Can ~~Kerr-NUT-(A)dS~~ Myers-Perry be charged in higher dimensions?

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(based on PRD 110, 044035 and an upcoming paper with Marcello Ortaggio)

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Motivation

- Broad motivation: Generate/classify exact solutions in higher dimensional General Relativity.
- $n = 1$ time $+ (n-1)$ space.
- Field Equations:

$$R_{ab} - \frac{1}{2} g_{ab} R + \Lambda g_{ab} = \kappa T_{ab}.$$

Exact solutions in higher dimensions

- Generalization of black hole solutions to HD:

4D	Higher dimensions
Schwarzschild, RN	Schwarzschild-Tangherlini [1]
Kerr	Myers-Perry [2]
Kerr-Newman	**???**

Table: Exact solutions in HD vs 4D GR.

- Exact solution of charged rotating black hole in HD **Einstein-Maxwell** theory has been elusive.

[1] Tangherlini. "Schwarzschild field in n dimensions and the dimensionality of space problem". 1963

[2] Myers and Perry. "Black holes in higher dimensional space-times". 1986

Outline of our work

- "Can Myers-Perry be charged?"
- Kerr-(Newman), Myers-Perry $\in$ Kerr-Schild class.
- We study electrovacuum solutions in the Kerr-Schild class and try to give a qualified answer to the question.

Overview

Kerr-Schild spacetimes

- Spacetimes whose metric can be cast as

$$\mathbf{g} = \eta - 2H\mathbf{k} \otimes \mathbf{k}$$

for some null (co)-vector field $\mathbf{k}$, scalar function H and η maximally symmetric spacetime.

Kerr-Schild structure of Kerr(-Newman)

- Kerr-Schild form of Kerr and Kerr-Newman

$$
\begin{aligned}
\eta =& - du^2 + 2dr(du + a\sin^2\theta d\phi) \\
& + (r^2 + a^2\cos^2\theta)d\theta^2 + (r^2 + a^2)\sin^2\theta d\phi^2, \\
\mathbf{k} =& du + a\sin^2\theta d\phi,
\end{aligned}
$$

- The Kerr metric is a vacuum solution with

$$
2H_{\text{Kerr}} = -\frac{2mr}{r^2 + a^2\cos^2\theta}.
$$

Kerr-Schild structure of Kerr(-Newman)

- The Kerr-Newman metric is a solution to the Einstein-Maxwell equations with

$$\begin{aligned} \mathbf{A} &= -\frac{er}{r^2 + a^2\cos^2\theta}\mathbf{k}, \\ 2H_{\mathsf{KN}} &= -\frac{2mr - e^2}{r^2 + a^2\cos^2\theta} \\ &= 2H_{\mathsf{Kerr}} + \frac{e^2}{r^2 + a^2\cos^2\theta}. \end{aligned}$$

- Explicitly, $\mathbf{g}_{\mathsf{KN}} = \mathbf{g}_{\mathsf{Kerr}} - \underbrace{\frac{e^2}{r^2 + a^2\cos^2\theta}\mathbf{k}\otimes\mathbf{k}}_{\text{Kerr-Schild transformation}}.$

Setup

- Einstein-Maxwell theory (with arbitrary Λ) in spacetime dimensions $n \geq 4$:
    1. $\mathbf{g}_{\text{Charged}} = \mathbf{g}_{\text{Einstein-KS}} - \underbrace{2\mathcal{H}\mathbf{k} \otimes \mathbf{k}}_{\text{KS transformation}}$.
    2. $\mathbf{A} = \alpha \mathbf{k}$.

Results

- Rotating BH: $\theta \neq 0 \neq \omega$ for $\mathbf{k}$.

Theorem

For the assumptions we made, a charged KS spacetime with an expanding, twisting $\mathbf{k}$ can exist **only if $\mathbf{k}$ is shearfree**.

- Kerr-Newman consistent since it has shearfree $\mathbf{k}$.

Can Myers-Perry be charged?

- Myers-Perry with any number of rotations have shearing $\mathbf{k}$.
- Hence, the charging procedure

$$\mathbf{g}_{\text{M-P}} \xrightarrow{\mathbf{A}=\alpha\mathbf{k}} \mathbf{g}_{\text{charged}} = \mathbf{g}_{\text{M-P}} - H_{\text{charge}}\mathbf{k}\otimes\mathbf{k},$$

  has no solution.
- We have a “No-Go” Theorem.
- Upcoming paper addresses: "Can Kerr-NUT-(A)dS be charged in higher-dimensions?".

Thanks for the attention.