# DARK MATTER AND ITS CANDIDATES


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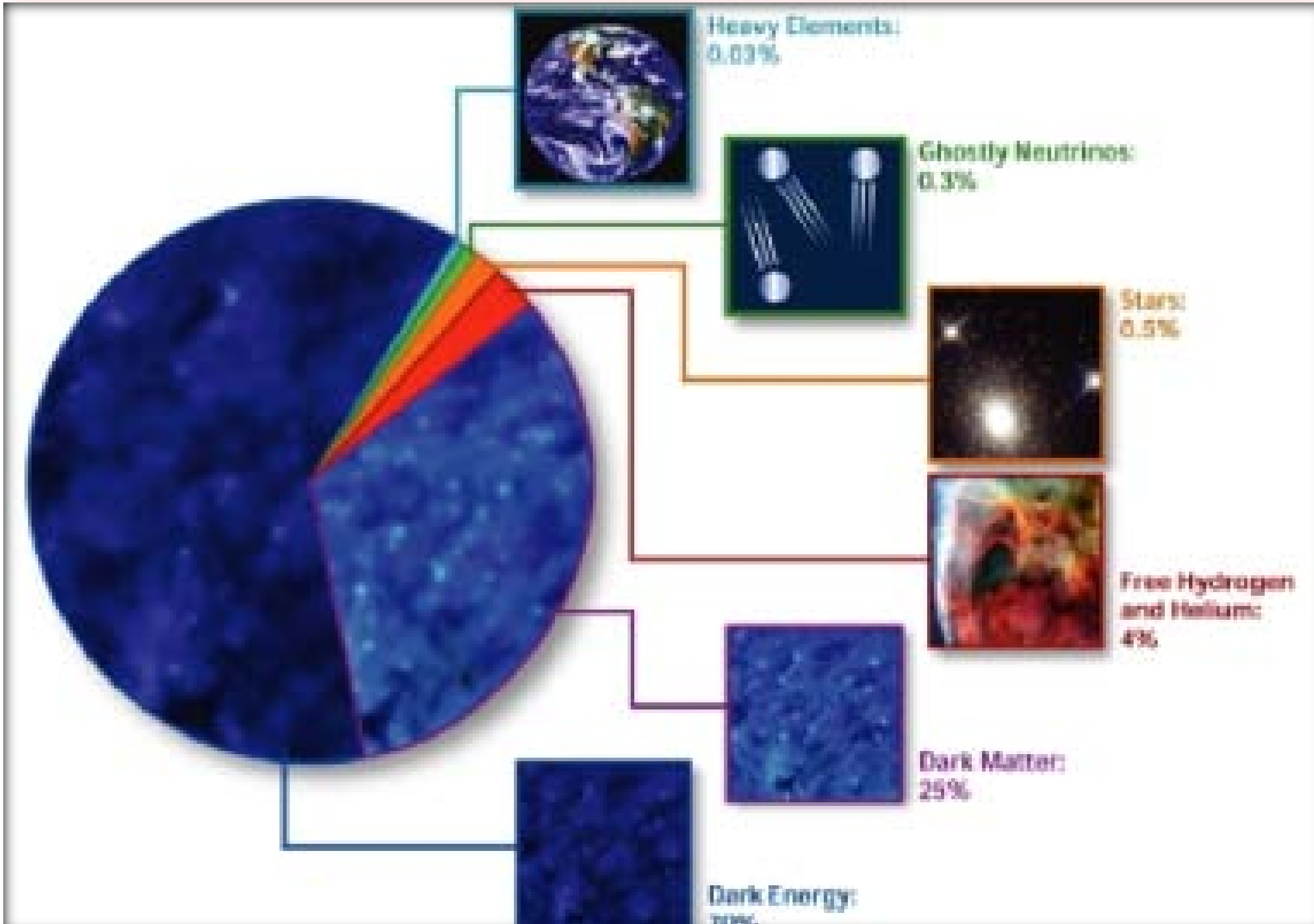
# Outline

- Why Dark Matter?
- What does a high energy physicist have to do with dark matter?
- WIMP dark matter
- How about other possibilities?
- Summary

# WHY Dark Matter is necessary?



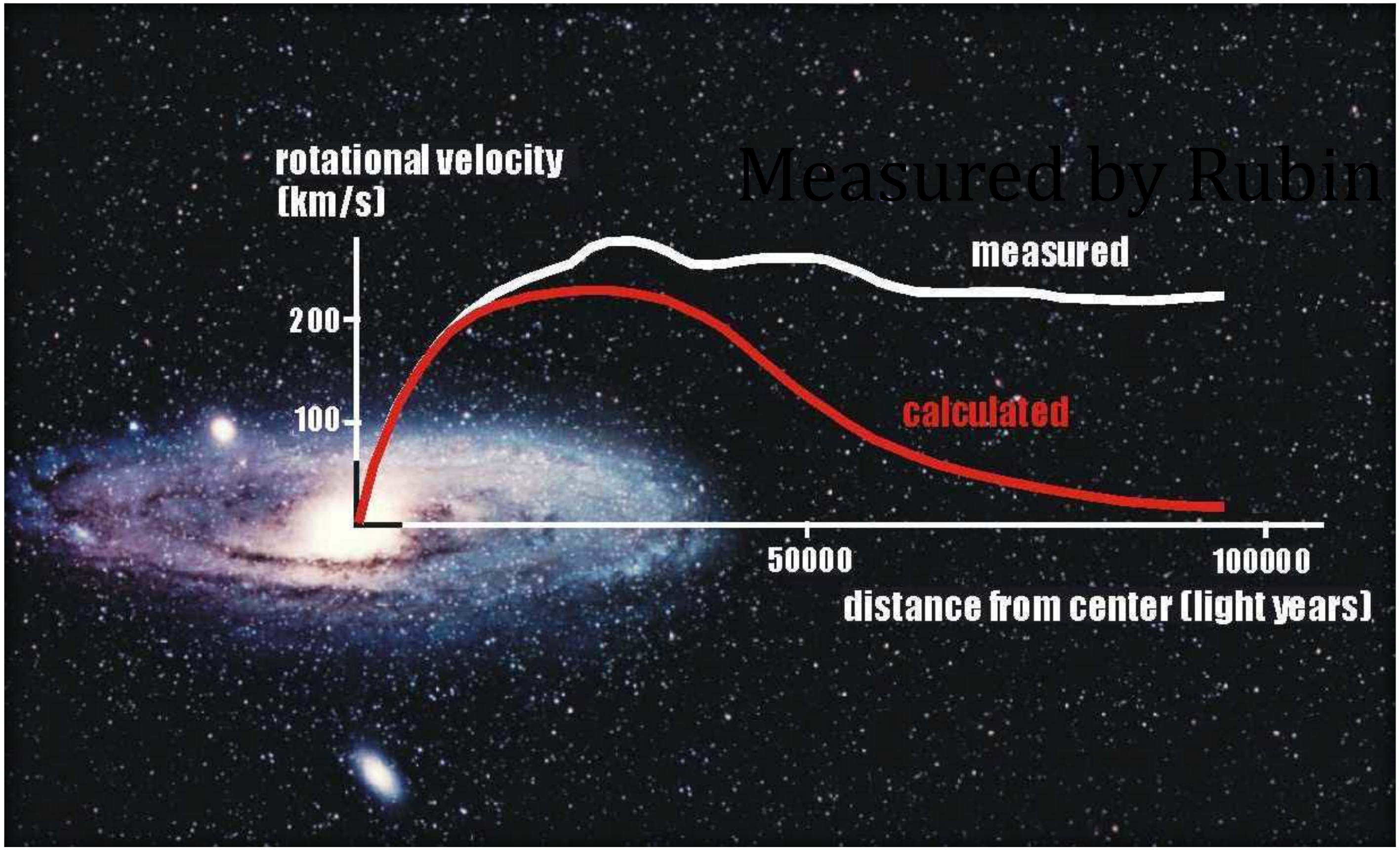

http://www.mpi-hd.mpg.de/lin/research_DM.en.html

# Inconsistent observations with Newtonian gravity

- Coma cluster (1933) observed by Zwicky
- Velocities too high to be produced by the gravitation of observed matter
- Luminous matter ~0.5% of required

Image credit: NASA/JPL-Caltech/GSFC/SDSS

# Evidence from galactic rotation curves



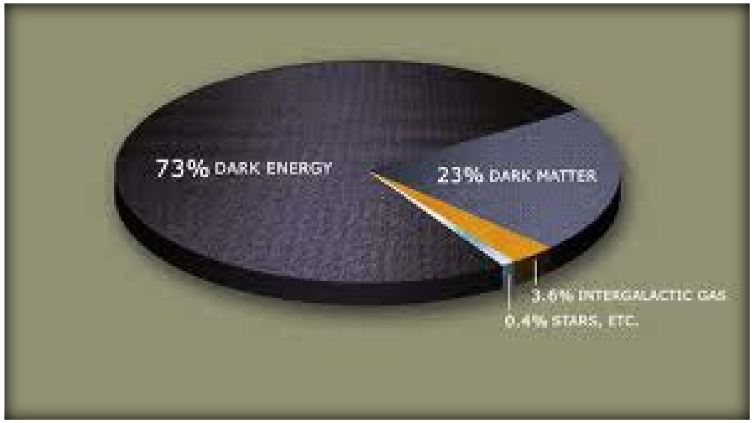

Prediction of Newton's
law of gravity

$$\frac{GMm}{r^2} = \frac{mv^2}{r} \rightarrow v = \sqrt{\frac{GM}{r}}$$

# The Ultimate picture

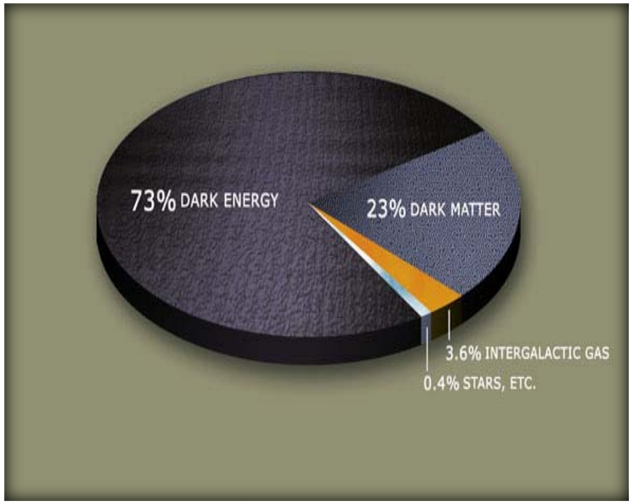
- Other explanations than the Dark Matter proposal
- Today Dark Matter is well accepted by the community and is supposed to constitute about 22% of our universe.

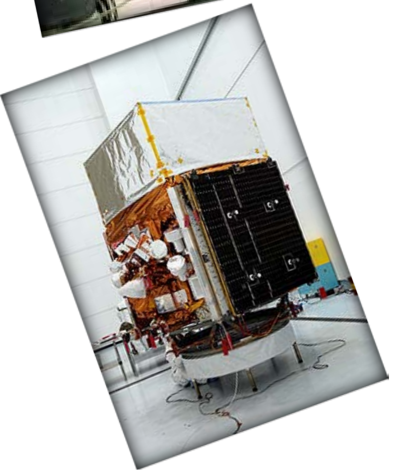
http://www.daviddarling.info/encyclopedia/D/dark_halo.htmlCredit: Jose Wudka

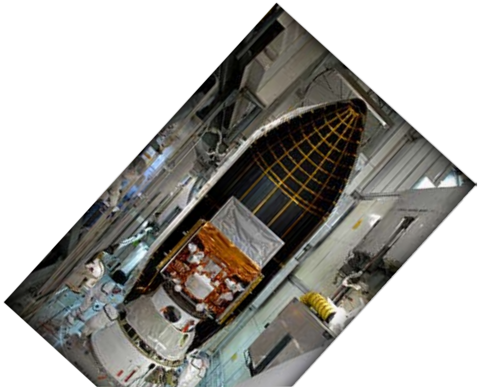


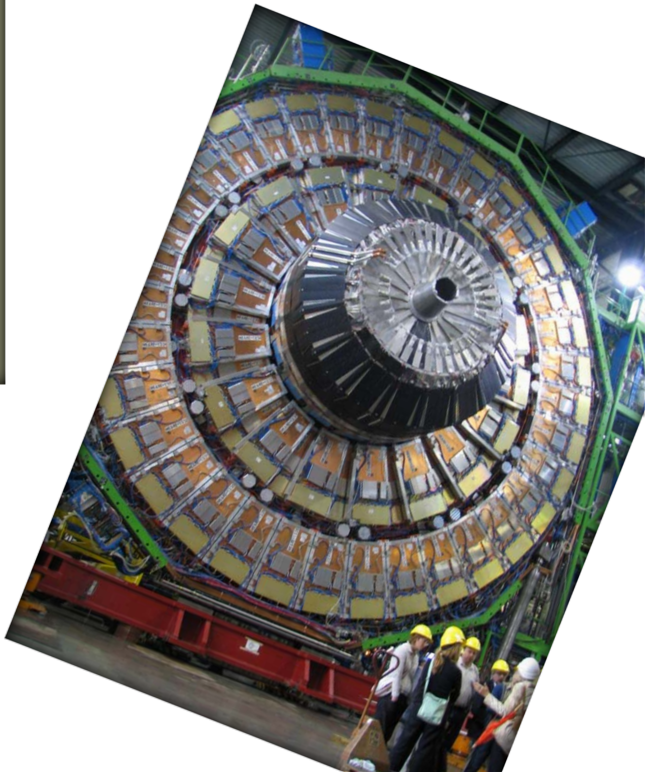

http://www.homodiscens.com/home/embodied/mortalis_astonishing/landmarks_sub/matter/index.htm
**Image source: Edelweiss II**

# What does a high energy physicist have to do with dark matter?







# What does Dark Matter consist of?

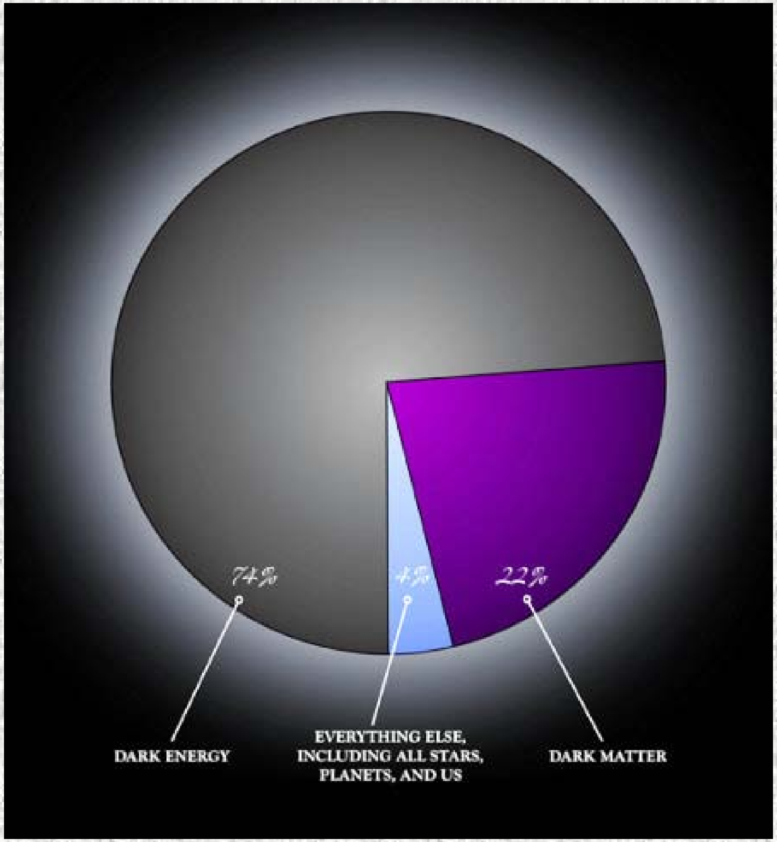
- Baryonic matter :
- Massive compact halo objects(MACHOs)
- Black holes
- Neutron stars
- Brown dwarfs

- These can provide only about 10% Of expected DM

Non-baryonic DM is needed to
Account for the remaining fraction

# GENERAL properties of DM

- No EM interactions
- Stable: Life time of the order of the universes age
- Should make around 22 percent of our universe




http://scienceblogs.com/startswithabang/2011/05/25/do-more-planets-gas-and-stars/

# NON-baryonic DM candidates

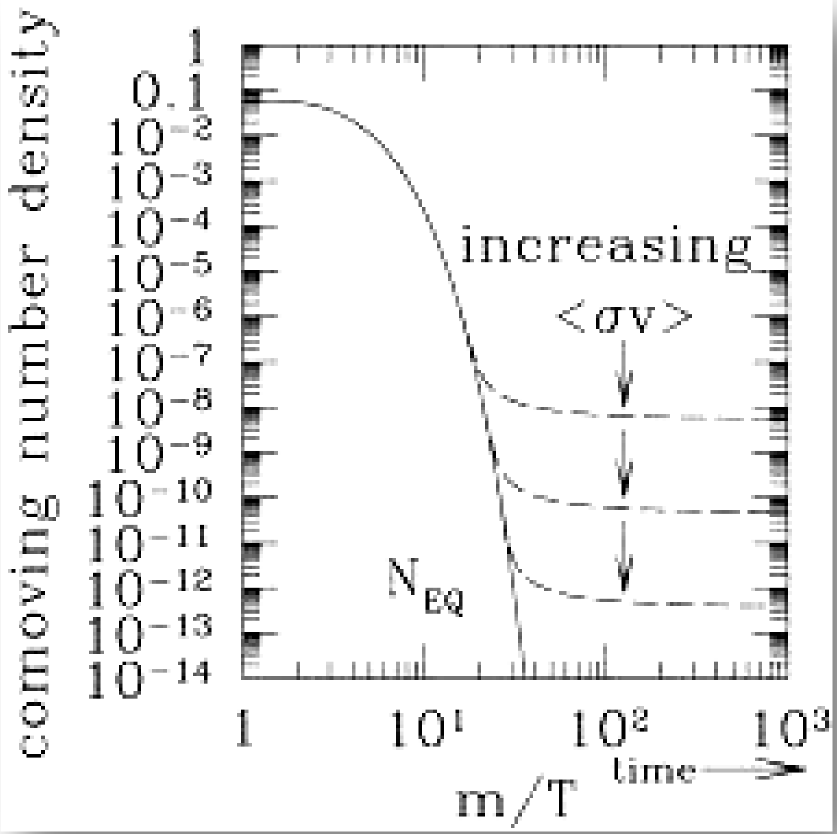
- the most popular candidate :

  Weakly Interacting Massive Particles (WIMPs)

- Other BSM candidates

# WIMP Dark Matter

# Freeze out of WIMPs




## Boltzmann equation

$$\frac{dn}{dt} + 3Hn = -\langle\sigma v\rangle \left(n^2 - (n^{eq})^2\right)$$

$$H(t) \equiv \frac{\dot{R}(t)}{R(t)}$$

For WIMP mass~100GeV

The result will be:

$$\Omega_X h^2 \approx \frac{3\times10^{-27}\mathrm{cm}^3\mathrm{s}^{-1}}{\langle\sigma v\rangle}$$ WIMP miracle

# An appealing WIMP candidate from SUSY

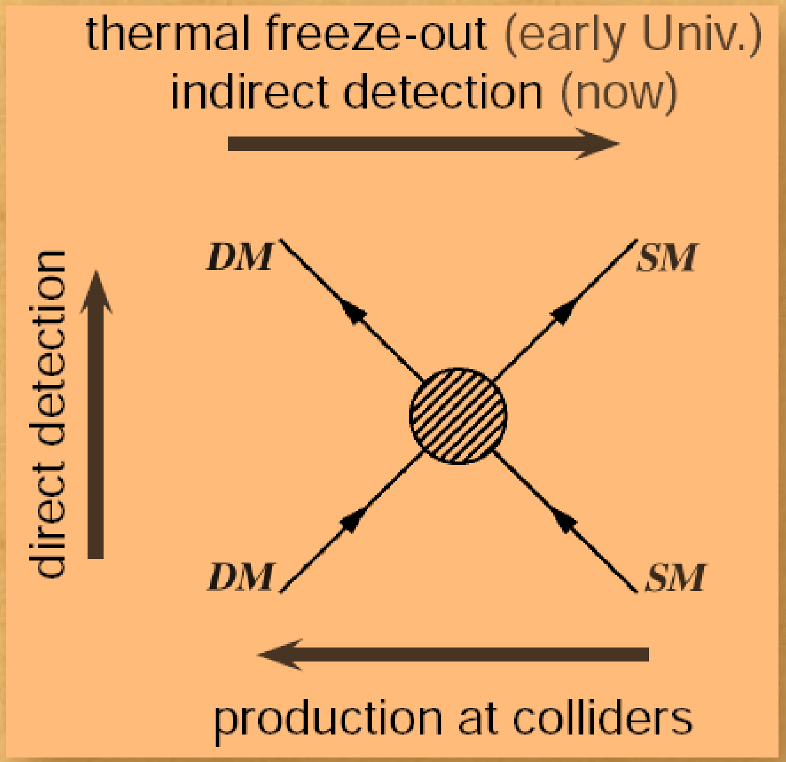
- Lightest supersymmetric particle (LSP)
- Electrically uncharged
- $Z_2$ symmetry : interacting with SM particles in such way that always an even number of LSPs participate.

LSP remains stable

# How to detect these WIMPs?

- Direct detection
- Indirect detection
- Particle colliders

No firm evidence till now for the existence of such WIMPs

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# How about other possibilities?

# Freeze-in vs Freeze-out

L. J. Hall, K. Jedamzik, J. March-Russell and S. M. West, JHEP 1003, 080 (2010) [arXiv:0911.1120 [hep-ph]]

- Freeze-in of FIMP DM

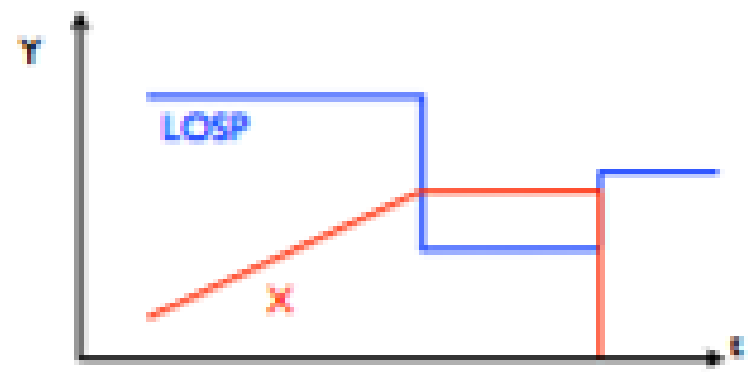
  $\lambda \sim 1.5 \times 10^{-12}$

- Experimental evidence:

  Long-lived LOSP decays at the LHC


- FIMP freeze-in and decay to LOSP DM
- Experimental evidence:

  Enhanced direct and indirect detection signals of DM



# Summary

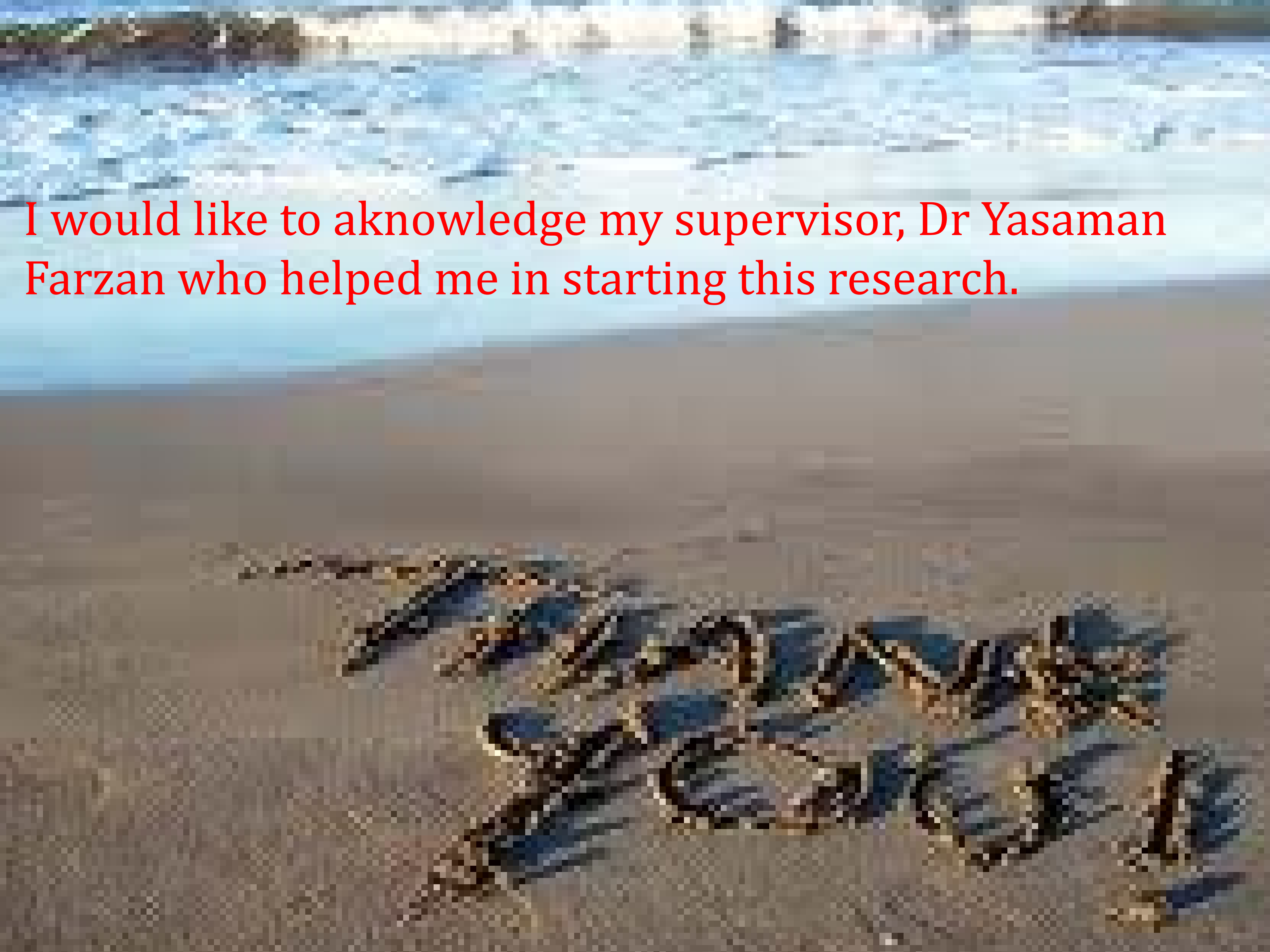
DM is well accepted by the community.

Particle phenomenologists are making a big jungle of models explaining non-baryonic DM.

WIMP particles from supersymmery provide some appealing candidates for Dark Matter satisfying all needed criteria.

# references


- Todd Duncan, Craig Tyler,Your Cosmic Context: An Introduction to Modern Cosmology, Pearson Addison Wesley, ©2009
- B. Gianfranco, ed., Particle Dark Matter. Cambridge University Press
- Dark Matter Candidates from Particle Physics and Methods of Detection Jonathan L. Feng
- L. J. Hall, K. Jedamzik, J. March-Russell and S. M. West, JHEP 1003, 080 (2010) [arXiv:0911.1120 [hep-ph]]



I would like to aknowledge my supervisor, Dr Yasaman Farzan who helped me in starting this research.