Patras 2023

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BRASS-p Status, Signal Scan Result, and Searches for Exotic WISPy Phenomenon

Contents:

- BRASS-p upgrade and status
- First result on HPDM search over 12-18 GHz
- BRASS-p search for exotic WISPy DM

Setup of BRASS-p Experiment in University of Hamburg

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BRASS-p Upgrade and Status.

[arxiv:2306.05934]

First results from BRASS-p broadband searches for hidden photon dark matter

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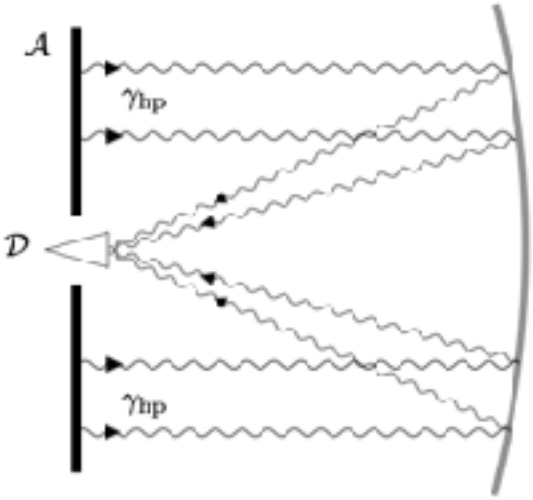
Abstract. We discuss first results from hidden photon dark matter searches made with a prototype of the Broadband Radiometric Axion/ALPs Search Setup (BRASS-p) in the range of particle mass of 49.63 μeV to 74.44 μeV (frequency range of 12 GHz to 18 GHz). The conceptual design of BRASS and a detailed description of its present prototype, BRASS-p, are given, with a view of the potential application of such setups to hidden photon, axion, and axion-like particle (ALP) dark matter searches using heterodyne detectors in the range of particle mass from 40 μeV to 4000 μeV (10 GHz to 1 THz). Pioneering measurements made with BRASS-p achieve the record sensitivity of $(0.3–1.0)\times10^{-12}$ to the kinetic mixing between the normal and hidden photons, assuming the dark matter is made entirely of unpolarized hidden photons. Based on these results, a discussion of further prospects for dark matter searches using the BRASS-p apparatus is presented.

BRASS Experiment



Hidden Photon

$$\chi_{sens} = 4.5 \times 10^{-14} \left(\frac{P_{det}}{10^{-23}\,\mathrm{W}}\right)^{\frac{1}{2}} \left(\frac{0.3\,\mathrm{GeV/cm^3}}{\rho_{CDM,halo}}\right)^{\frac{1}{2}} \left(\frac{1\,\mathrm{m^2}}{A_{dish}}\right)^{\frac{1}{2}} \left(\frac{\sqrt{2/3}}{\alpha}\right).$$

Axion/ALPs

$$g_{\phi\gamma\gamma,\,sens} = \frac{3.6 \times 10^{-6}}{\mathrm{GeV}} \left(\frac{5\,\mathrm{T}}{\sqrt{\langle|B_{\|}|^2\rangle}}\right) \left(\frac{P_{det}}{10^{-23}\,\mathrm{W}}\right)^{\frac{1}{2}} \left(\frac{m_\phi}{\mathrm{eV}}\right) \left(\frac{0.3\,\mathrm{GeV/cm^3}}{\rho_{DM,halo}}\right)^{\frac{1}{2}} \left(\frac{1\,\mathrm{m^2}}{A_{dish}}\right)^{\frac{1}{2}},$$

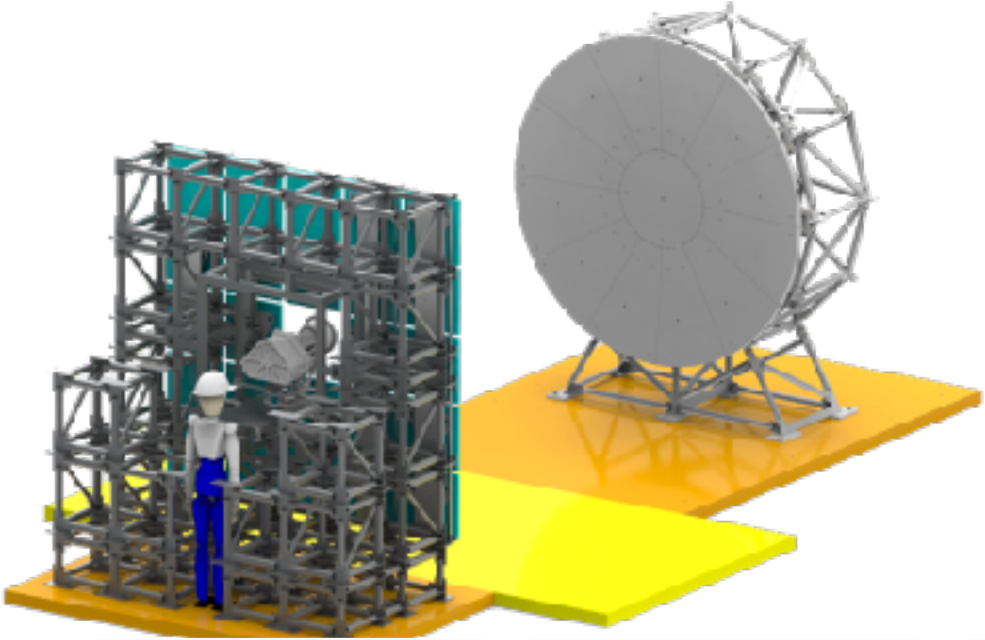
Broadband sensitivity to a large parameter space and resonant enhancement is compensated by the large surface area.

Prototype: BRASS-p

"Dish Antenna Search for Light Dark Matter", Horns et al. 2013

BRASS-p Setup

[arxiv:2306.05934]



Illuminated Area: $A = 4.44\ m^2$	Parabolic mirror: D = 2.5m, f = 4.8m	Broadband Receiver: 12-18 GHz	IF Bandwidth: 4 GHz $\Delta f = 5 - 125 Hz$

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System Temperature

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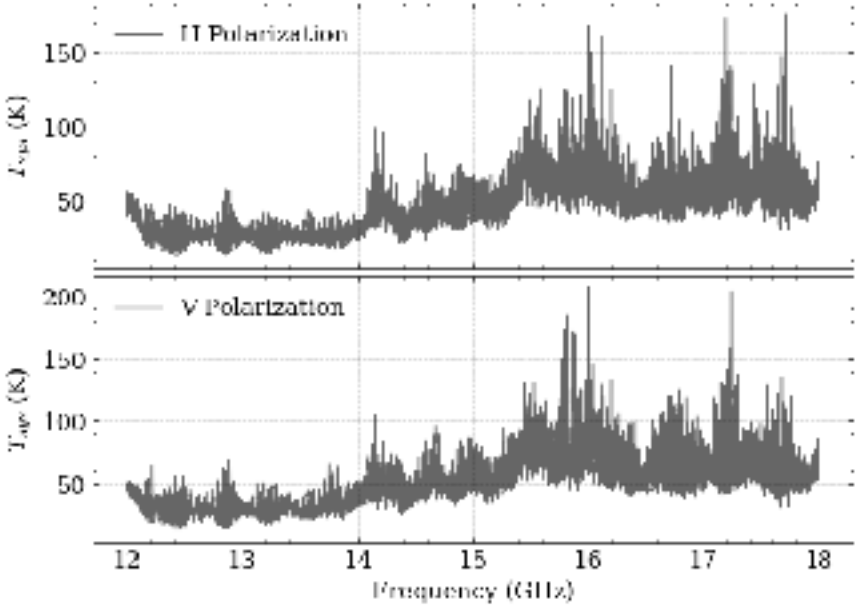
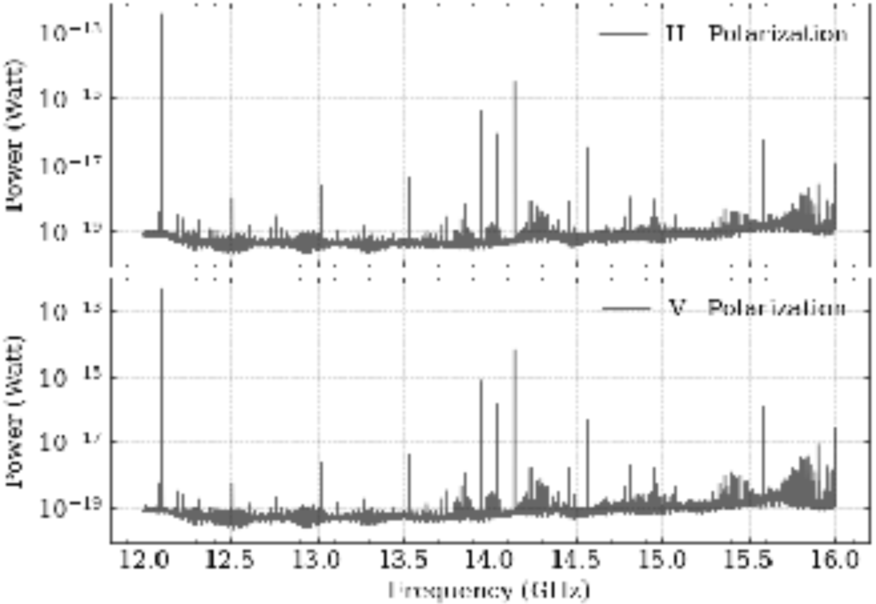
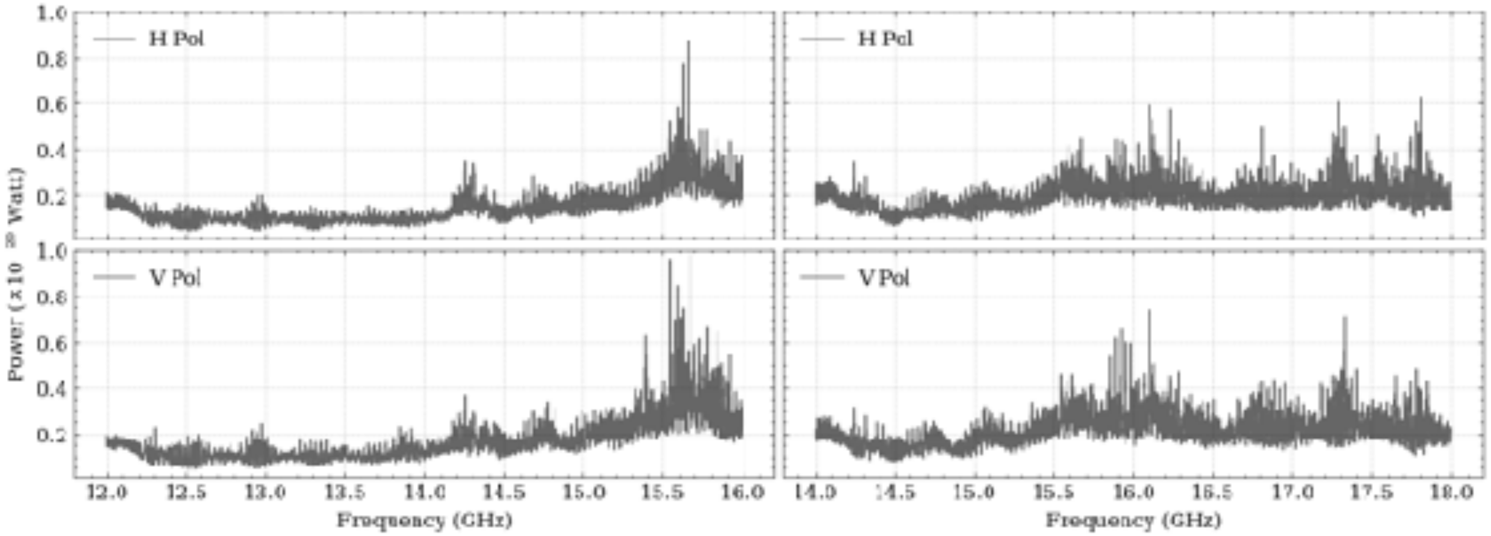




Low temperature for a *room-temp* experiment.
(sub 15K achievable)

Raw spectrum with IF BW of 4 GHz
with 125 Hz resolution

BRASS-p standard spectrum



Lowest detectable power within a 125 Hz channel

Important for transient stream/tidal dark matter signal.

<u>Lowest det power is 10^{-21} Watt over 12-16 GHz/14-18 GHz in only 19.8 sec</u>

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Hidden photon dark matter search

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	SR1a	SR1b
Frequency band:	12-16 GHz	14-18 GHz
Number of polarization channels:	2	2
Spectral resolution:	125 Hz	125 Hz
Starting date:	13 Nov 2022	24 Nov 2022
Ending date:	19 Nov 2022	2 Dec 2022
Number of spectra collected:	9998	12012
Total measurement time:	54.989 hours	66.096 hours

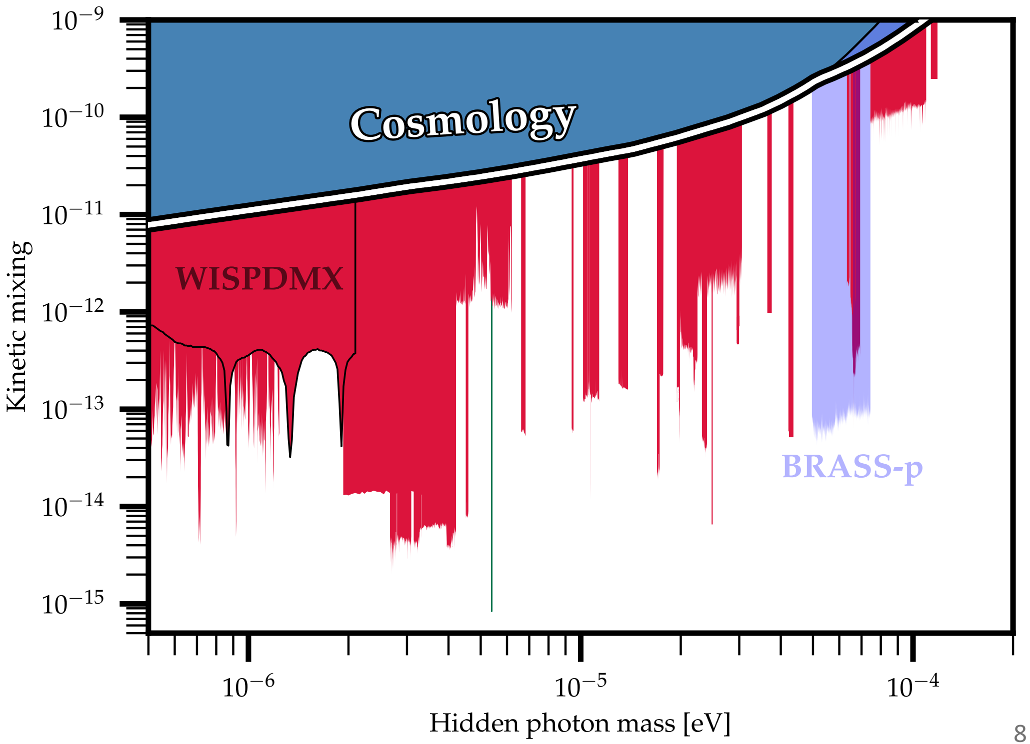
Lowest det pow of 10^{-23} Watt

Maxwellian DM span over multiple channels

$$\chi(\nu) = 3.2 \times 10^{-14} \left(\frac{\sigma_{\rm det}(\nu) N_{\rm ch}(\nu)^{-1/2}}{10^{-23}\ \rm W} \right)^{\frac{1}{2}} \times \left(\frac{0.3\ \rm GeV/cm^3}{\rho_{\rm DM}} \right)^{\frac{1}{2}} \left(\frac{1\ \rm m^2}{A_{\rm eff}} \right)^{\frac{1}{2}} \left(\frac{\sqrt{2/3}}{\alpha} \right)$$

$A_0 \cdot \eta_A$

$\sqrt{2/3}$



👉[github.com/cajohare/AxionLimits]👍

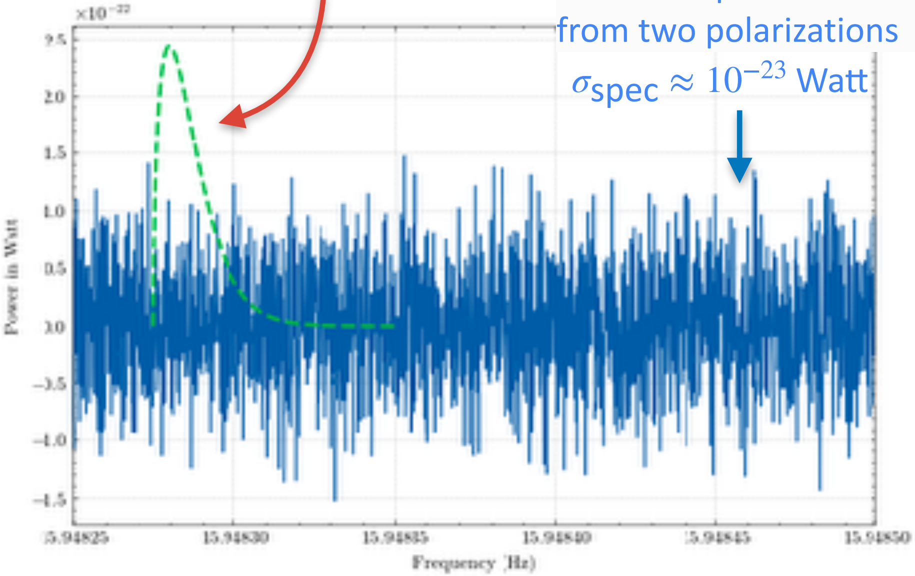
HP Dark Matter Signal Scan Result

$P_{sg} \cdot f_{\text{Maxwellian}}(m_{HP}, v_{dis})$

$\sigma_{sg} = \sigma_{spec} \cdot N_{sg}^{1/2}$

Combine spectrum from two polarizations

$\sigma_{spec} \approx 10^{-23}$ Watt

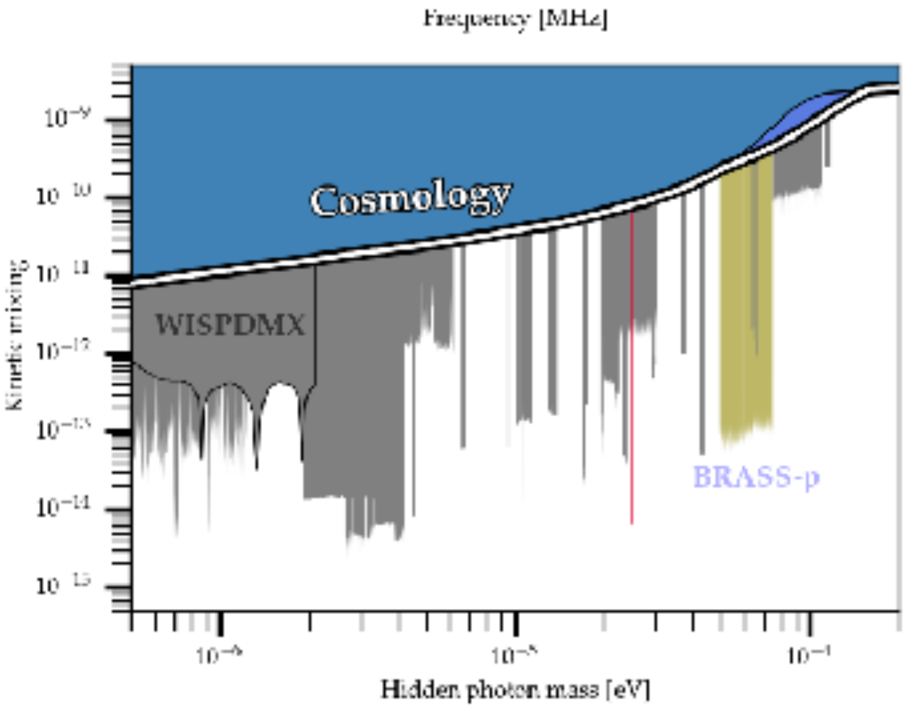


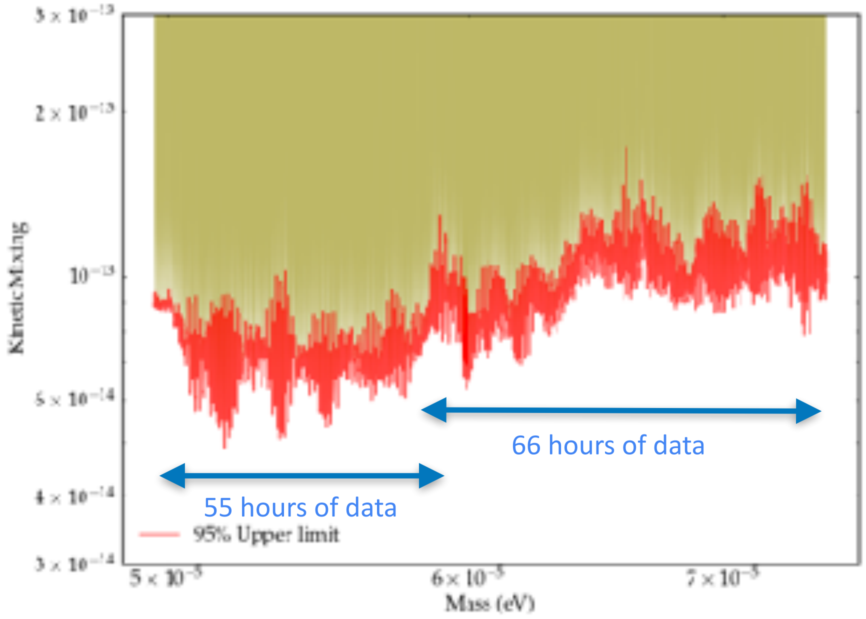
BRASS-p: $\alpha = 2/3$

$$P_{sg} = \left(\frac{\chi}{3.2 \cdot 10^{-14}}\right)^2 \frac{\rho_{DM}}{0.3\ \text{GeV/cm}^3} \frac{A}{1\ \text{m}^2} \frac{\sqrt{\alpha}}{\sqrt{2/3}}$$

No signal above LEE's Detection Threshold (7.5σ_{SG}) → **Set 95% upper limit**

HP Dark Matter Signal Scan Result





[arxiv:2310.xxxxxx]

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Axion/ALPs Search

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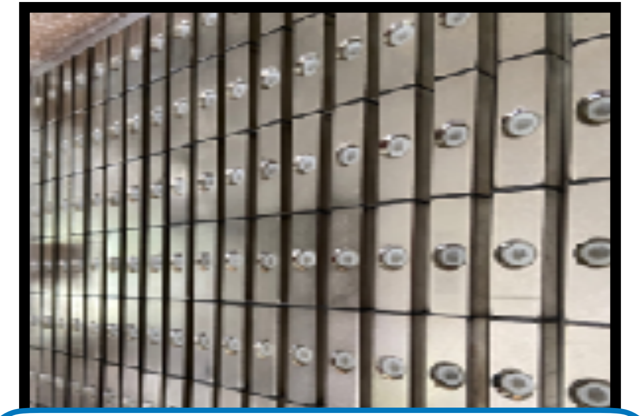
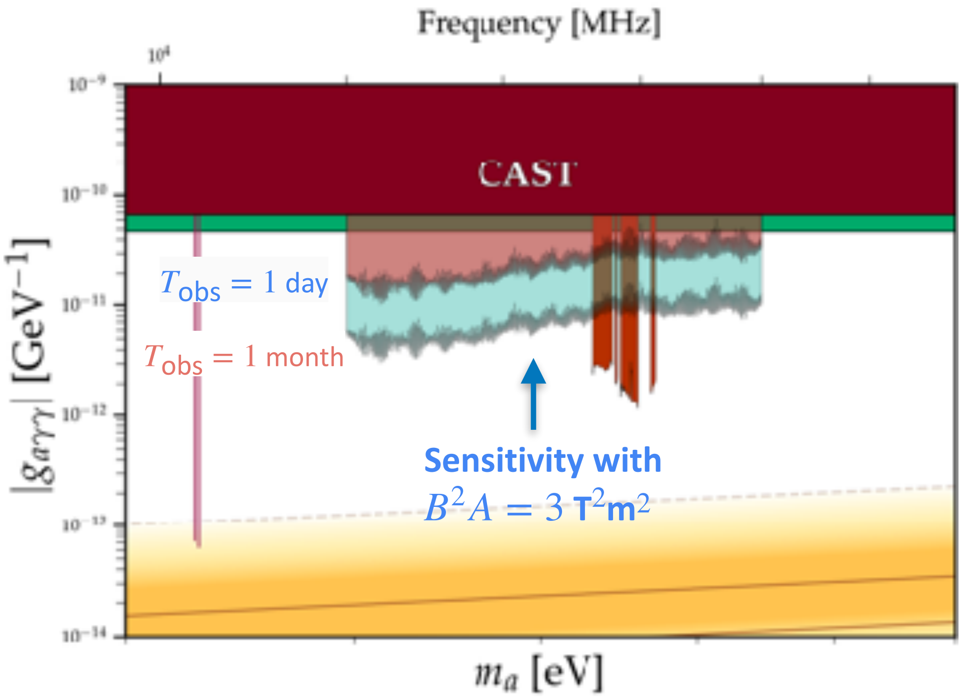
$$g_{a\gamma\gamma} = \frac{3.6\times 10^{-8}}{\mathrm{GeV}} \left(\frac{\sigma_{\mathrm{det}}(\nu) N_{\mathrm{ch}}(\nu)^{-1/2}}{10^{-23}\ \mathrm{W}}\right)^{\frac{1}{2}} \left(\frac{5\ \mathrm{Tesla}}{B_{\mathrm{ex}}}\right) \times \left(\frac{m_a}{\mathrm{eV}}\right) \left(\frac{0.3\ \mathrm{GeV/cm^3}}{\rho_{\mathrm{DM}}}\right)^{\frac{1}{2}} \left(\frac{1\ \mathrm{m^2}}{A_{\mathrm{eff}}}\right)^{\frac{1}{2}}$$



Averaged horizontal field strength is approx 0.9 Tesla



Data taking this year!

Search for exotic WISPy DM phenomenon with BRASS-p

Axion/ALPs

Talk by Zhitnitsky ,Özbozduman, and Jinsu Kim

Axion Quark Nugget

Relativistic Axion

Cosmic Axion Background

Talk by Nitta

SHM with $\rho_{\mathrm{DM}} = 0.45 \frac{\mathrm{GeV}}{\mathrm{cm}^3}$ and $v_{\mathrm{dis}} \approx 220$ km/s

Minivoid $\rho_{\mathrm{DM}}^{\mathrm{void}} = 0.075 \rho_{\mathrm{DM}}$

Minicluster Streams/Tidal Gravitational Focusing

Hidden Photon

Polarized HPDM

Standard DM Signal

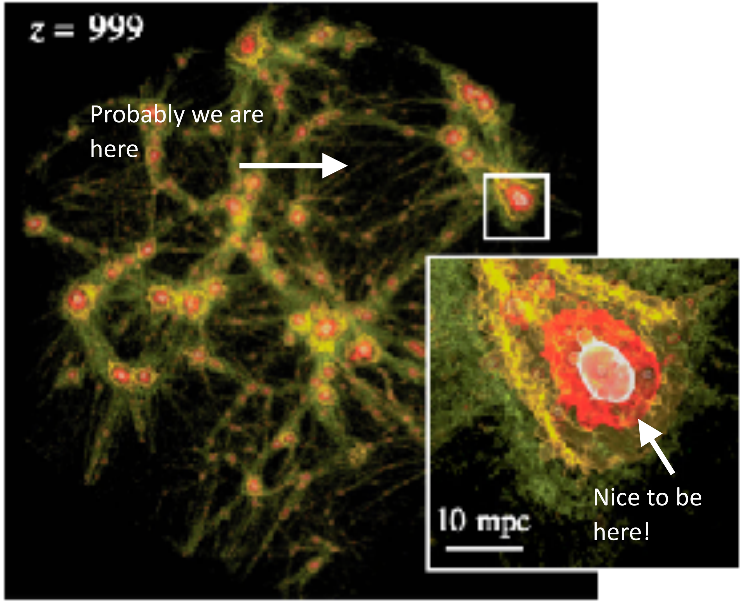
- Axion dark matter density is considered uniform
  - SHM dark matter with $\rho_{stdDM} \approx 0.45$ GeV/cm^3
  - Solar system within the minivoid ($\rho_{\text{minivoid}} \approx 0.075\rho_{stdDM}$)

→ Stronger magnet panel (2-3 Tesla), larger surface area (x 10), dielectric implementation.

SHM with $\rho_{\text{DM}} = 0.45\frac{\text{GeV}}{\text{cm}^3}$

and $v_{\text{dis}} \approx 220$ km/s

Minivoid $\rho_{\text{DM}}^{\text{void}} = 0.075\rho_{\text{DM}}$

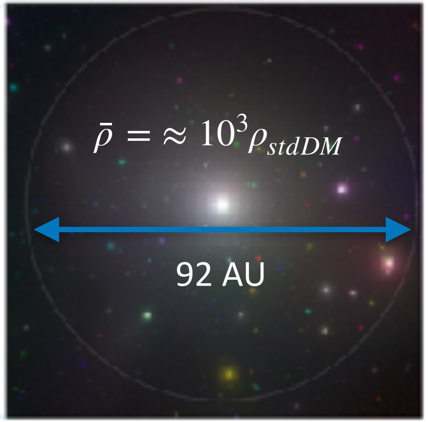


EGGEMEIER et al. PRD 107, 083510 (2023)

Transient and Narrow DM Signal

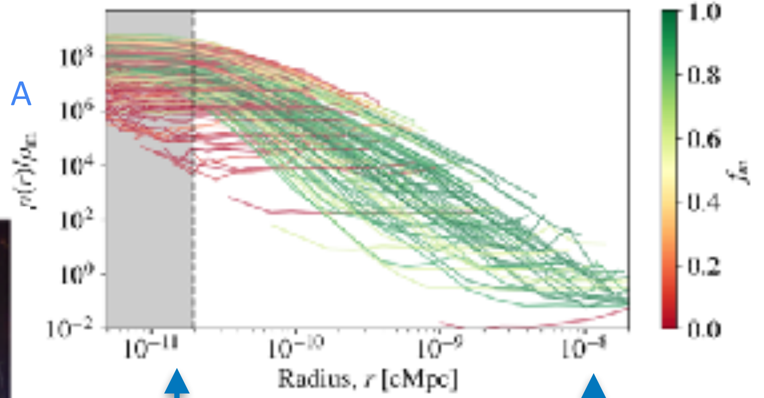
- **Minicluster/axion stars colliding** $(\rho \approx (10^2 - 10^8)\rho_{stdDM})$

Minicluster is morelikely to be gravitational disrupted and creates streaming and tidal effects



Eggemeier et al. Phys. Rev. Lett., 125.4 (2020)

v⊙ = 0.2 mpc/year

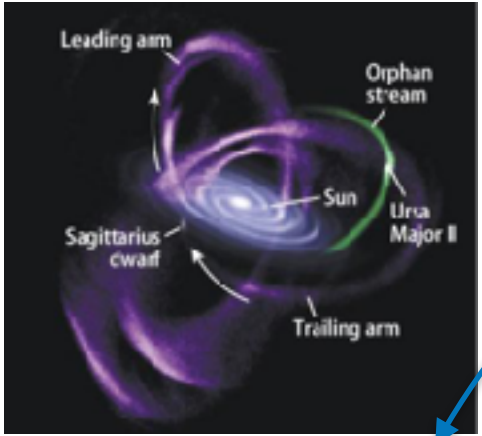


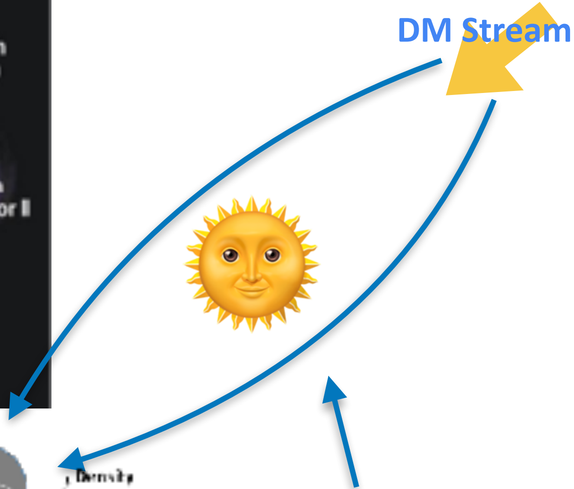
High DM density but colliding time is only 18 days

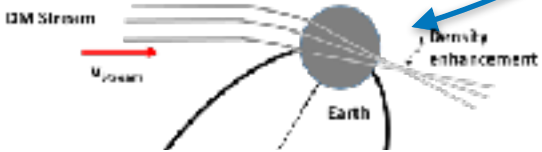
this is 50 years

Ellis et. al 10.1103/PhysRevD.106.103514

Transient and Narrow DM Signal







Focusing by the Sun or Jupiter

Focusing of fine grained streams in the solar neighbourhood.

A. Gardikiotis et al. 2018 - DESY-PROC-2017-02, W. Purcell et al. JCAP08(2012)027

- **DM Stream/tidal/seasonal gravitation focusing**

$$F \sim \frac{v^2}{(11.2\,\mathrm{km/s})^2} R_E .$$

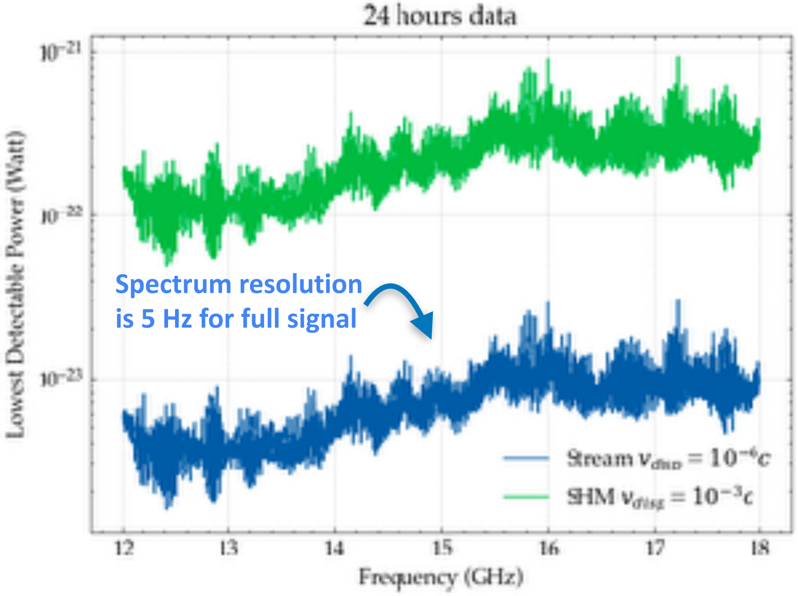
TABLE I. Streams with different densities before gravitational focusing (GF) and for hairs after GF.

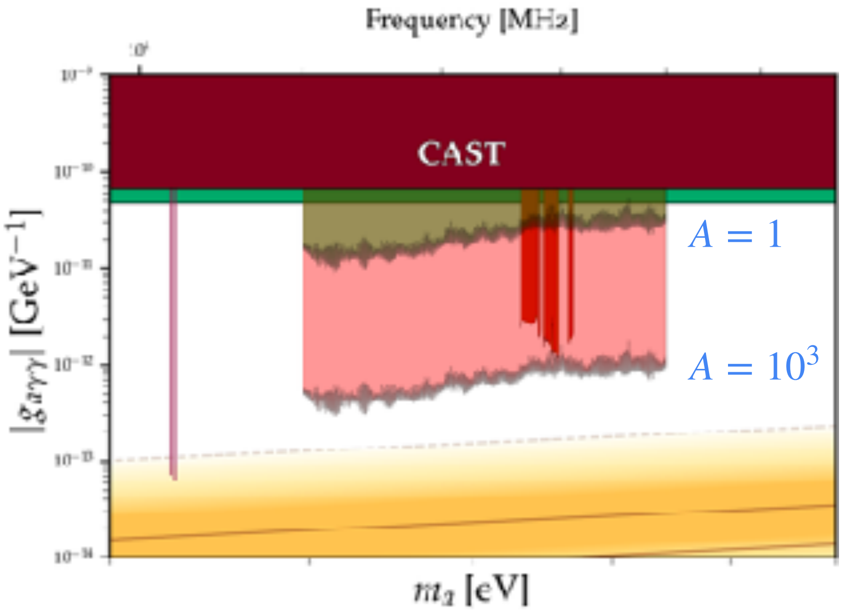
Density before GF (ρ_s/ρ_0)	Number of streams	Density after GF ($A\rho_s/\rho_0$)
1	1	10^8
0.1	1	10^7
0.01	1	10^6
10^{-3}	10	10^5
10^{-4}	500	10^4
10^{-5}	$2 \cdot 10^4$	10^3
10^{-6}	$4 \cdot 10^5$	10^2
10^{-7}	$2 \cdot 10^6$	10

Arza et al. 2212.10905
Kryemadhi et al. 2210.07367
Kryemadhi talk @ PATRAS 2022

BRASS-p Capability on Tidal and Stream

- Wide bandwidth (4 GHz IF)
- High resolution (5 Hz to 125 Hz)
- Long data taking campaign (low electricity consumption)
- Second polarization for axion dm veto.



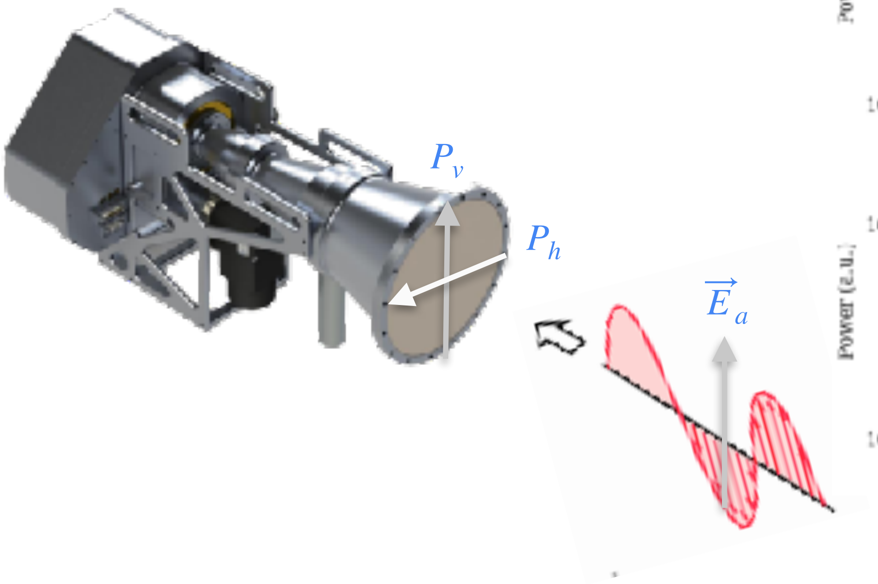


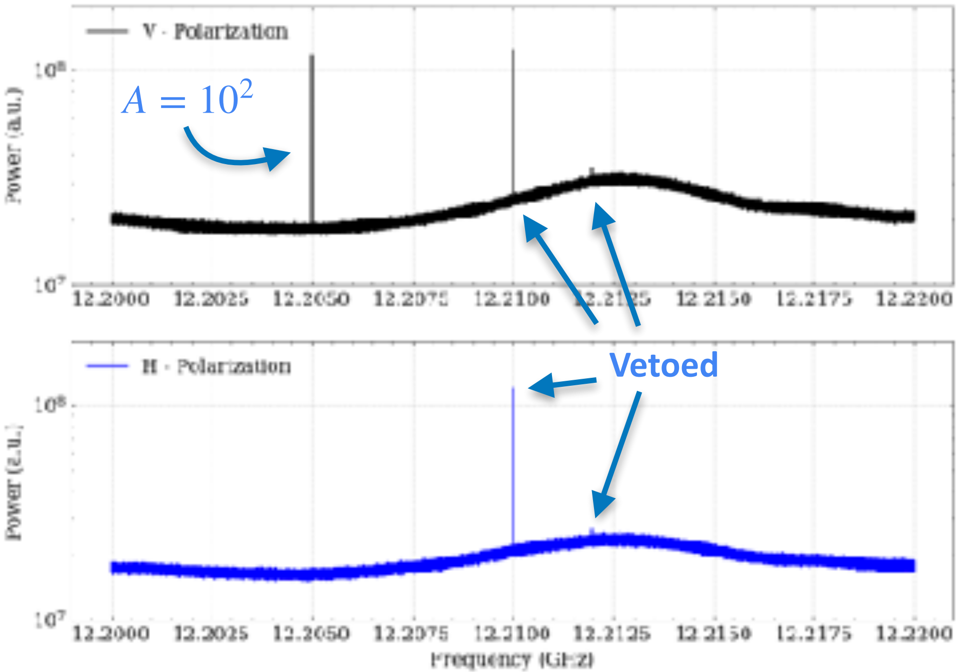
Local sensitivity for stream

- No signal → set limit on stream existence

BRASS-p Capability on Tidal and Stream

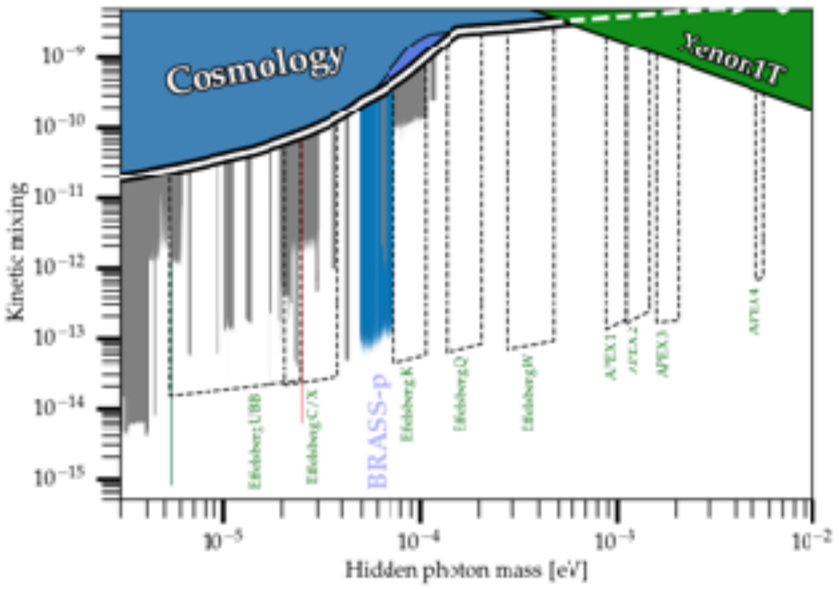
- Wide bandwidth (4 GHz IF)
- High resolution (5 Hz to 125 Hz)
- Long data taking campaign (⚡40 eur/day)
- Second polarization for axion signal veto.





Future Development and Conclusion

- BRASS is the synergy between radio astronomy and WISPs direct search.
- State-of-art receiver and digitizer (4 GHz, 125 Hz)
- Sensitive to various scenarios of WISPs (non-polarization HP, polarized HP, Thermal Virialized DM, Transient DM) during one instance of acquistion.
- Future
  - Mounting magnet panels for ALPs search (2023)
  - Implementation of dielectric configuration for magnet panel.
  - Different frequency band with different receiver + next gen digitizer (16/32 GHz)



Sensitivity of the BRASS-p (probably exclusion limit too)
with the other future implementation of available receiver in MPIfR.

Thank you for your attention

Have fun!