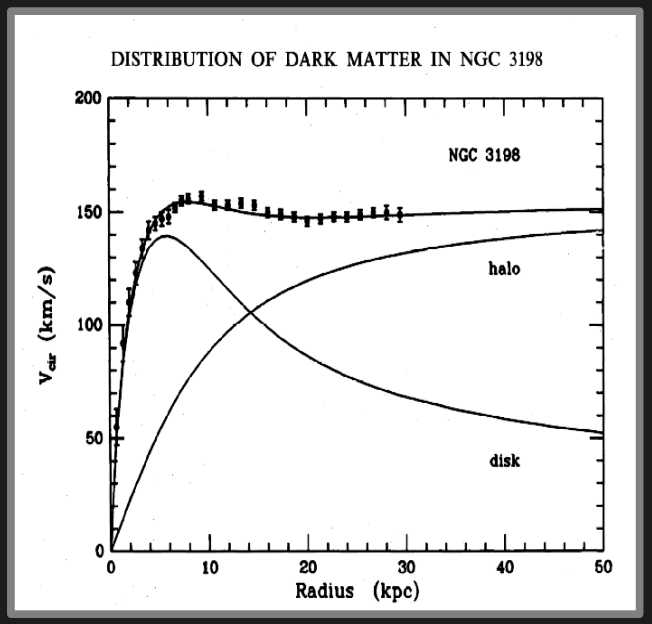
Dark matter

Maxim Laletin
STAR Workshop
15/09/2017

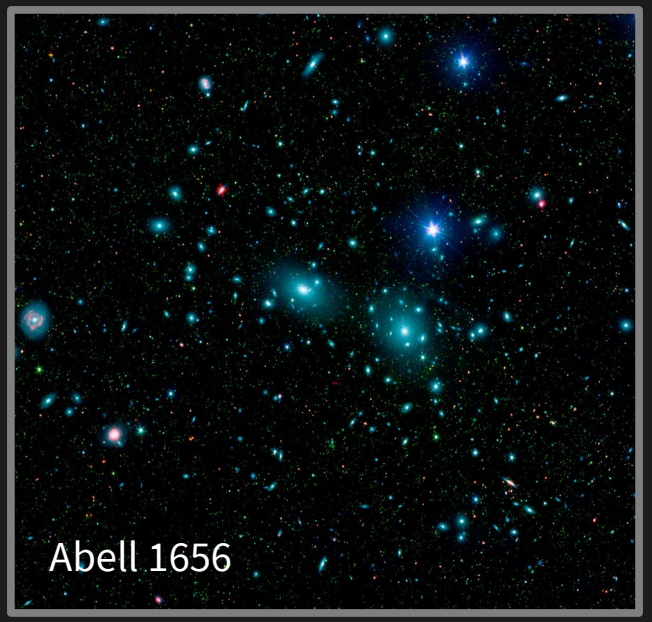
OUTLINE

- Observational evidence
- Hypotheses
- Search strategies
- What’s new?

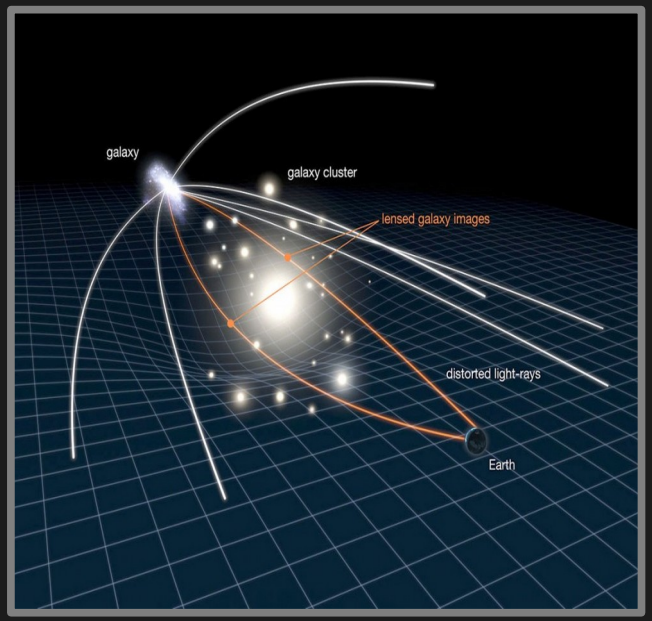
OBSERVATIONAL EVIDENCE



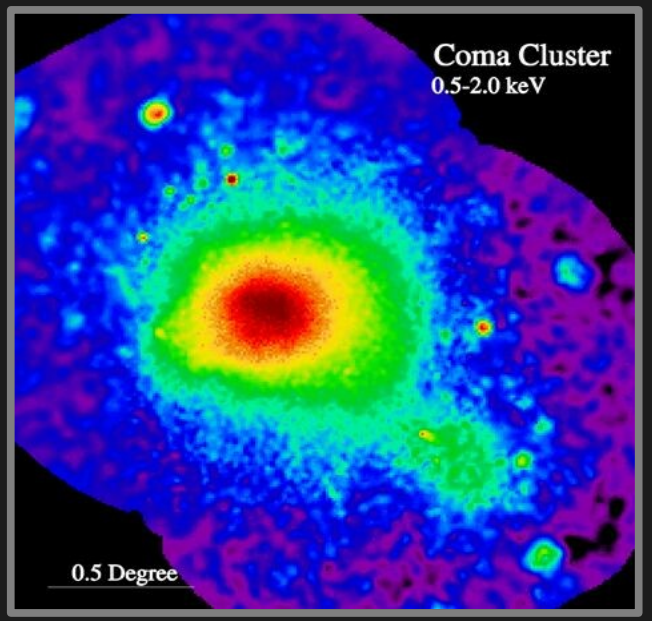
Galaxy
rotation curves



Motion of
galaxies
In clusters

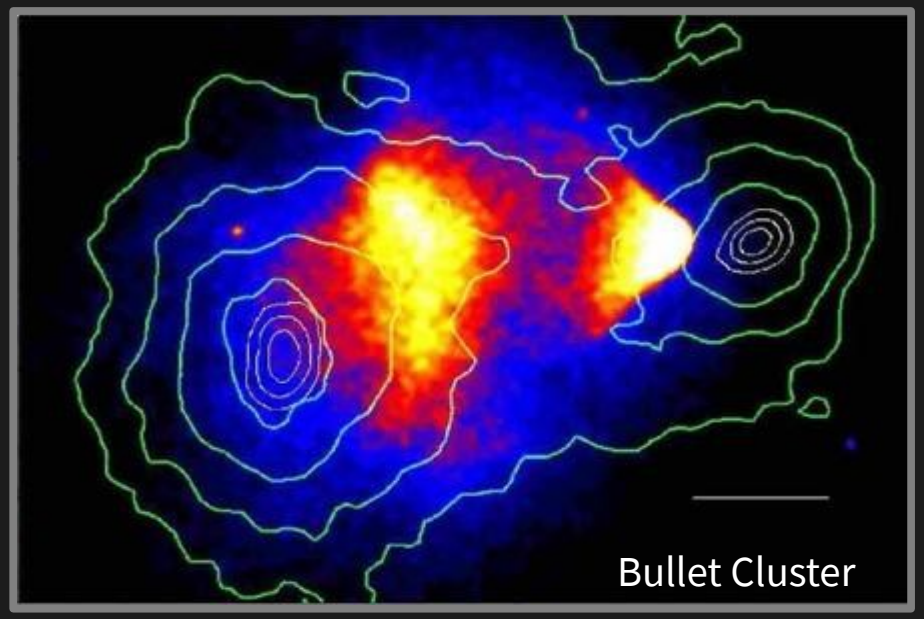


Gravitational
lensing
of clusters



X-ray
Observations
Of clusters

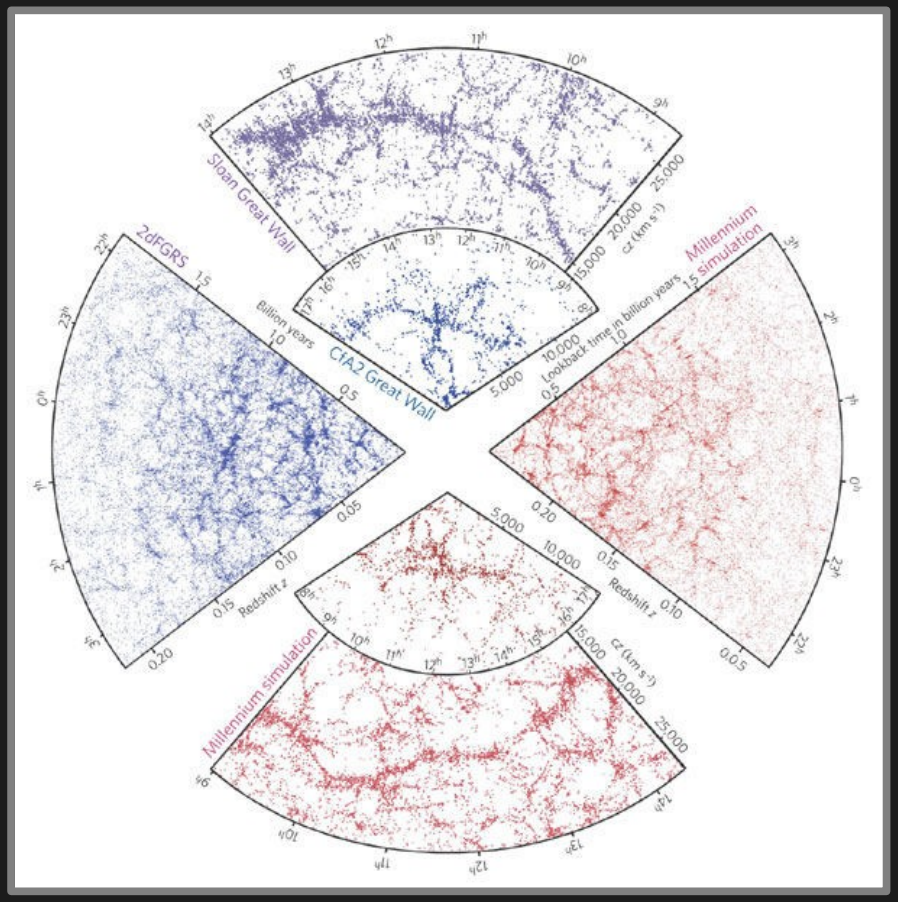
OBSERVATIONAL EVIDENCE



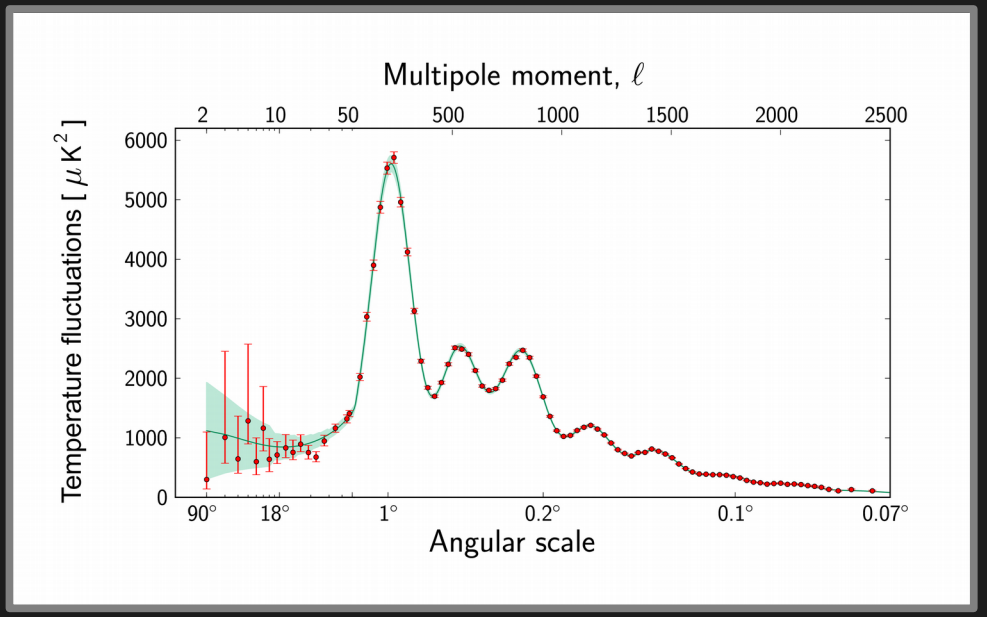
Separation of matter in cluster collisions

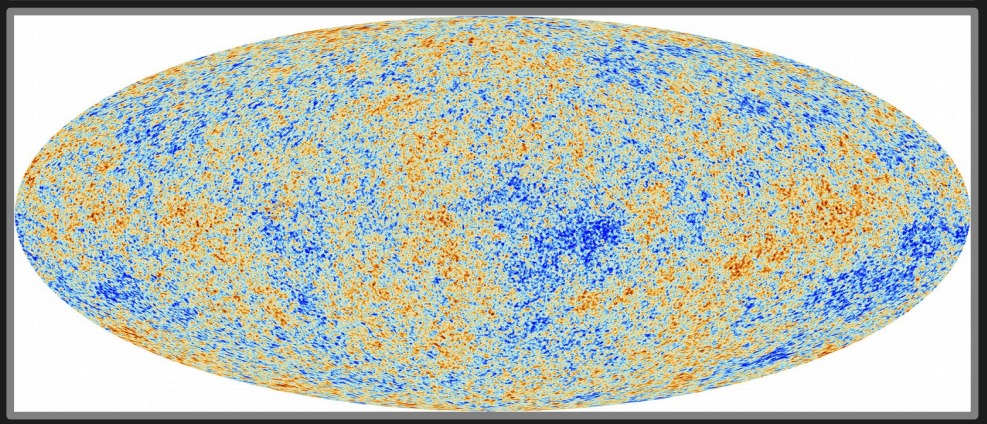
OBSERVATIONAL EVIDENCE

https://lambda.gsfc.nasa.gov/education/cmb_plotter/



Large scale structure
of the Universe





Cosmic microwave background
power spectrum

What do we know about dark matter from observations?

- It **gravitates**;
- It is **dark** (doesn't radiate much, *probably* doesn't even interact electromagnetically);
- It makes up **~ 26%** of the energy density in the Universe;
- Cosmologically **stable** (or long-lived);
- It is **collisionless** (or doesn't collide much)

SOME CANDIDATES

- Weakly Interacting Massive Particles (WIMPs):

  The most trivial and well elaborated group of models; many beyond SM physics models predict such particles (e.g. SUSY, Inert Doublet Models, sterile neutrino, etc.)

- Particles with non-trivial interactions:

  Various particle physics models providing some features that WIMPs don’t have, such as sizable self-interaction, complicated production mechanism or thermal evolution and so on (e.g. axions, mirror DM, composite DM, FIMPs, SIMPs, PIMPs, etc.)

- Primordial black holes (PBH)

  A new wave of interest in PBH as DM candidate started recently due to LIGO’s observation of gravitational waves from merging black holes.

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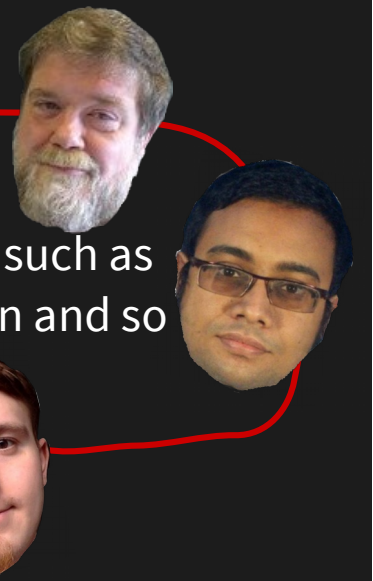

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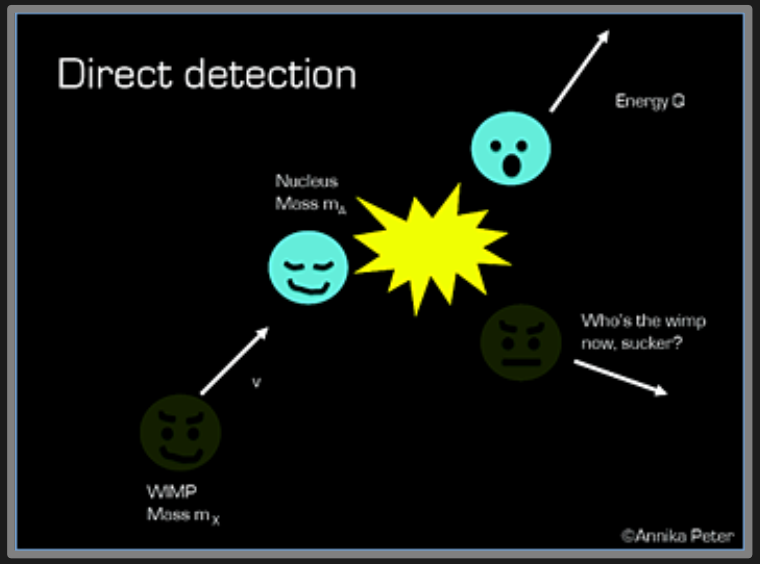
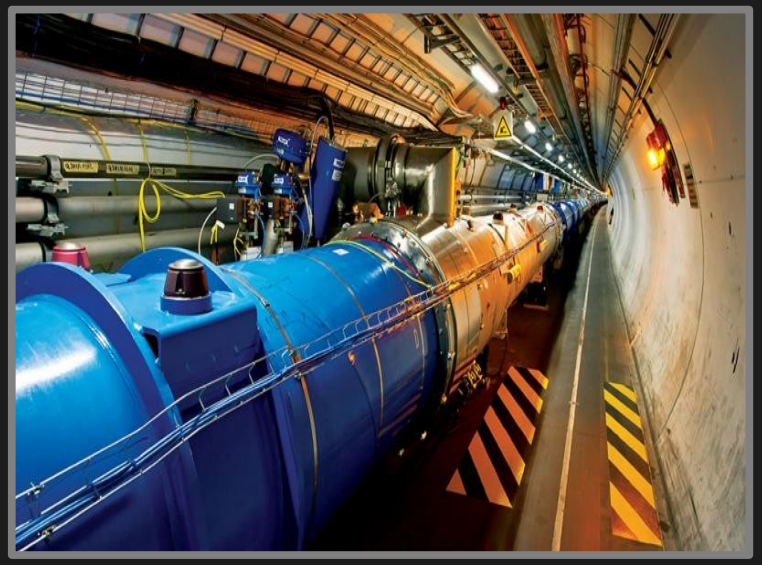
SEARCH STRATEGIES

Direct detection



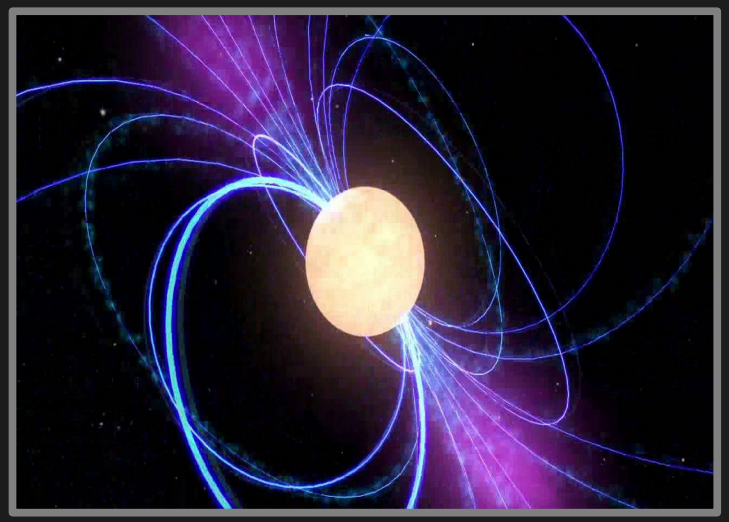
Indirect detection

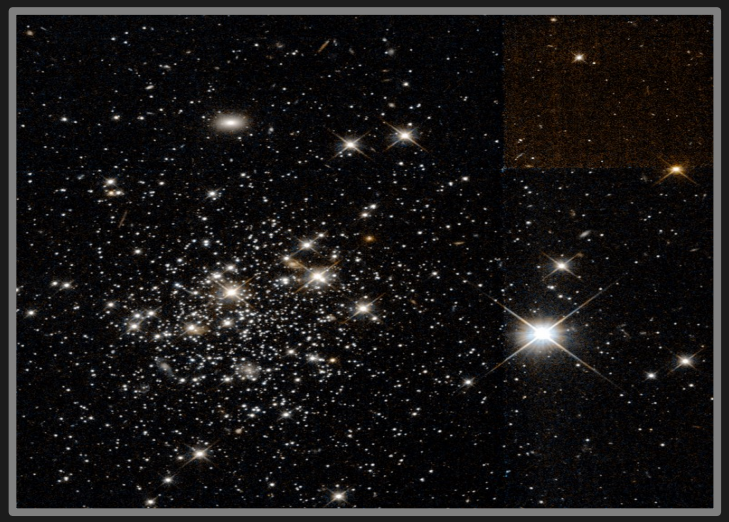


Production at colliders

SEARCH STRATEGIES

In indirect searches astrophysics is really involved...





C. Kouvaris, M. Angeles Perez-Garcia,
"**Can Dark Matter explain the Braking Index of Neutron Stars?**",
Phys.Rev. D89 (2014) no.10, 103539, 1401.3644

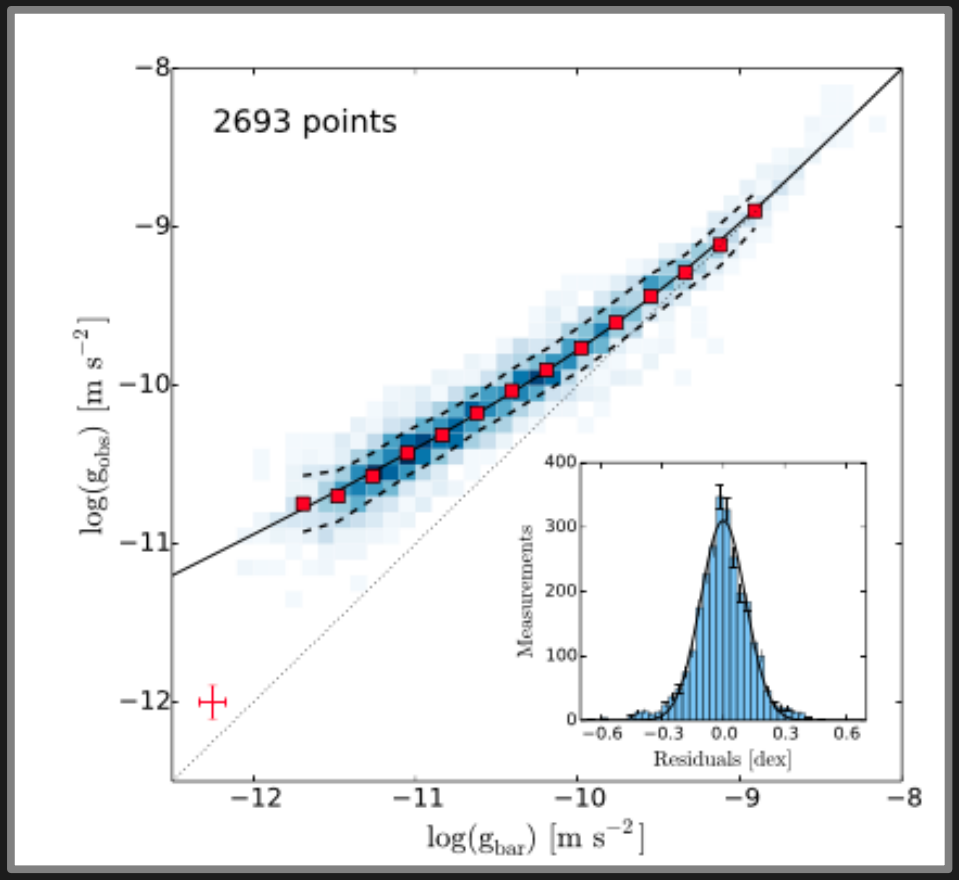
F. Contenta et al.,
"Probing dark matter with star clusters: a dark matter core in the ultra-faint dwarf Eridanus II", 1705.01820

L. Gabriel Gómez et al.,
"Dark-matter dynamical friction versus gravitational-wave emission in the evolution of compact-star binaries",
Phys.Rev. D96 (2017) no.6, 063001, 1706.06801

A. Khmelnitsky, V. Rubakov,
"Pulsar timing signal from ultralight scalar dark matter",
JCAP 1402 (2014) 019 , 1309.5888

L. Tolos, J. Schaffner-Bielich,
"Dark Compact Planets",
Phys.Rev. D92 (2015) 123002 , 1507.08197

WHAT'S NEW?

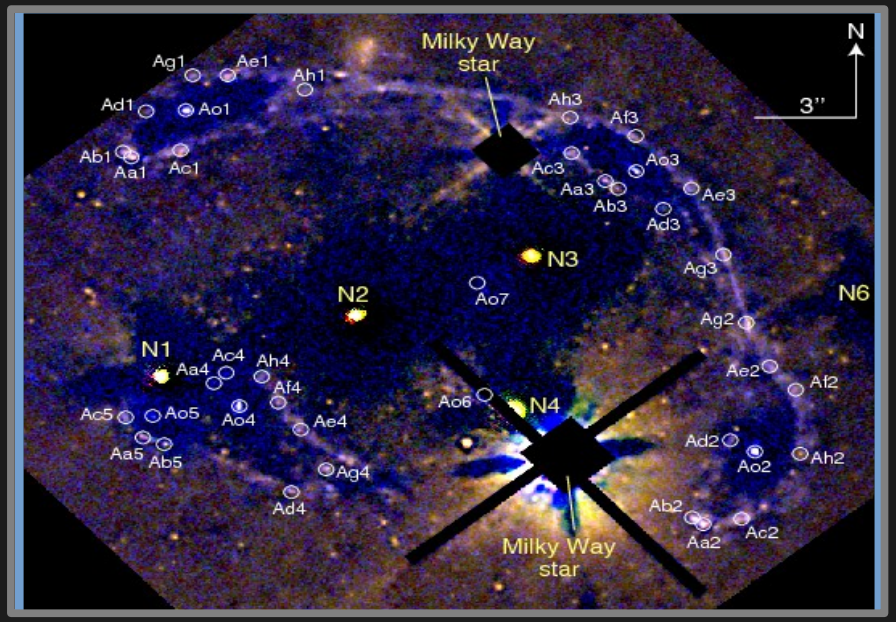


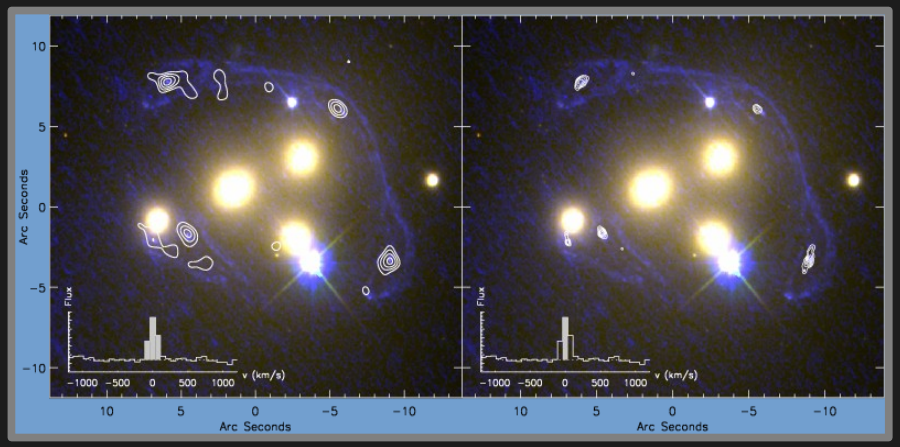
Strong relation between radial acceleration traced by rotation curves and that predicted by the observed distribution of baryons was **observed**.

(do not confuse with Tully-Fischer relation)

S. McGaugh, F. Lelli, J. Schombert,
"Radial Acceleration Relation in Rotationally Supported Galaxies"
Phys.Rev.Lett. 117 (2016) no.20, 201101, 1609.05917

WHAT'S NEW?





In 2015 Massey et al. found a **discrepancy** between the observed mass distribution in Abell 3827 galaxy cluster and that predicted within standard cold DM model. They attributed the effect to **self-interacting** dark matter.

The **refined analysis** from 2017 revealed that the dynamics in this cluster **consistent** with standard cold dark matter.

D. Harvey et al., "Dark matter dynamics in Abell 3827: new data consistent with standard Cold Dark Matter", 1708.04245

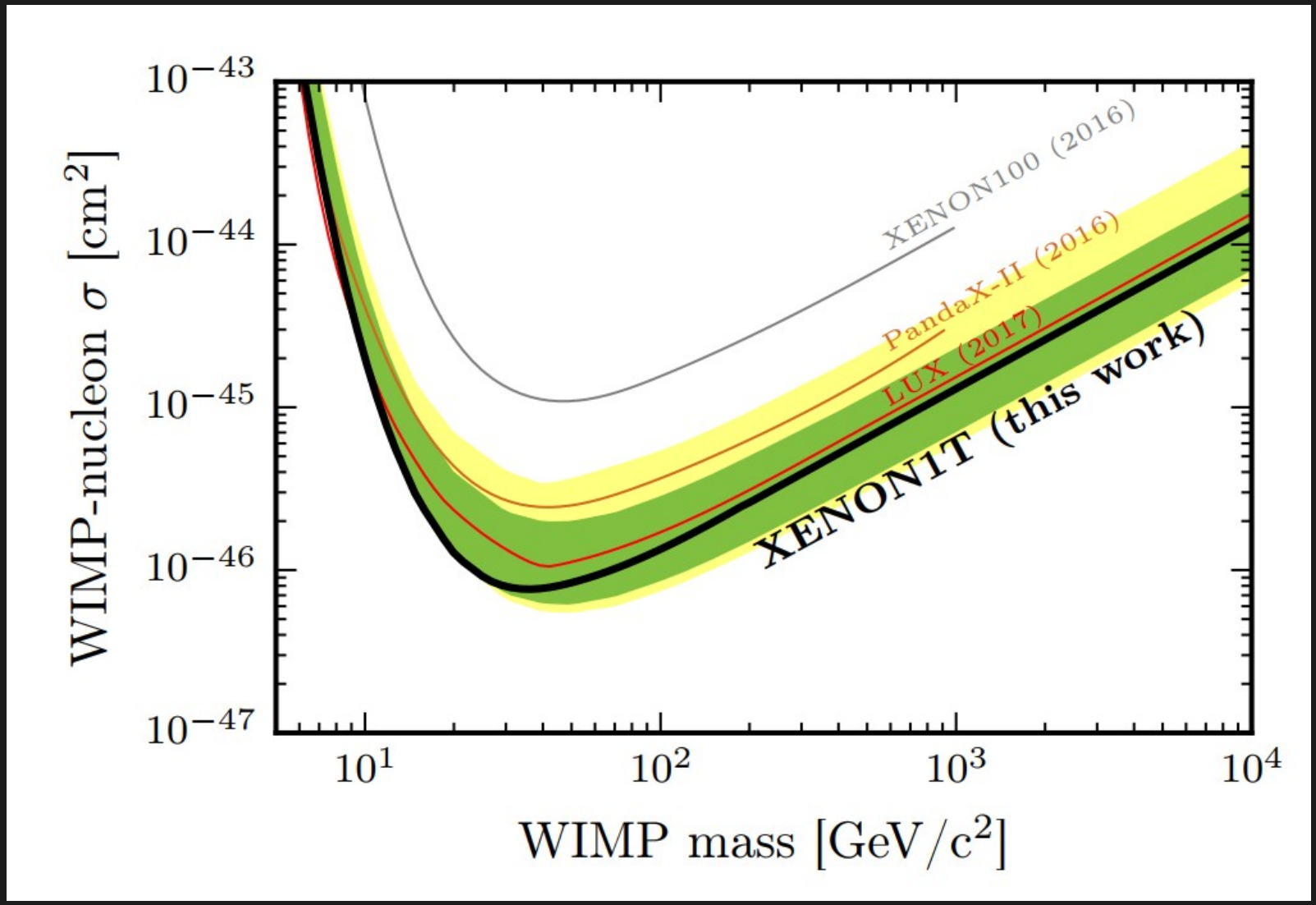
CONCLUSION

- Multiple observational **evidence** indicate the presence of new physics on different scales, which can be associated with the existence of **dark matter**.
- But we still don’t know the **nature** of DM. Direct, indirect and collider searches give **null results**.
- On the other hand, we know pretty much about what dark matter **is not**.
- We’re trying hard to reveal at least a little more **properties** of dark matter. Detailed study of **astrophysical systems** (stars, clusters, pulsars, etc.) is one of the ways to do it.

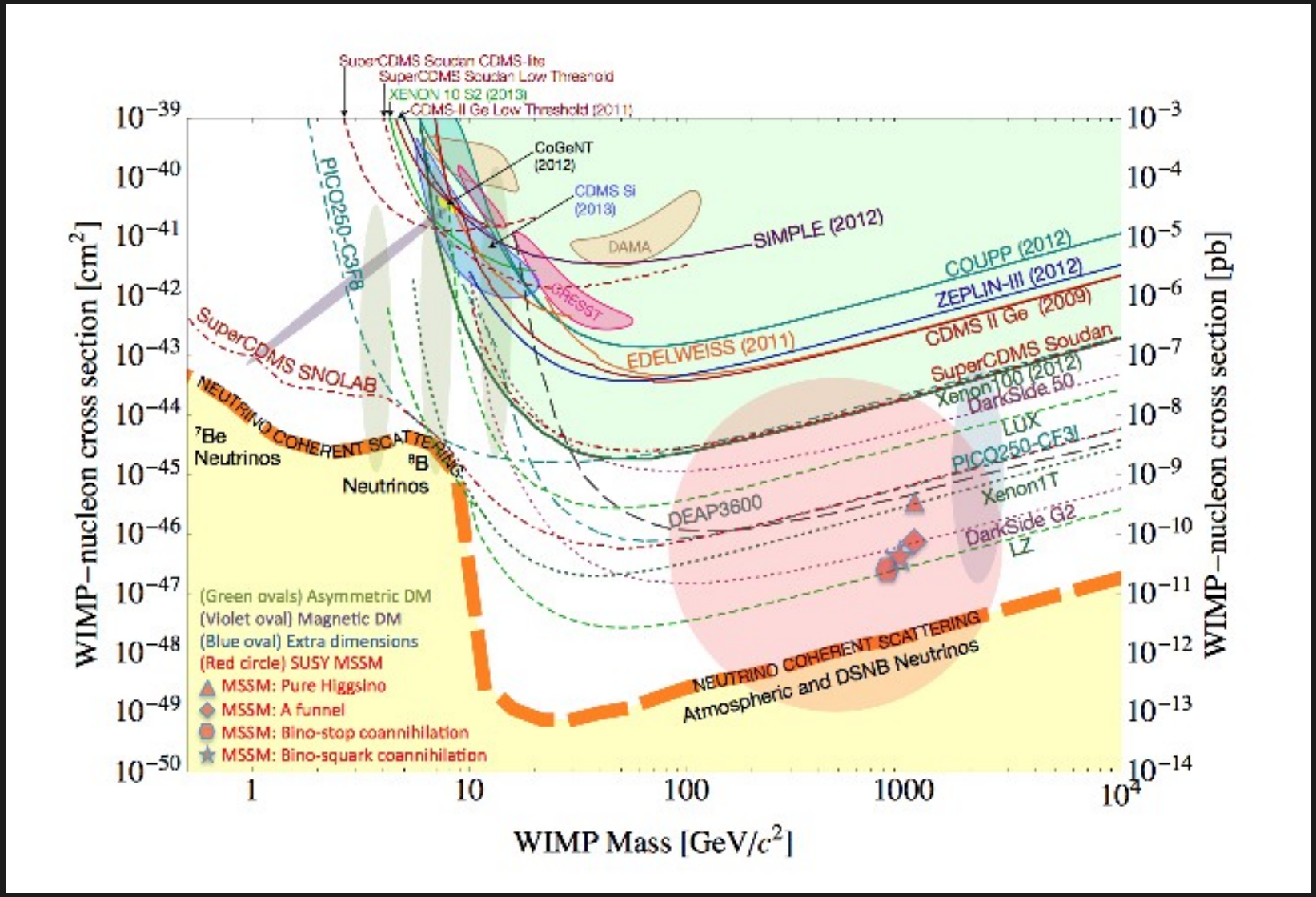
Thank you for attention!

BACKUP

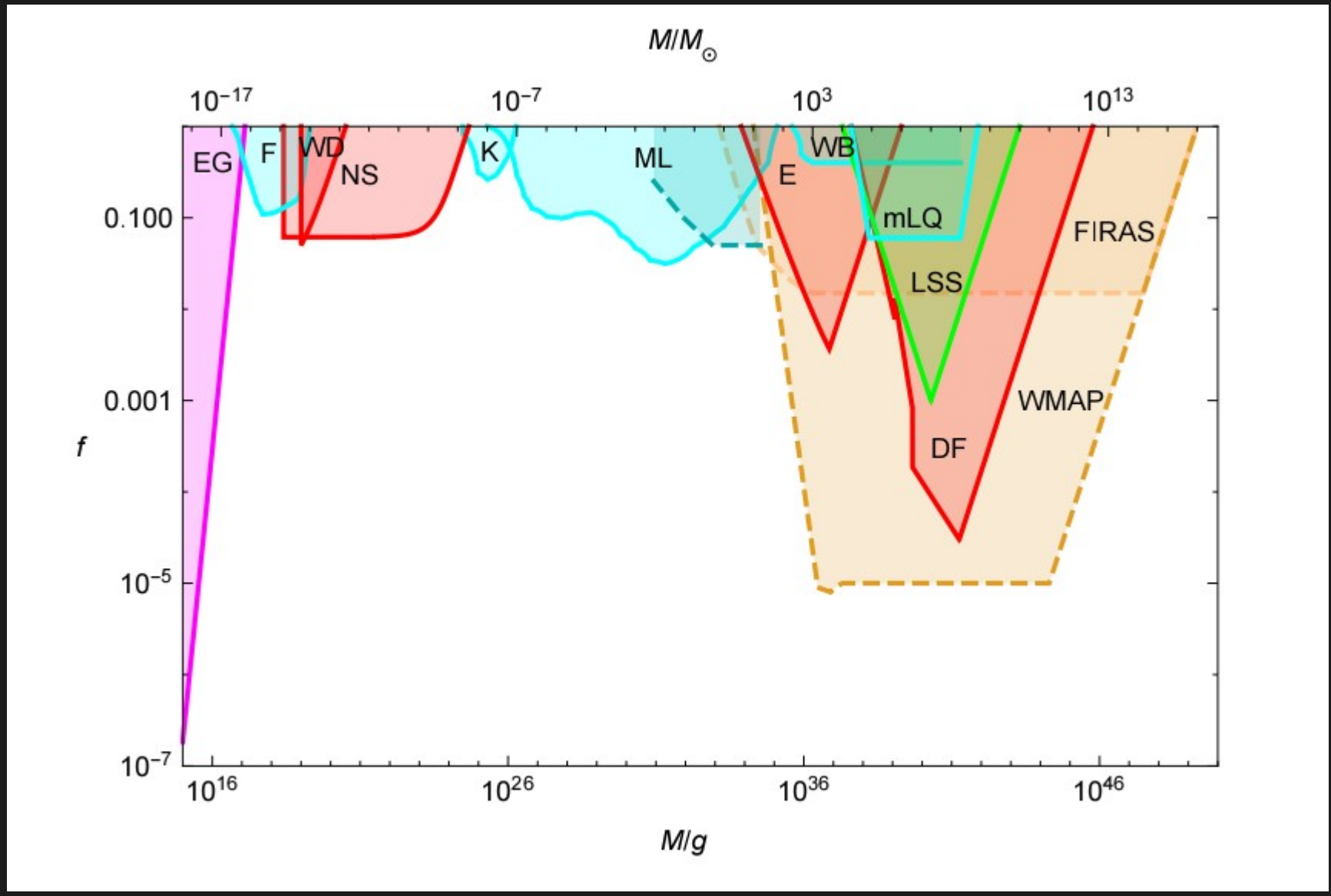
Direct detection results



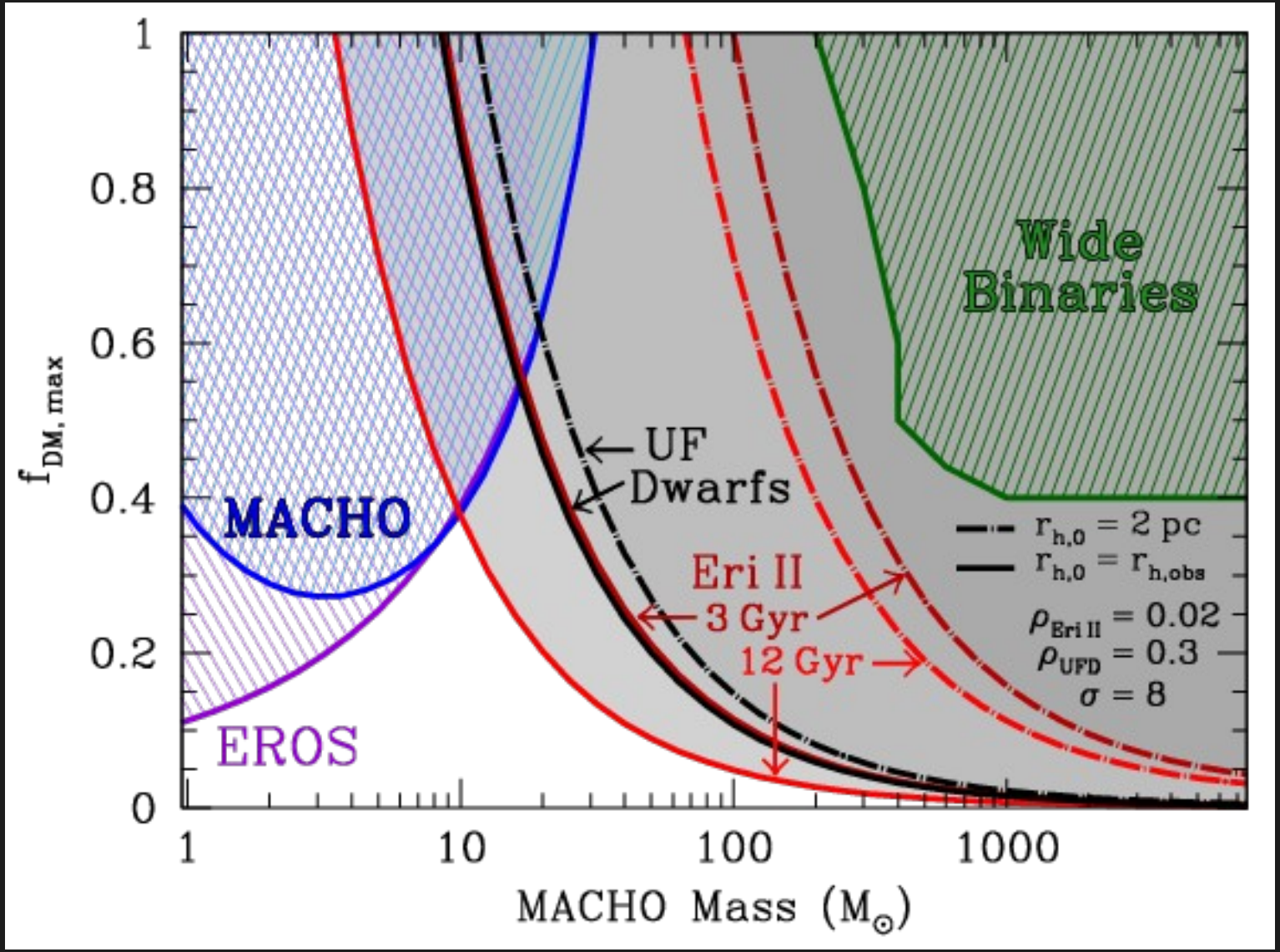
Direct detection results



Constraints on PBH



Constraints on MACHOs



Big Bang nucleosynthesis