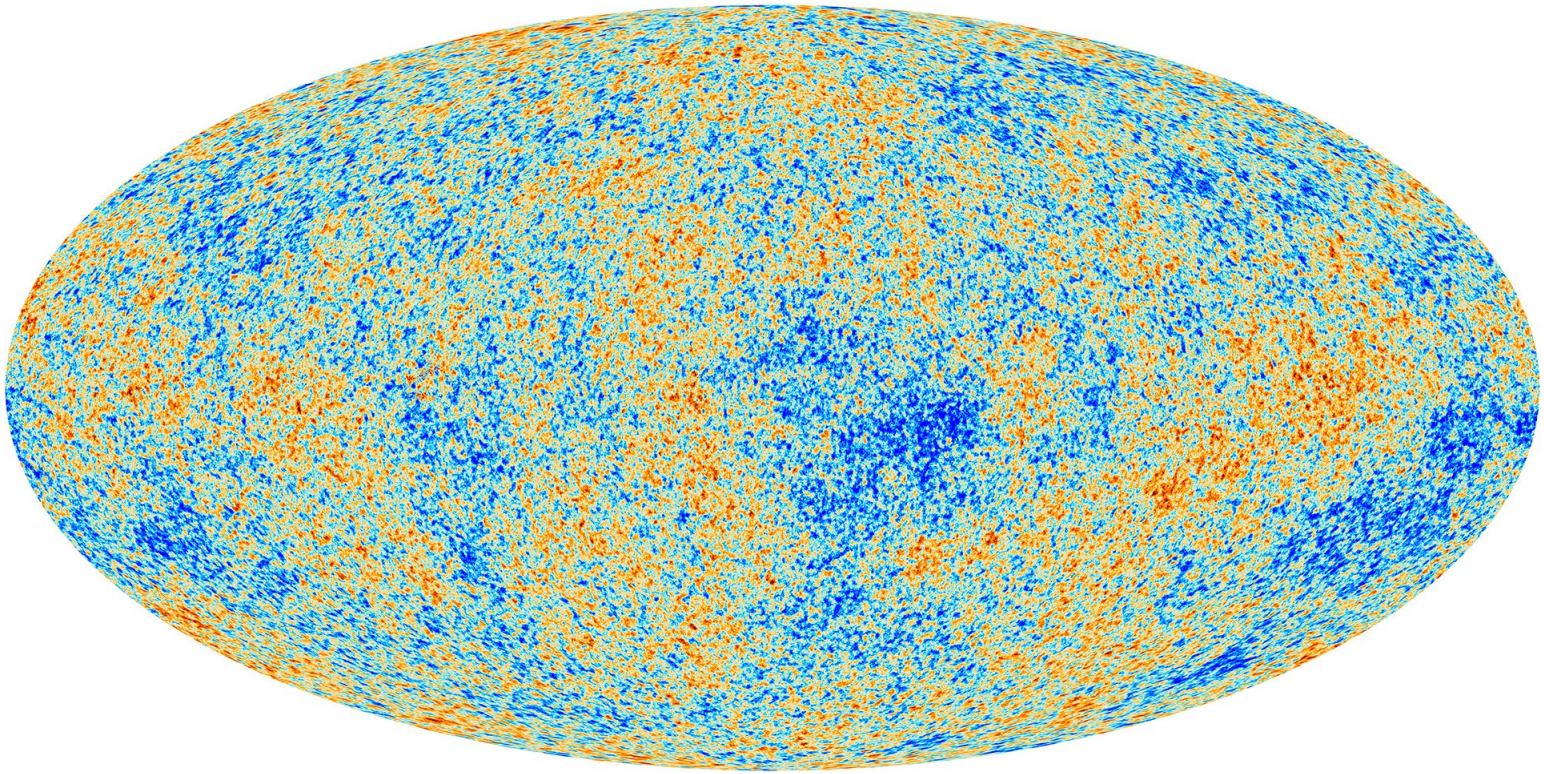
The Bullet Cluster



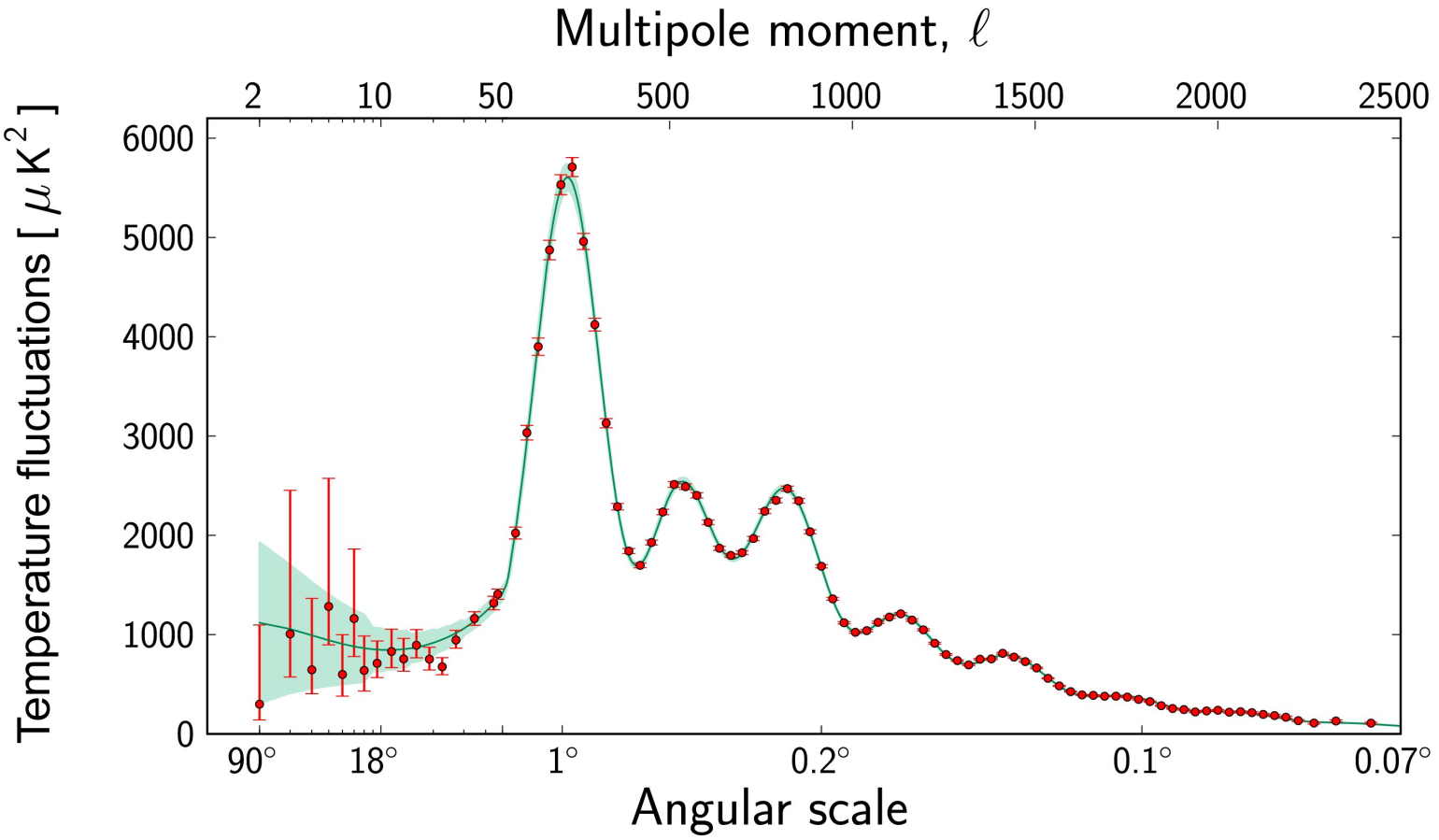
The Bullet Cluster



Cosmic Microwave Background

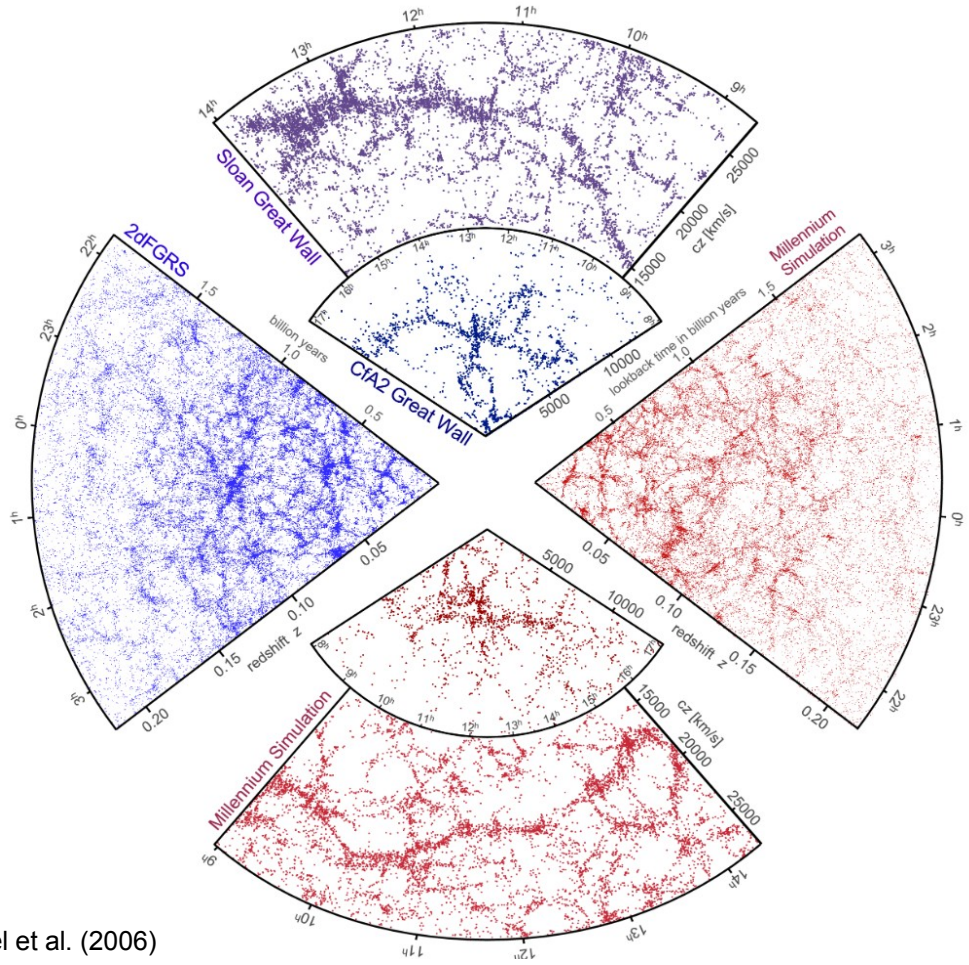


Cosmic Microwave Background (power spectrum)



N-body simulations

- https://www.youtube.com/watch?v=xfgDoExbu_Q

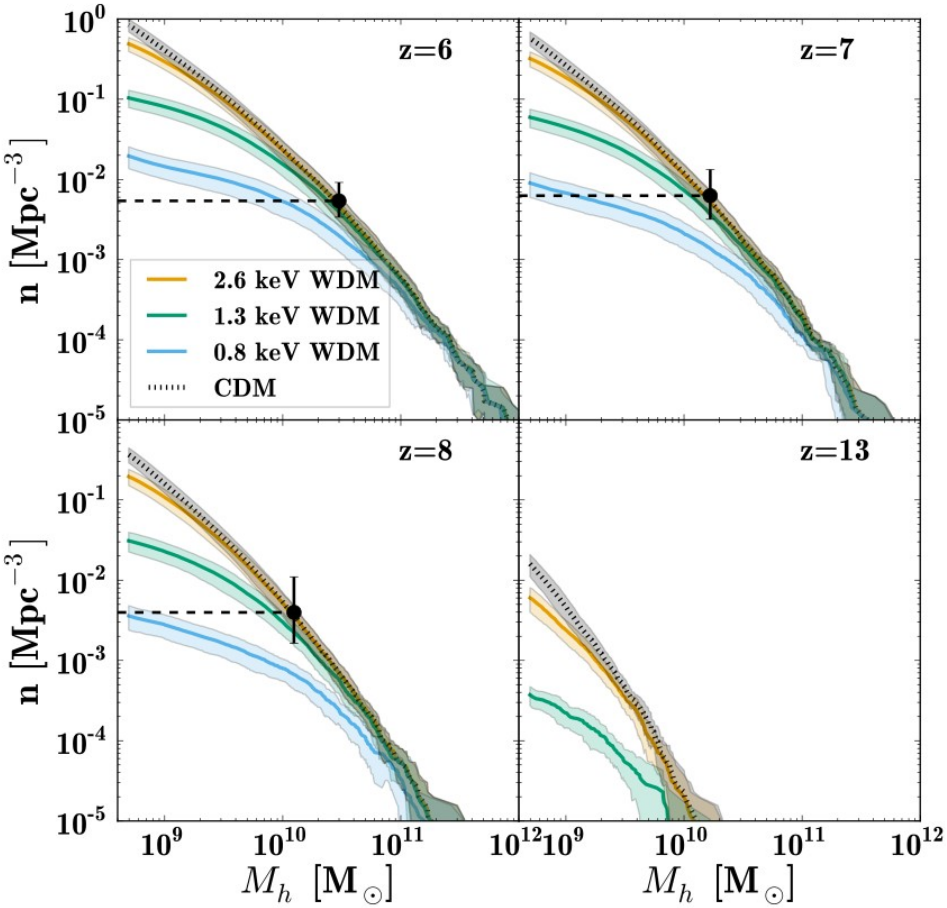


Springel et al. (2006)

Halo mass functions

The High-z Universe Confronts Warm Dark Matter: Galaxy Counts, Reionization and the Nature of Dark Matter

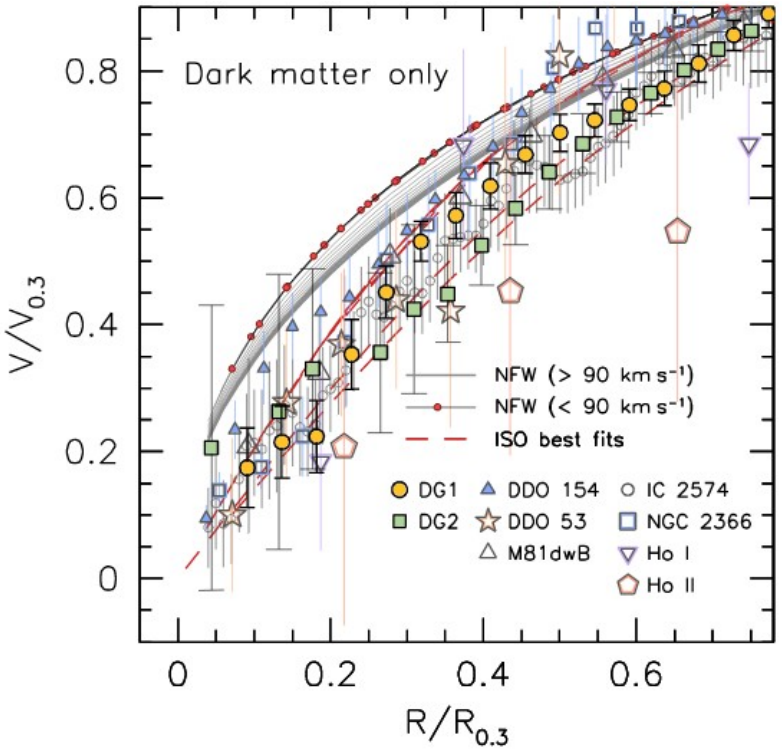
Christian Schultz[1,2⋆], Jose Oñorbe[1], Kevork N. Abazajian[1], James S. Bullock[1]

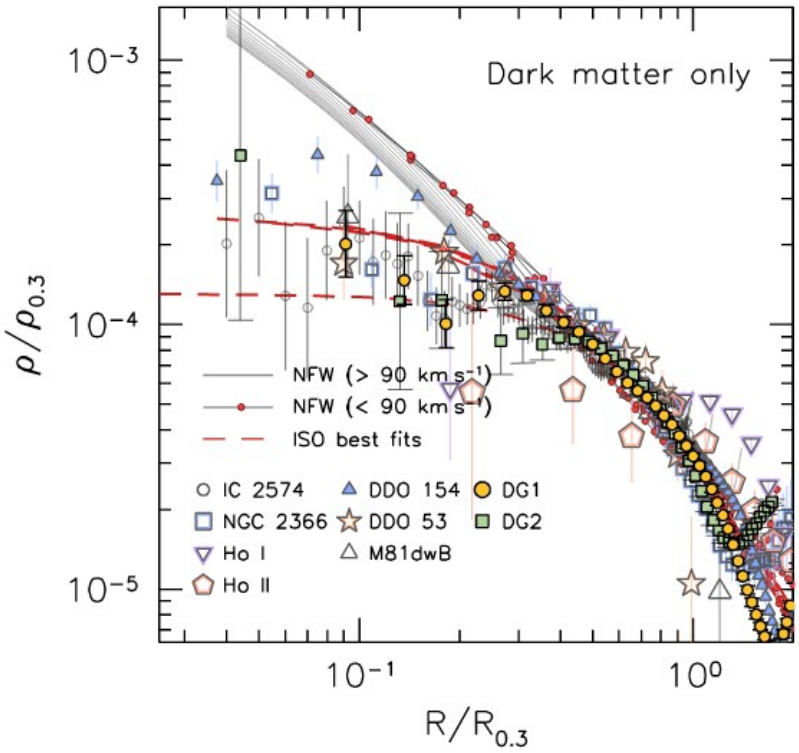


Small-scale problems

THE CENTRAL SLOPE OF DARK MATTER CORES IN DWARF GALAXIES: SIMULATIONS VS. THINGS

Se-Heon Oh[1,8], Chris Brook[2], Fabio Governato[3], Elias Brinks[4], Lucio Mayer[5], W.J.G. de Blok[1], Alyson Brooks[6] and Fabian Walter[7]





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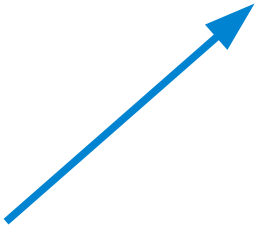

We will start at 9:30 s.t. (45 min earlier)

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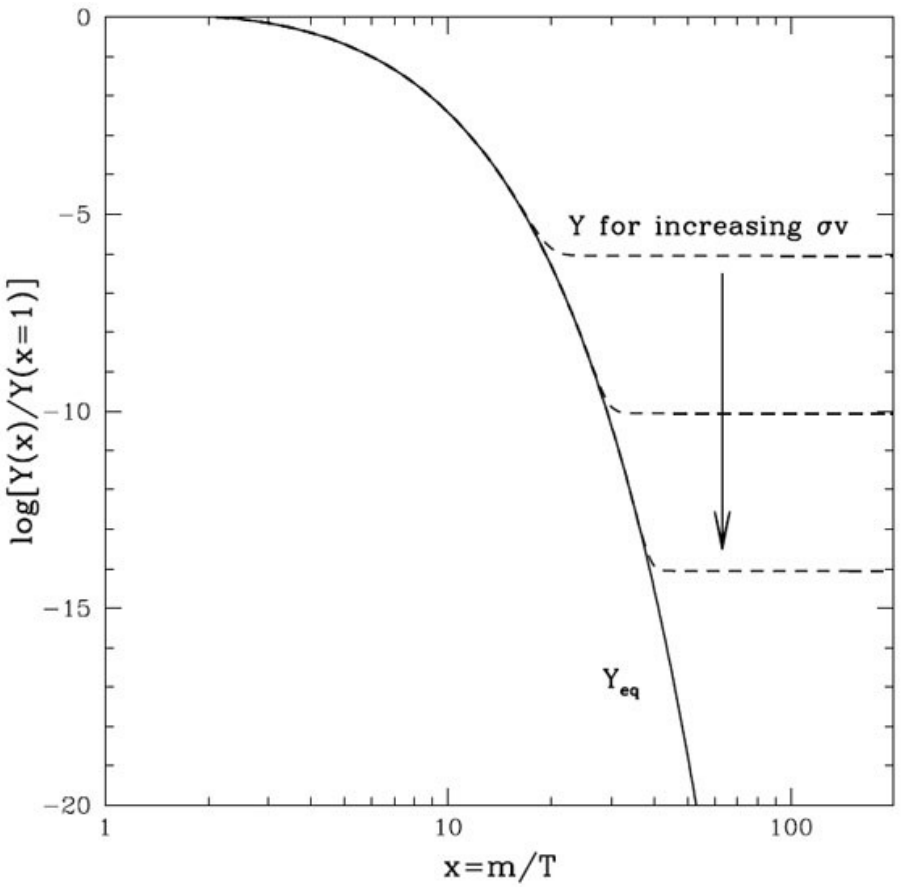
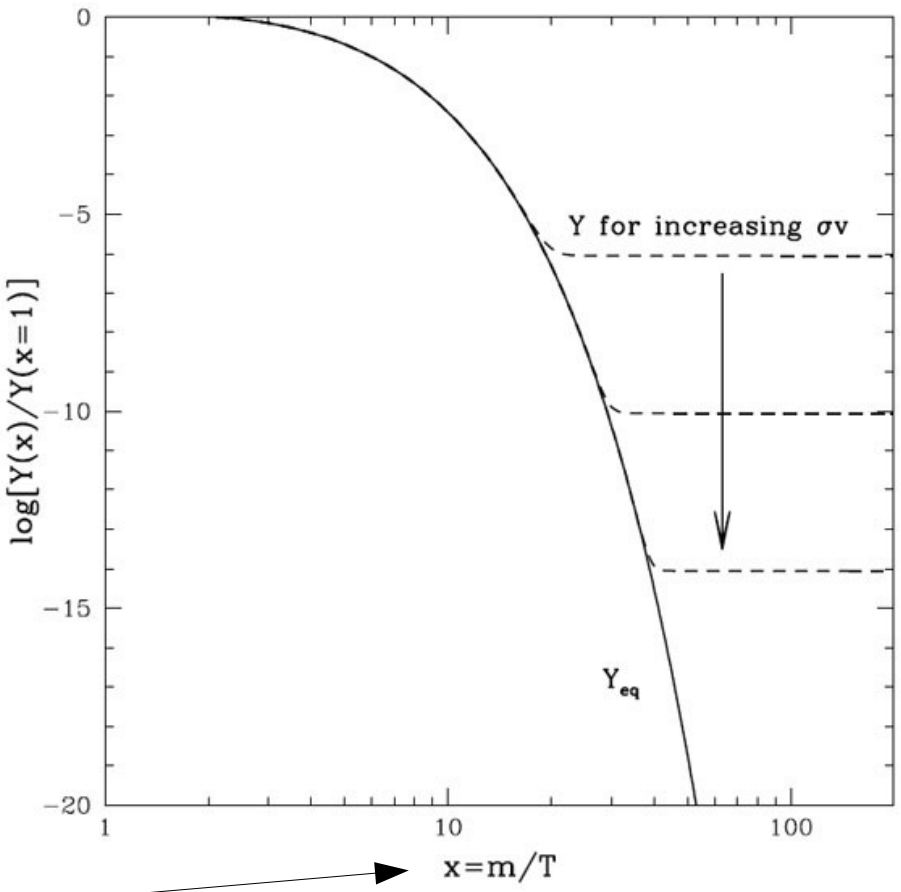
Freeze-out



Freeze-out

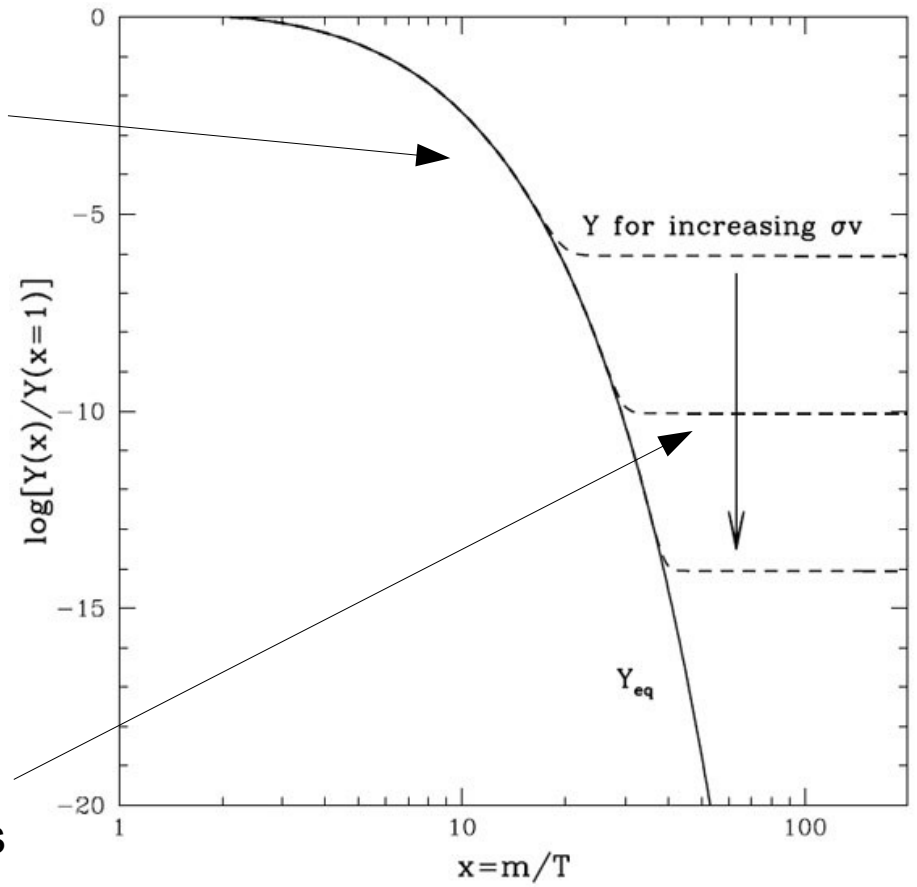
Y is the number density n_X divided by the entropy density (to obtain a dimensionless quantity)



x is the dimensionless inverse temperature: Larger x corresponds to smaller temperature, corresponds to later time

Freeze-out

Equilibrium distribution is exponentially suppressed:
Y ~ exp(-x)



Once <σv> is smaller than the Hubble rate, Y becomes constant. Larger σv means departure from thermal equilibrium happens later.

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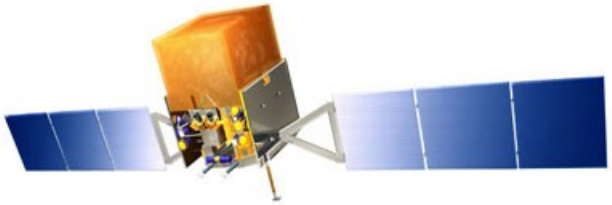
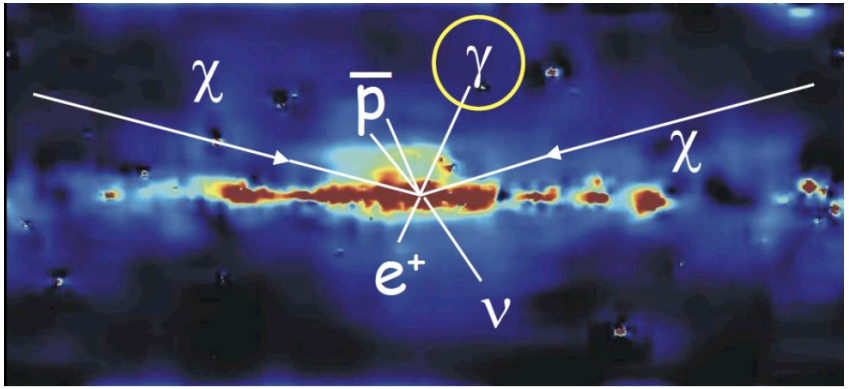
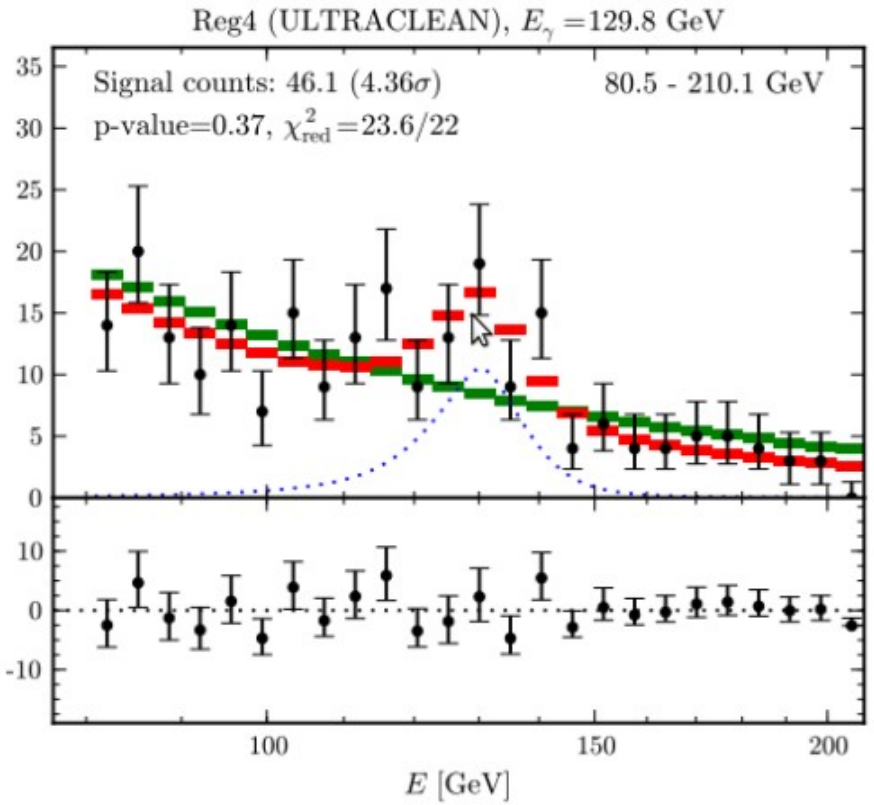
5. Beyond WIMPs
    1. The misalignment mechanism

Particle physics: Today

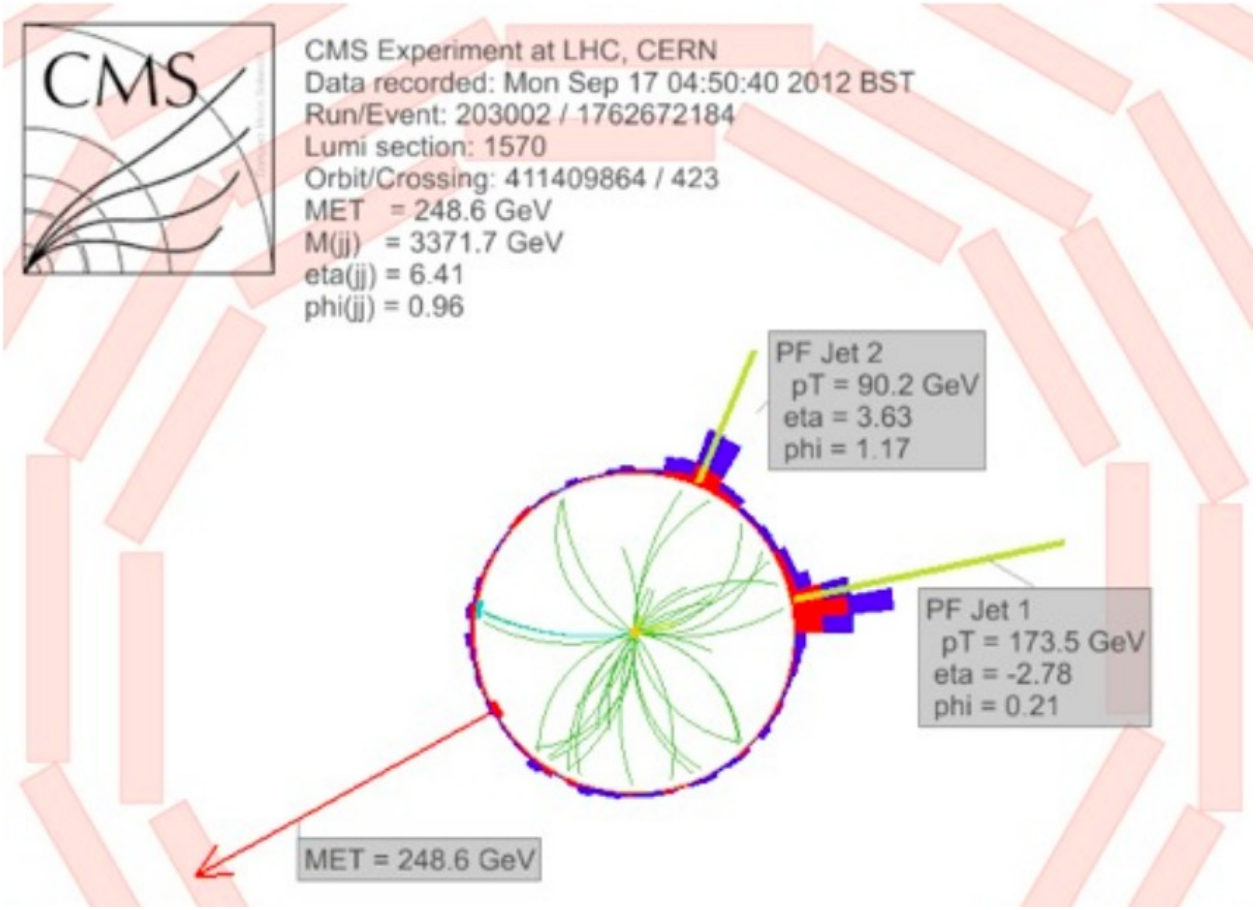
Indirect detection







Invisible Higgs decays



Global fit of scalar singlet dark matter