Optical Microlensing by Primordial Black Holes with IACTs.

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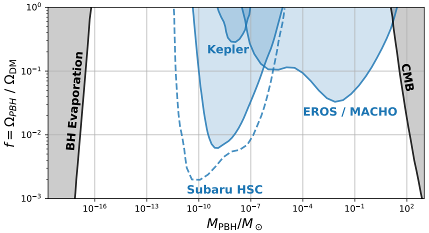
Primordial Black Holes

- Primordial Black Holes (PBHs) are a **DM candidate** [1]
- Hypothetical formation at wide range of masses in early universe due to density perturbations
- **Unconstrained range** from 10^{-10} to $10^{-16} M_\odot$



Microlensing by PBHs

- PBH act as lens when close to line of sight to star causing **temporal apparent brightening**
- Powerful method to constrain ~11 orders of PBH mass
- Sampling speed limiting factor at low M_{PBH}

Optical Observations with IACTs

- **VERITAS** used as example for current generation
- **Large reflective** area reduces scintillation noise → suited for fast optical astronomy
- Modest optical quality

IACTs vs previous microlensing studies

IACTs (VERITAS) [2]	**Traditional** (Subaru HSC) [3]
Up to GHz sampling possible	2 min to 24 hours
10% error for 10.2mag (2400Hz)	Flux changes down to 26 mag
499 Pixels (3.5deg FoV)	870 Megapixels (1.5deg FoV)

Microlensing Review

IACTs could constrain low M_{PBH} → finite source limit [4]

Optical depth

$$\tau_{\mathrm{FS}} = \frac{\pi D_s \rho_0 R^2 x_{\max}^3}{3 M_{\mathrm{PBH}}}$$

Detectable event rate [5]

$$\Gamma_{\mathrm{FS}} \approx 2 \frac{\tau_{\mathrm{FS}} v_c}{\pi x_{\max} R}$$

D_s, R, m- Distance, Radius and magnitude of star | ρ_0 - Local DM density

v_c - halo circular velocity | $x_{\max}$ - maximum PBH distance to detect event

For **low masses** (VERITAS $M_{\mathrm{PBH}} \lesssim 10^{-8} M_\odot$)

$$x_{\max} \propto \frac{D_s f(m)}{R^2} M_{\mathrm{PBH}} \longrightarrow \Gamma_{\mathrm{FS}} \propto \frac{D_s^3 f(m)^2}{R^3} M_{\mathrm{PBH}}$$

$f(m)$ - magnitude dependence: $\propto 10^{-0.2m}$ for $m \lesssim 13$ and $\propto 10^{-0.8m}$ for $m \gtrsim 13$

Event duration $\langle t_e \rangle \propto M_{\mathrm{PBH}}$ → fast detectors for small M_{PBH}

Target selection

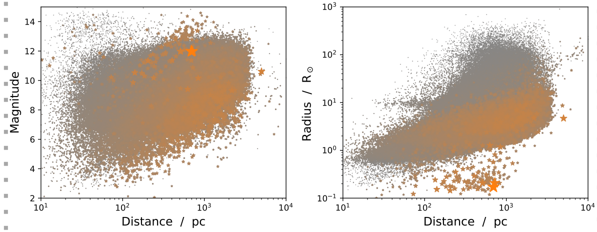
Assumptions

- **Only one star** can be monitored (large pixels, modest optics)
- Select star to **optimise event rate** for low PBH masses
- Shot noise -> relative flux uncertainty $\propto N_{\mathrm{photons}}^{-0.5}$
- Constant night sky background level of $m = 9$

Results

- Tradeoff between large distance, small magnitude and radius
- Majority of good targets (*large, orange markers*) are B-type stars
- Best candidate is hot subdwarf **PG 0240+046** [6]

$$m = 11.98 \quad D_S = 692\ \mathrm{pc} \quad R = 0.174 R_\odot$$



Event Rate and Duration

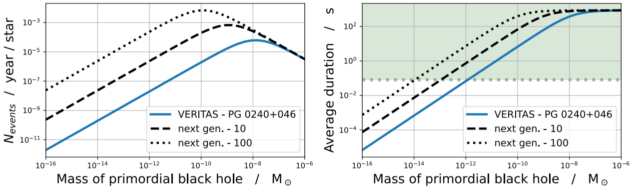
- Scaled uncertainty to **50Hz** → 4 consecutive samples above 3σ

VERITAS *(Blue solid line)*

- Duration detectable down to $10^{-12}\ M_\odot$
- $< 10^{-6}$ events per year $< 10^{-10}\ M_\odot$

Next-generation improved sensitivity by factor 100 *(black dotted line)*

- Timescales detectable down to $10^{-14}\ M_\odot$
- $< 10^{-2}$ events per year below $10^{-10}\ M_\odot$



Conclusions

Imaging Air Cherenkov telescopes can be powerful instruments for fast optical astronomy. We investigated the possibility of IACTs to detect microlensing of primordial black holes in the currently unconstrained mass range $M_{\mathrm{PBH}} < 10^{-10} M_\odot$. The event duration decreases with M_{PBH} making a fast sampling speed with high signal to noise crucial.

The low number of stars and modest optics limit the expected event rate. No detectable PBH-induced microlensing events are expected over the VERITAS lifetime. This search would still not be competitive, even assuming an increase of factor 100 in sensitivity for a possible next-generation instrument. Besides the fast sampling, also good sensitivity and a large number of observed stars are required to constrain the PBH abundance with $M_{\mathrm{PBH}} < 10^{-10} M_\odot$.

References

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