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Gravitational and Electromagnetic Waves on the Null Cone

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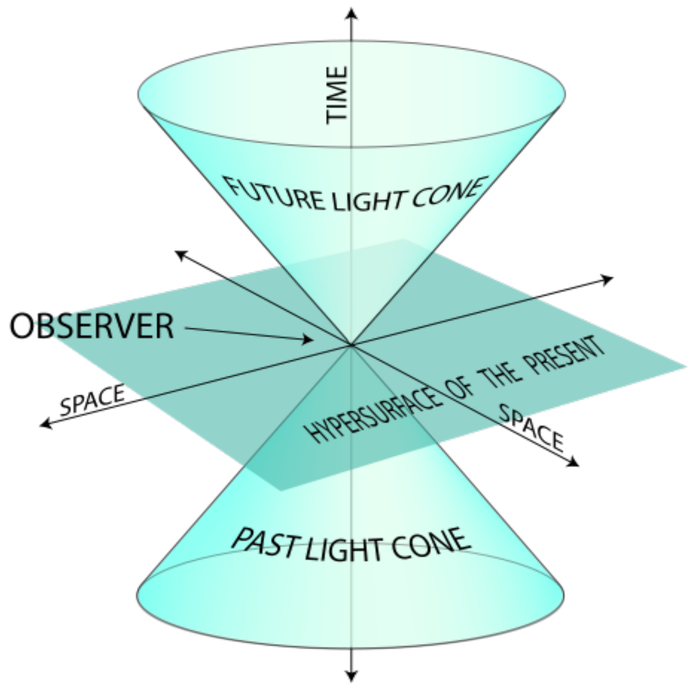
Choosing the Path

- Gravitational and electromagnetic radiation travels along ***principal null directions*** in space-time, called ***rays*** or ***characteristics.***
- Along characteristics, Maxwell's and Einstein's vacuum equations reduce to ordinary differential equations.
- The solutions are obtained by integrating along the characteristics from initial data.



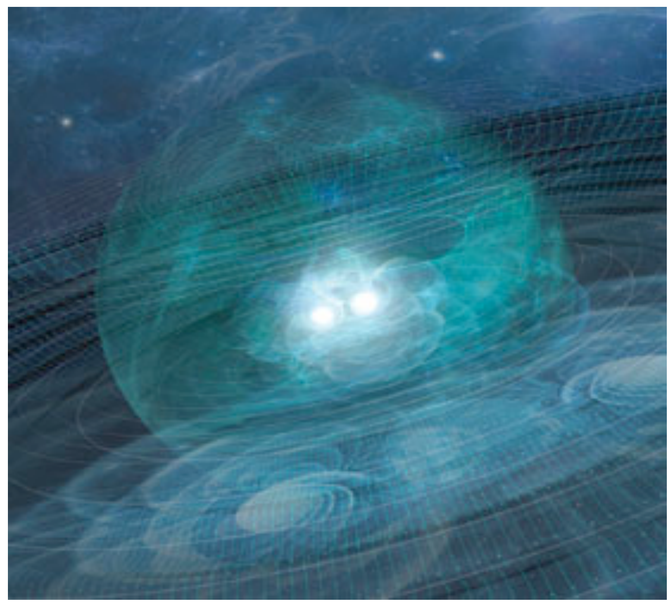
- Bondi (1962) showed that gravitational waves end up at future null infinity, where they should be measured. He found an exact metric for the gravitational waves:

$$ds^2 = -\left(e^{2\beta}\frac{V}{r} - r^2 h_{AB}U^A U^B\right)du^2 - 2e^{2\beta}dudr$$
$$- 2r^2 h_{AB}U^B dudx^A + r^2 h_{AB}dx^A dx^B$$

- He analyzed the energy radiated by a source of gravitational waves, and calculated the loss of mass by emission of gravitational waves by introducing a term called ***news***.
- In his words: *The mass of a system is constant if and only if there is no **news**. If there is **news**, the mass decreases monotonically as long as the news continues.*

Enlightening the Gravity

- Do black hole mergers produce light signals?
- Merging black holes are usually surrounded by gas, accretion disk, magnetic fields…
- Other sources of both kinds of radiation: Gamma-ray bursts, supernovae…
- Electromagnetic counterparts of gravitational waves can point to gravitational sources—help identify them & give info on the source type.
- Gravitational counterparts to visible bursts can test source models.



- Calculate the main evolution equations from the Einstein-Maxwell and Maxwell field equations for the Bondi metric.

$$R_{\alpha\beta} + 2\left(F_{\alpha\gamma}F^{\gamma}_{\ \beta} - \frac{1}{4}g_{\alpha\beta}F_{\gamma\delta}F^{\gamma\delta}\right) = 0$$

$$F_{\alpha\beta,\gamma} + F_{\beta\gamma,\alpha} + F_{\gamma\alpha,\beta} = 0;\ \ F^{\alpha\beta}_{\ \ ;\beta} = 0,\ R^{\alpha\beta}_{\ \ ,\beta} = 0$$

- Start with a simple 2D characteristic metric and a simple null electromagnetic field

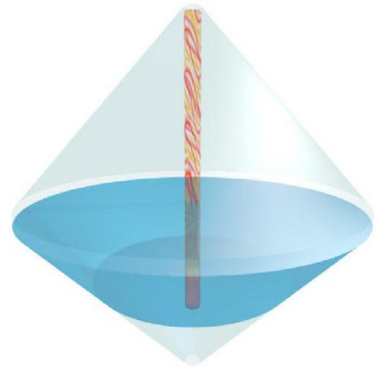
$$ds^2 = -e^{2\beta}\frac{V}{r}du^2 - 2e^{2\beta}dudr$$
$$+ r^2(d\theta^2 + \sin^2\theta d\varphi^2)$$
$$F = F_{u\theta}du\wedge d\theta + F_{u\varphi}du\wedge d\varphi$$
$$+ F_{r\theta}dr\wedge d\theta + F_{r\varphi}dr\wedge d\varphi$$

Adding to the News

- The radiated energy will be given by four Bondi News: *two for the gravitational part and two for the electromagnetic part*
- The loss of mass by emission of gravitational and electromagnetic radiation:

$$M_{,u} = -\frac{1}{2}\int_0^{\pi}(N_{\oplus}^2 + N_{\otimes}^2 + X_{\leftrightarrow}^2 + X_{\updownarrow}^2)\sin\theta d\theta$$

A New Null Code



- Our current **PITT NULL CODE** models pure gravitational radiation at null infinity.
- From this, I am developing a new version incorporating electromagnetic waves.
- To do this, translate the Einstein-Maxwell field equations on a Bondi Metric into a form suitable for numerical integration and write a new characteristic code, including the lessons learned from the past regarding:
  - Stability and well-posedness
  - Accuracy and convergence
  - Initial data on the worldtube
- Collaborators welcome!

  I would be happy to have collaborators for this project, including a possible post-doc (depending on funding).
  - Contact me: babiuc@marshall.edu

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