Faster-Than-Light Electromagnetic Sources

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Outline

- What can go faster-than-light?
- Rectilinearly accelerating sources
- Properties of superluminal sources
- How to simulate a superluminal source with a phased array
- Results of superluminal theory
- Applications to astrophysical objects
- Questions and comments

What can go faster-than-light?

- Einstein's theory of special relativity
  - No particle (or information) can go faster-than-light (i.e. superluminal).
- But there is no restriction on phase speeds or patterns of particles.
- Examples include:
  - Phased arrays of polarization currents
  - "Laser on the moon" analogy
  - Astrophysical systems

Rectilinearly accelerating sources

- Sources of electromagnetic radiation that accelerate in a straight line.
- Simple motion described by:

$$x(t) = x_0 + v_0 t + \frac{1}{2} a t^2, \; y(t) = y_0, \; z(t) = z_0$$

- However, since superluminal sources cannot be point-like, one must consider a moving pattern of sources.

Properties of superluminal sources

- As seen in supersonic theory, when a source exceeds its wave speed, a cusp is formed:

How to simulate superluminal sources

- Phased array of electric dipoles
  - The phase speed can be arbitrarily high
  - Fix a reference frequency *f*, and set delay times τ_k
  - The electric field can be calculated as follows:

$$\vec{E}(x,y,z,t)=\sum_{k=1}^{n}\frac{\vec{P}_k e^{2\pi i f(\tau_k - t + \rho_k/c)}}{\rho_k},\quad \tau_k=\frac{x_k}{\sqrt{v_0^2+2ax_k}}$$

$$\rho_k(x,y,z)=\sqrt{(x-x_k)^2+(y-y_k)^2+(z-z_k)^2}$$

Example: Doppler effect

- If $v_0 = 0.8c$, $v_f = 0.8c$, $n = 32$ (dipoles)

Example: Cusp radiation

- If v_0 = 0.8c, v_f = 2.0c, n = 32 (dipoles)

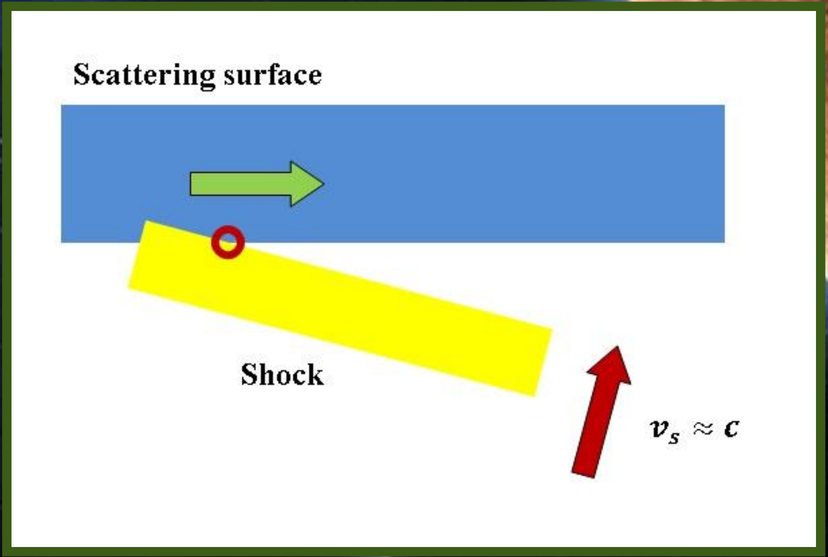
Results of superluminal theory

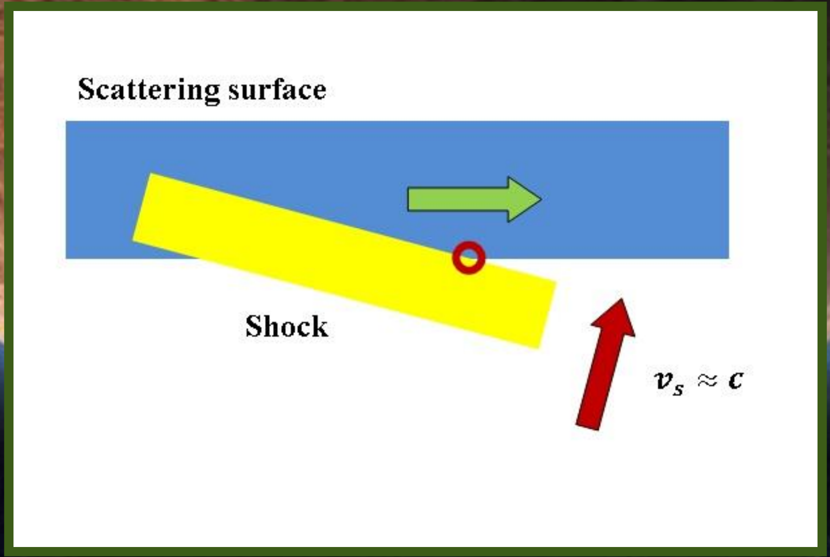
- The cusp inherently focuses energy.
- The cusp arises from source emission regions that approach the observer at the speed of light with zero acceleration.
- The power along the cusp decays slower than $1/r^2$ causing objects to appear brighter than expected at longer distances.
- Energy is conserved since the power decays faster than $1/r^2$ when not along the cusp.

Applications to astrophysical objects

- The rotating source is applicable to rapidly rotating objects interacting with a medium outside of its light cylinder such as pulsars.
- The rectilinear source can be applied to gamma ray bursts when considering a relativistic shock colliding with a surface at a small angle to form a superluminal source.
- Different accelerations are possible depending on the shapes of the surface and shock.

Simplified example of a shock





A shock colliding with a surface at two times. Note: the boundary of intersection (red circle) travels faster than the shock itself.

Questions and Comments

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