Galileon and black holes

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OUTLINE

- galileon and covariant galileon
- accretion onto a black hole
- DGP scalar in the neighborhood of a black hole
- another form of galileon near black hole
- Carter-Penrose diagrams, communicating with a parallel universe
- conclusion

Galileon

Scalar field with the "Galilean" symmetry (motivated by Dvali-Gabadadze-Porrati model of gravity),

$$\pi(x) \to \pi(x) + b_\mu x^\mu + c$$

Galilean-invariant terms $\mathcal{L}_1,\ \mathcal{L}_2,\ \mathcal{L}_3,\ \mathcal{L}_4,\ \mathcal{L}_5$

Nicolis et al'09

Equations of motion contain only second derivatives of π

However the analysis was made for flat space-time
(no perturbations of metric)

Galileon

Covariant galileon

Deffayet et al'09

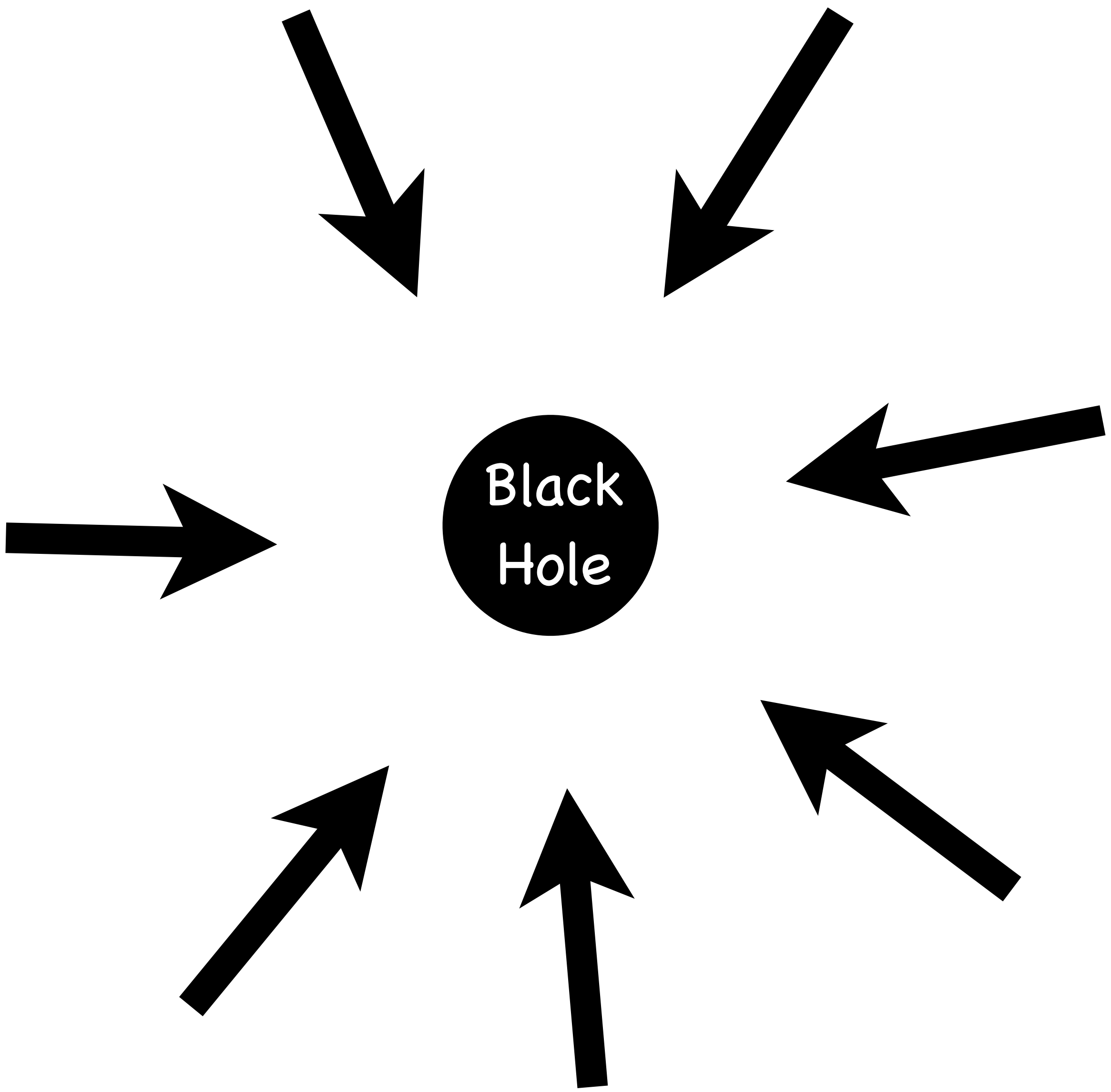
$$\mathcal{L}_\pi = \sum_{i=1}^{i=5} a_i \mathcal{L}_i ,$$

$$\mathcal{L}_1 = \pi, \quad \mathcal{L}_2 = \partial_\mu \pi \partial^\mu \pi, \quad \mathcal{L}_3 = (\partial\pi)^2 \Box\pi$$

$$\mathcal{L}_4 = -\left(\pi_{;\alpha}\pi^{;\alpha}\right)\left[2\left(\Box\pi\right)^2 - 2\left(\pi_{;\mu\nu}\pi^{;\mu\nu}\right) - \frac{1}{2}\pi_{;\mu}\pi^{;\mu}R\right]$$

$\mathcal{L}_5 = \ldots$ {complicated expression}

Testing Galileon in black hole background



Galileon accreting on black holes.

One may expect interesting effects (e.g. phantom, ghost condensate, k-essence...)

DGP scalar

Decoupling limit in DGP model (a part of Galileon)

$$S_\pi = \int d^4x\sqrt{-g}\,\left[\left(\partial\pi\right)^2 + a_3\left(\partial\pi\right)^2 \Box\pi\right]$$

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convenient rescaling,

$$x^\mu \to r_g x^\mu, \qquad \pi \to C^2 r_g \pi,$$

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$$S_\pi = r_g^4 C^4 \int d^4x\sqrt{-g}\,\left[(\partial\pi)^2 + \kappa\,(\partial\pi)^2\,\Box\pi\right], \quad \kappa = C^2 a_3/r_g$$

Eom: $\nabla_\mu j^\mu, \quad j_\mu \equiv 2\pi_{,\mu} + \kappa\left(2\pi_{,\mu}\Box\pi - \partial_\mu\,(\partial\pi)^2\right)$

accretion of DGP scalar

Metric in Eddington-Finkelstein coordinates:

$$ds^2 = -f dv^2 + 2dvdr + r^2 d\Omega$$

Ansatz:

$$\pi(v, r) = v - \int \frac{dr}{f} + \psi(r)$$

Boundary condition:

$$C^2 = \partial_t \pi|_{r=\infty} = \partial_v \pi|_{r=\infty}$$

Eom can be integrated once to give,

$$2f\psi' + \kappa \left(-\frac{f'}{f} + f f' \psi'^2 + \frac{4f^2\psi'^2}{r} \right) = \frac{A}{r^2}$$

solutions for accretion of DGP scalar (I)

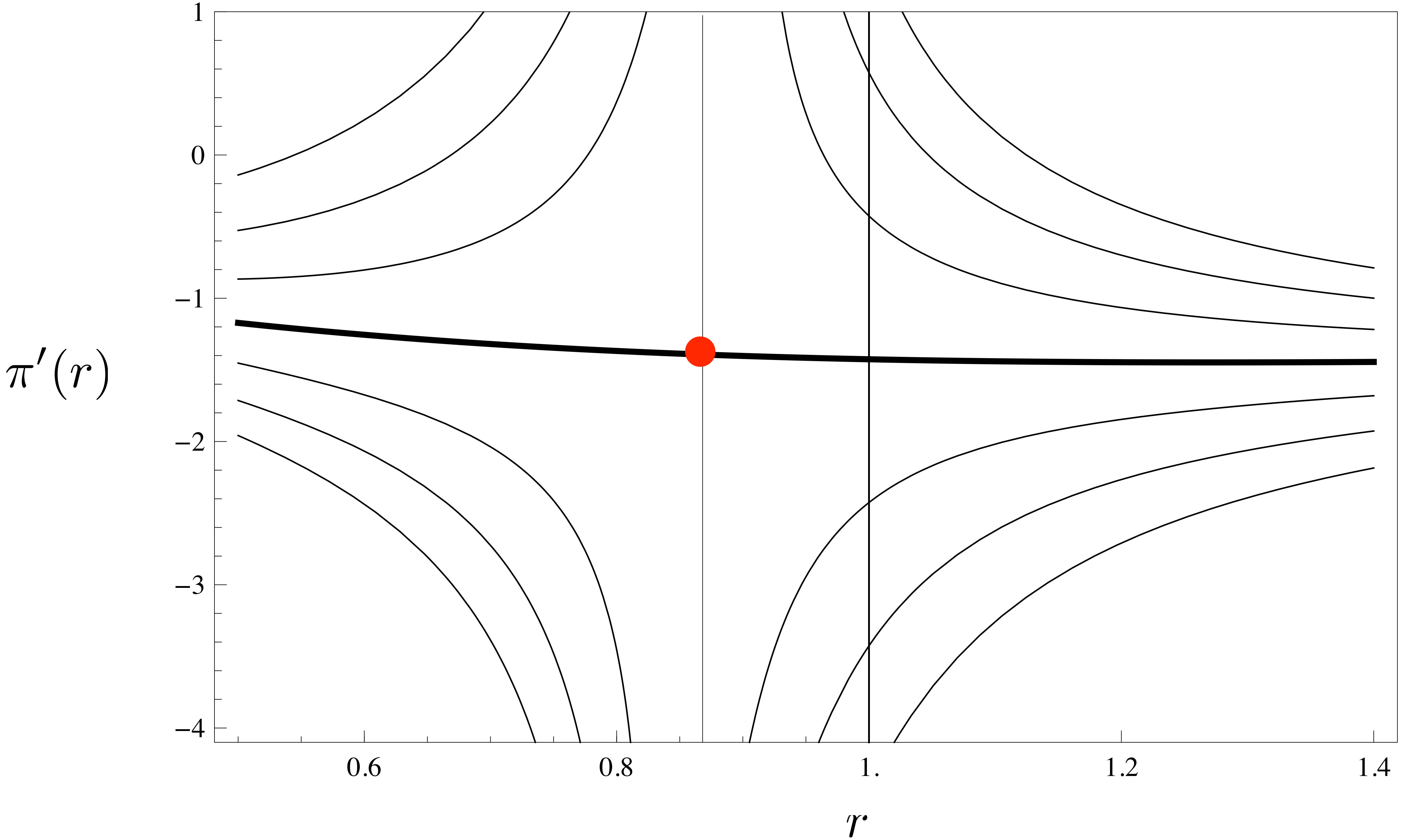
$$\psi'_{1,2} = -\frac{r^2 f \pm \sqrt{r^4 f^2 + \kappa r \left(Af + \kappa r^2 f'\right)\left(r f' + 4f\right)}}{\kappa r f \left(r f' + 4f\right)}$$

How to choose the "correct" physical solution?

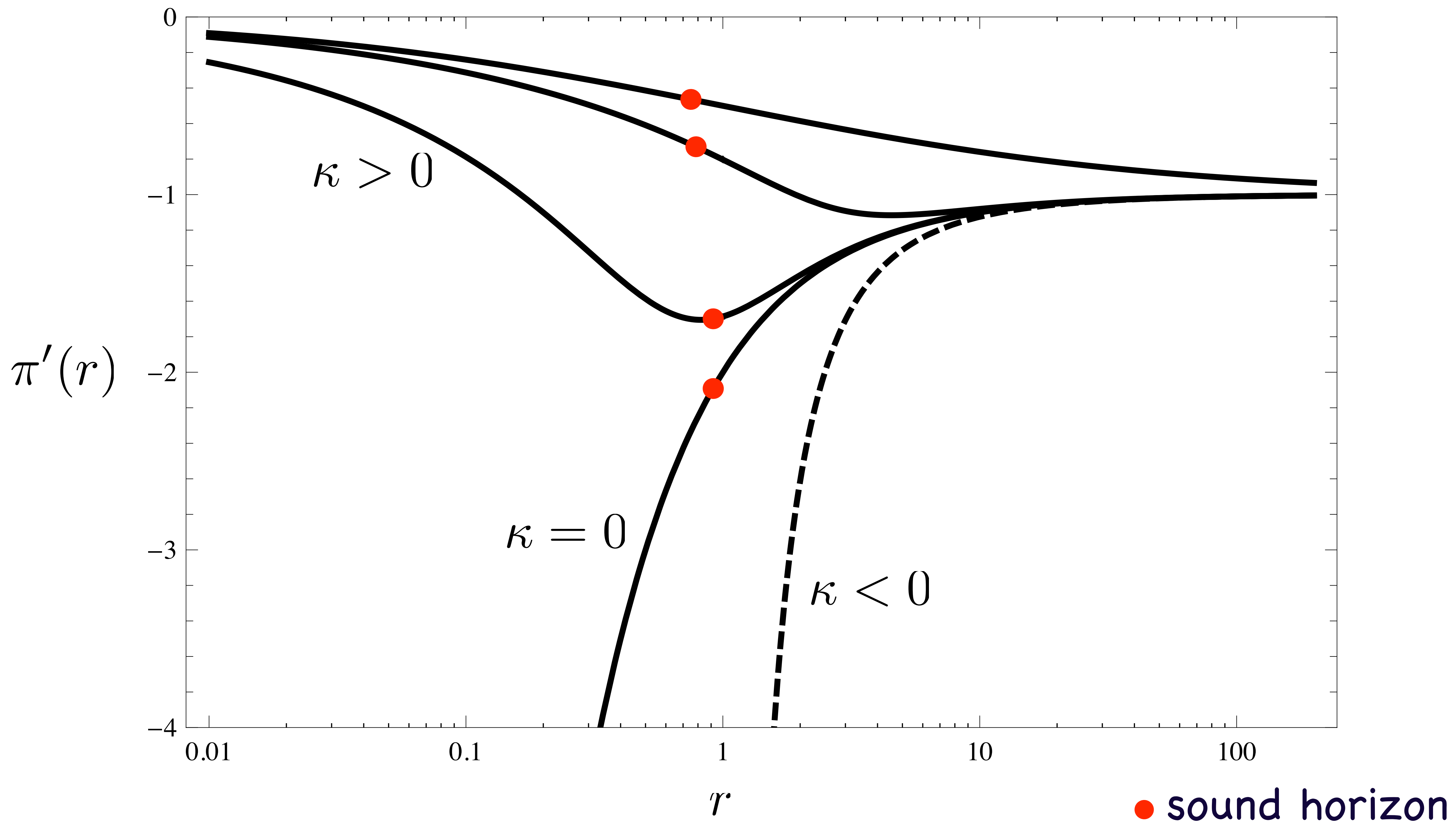
Analyze the positions of singularities in solution and the sound horizon.

$$G^{\mu\nu}\nabla_\mu\nabla_\nu\delta\pi = 0, \quad G^{\mu\nu} = \left(1 + 2\kappa\Box\pi\right) g^{\mu\nu} - 2\kappa\nabla^\mu\nabla^\nu\pi.$$

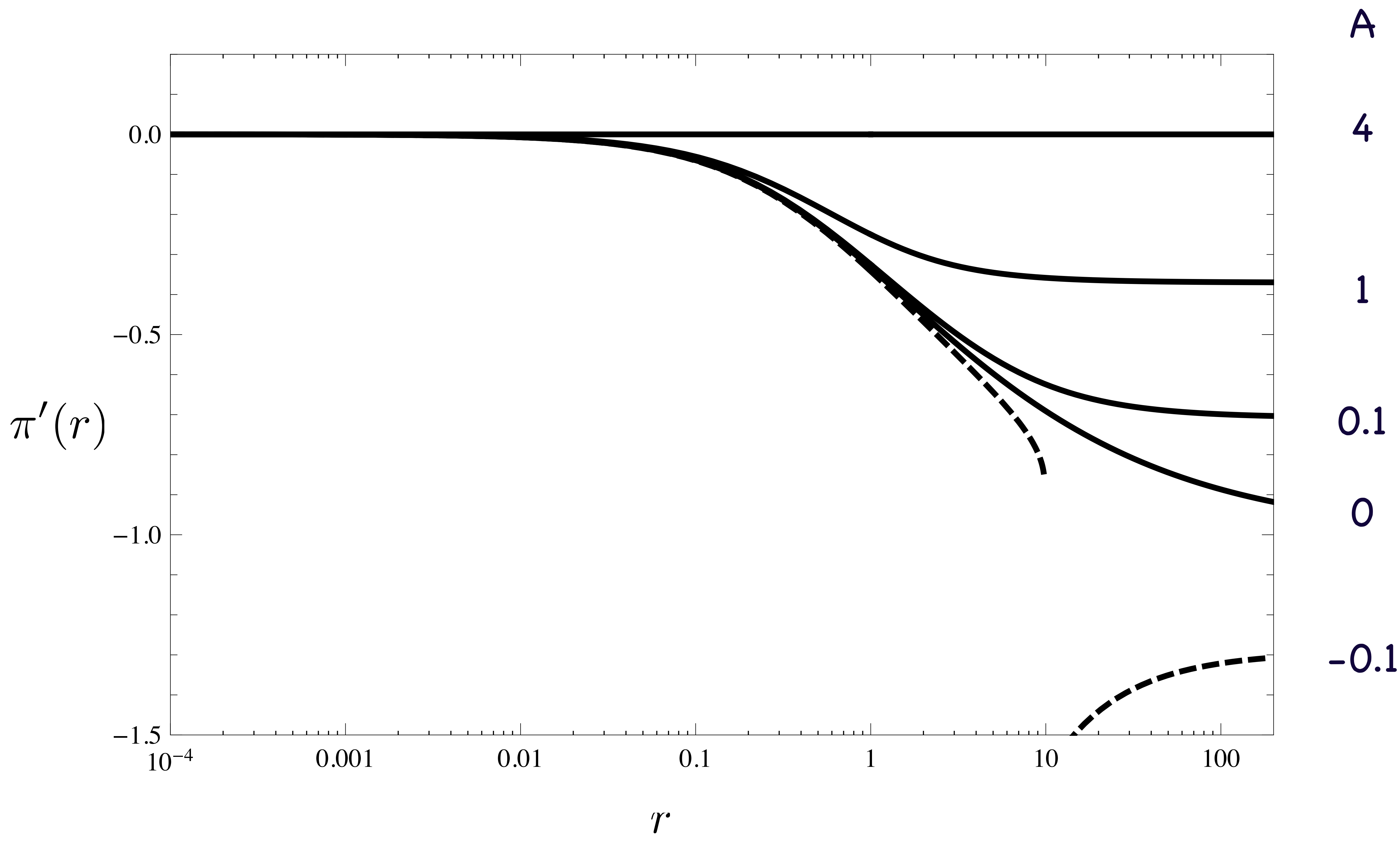
solutions for accretion of DGP scalar (II)



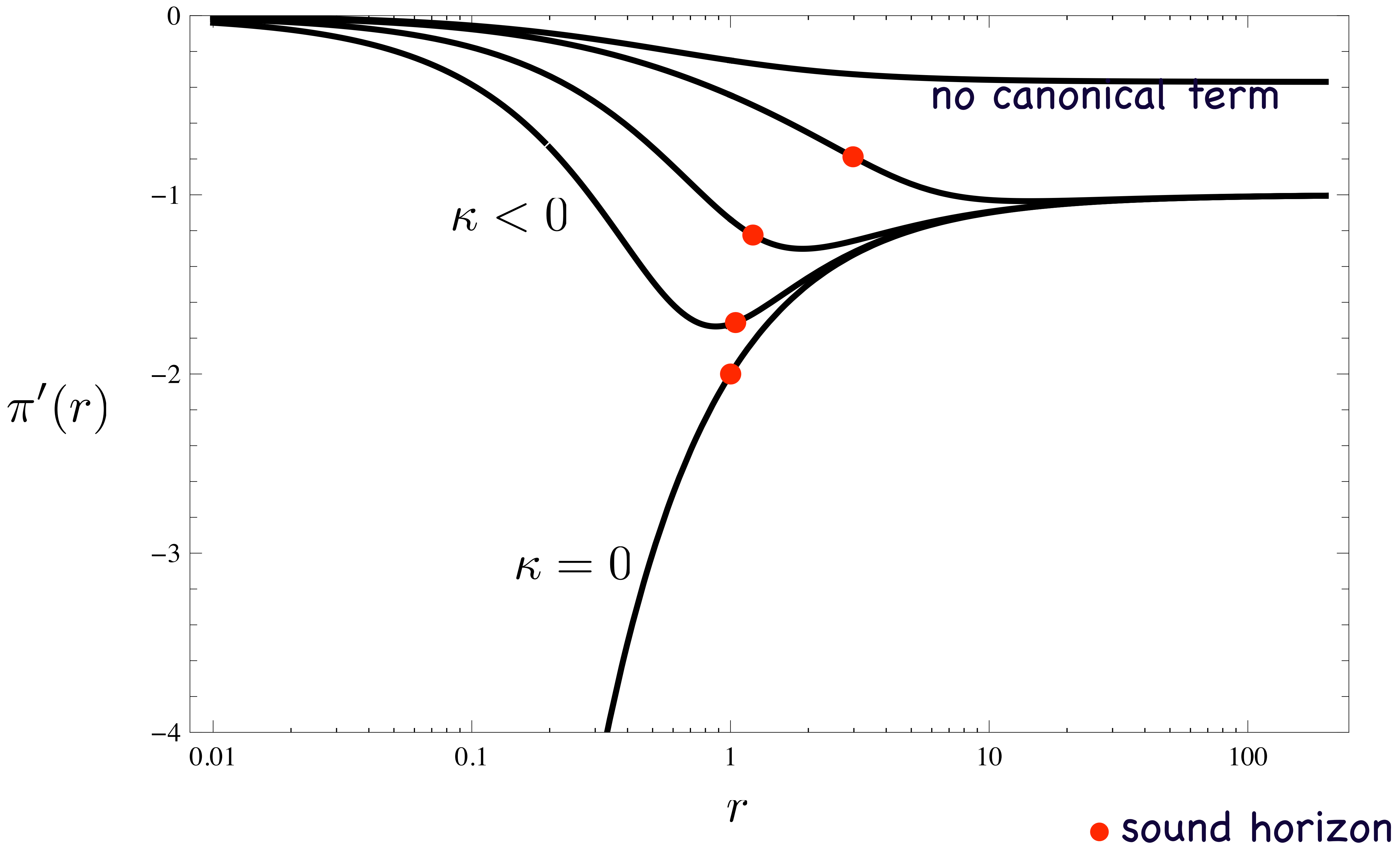
Different models



$\mathcal{L}_4$

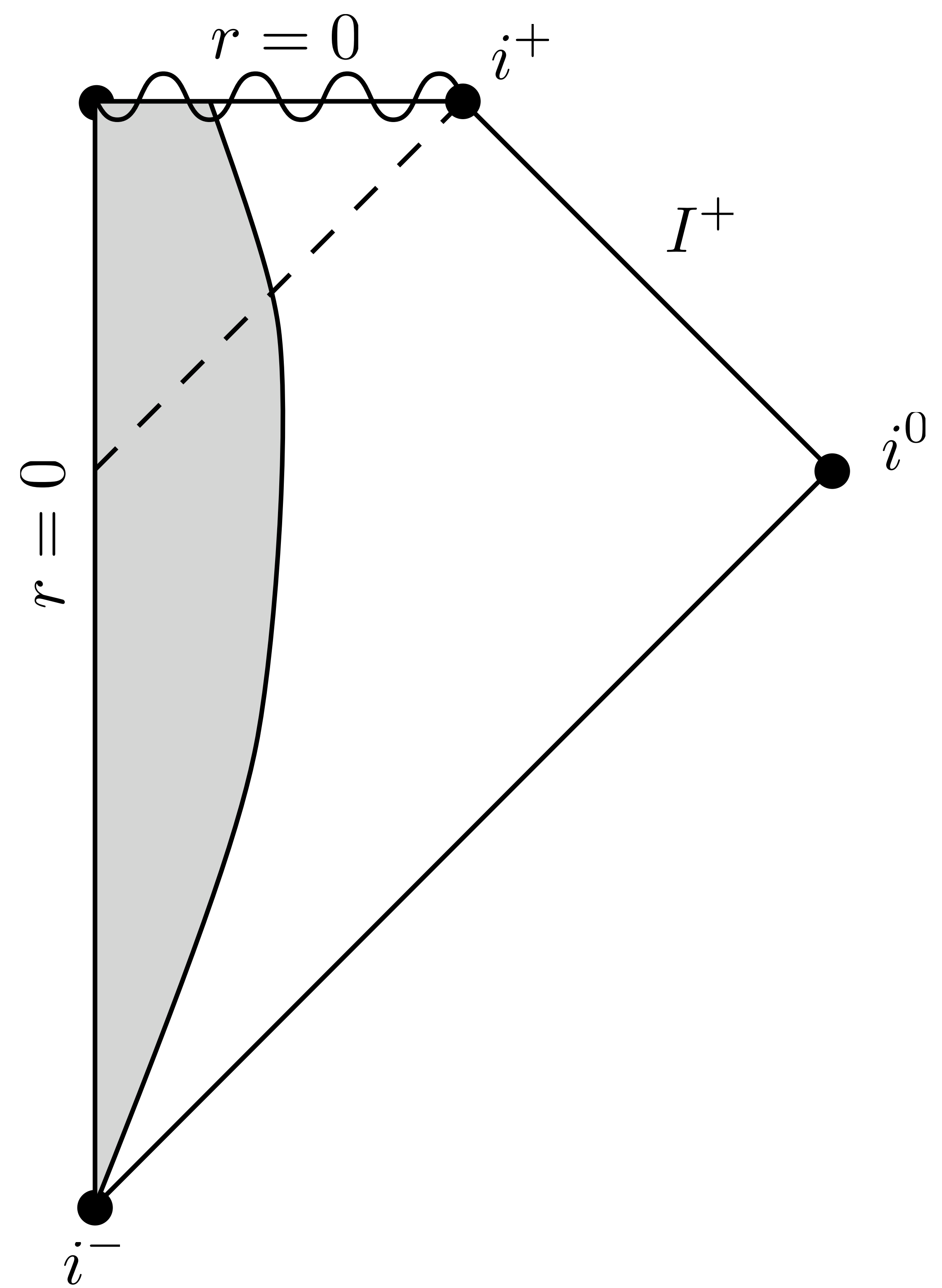


canonical term + $\mathcal{L}_4$



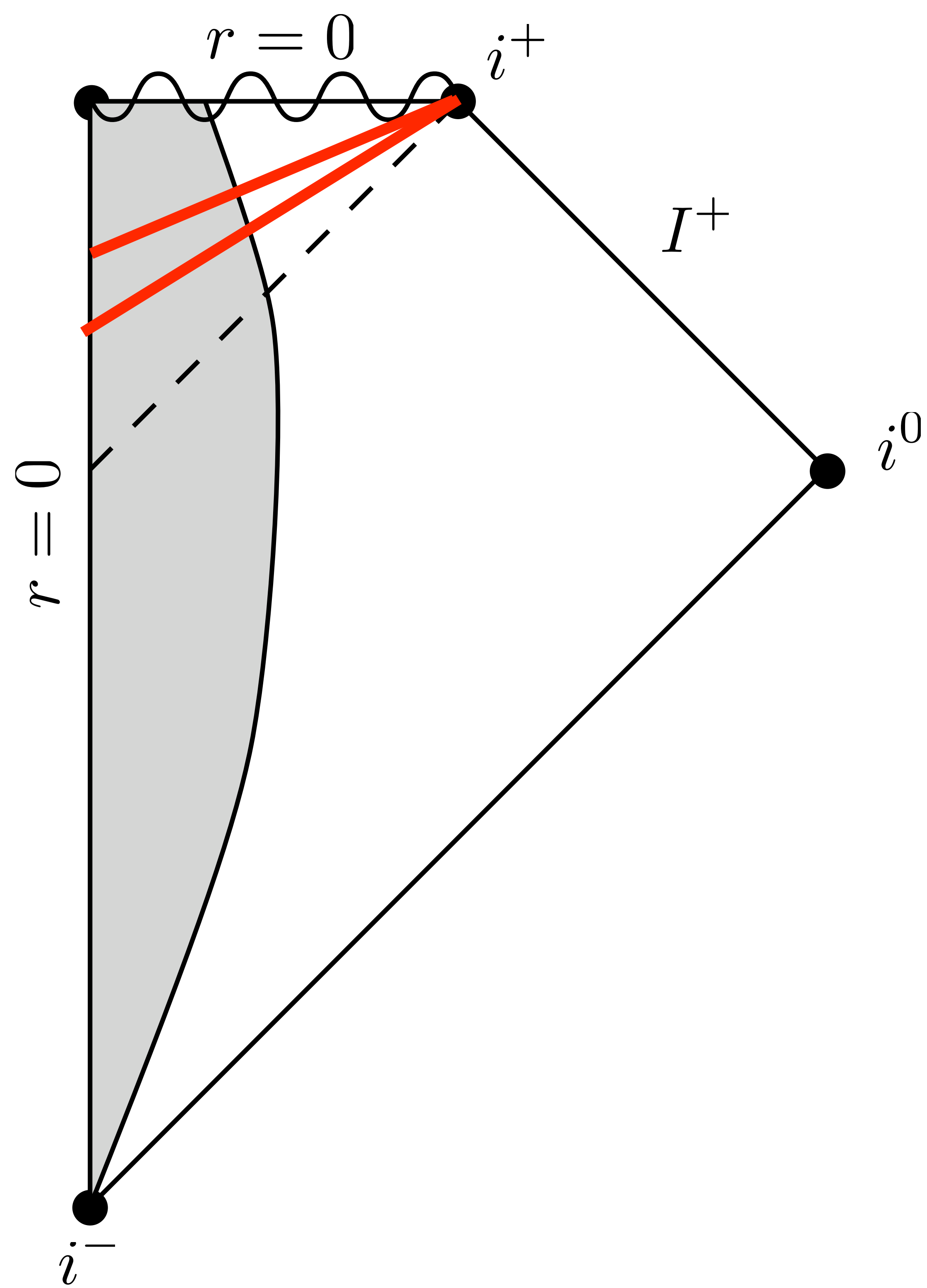
Carter-Penrose diagrams (I)

canonical term



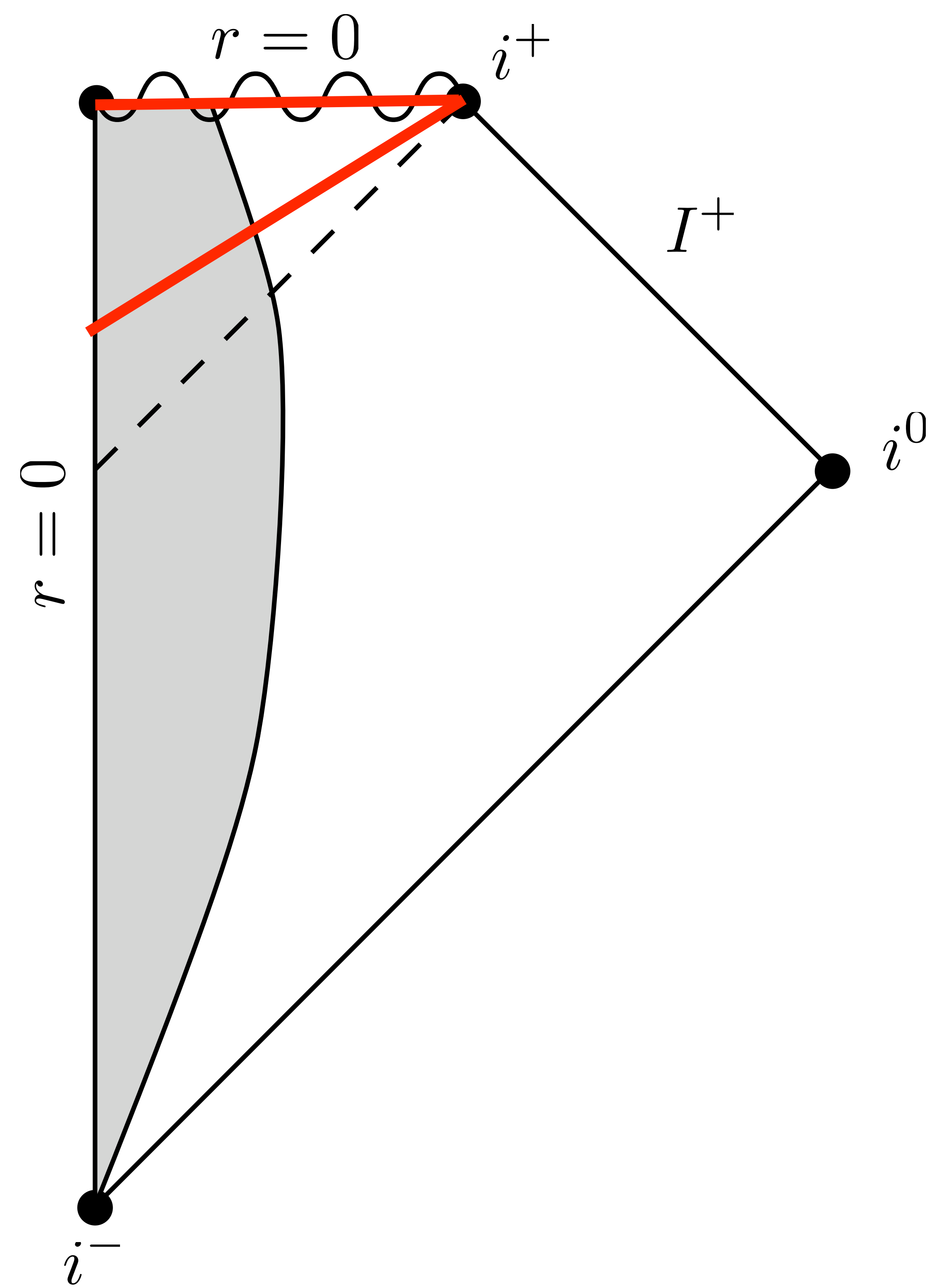
Carter-Penrose diagrams (II)

DGP scalar



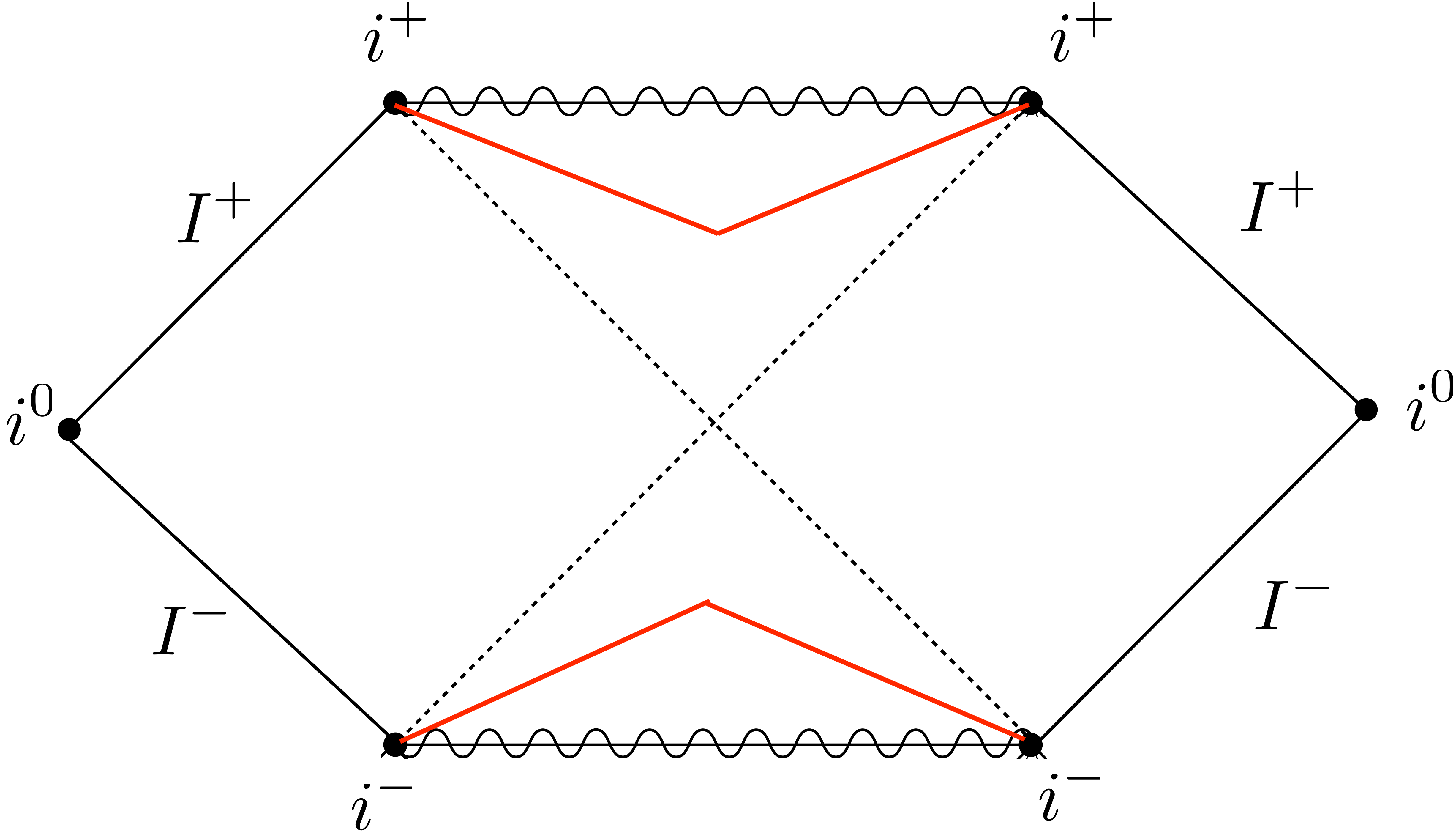
Carter-Penrose diagrams (III)

$\mathcal{L}_4$



message to/from a parallel universe?

eternal black hole



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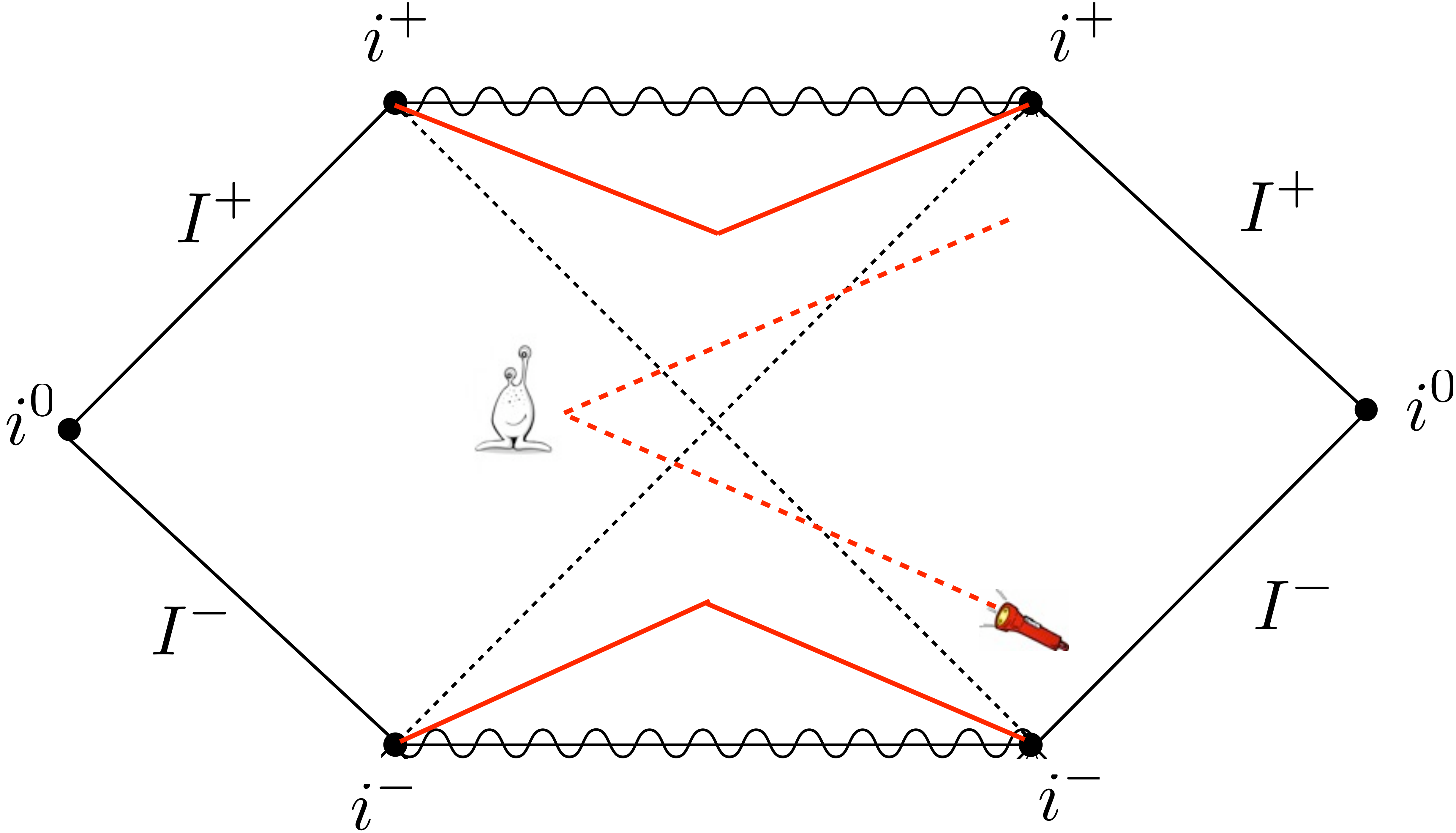

CONCLUSION

- It is possible to look inside a black hole using galileon (if the physical solution(s) exist). This is similar to superluminal k-essence.
- For a particular choice of galileon the only solutions are those with zero radius of the sound horizon.
- For some regions of parameters regular solutions do not exist.
- Are there problems for galileon if BH is included?
- Change of thermodynamics of black holes?
- Signals to/from a parallel universe?