Asymmetric dark matter and pulsar falling into black holes at the galactic center

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MICA II

Work with Tim Linden, Fatemah Elahi

DARK MATTER

- -galactic curves
- -cosmic microwave
- -bullet clusters

Rotation curves, bullet clusters, CMB

There are dark massive particles.

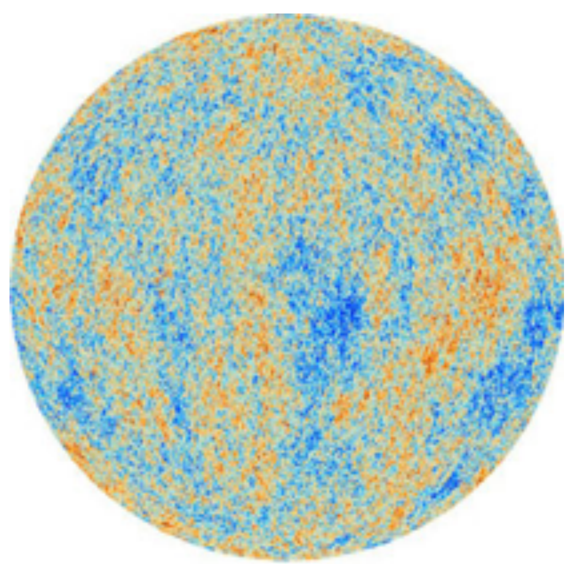
-Rotation curves show galaxies and galactic clusters missing visible mass.

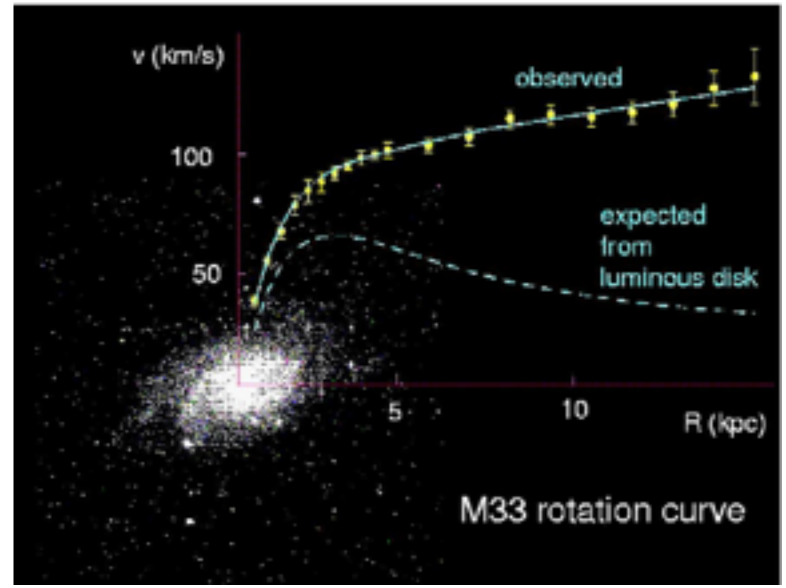
-Bullet cluster x-ray emitting gas is displaced from gravitationally lensed mass distribution.

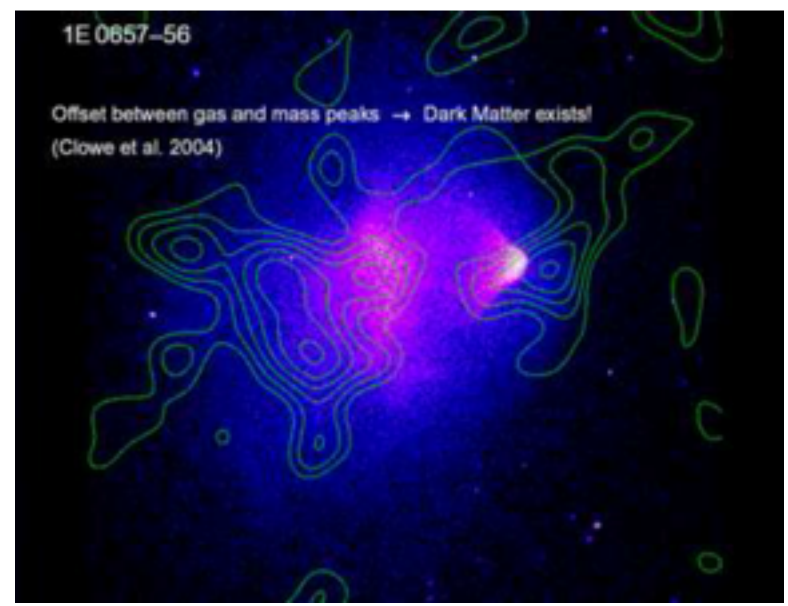
-ΛCDM fits of Planck (WMAP), large scale galaxy distribution, type 1a SN, and BAO data.

~DM is 20% mass of the universe

~5:1 ratio with visible matter



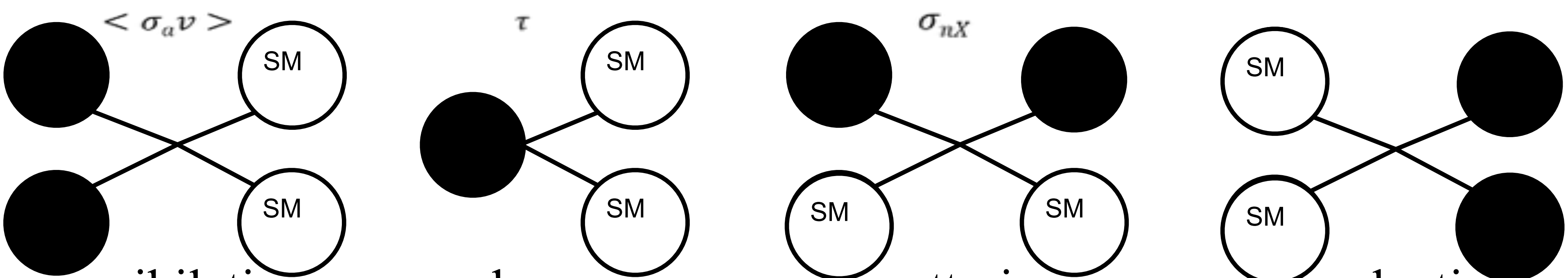




Dark matter has a gravitational interaction, the exciting question is, what other interactions might it have?

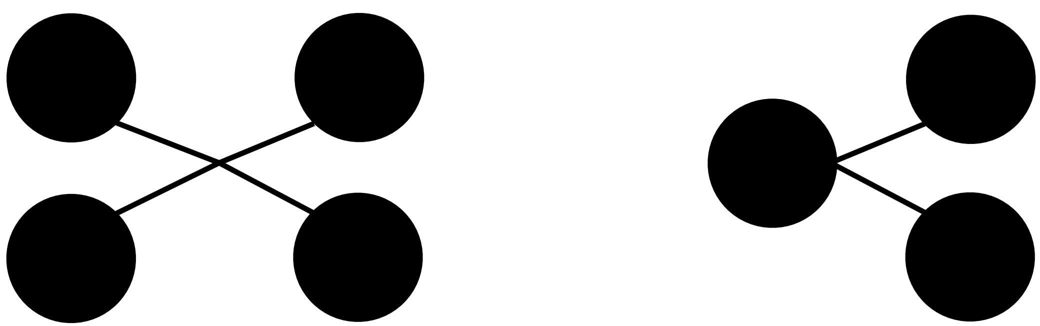
Interactions

-Signals of dark matter at satellites, space stations, colliders, vats of cold inert gas, supercooled semiconductors.



annihilation decay scattering production

-Exclusively **dark sector** interactions also have phenomenological consequences: halo structure, dwarf galaxy population, relic abundance, separation of gas and mass in bullet clusters.

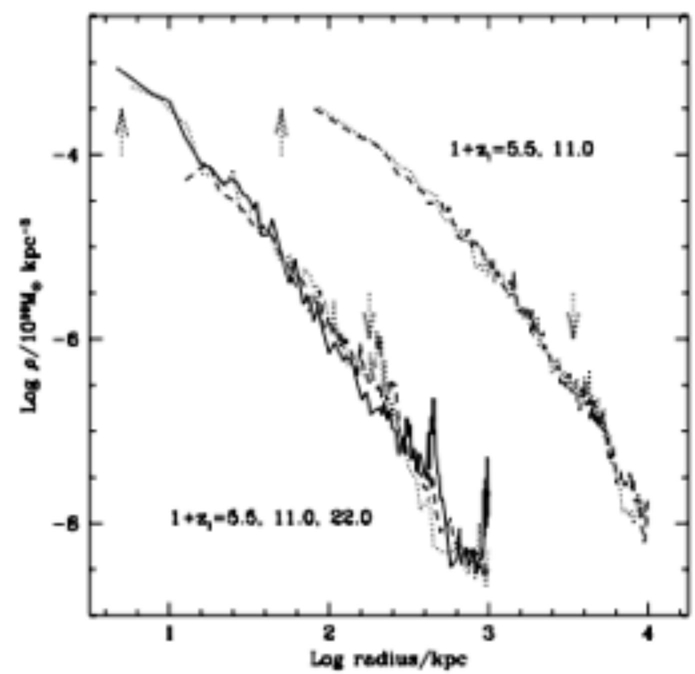


The NFW profile

-Cold collisionless dark matter has been simulated coalescing into DM halos

-The NFW profile was designed as an analytic formula matched to simulations of cold, collisionless DM forming halos

-Note especially that the density of the simulated galaxy halos rises sharply at small radius, (10^{11} and 10^{15} solar mass halos displayed, respectively)



astro-ph/9508025

7 dwarves with mined out DM halos

-7 dwarf galaxies measured by THINGS do not show a cold, collisionless NFW profile which would **cusp** at center (vs. **cored shape**)

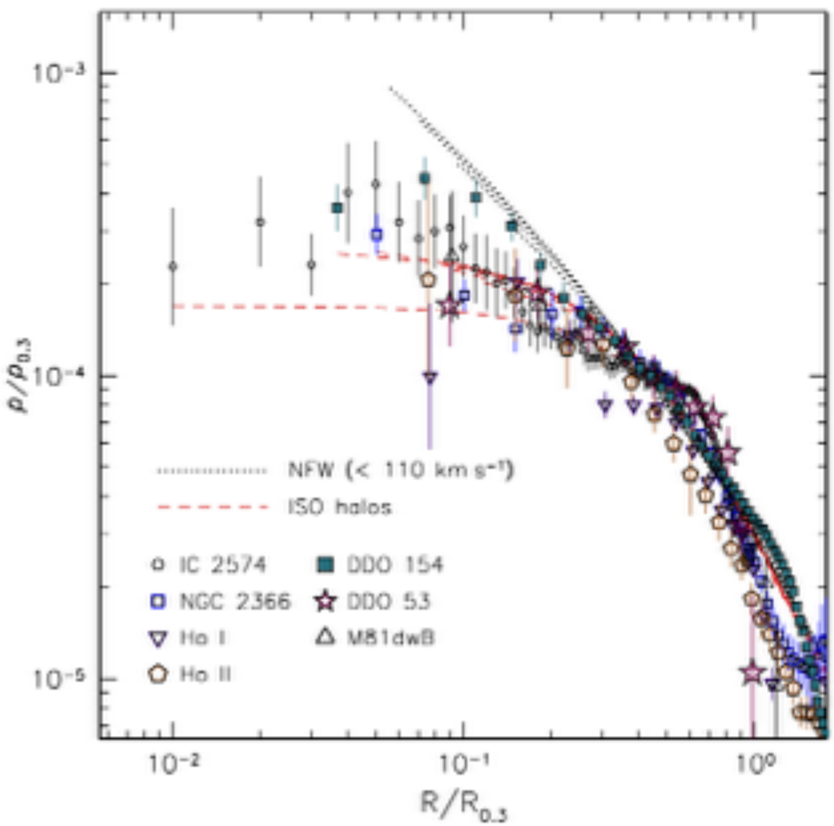
-Caveat: Baryonic outflow via SN

-Counter: less luminous galaxies should not experience outflow, still seem to be cored

-Also, many simulations suggest that we should have ~50 subhalos in the MW, we see only 12

-Caveat: Different models of star formation, subhalos too dim.

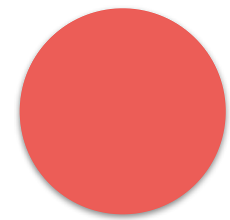
-Counter: Too big to fail to form star subhalos not seen.



(1011.0899)

A neutron star is a ball of fermions formed from the supernova of a 10 solar mass progenitor star.

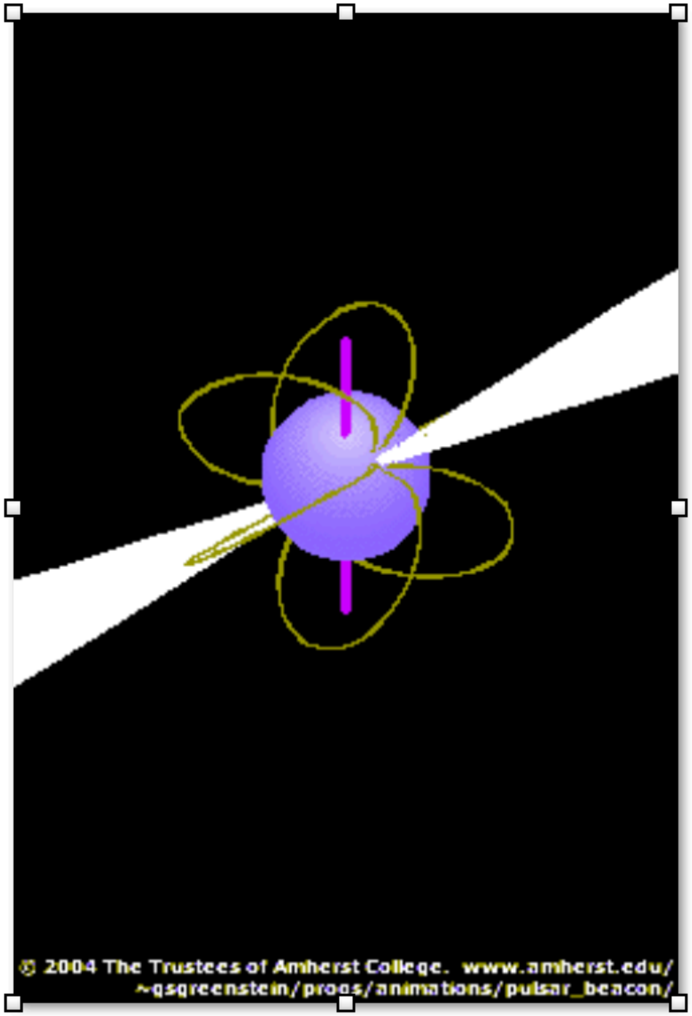
$$N_f = \frac{m_{pl}^3}{m_X^3}$$



The bound above can be compared to the same limit on a ball of bosons.

$$N_b = \frac{m_{pl}^2}{m_X^2}$$

A pulsar is a spinning neutron star, observed as a regularly radiating revolving magnetic dipole.



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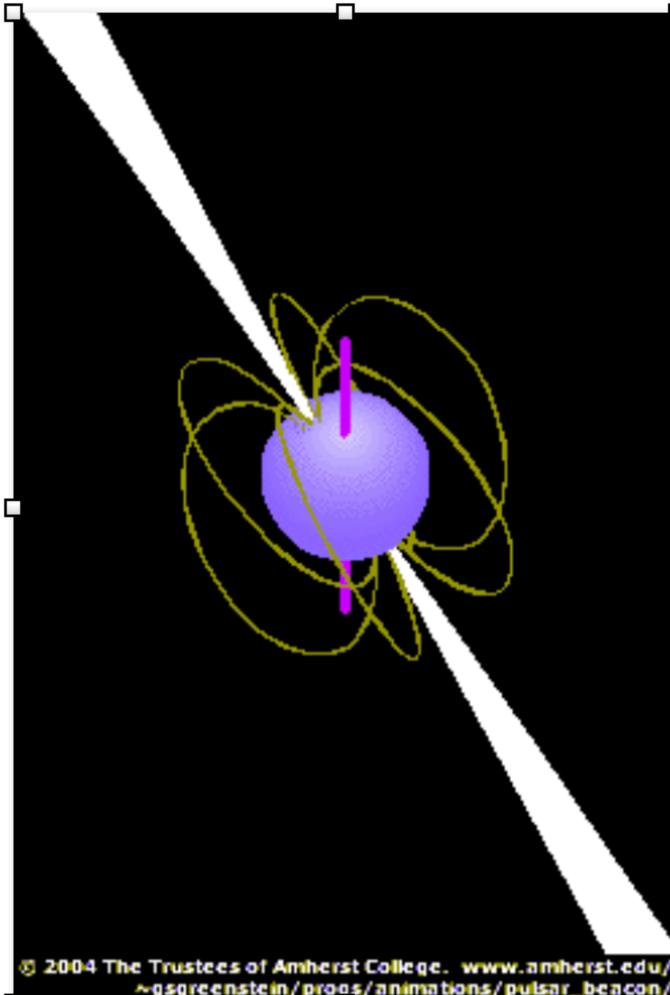

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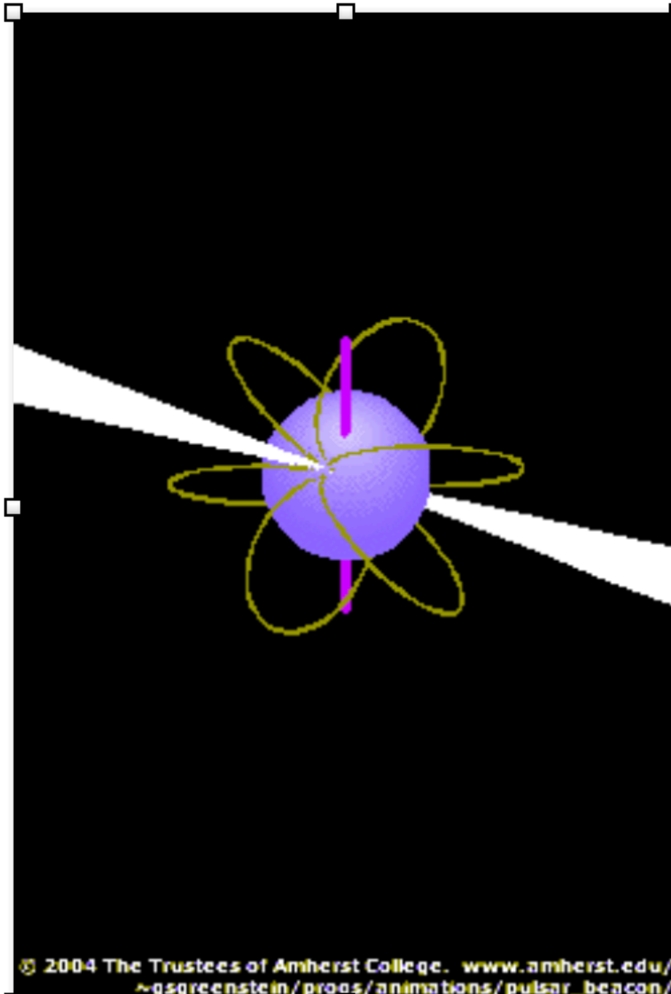

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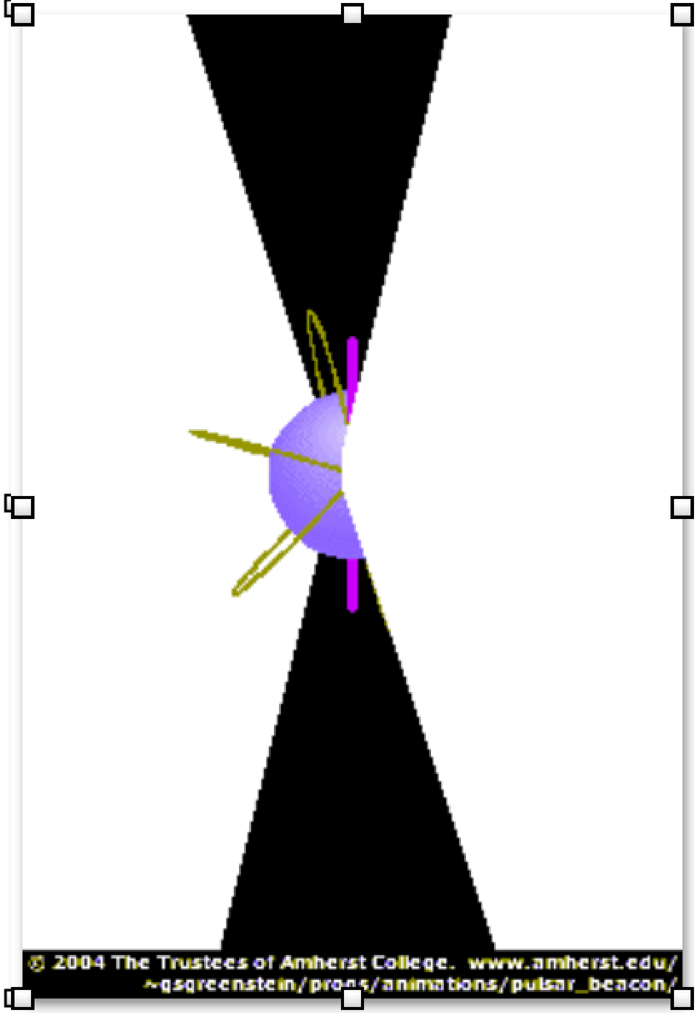
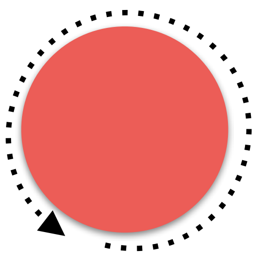
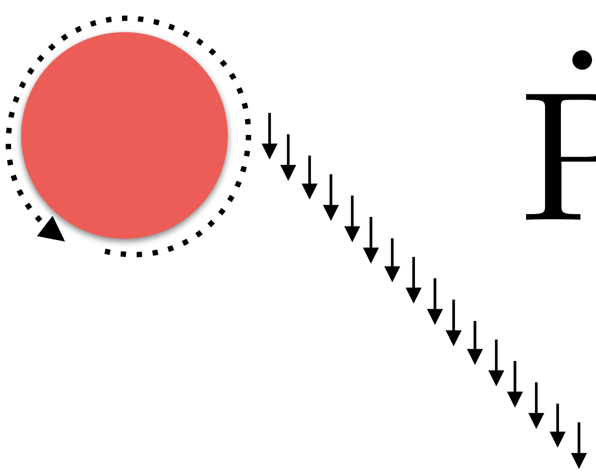


A pulsar is a spinning neutron star, observed as a regularly radiating revolving magnetic dipole.

How old is it?



P



$\dot{P}$

A pulsar is a spinning neutron star, observed as a regularly radiating revolving magnetic dipole.

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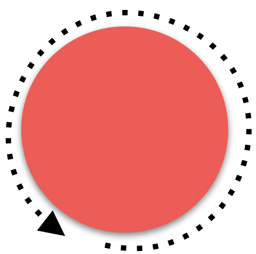
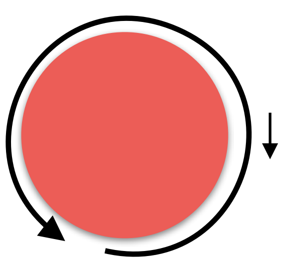
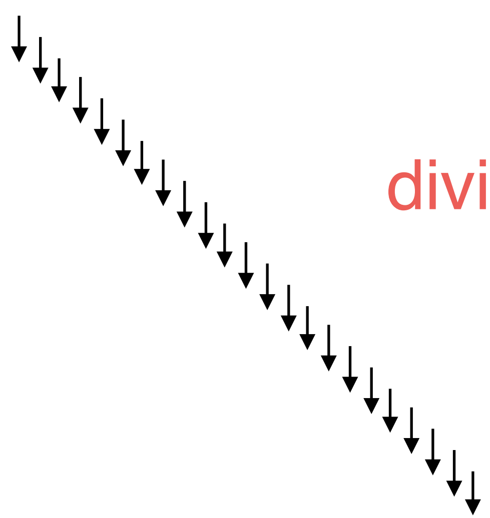


$$\mathrm{P}$$

$$t_{NS} = \frac{\mathrm{P}}{2\dot{\mathrm{P}}}$$



$$\dot{\mathrm{P}}$$



divided by

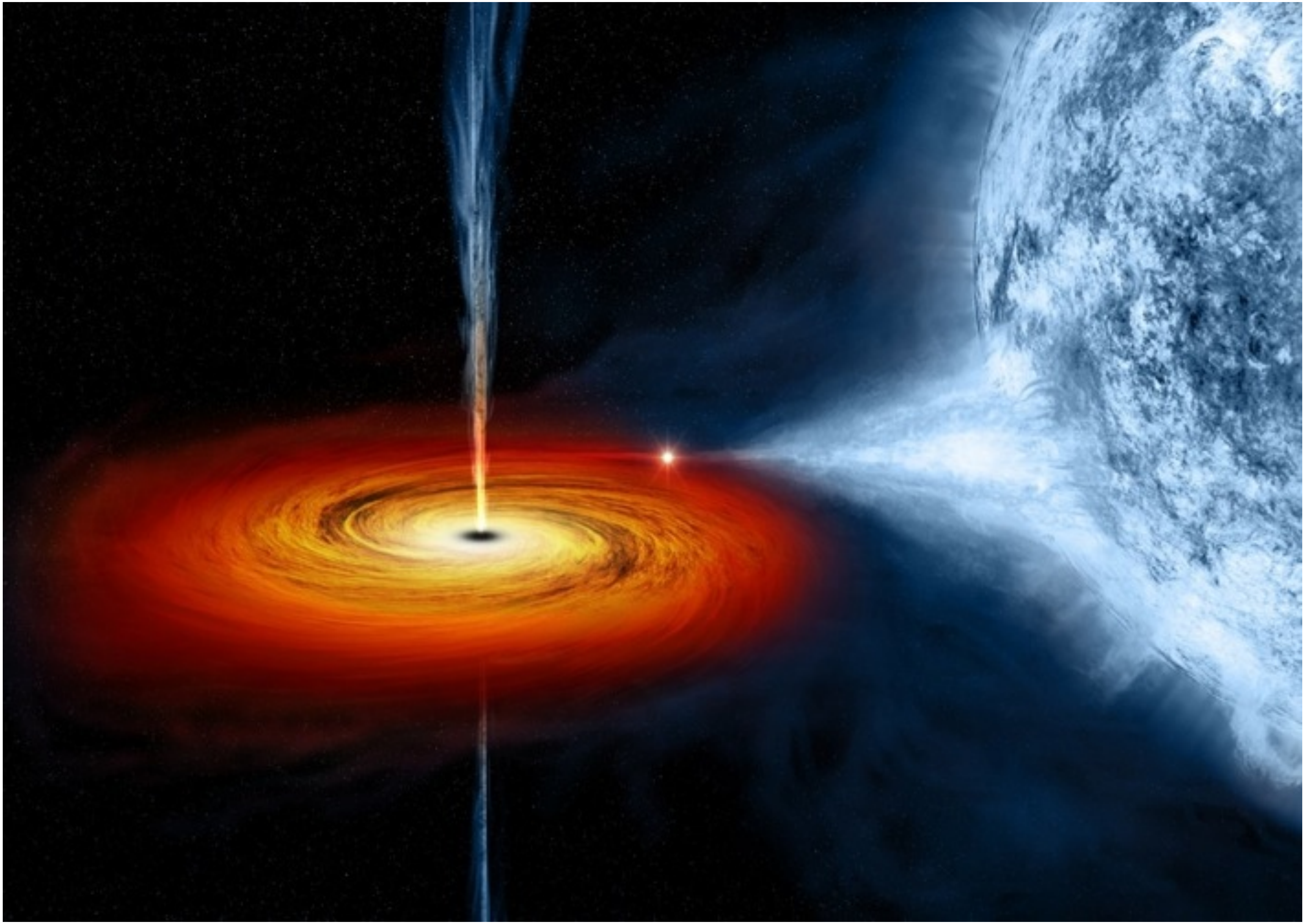
The missing pulsar problem

Prior to the detection of a very luminous magnetar one tenth of a parsec away from the ($10^8 \odot$ mass) black hole at the galactic center, it was assumed that pulsars had not been detected there, because a charged screen of material at the galactic center was broadening pulse signals. Pulsars are expected because of a large population of high mass progenitor stars and X-ray binary systems.

The missing pulsar problem

However, measurements of radio pulses from the newly discovered galactic center magnetar indicate a much cleaner path for radio pulses than was supposed. In addition, measurements of the radio pulses' angular broadening match those of SgA*. This is evidence that the scattering screen is homogeneous.

(Older) millisecond pulsars form from x-ray binaries



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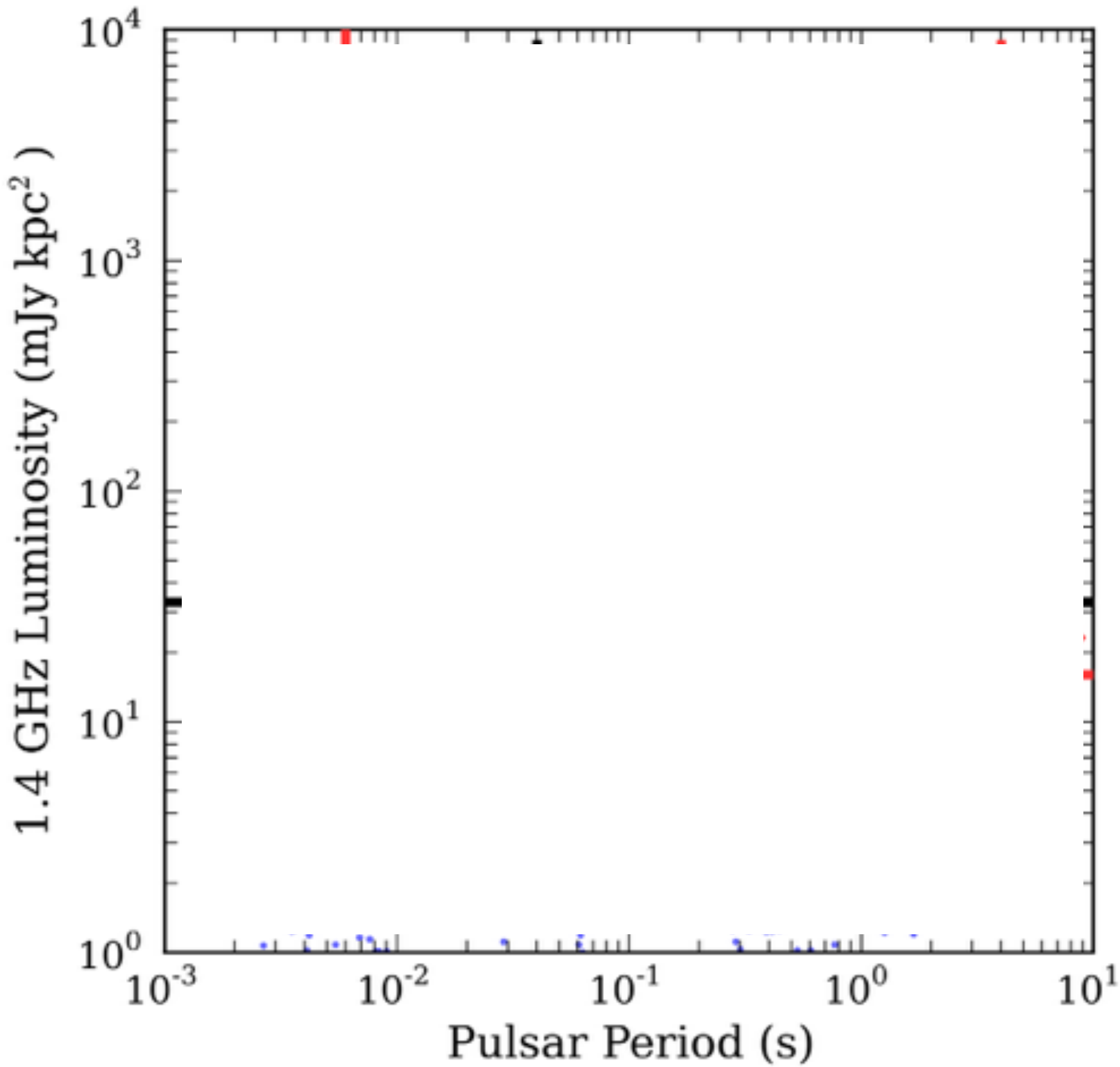
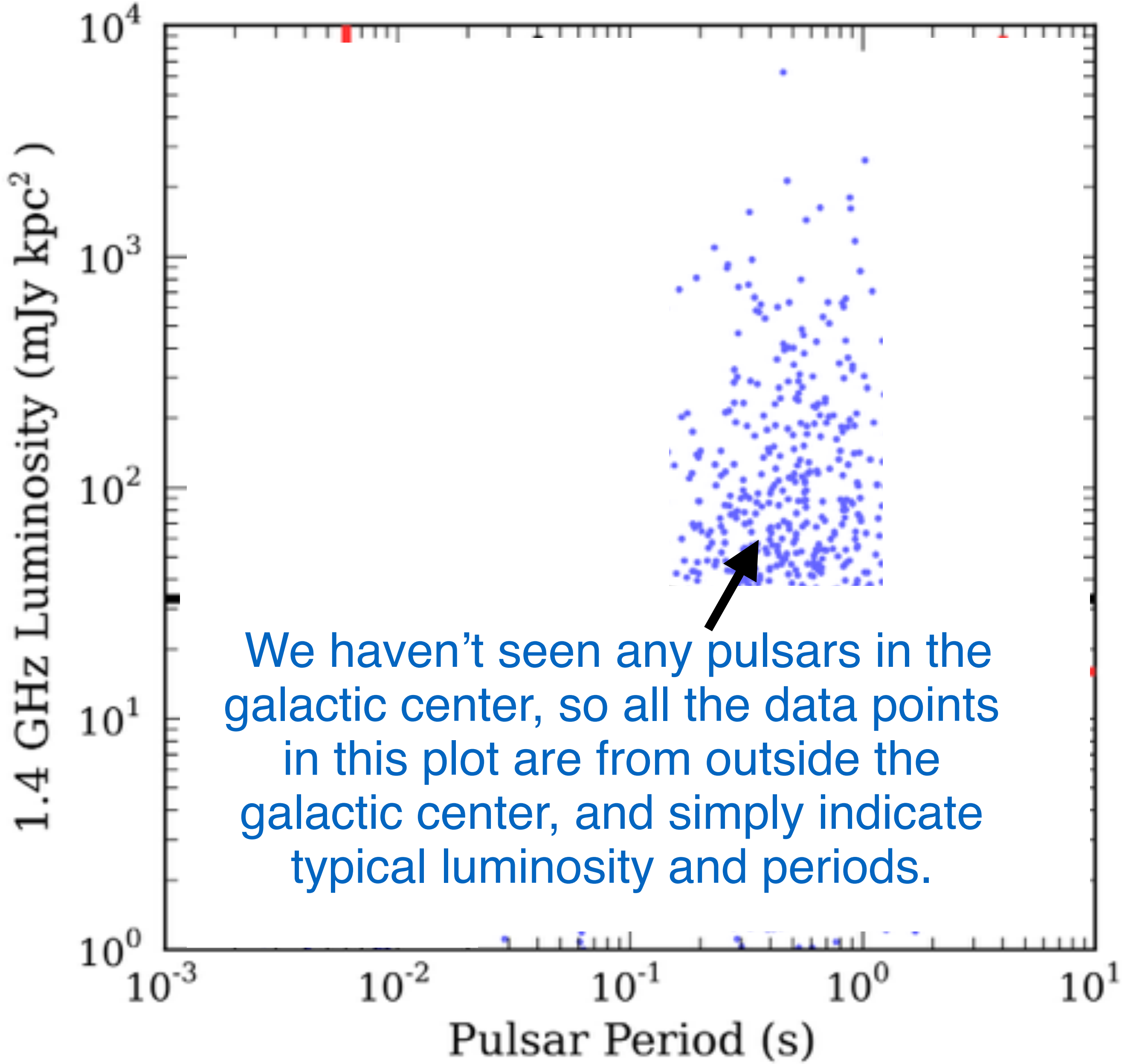
This creates two missing pulsar problems. Both young and old millisecond pulsars seem to be absent. There are 50-500 missing millisecond pulsars.

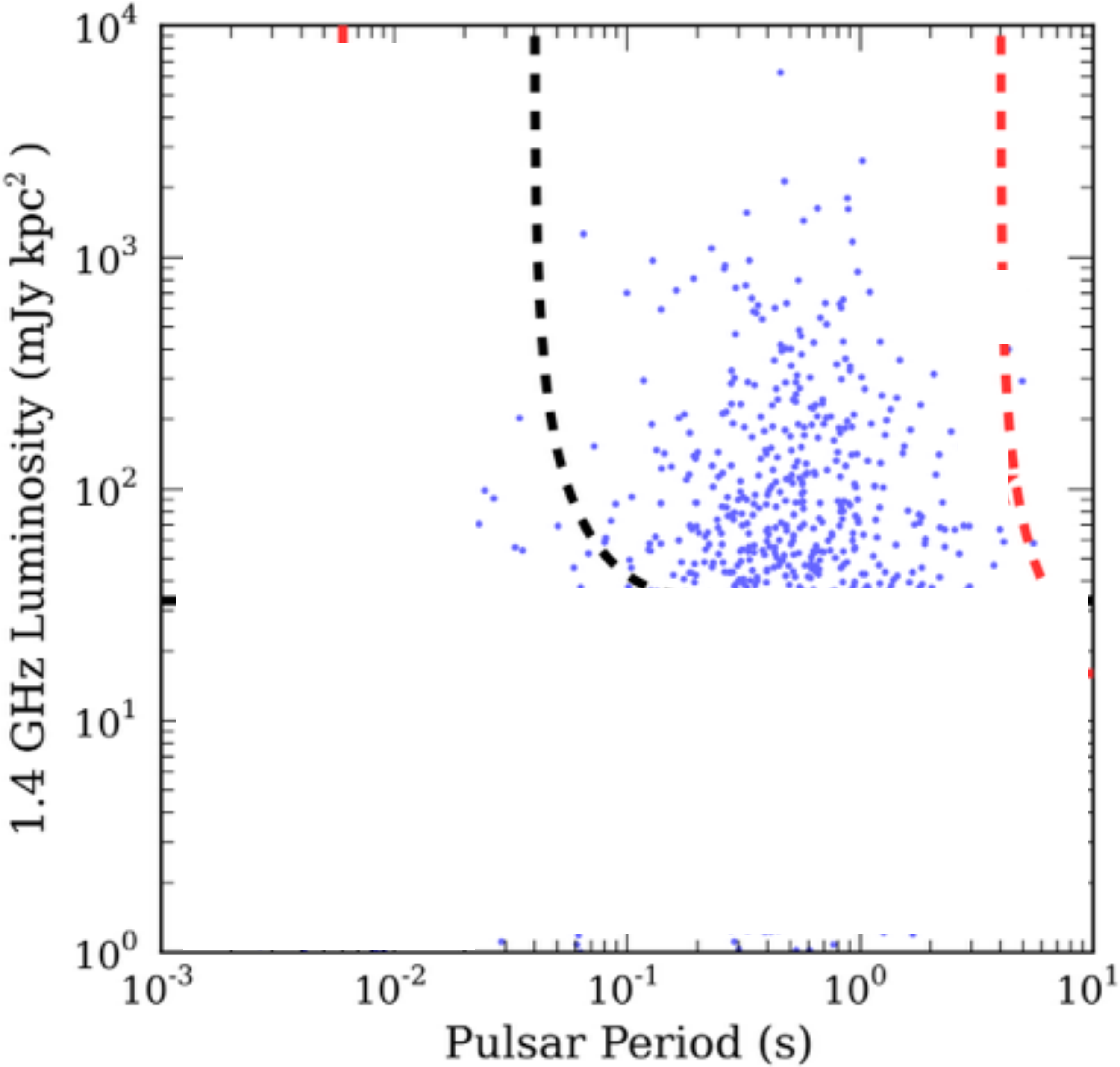
The missing pulsar problem



Dexter, O’Leary
1310.7022

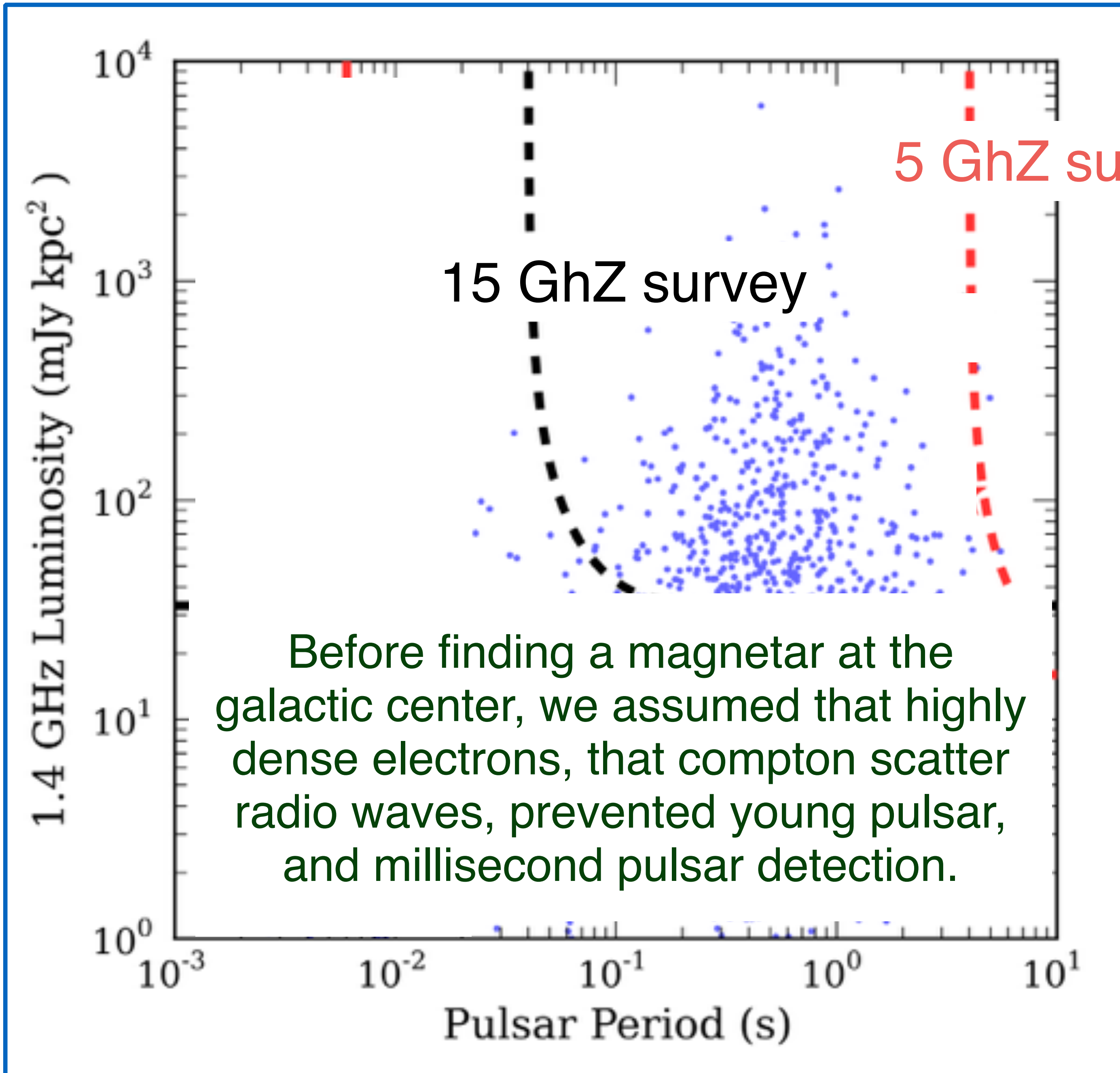


1.4 GHz Luminosity (mJy kpc^2)
Pulsar Period (s)
We haven't seen any pulsars in the galactic center, so all the data points in this plot are from outside the galactic center, and simply indicate typical luminosity and periods.

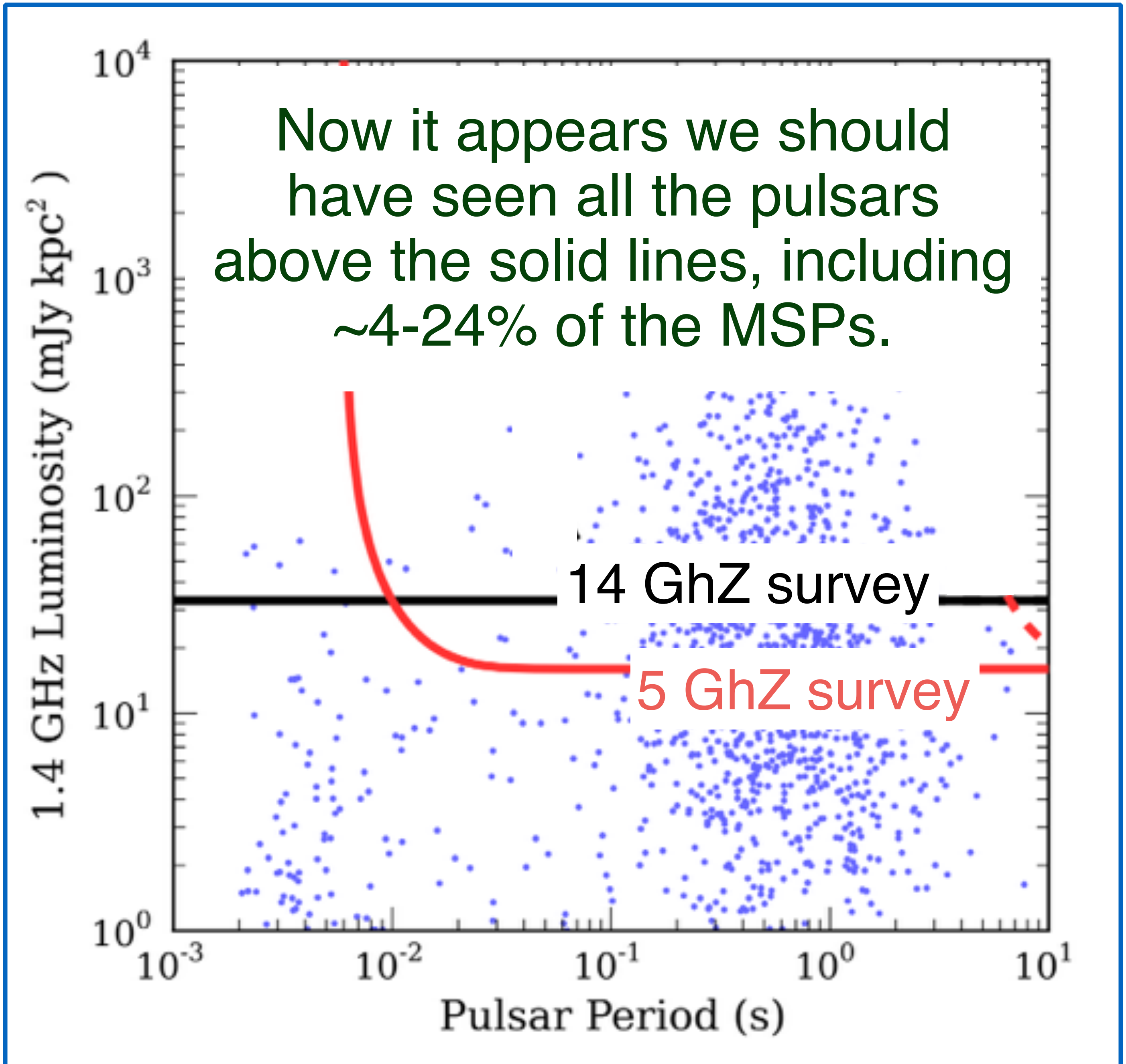


10^4
10^3
10^2
10^1
10^0
1.4 GHz Luminosity (mJy kpc^2)
10^{-3}
10^{-2}
10^{-1}
10^0
10^1
Pulsar Period (s)

Survey sensitivity before magnetar

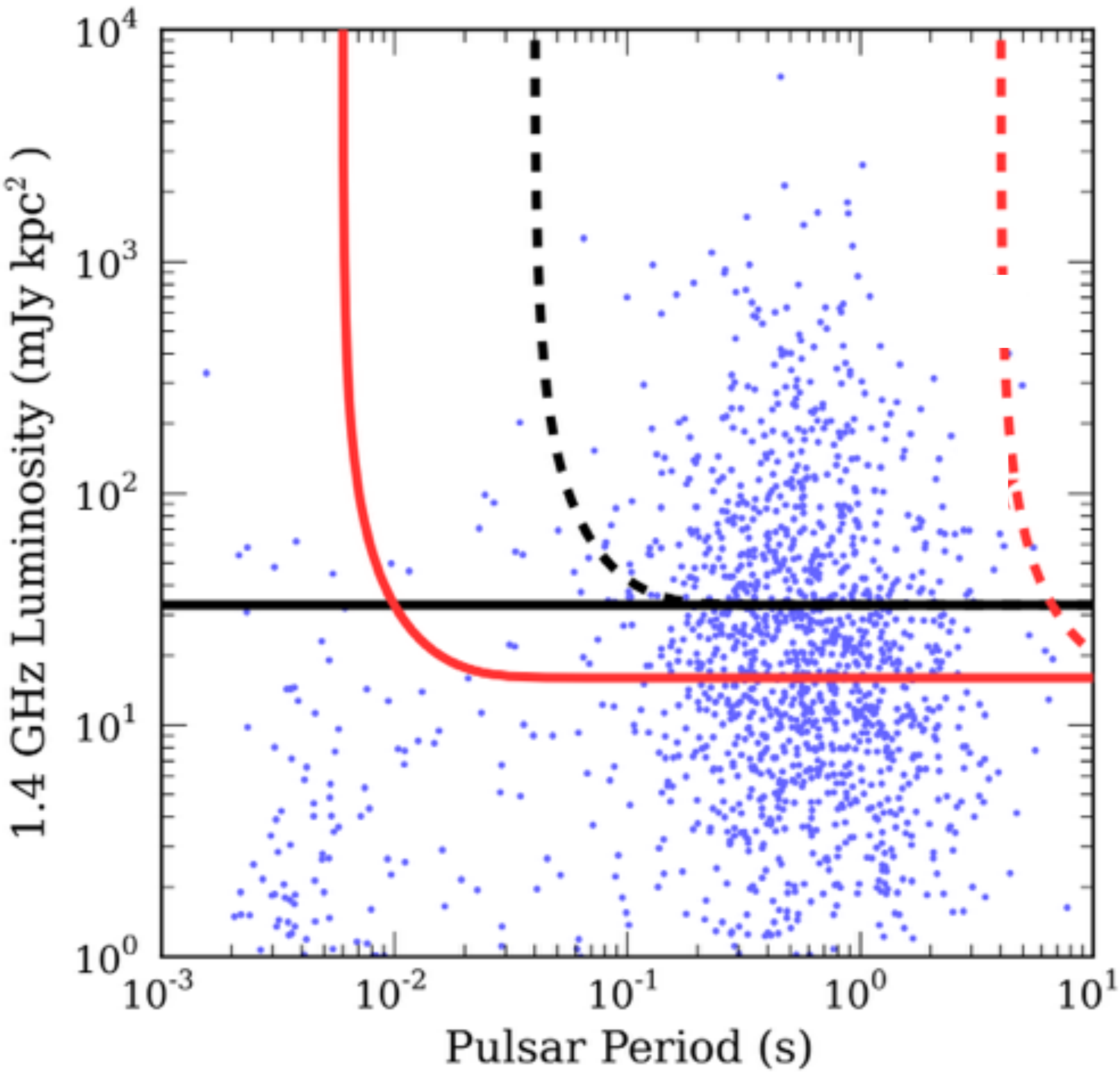


Before finding a magnetar at the galactic center, we assumed that highly dense electrons, that compton scatter radio waves, prevented young pulsar, and millisecond pulsar detection.



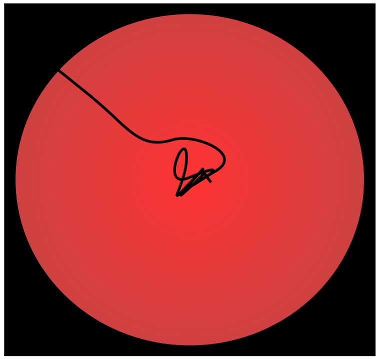
Now it appears we should have seen all the pulsars above the solid lines, including ~4-24% of the MSPs.
14 GhZ survey
5 GhZ survey
1.4 GHz Luminosity (mJy kpc^2)
Pulsar Period (s)
10^{4}
10^{3}
10^{2}
10^{1}
10^{0}
10^{-3}
10^{-2}
10^{-1}
10^{0}
10^{1}

So where are the galactic center pulsars?

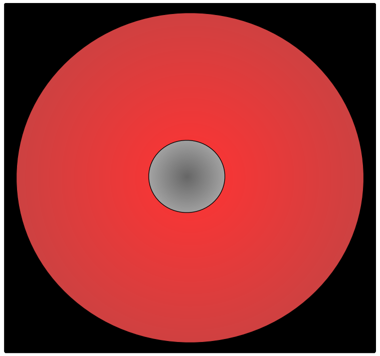


Dexter, O'Leary
1310.7022

1] DM captured

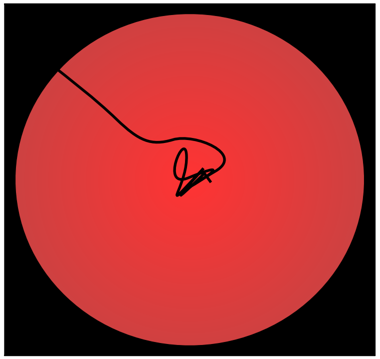


2] DM thermalizes



Asymmetric dark matter models suppose that dark matter in the halo, like ordinary matter in the halo, is composed of particles and not antiparticles charged under a continuous symmetry. This asymmetric abundance precludes X-X (as opposed to X*-X) annihilations.

1] DM captured



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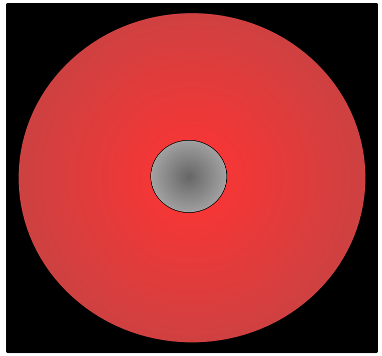
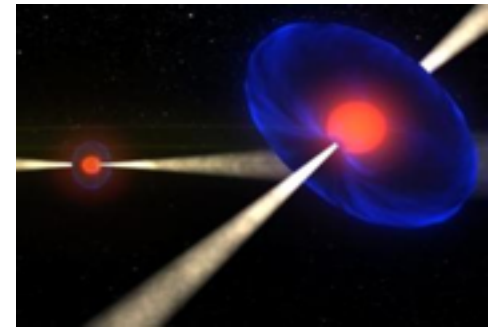
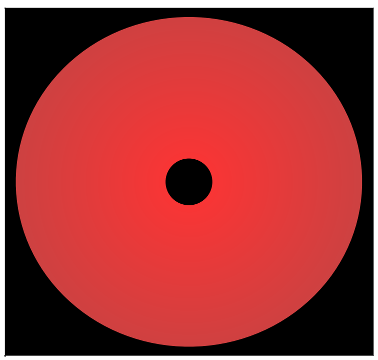


if it shrinks, (Hawking)

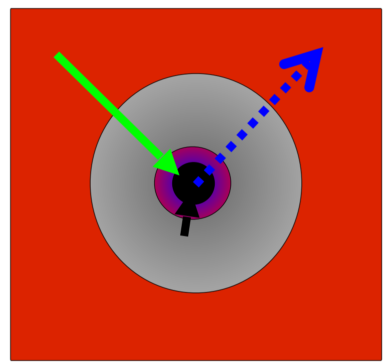


no bound

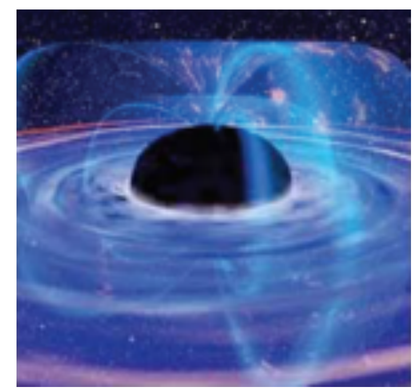
3] DM **collapses**



4] BH accretes, radiates

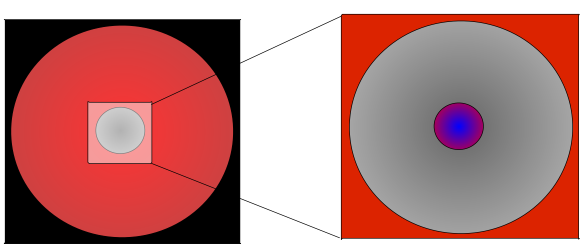


if it grows rapidly, then



bound

(Bosonic DM forms a BEC first



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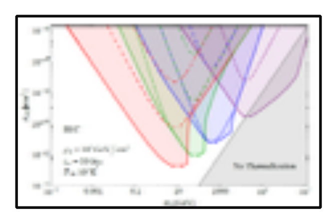
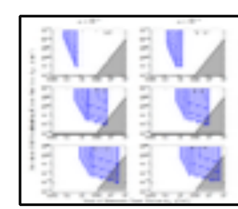


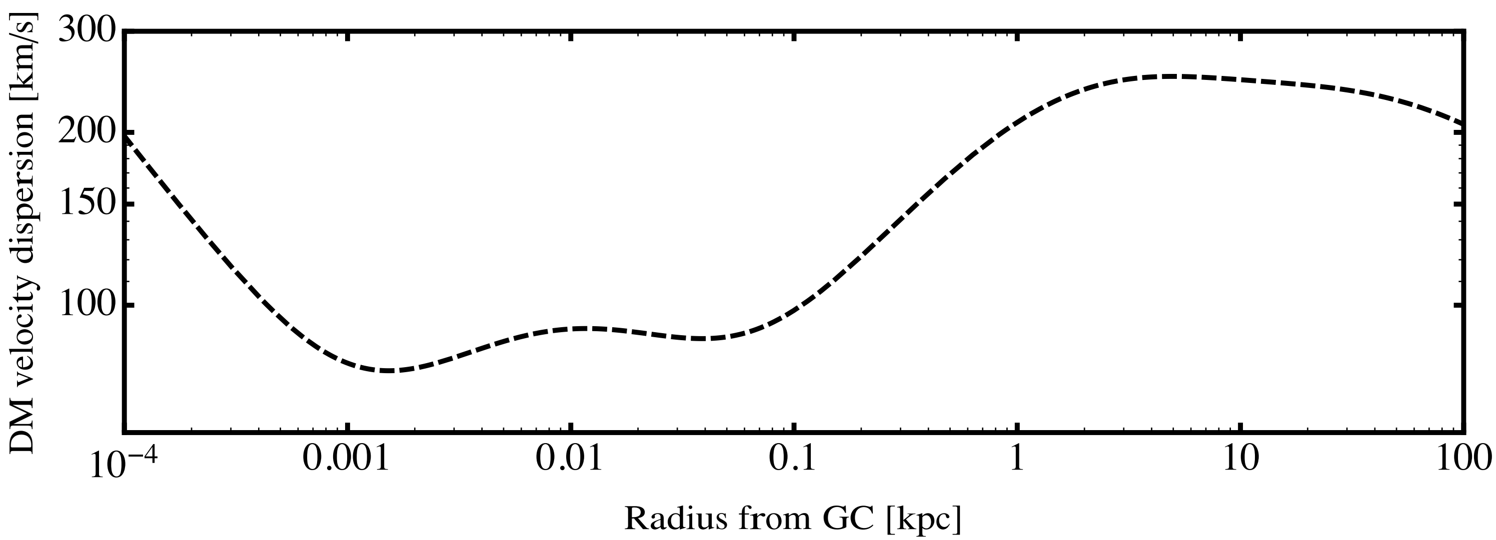


Asymmetric Dark Matter Imploding Pulsars

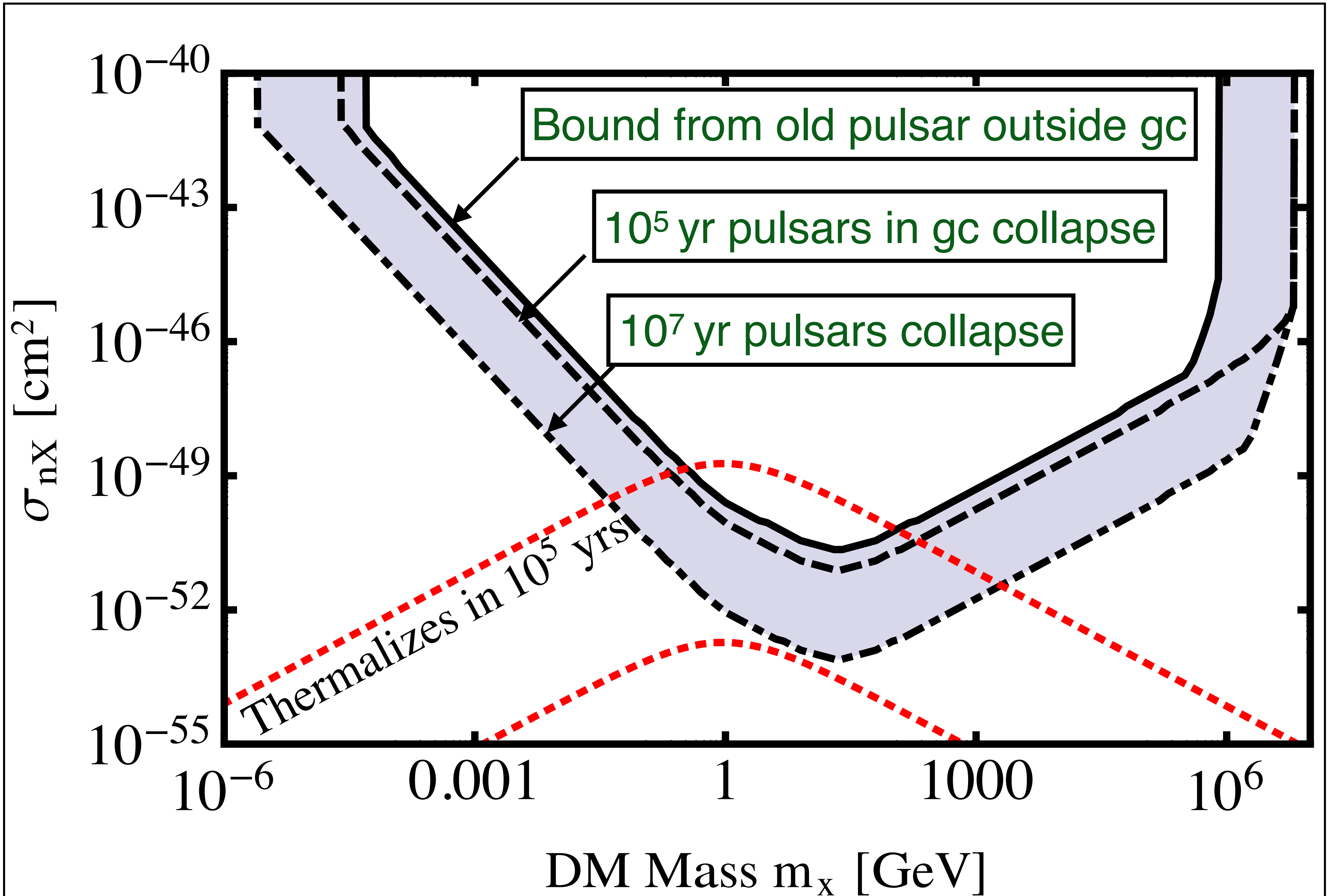
The capture rate for dark matter on pulsars scales inversely with velocity dispersion and linearly with the local dark matter density.

$$C_X \propto \frac{\rho_X}{\bar{v}} \sigma_{nX}$$

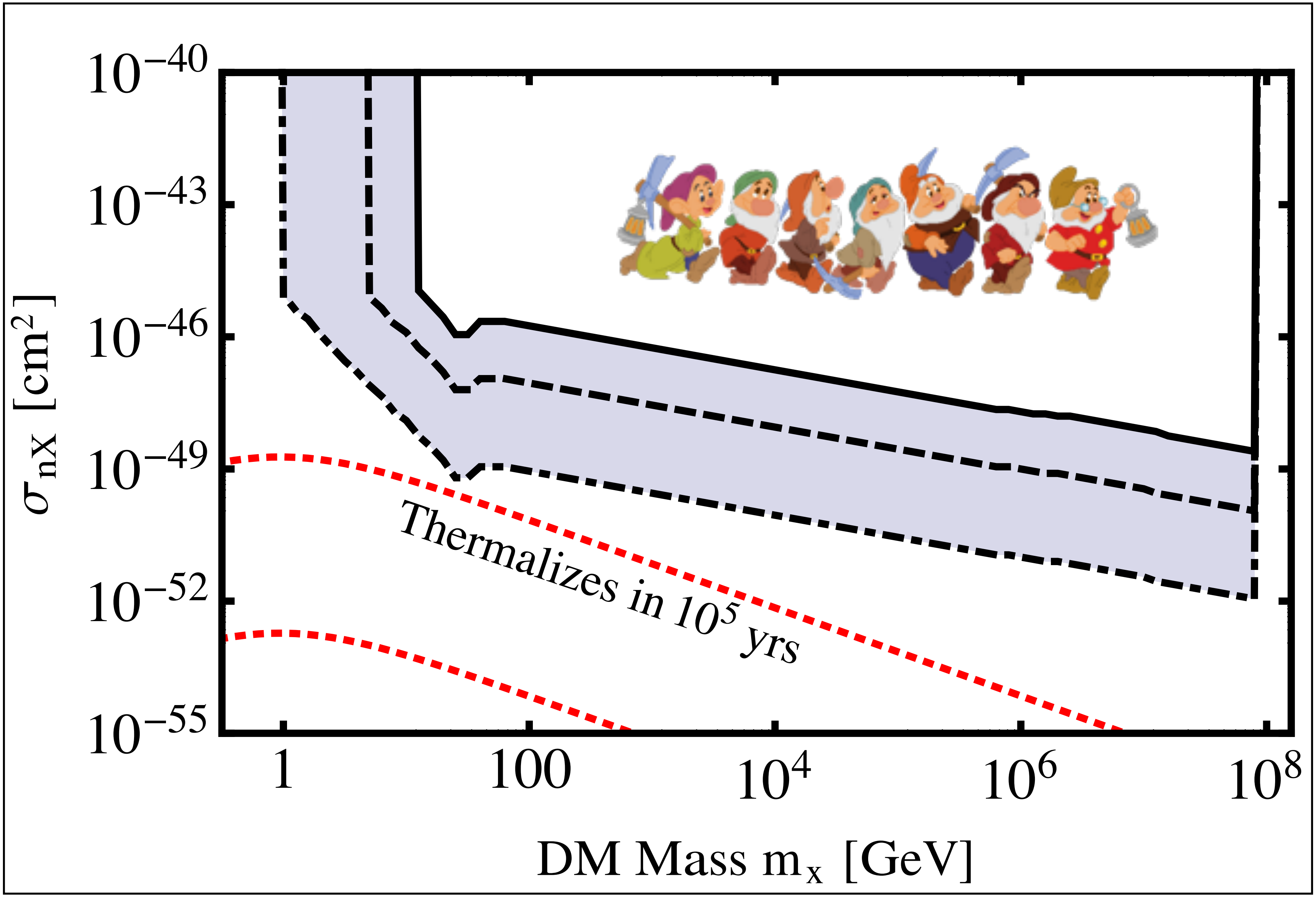
Model our galaxy's dark matter profile using disc and galactic center star velocity measurements (NFW).



Bosons Imploding Pulsars

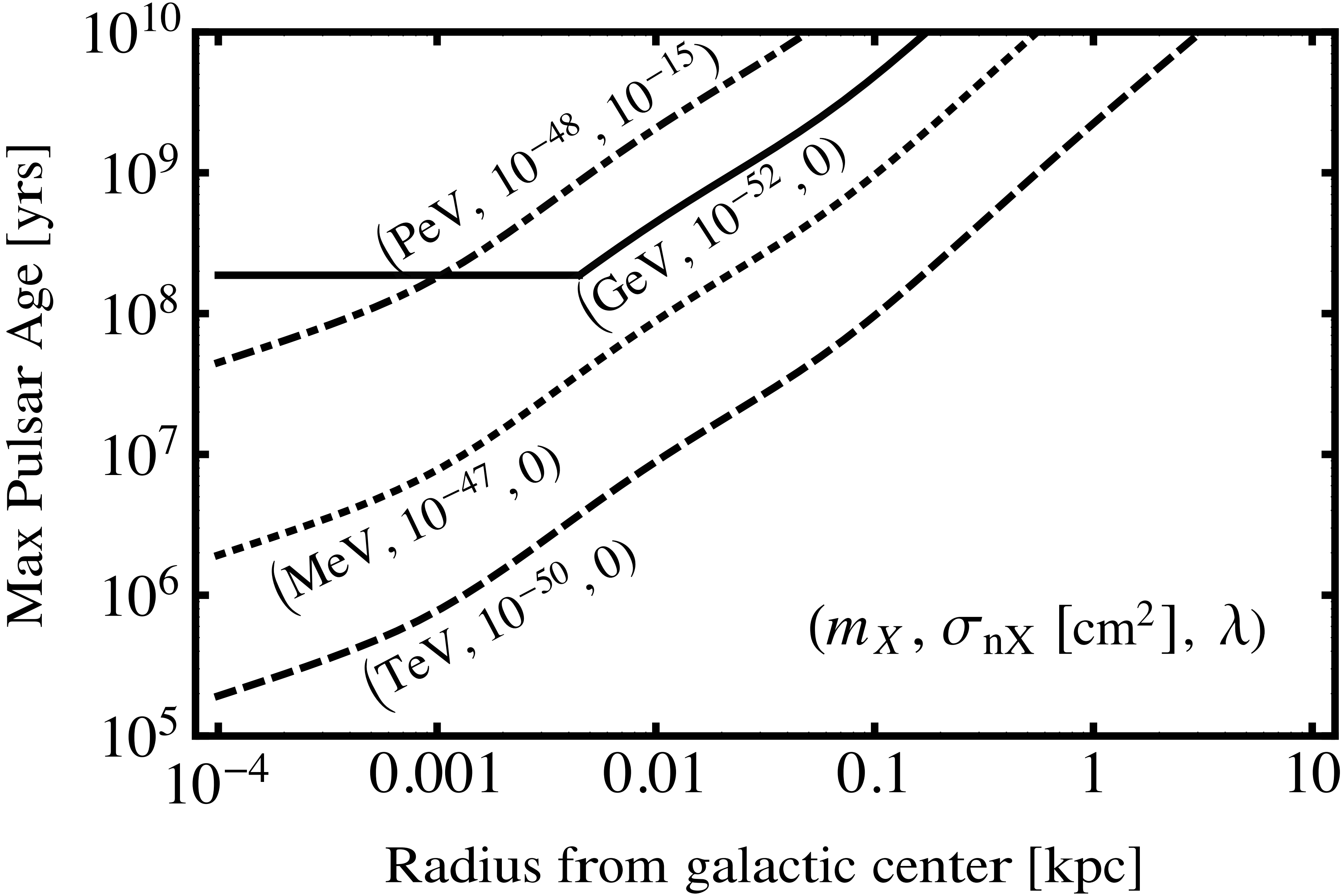


Fermions Imploding Pulsars

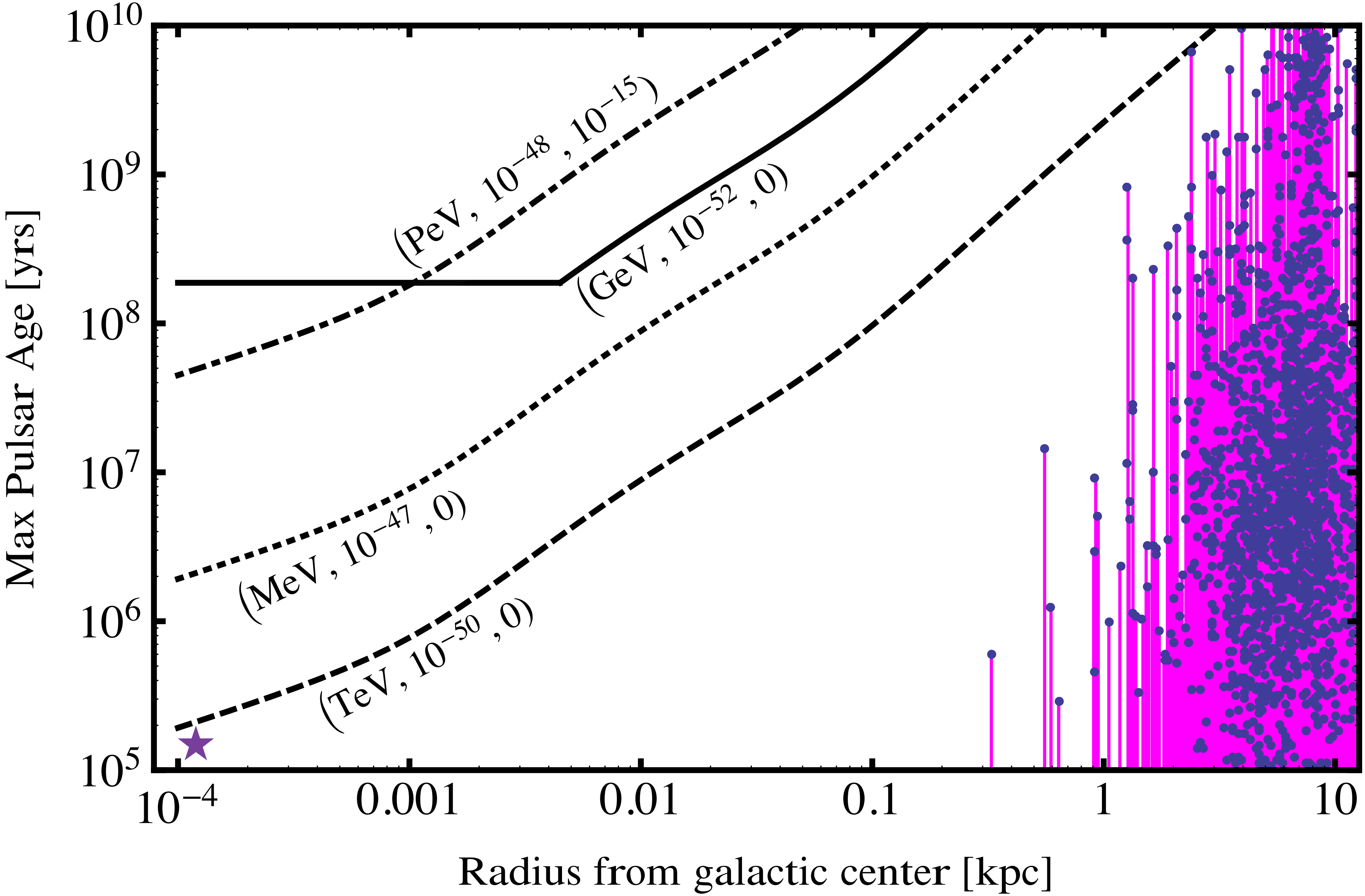


$m_\phi = 10$ MeV, $\alpha = 0.1$

Prediction of Pulsar Age Curves



Prediction of Pulsar Age Curves



Conclusions

There is an exciting method to distinguish asymmetric from majorana or mixed dark matter. Pulsar age distributions could also be applied to bounds on and searches for multicomponent dark matter.