What can we learn from Gaia about Dark Matter?

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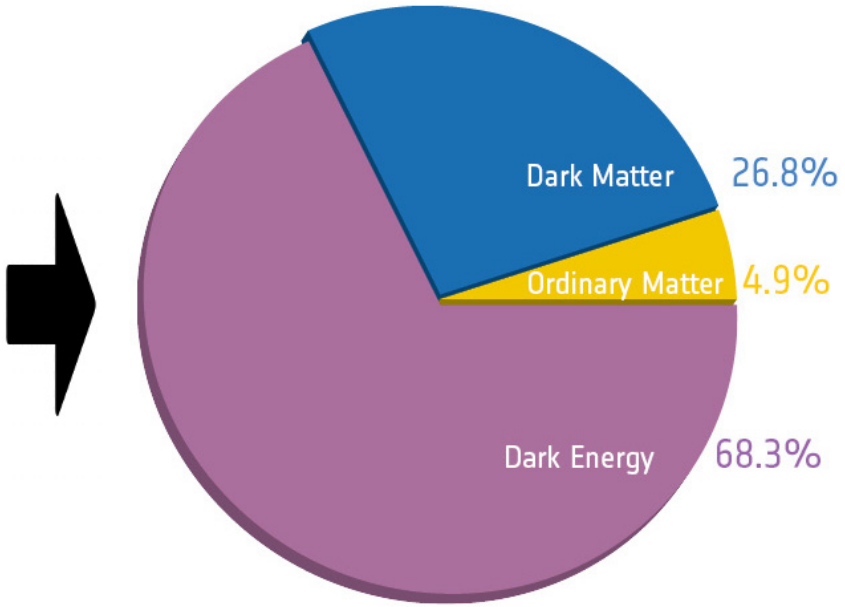
The missing mass

Many independent probes imply existence of Dark Matter

- Galactic rotation curves
- Cosmic Microwave Background
- Formation of Large Scale Structures
- Gravitational lensing
- Big Bang Nucleosynthesis



What we know about DM

Known properties:

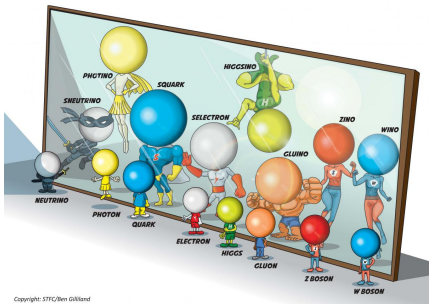
- Cosmological **abundance**
- Behaves as **non-relativistic** particles
- Must be **stable** or extremely long-lived
- It must consist of **non-Standard Model particle(s)**
- Strong **constraints on coupling** to ordinary matter

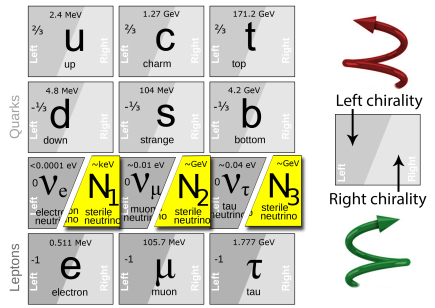
Despite great theoretical and experimental efforts not much is known about DM!

What we don't know about DM

Some pressing questions regarding DM

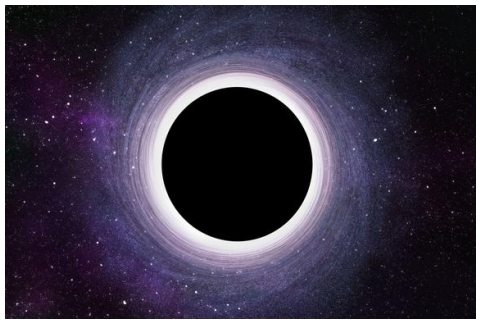
- Production mechanism?
- Single particle or multiple components?
- Distribution on small scales?





Myriad of theoretical proposals

- Supersymmetry
- Sterile neutrinos
- Primordial Black Holes
- ...

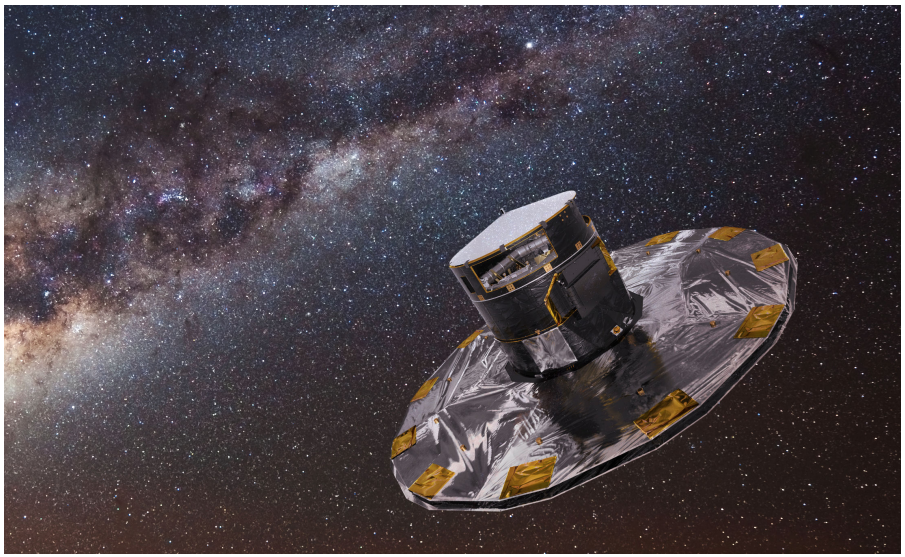


⇒ **Need new observations** to rule out or confirm models

Importance of Gaia for studying DM

Gaia mission is expected to provide answers to many fundamental questions regarding DM by addressing:

- **Distribution of DM** within Milky Way
- Provide information regarding **DM substructure**
- Constrain **MACHOs**



Distribution of DM in Milky Way

By mapping **proper motions of stars** one can reconstruct the total gravitational potential and hence also DM distribution in our galaxy

Knowledge DM distribution is **crucial for DM** searches

- **Direct Detection** (of DM scattering with nuclei):

$$\frac{\mathrm{d}R}{\mathrm{d}E}(E,t) = \frac{\rho_{\mathrm{DM}}(r_\odot)}{m_\chi m_A} \int \mathrm{d}^3 v \, \frac{\mathrm{d}\sigma}{\mathrm{d}E}(E,v) \cdot f(\vec{v},t) \cdot v$$

- **Indirect Detection** (of DM decay or annihilation products):

$$\frac{\mathrm{d}\Phi}{\mathrm{d}E} = \frac{\sigma_0}{8\pi m_\chi^2} \frac{\mathrm{d}N}{\mathrm{d}E} \int \mathrm{d}\Omega \int \mathrm{d}\ell \, \rho_{\mathrm{DM}}^2(\vec{r})$$

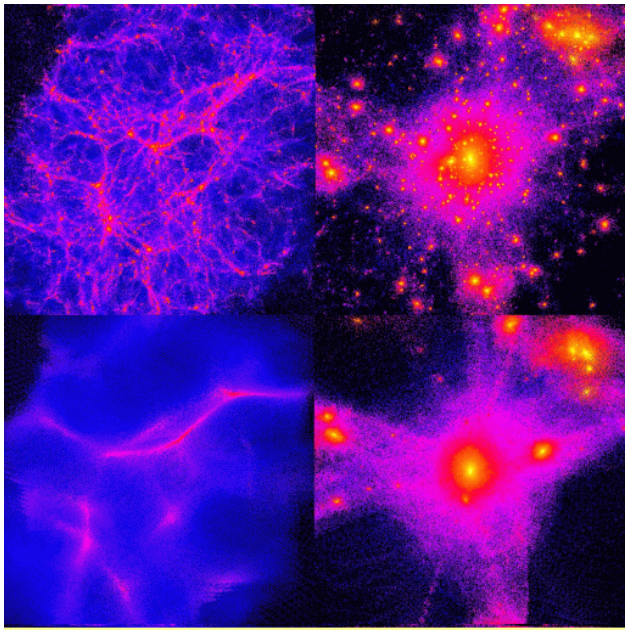
DM substructure

By measuring **proper motions of stars** one can study the amount of DM substructure

- Disruption of Globular Clusters' tidal streams
- Stellar wakes

This could provide crucial information regarding DM nature:

- Significance of **self-interactions**
- Is DM **"warm"** or **"cold"**
- Might provide insights into **production mechanism**
- Consistency check for simulations



MACHOs

Significant amount (if not all) DM could be in form of **MAssive Compact Halo Objects**

Most popular MACHOs:

- Primordial Black Holes
- Neutron stars
- Brown dwarfs
- Unassociated planes

Primordial Black Holes are considered as most probable MACHOs candidate

Primordial Black Holes - current status

Shrinking gap for fraction of Primordial Black Holes

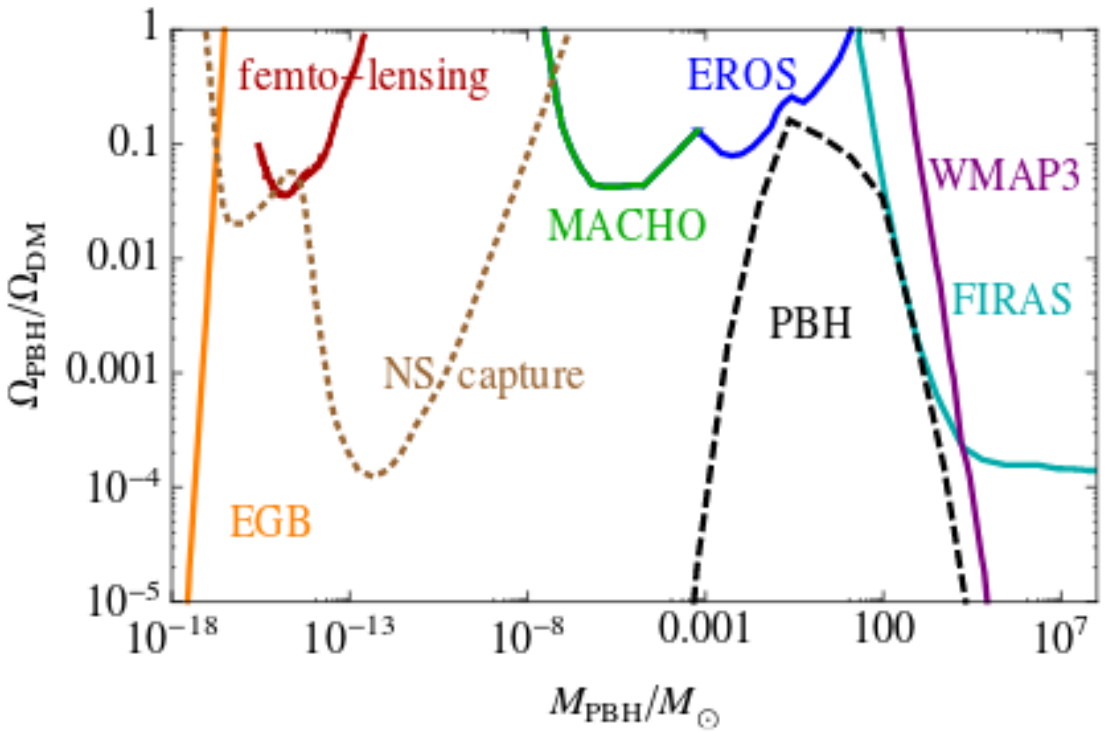


Figure: Clesse, Sébastien et al. Phys.Rev. D92 (2015) no.2, 023524

Conclusions

Gaia has the ability to provide new observations that could be crucial for our understanding of DM

Valuable observations for many DM related research programs

- DM distribution within Milky Way $\rightarrow$ Direct and Indirect Detection experiments
- DM power spectrum down to the smallest scales $\rightarrow$ fundamental properties of DM
- Search for exotic components in form of MACHOs

Exciting era for DM physics!