Axions in the galactic centre

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DARK MATTER

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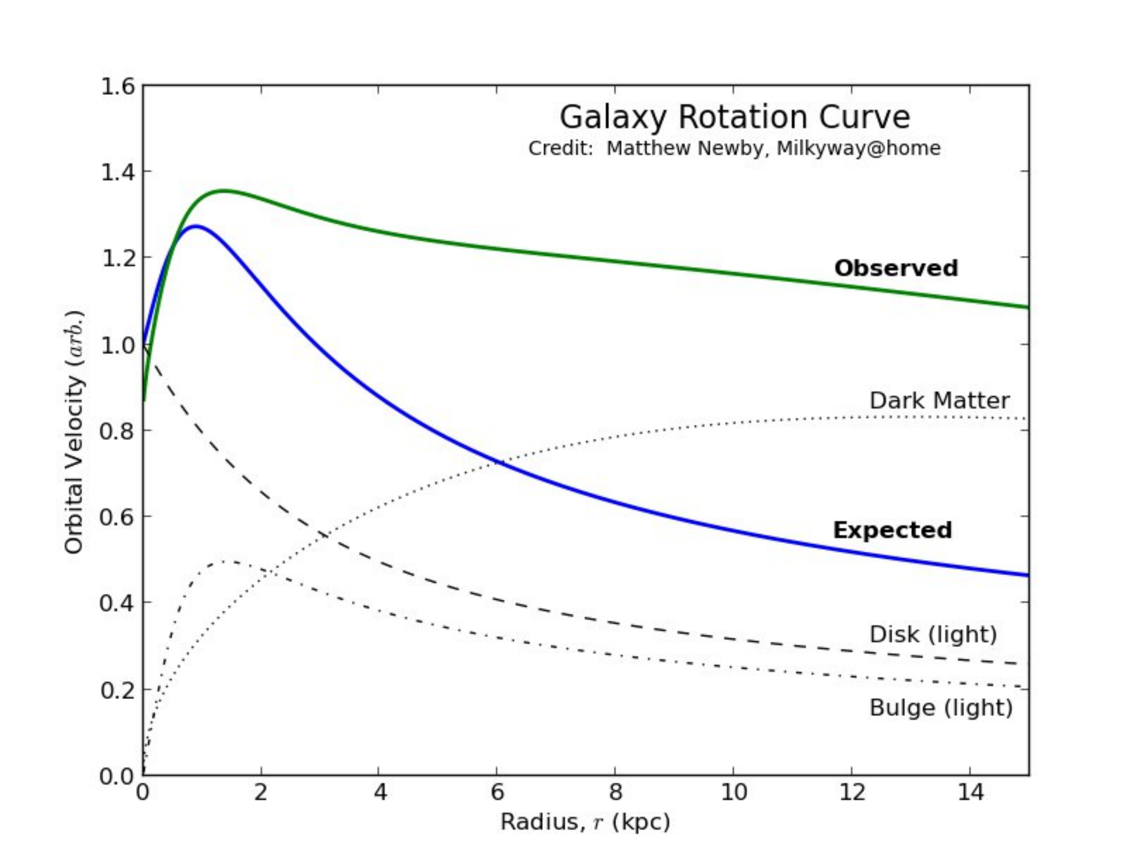
Talk outline

- Why dark matter matters
- What the @#$! is an axion?
- Stimulated emission
- Dark matter around black holes
- Why we need VLBI
- Conclusion

Why believe in dark matter?

Stars in galaxies move too fast to be gravitationally bound by the visible matter!



Why believe in dark matter?

Dark matter explains the CMB power spectrum!

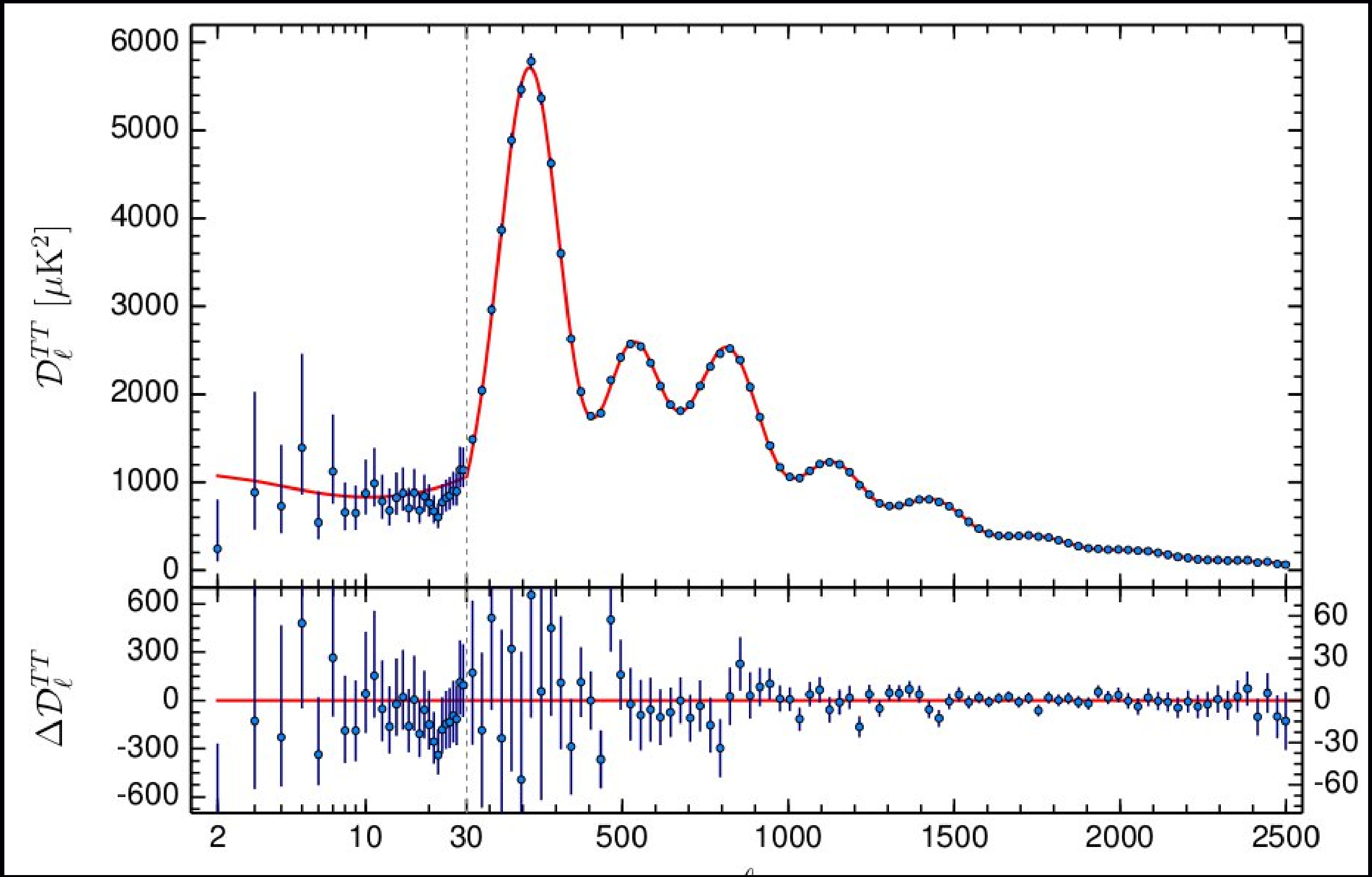


Image: Planck

Why believe in dark matter?

Gravitational lensing: the pink is the matter, the blue is where the lensing (mass) is - very hard to do with modified gravity!

Image: NASA

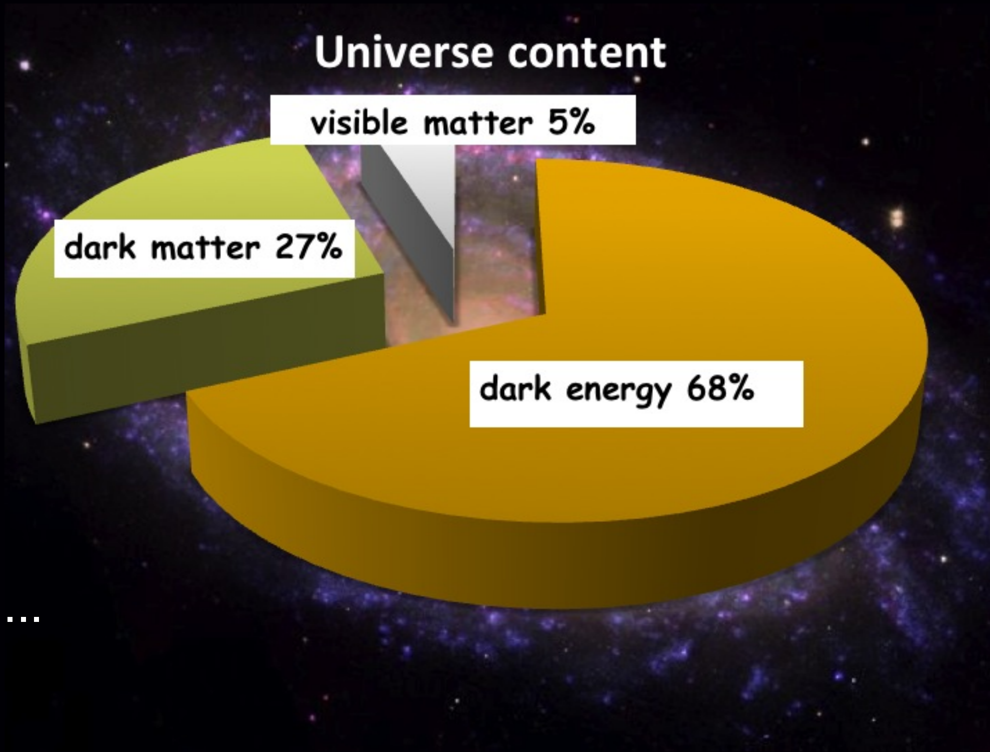
Why believe in dark matter?

An abundance of evidence says

DARK
MATTER
MATTERS

What do we know about dark matter?

- It's important
- It's massive
- It's probably a particle
- Electrically neutral



That's not much to go on....

What the @#$! is an axion?

This is an axion! Dark matter solved!?

Not so fast....

Axion is an american detergent
Needed to “clean up” the Standard Model

Why?
Neutrons have no electric dipole moment
SM lagrangian says they could have one
Parameter that controls this cannot be predicted

$$\mathscr{L} \propto \theta \, \tilde{G}_{\mu\nu} \, G^{\mu\nu}$$

- A problem if you want “naturalness”
- Theorists don’t like fitting parameters....
- So they add a new symmetry that cancels theta out
- This symmetry adds a new particle: the axion

Relax Lagrangians don't bite

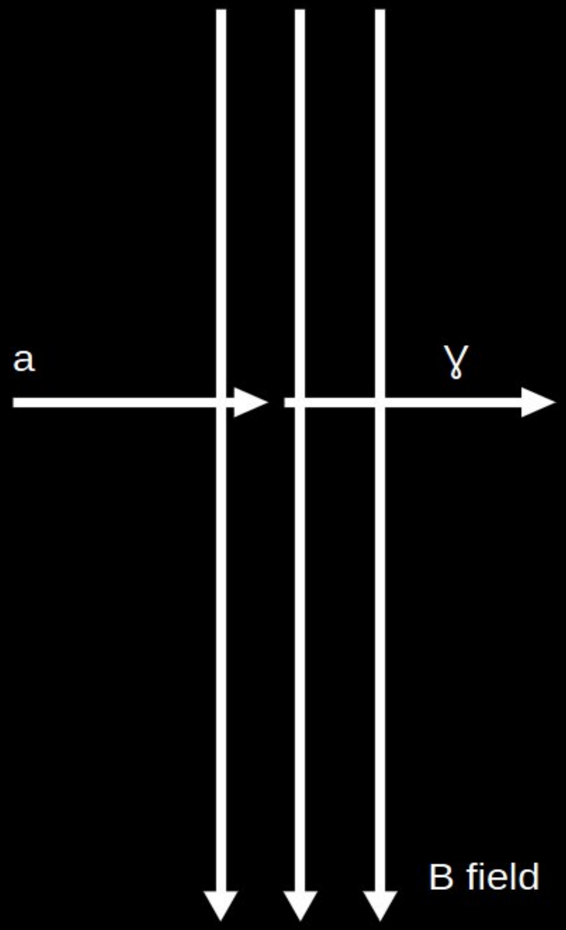
ussually....just tell it you *really* like theory

$$\mathscr{L} \propto (\theta - a\lambda)\tilde{G}_{\mu\nu} G^{\mu\nu}$$

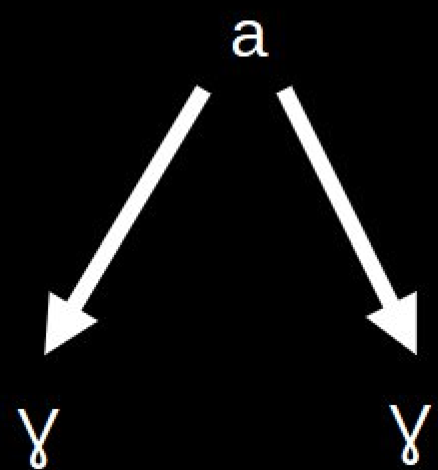
- New Lagrangian part must have axions couple to gluons
- Gluons couple to quarks
- Quarks are charged -> couple to photons
- Thus, axions couple to photons!
- Here is where things get weird

Axions are weird

Magnetic conversion to photons!



Plain old decay (very slow)

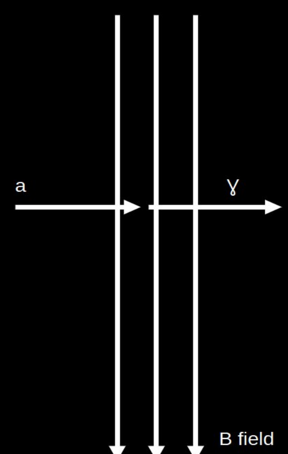


Photons at frequencies given by energy of axion

What to look for?

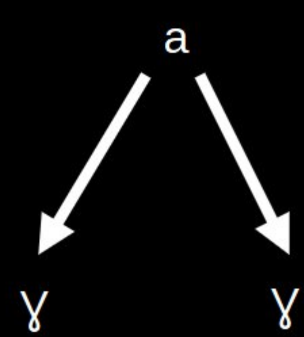
Magnetic conversion:

- Missing photons (turned into axions)
- New photons (from axions)
- Need a strong magnetic field
- Neutron stars often used
- Jets of AGN?



Plain old decay

- Narrow emission line
- Frequency at half axion mass
- For m < 10^{-4} eV this is radio
- Stimulated decay
- Need large photon background at same frequency



Predicting emissions: Axions

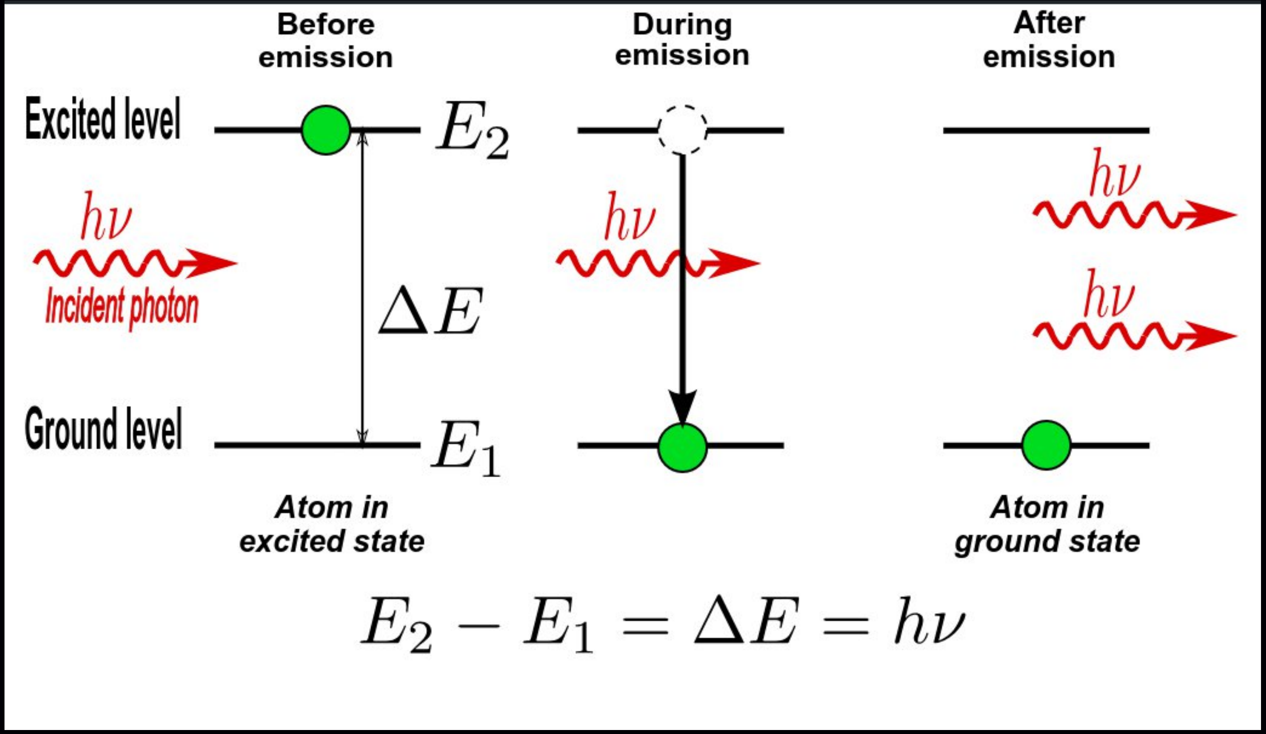
$$I(R) = \frac{\Gamma}{4\pi}\frac{\sigma}{c}\int dl\ \rho(r)$$

- ρ is the axion density
- Γ is the decay/conversion rate
- σ is velocity dispersion of the halo
- l is the line of sight through the halo

Decay rate can be hard to compute...

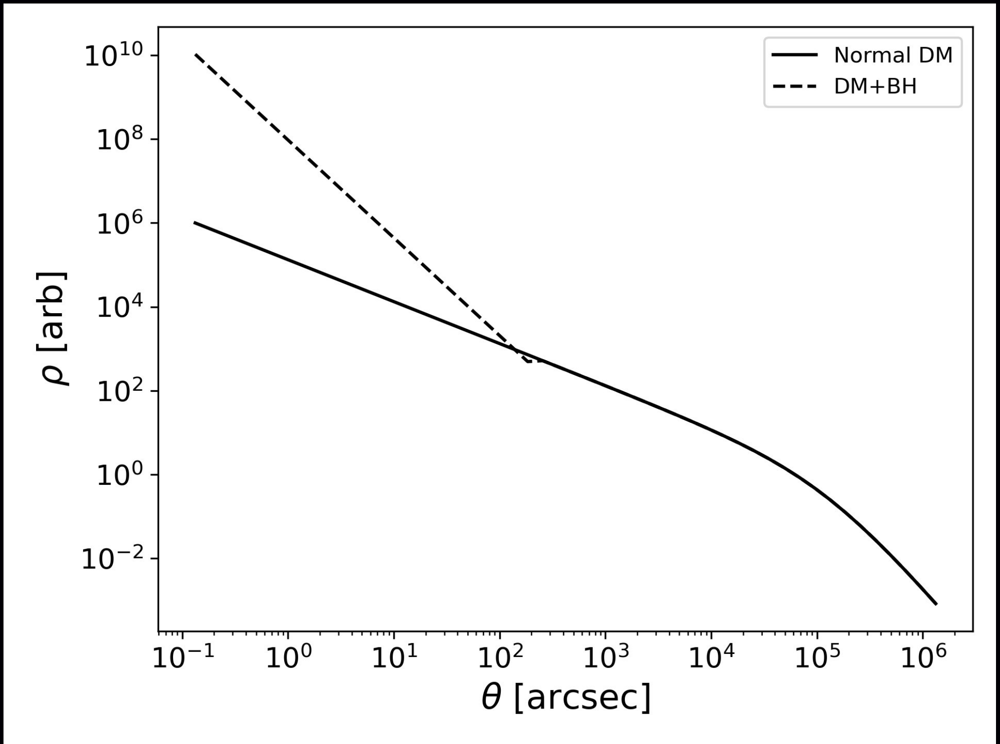
Stimulated emission

- Photons at the right frequency make axions decay faster
- Transition state has a dipole
- Photon excites that dipole making decay more likely



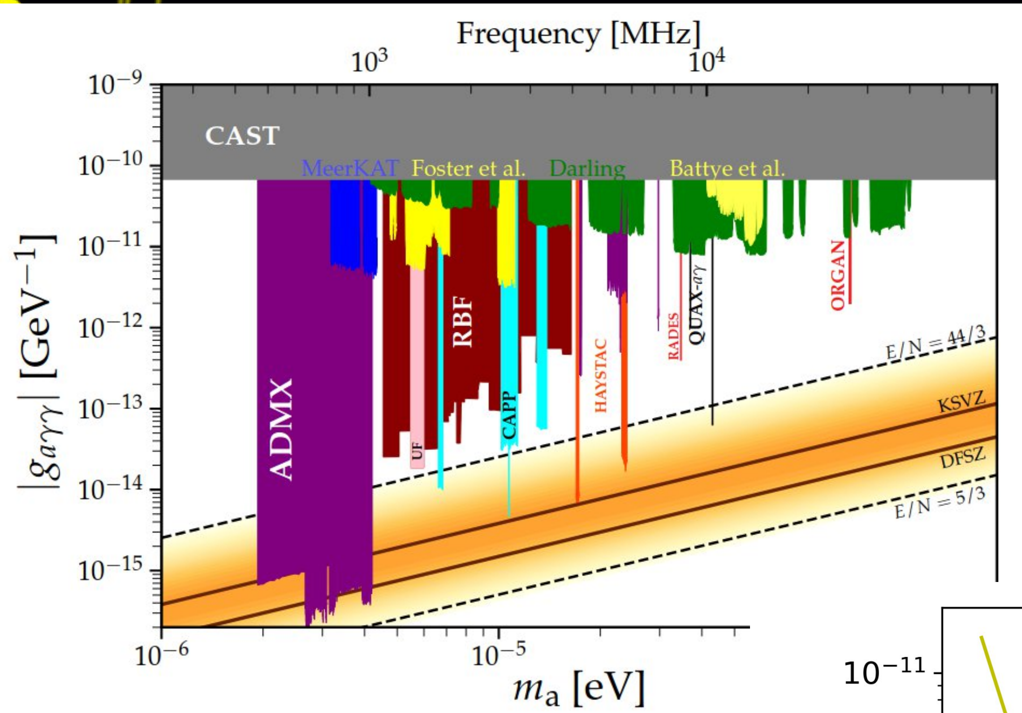
Black holes and dark matter

- Black hole gathers dark matter around it
- No real friction so it just builds up in giant density spike
- More axions -> more decay signal
- Lots of continuum photons -> stimulated emission
- Line signal can be subtracted off
- But the region is very small, how to see the effect?



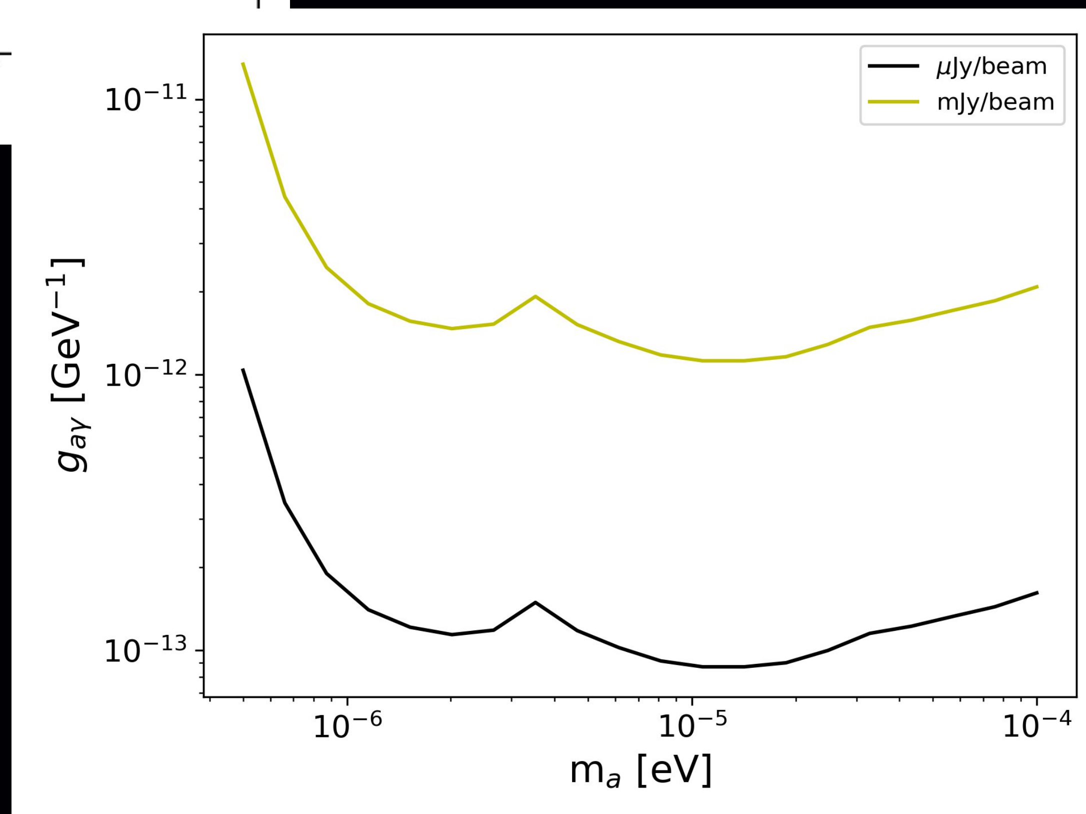
VLBI to the rescue

- Use SKA line sensitivity (20 hours) + “Hot sky” factor
- Adjust for axion decay width and halo velocities
- Compare to a “worst case” -> mJy/beam (a milli-SKA)
- Consider a modest milli-arcsecond beam



My results

- We probe open areas of the parameter space!
- Far superior to MeerKAT probes



Previous limits/projections

Conclusions and the future

- SKA low frequencies probe important open parameter space
- Axion searches may be viable in noisy environments
  - Bright continuum can even help!
- Worst case is 2 orders of magnitude advance on current data
- Requires mJy/beam with a milli-arcsecond beam

New avenue for fundamental science with VLBI