New Methods for Limiting Black Hole Dark Matter

One of the simplest points in exptl. physics...

If there is something between you and a source,

(beam pipe at LHC, window of your detector.
atmosphere in astronomy, cosmic rays...)

there will be a loss of angular resolution

If there are Black Holes in space there is 'something'

Einstein deflection of light:

$$\delta\alpha = 4GM/b = 2(r_s/b)$$

r_s =Schwzld radius of Sun, Black Hole ,
b =Impact parameter of photon

SPECTACULAR resolution of EHT project
$10\,, microarcsec$ that is $\sim 10^{-11} rad$

(Using earth diameter as baseline, resolution wavelength/earth)

IDEA: Use high resolution observations to set limits on Black Holes along the flight paths

WHERE: Galaxy, CMB, 'Spike' around Super Massive Black Hole (M87),...

ARGUMENT

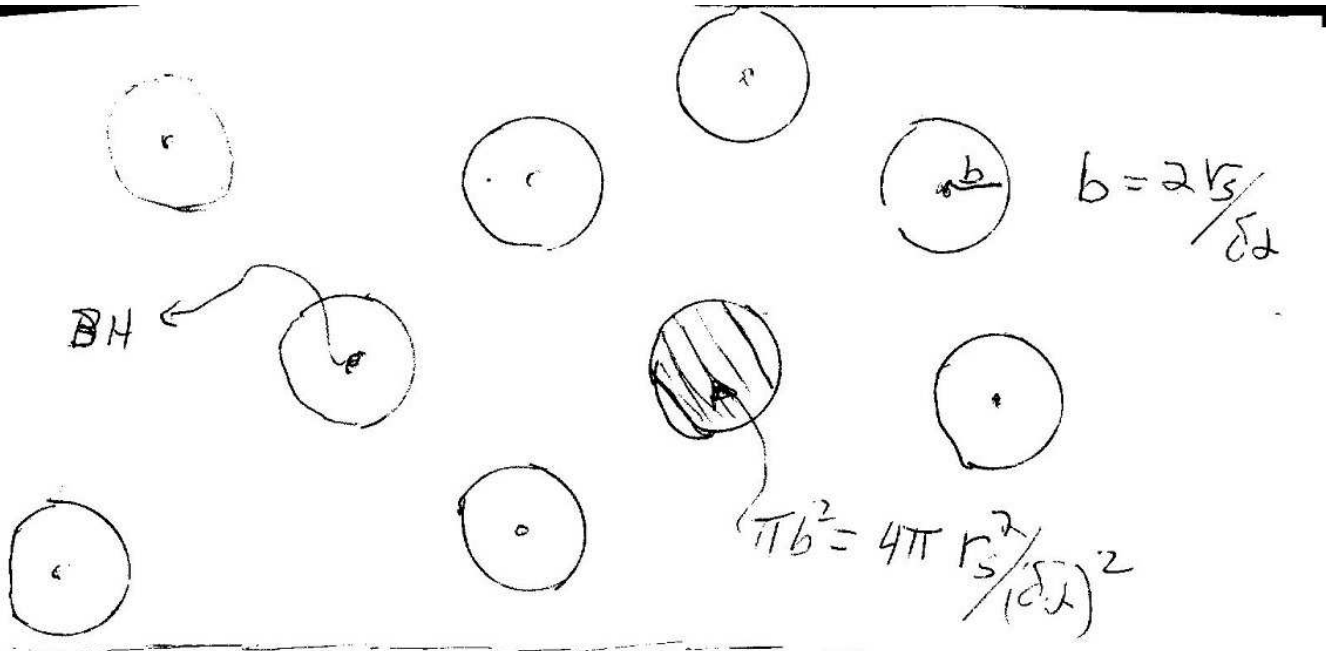
Rearrange Einstein formula and square:

$$\pi b^2 = 4\pi r_s^2 (1/\delta\alpha^2)$$

To every deflection $\delta\alpha$ there is a $crosssection(\delta\alpha)$

$$Prob(\delta\alpha) =$$
$$crosssection(\delta\alpha) \times column\, density\, BlackHoles$$

$$= 4\pi r_s^2 (1/\delta\alpha^2) \times column\, density$$


b
$b = 2r_s/\delta\lambda$
BH
$\pi b^2 = 4\pi r_s^2/(\delta\lambda)^2$

When $Prob(\delta\alpha) \sim 1$, resolution $\delta\alpha$ not possible

OR

If resolution $\delta\alpha$ exists, then

$$column\,density \leq 1/(4\pi r_s^2(1/\delta\alpha^2) = (\delta\alpha)^2/(4\pi r_s^2)$$

COLUMN DENSITIES of BLACK HOLES

Column density
= (Dark Matter column density)/M(Black Hole)

Galaxy: $3.0 \times (M_\odot/M)/ly^2$
for $10^4 ly$ flight path

CMB: $9.2 \times (M_\odot/M)/ly^2 \times 7.2 \times 10^9$
$= 6.6 \times 10^{10}(M_\odot/M)/ly^2$

Factor 7.2×10^9 is due to GR, from higher density at early times and opening angle effect $\sim 1/a^5$

M87 Spike:

model: $\rho \sim r^{-3/2}$ $\quad\quad$ $3 \times 10^4/ly^2(M_\odot/M)$

model: $\rho \sim r^{-7/3}$ $\quad\quad$ $1 \times 10^8/ly^2(M_\odot/M)$

For spike of mass $10^8 M_\odot$

SENSITIVITY

Assuming 10 microarcsec resolution

Galaxy: $(M/M_\odot) \leq 6 \times 10^2$
for $10^4 ly$ flight path

CMB: $(M/M_\odot) \leq 2.7 \times 10^{-8}$
note: really *primordial*

M87 Spike: the resolution exists— EHT !

model: $\rho \sim r^{-3/2}$ $(M/M_\odot) \leq 7 \times 10^{-2}$

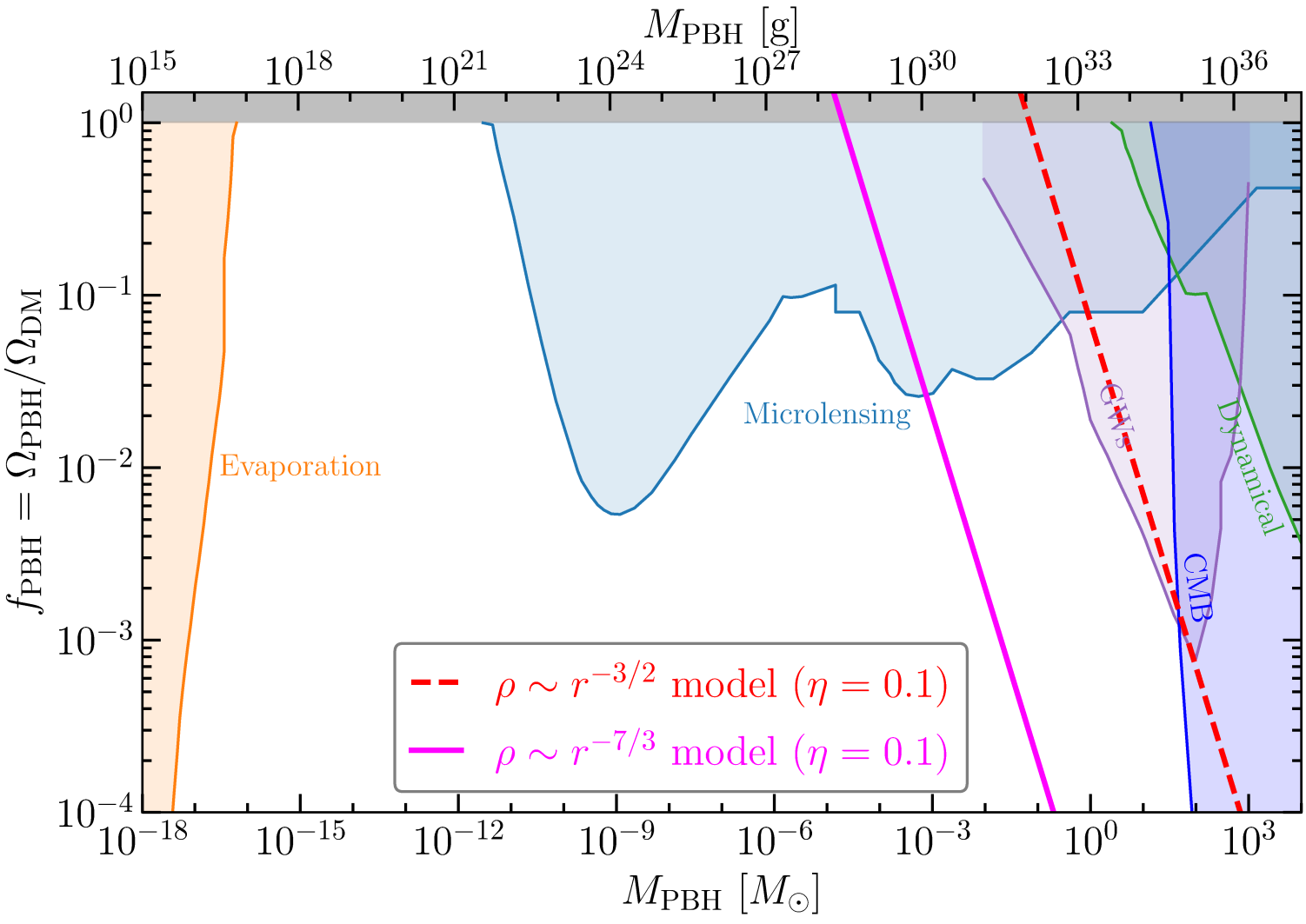
model: $\rho \sim r^{-7/3}$ $(M/M_\odot) \leq 2 \times 10^{-5}$

For spike of mass $10^8\, M_\odot$

When Black Holes a fraction of Dark Matter

Is often considered that primordial Black Holes are only a fraction, f_{PBH} of Dark Matter . Replace column density $\rightarrow f_{PBH} \times$column density.

For our M87 limits:



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L. Stodolsky, "Observational Aspect of Black Hole Dark Matter," Mod. Phys. Lett. A **36**, no.11, 2150077 (2021) doi:10.1142/S0217732321500772 [arXiv:1912.01325 [astro-ph.CO]].

J. Silk and L. Stodolsky, "Limits on primordial black holes from M87," Phys. Rev. D **105**, no.6, 063506 (2022) doi:10.1103/PhysRevD.105.063506 [arXiv:2201.03 [astro-ph.CO]]

Further

L. Stodolsky, "Primordial black holes in interferometry," [arXiv:2105.03648 [astro-ph.CO]].

Interesting theoretical issue:

If there are significant Black Holes , CMB is not a perfect Black Body

Intensity is like a BB, but there must be some hidden (angular) correlations

Can we see them ?