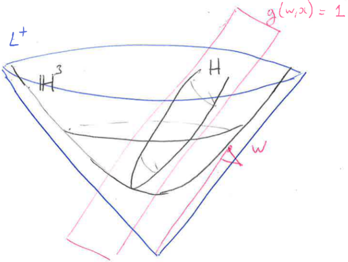
Spinors and horospheres

Daniel V. Mathews

Daniel.Mathews@monash.edu

Monash topology seminar
26 April 2023



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Paper on arXiv soon. Soon I tell you!

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General ideology: don't use vectors, use spinors for everything!

Penrose–Rindler

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Cast of characters:

- Spinor or spin vectors: elements of $\mathbb{C}^2$.
- Hermitian matrices: $A = A^*$.
- Minkowski space $\mathbb{R}^{3,1}$: coordinates (T, X, Y, Z), metric $dT^2 - dX^2 - dY^2 - dZ^2$.

How to do this?

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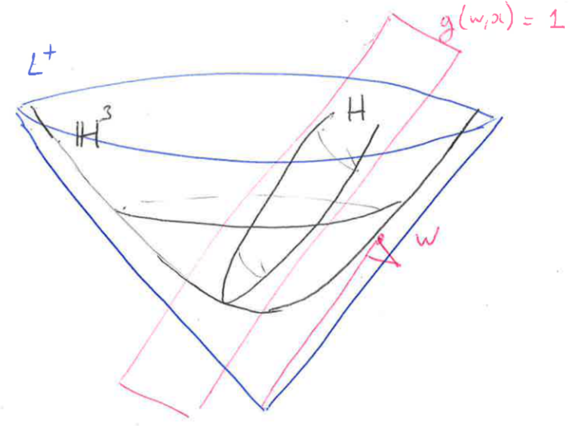
- Image ϕ $(= \phi_2 \circ \phi_1)$ = pos. light cone L^+ $(T^2 - X^2 - Y^2 - Z^2 = 0,\ T \geq 0)$

We understand some of the picture now



From $\kappa \in \mathbb{C}^2$, get a point $\phi(\kappa) = w$ on L^+.

Spinors	$\stackrel{\phi=\phi_2\circ\phi_1}{\longrightarrow}$	Pos. light cone
$\mathbb{C}^2$		L^+

Putting the spin in

$$\begin{array}{ccc} & & \text{Pointed null flags} \\ & \overset{\Phi}{\nearrow} & \downarrow \\ \begin{array}{c}\text{Spinors} \\ \mathbb{C}^2\end{array} & \xrightarrow{\phi=\phi_2\circ\phi_1} & \begin{array}{c}\text{Pos. light cone} \\ L^+\end{array} \end{array}$$

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Definition (Penrose–Rindler)

A pointed null flag is a point $p \in L^+$ together with a 2-plane V tangent to L^+ containing $\mathbb{R}p$.

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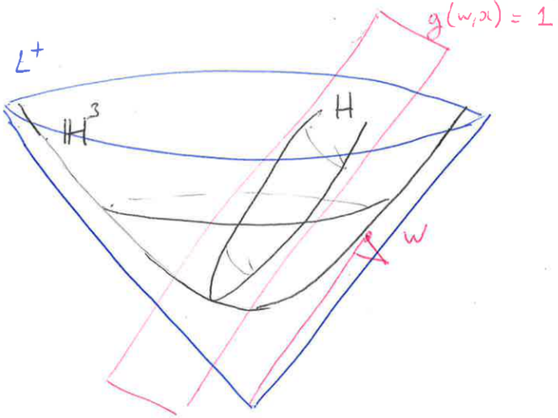

From $\kappa \in \mathbb{C}^2$, get a point on L^+ and a pointed null flag there.

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Spinoriality:

- Take $\kappa \in \mathbb{C}^2$ and consider rotating it: $e^{i\theta}\kappa$.
- $\phi(e^{i\theta}\kappa)$ is constant but $\Phi(e^{i\theta}\kappa)$ is not: plane V rotates.
- As κ rotates by θ, V rotates by 2θ.

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Robert Penner

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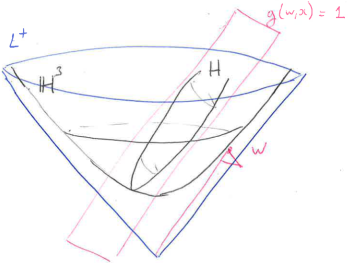
- The plane intersects hyperbolic space $\mathbb{H}^3$ $(T^2 - X^2 - Y^2 - Z^2 = 1,\ T > 0)$ in a horosphere



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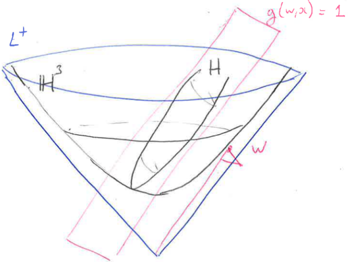

$\kappa \in \mathbb{C}^2 \overset{\text{Penrose–Rindler}}{\longrightarrow}$ Pointed null flags ($= p \in L^+$ and flag) $\overset{\text{Penner}}{\longrightarrow}$ Horospheres with $\cdots$

New developments

Theorem (M.)

There is a natural ($SL(2,\mathbb{C})$-equivariant) bijection $\mathbb{C}^2 \setminus \{0\} \longrightarrow \{$*Horospheres in* $\mathbb{H}^3$ *with spin directions*$\}$.

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$$\{\kappa, \omega\} = e^{\frac{d+i\theta}{2}}$$

Consequences:

- Ptolemy theorem for hyperbolic ideal tetrahedra
- New methods to compute hyperbolic structures on 3-manifolds (joint with J. Purcell)
- Equivalence of cluster algebras (Grassmannians / hyp. surfaces)
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Thanks for listening!

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