Inductive particle acceleration

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UHECR and the Hillas (Blandford/Waxman/Lovelace) limit

- $E < ZeBL$, can be expressed in terms of the dimensionless "strength parameter" $a_{\rm L} = 3.4 \times 10^{14} L_{46}^{1/2}$, as $E < m_{\rm e} c^2 a_{\rm L} \approx 10^{20} L_{46}^{1/2}$ eV.

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- Note: assuming $B.r =$ constant may be unduly restrictive. . .

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- The resulting centrifugal force causes bulk radial acceleration.
- Explicit solutions (using perturbation theory) lead to a maximum energy similar to the unipolar inductor mechanism, but the underlying physics is very different.

Where is it important?

- *In pulsar winds, as an explanation of the Crab flares*

PRL **119,** 211101 (2017) PHYSICAL REVIEW LETTERS week ending 24 NOVEMBER 2017

Inductive Spikes in the Crab Nebula: A Theory of γ-Ray Flares

John G. Kirk* and Gwenael Giacinti†
Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany
(Received 29 August 2017; published 21 November 2017)

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- *In AGN jets?*

Corrected version of ApJ 729, 104 (2011)
Preprint typeset using LaTeX style emulateapj v. 08/13/06

arXiv:1012.0307

CHARGE-STARVED, RELATIVISTIC JETS AND BLAZAR VARIABILITY

John G. Kirk and Iwona Mochol
Max-Planck-Institut für Kernphysik, Postfach 10 39 80, 69029 Heidelberg, Germany
Corrected version of ApJ 729, 104 (2011)

ABSTRACT

High energy emission from blazars is thought to arise in a relativistic jet launched by a supermassive

Pulsars: the striped wind

- Vacuum wave + plasma rearranges itself into ‘step-function’ wind

  Michel 1971, 1982

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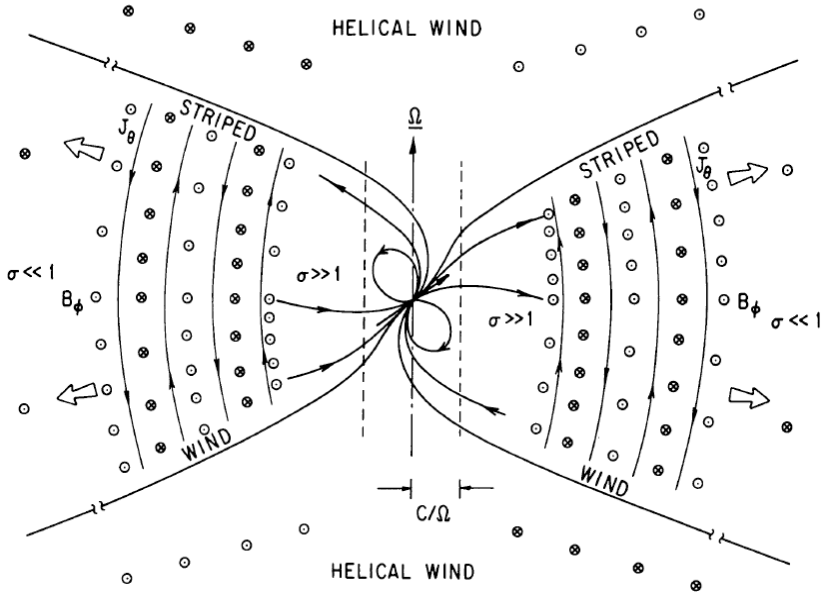
- Michel ’94: *“We show here that the reconnection process is simply inductive heating, which allows it to be calculated without appeal to existing phenomenology surrounding reconnection”.*



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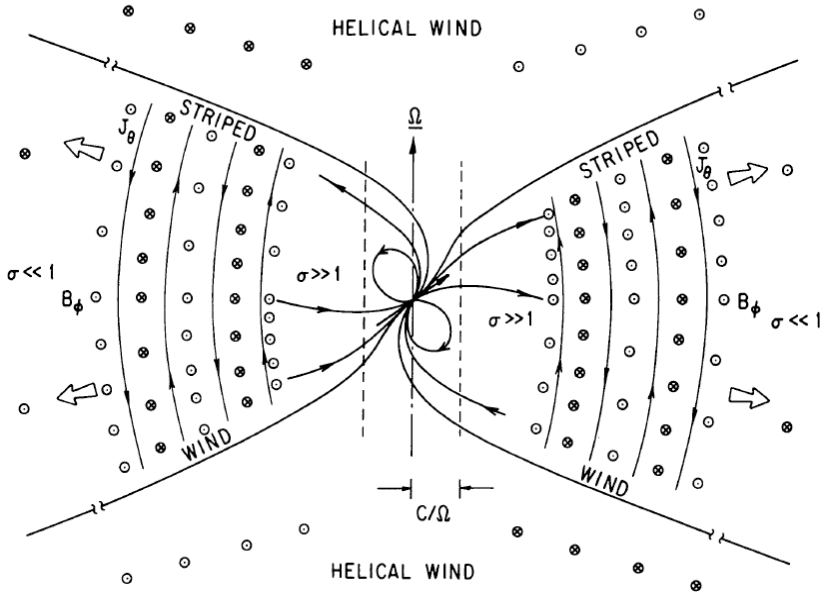

Bulk acceleration neglected!

Lyubarsky & JK (2001), Spruit et al (2001), Spruit & Drenkhahn (2002)

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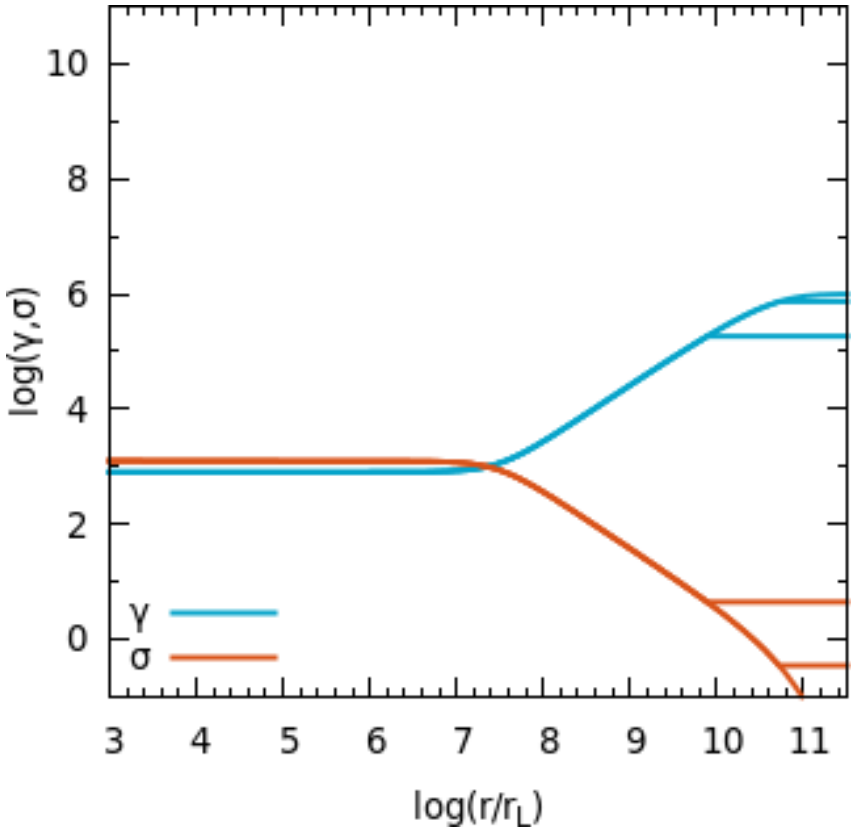
  3. Coasting, wave fully dissipated



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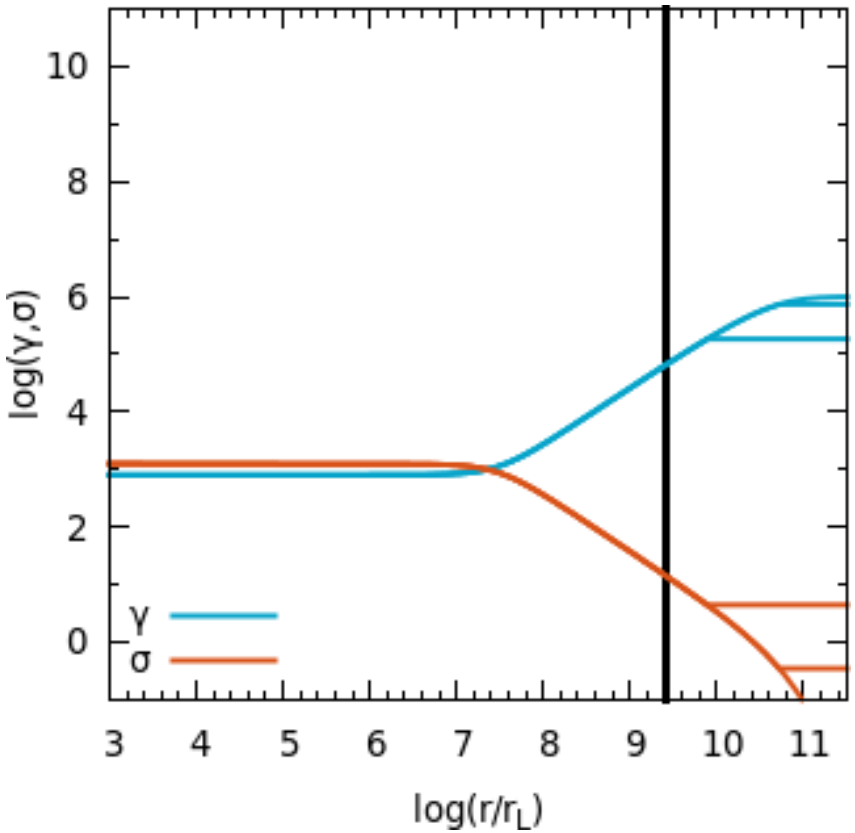

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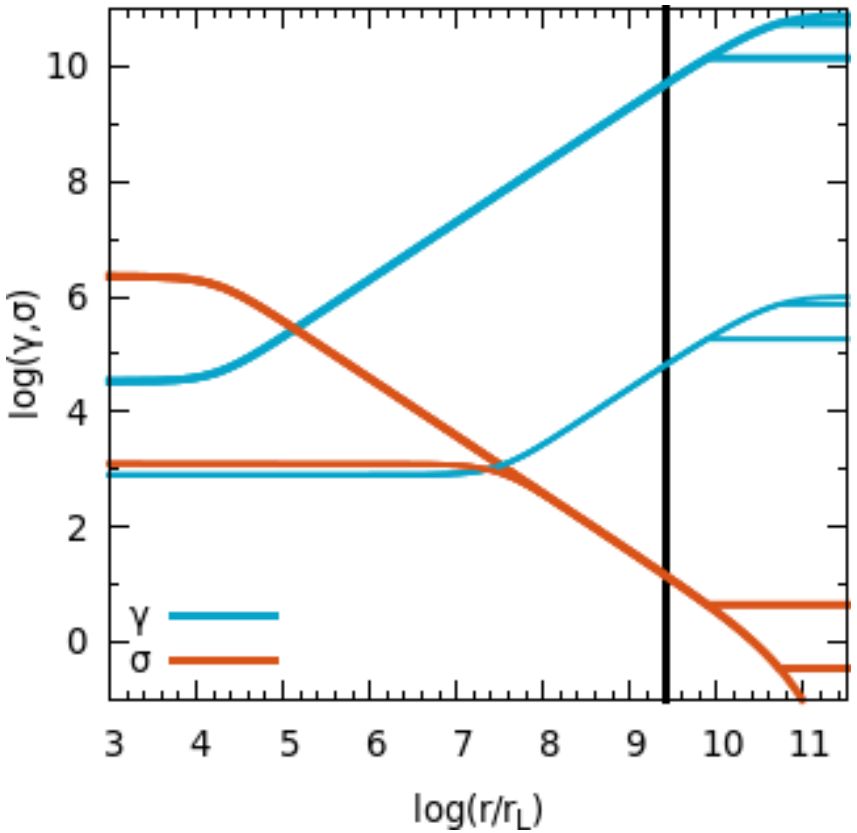

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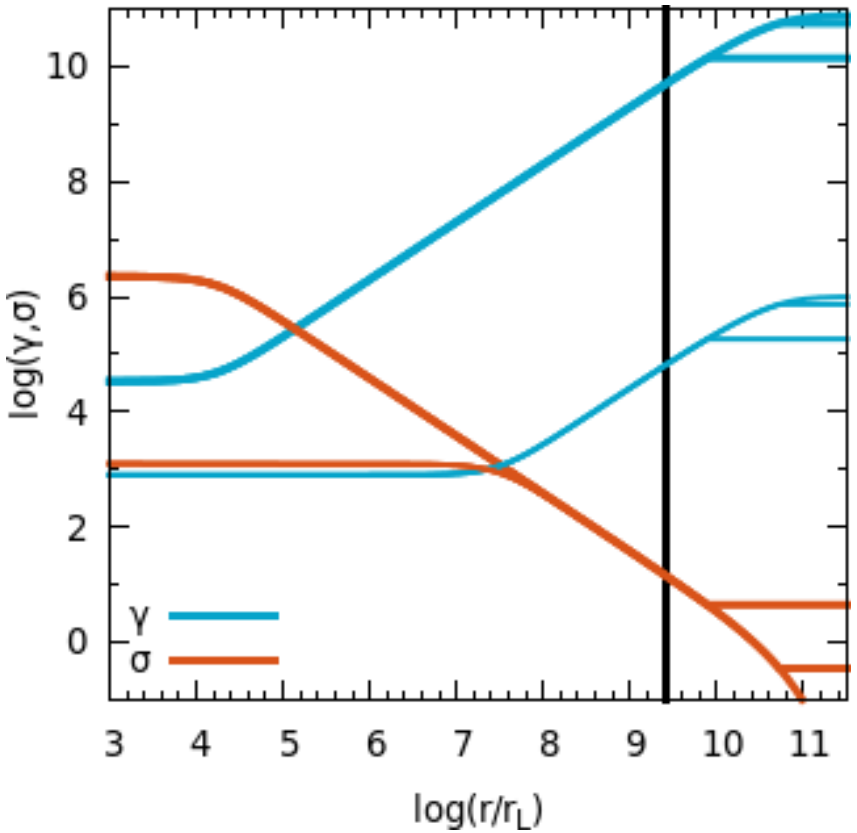
What happens when ions are added?



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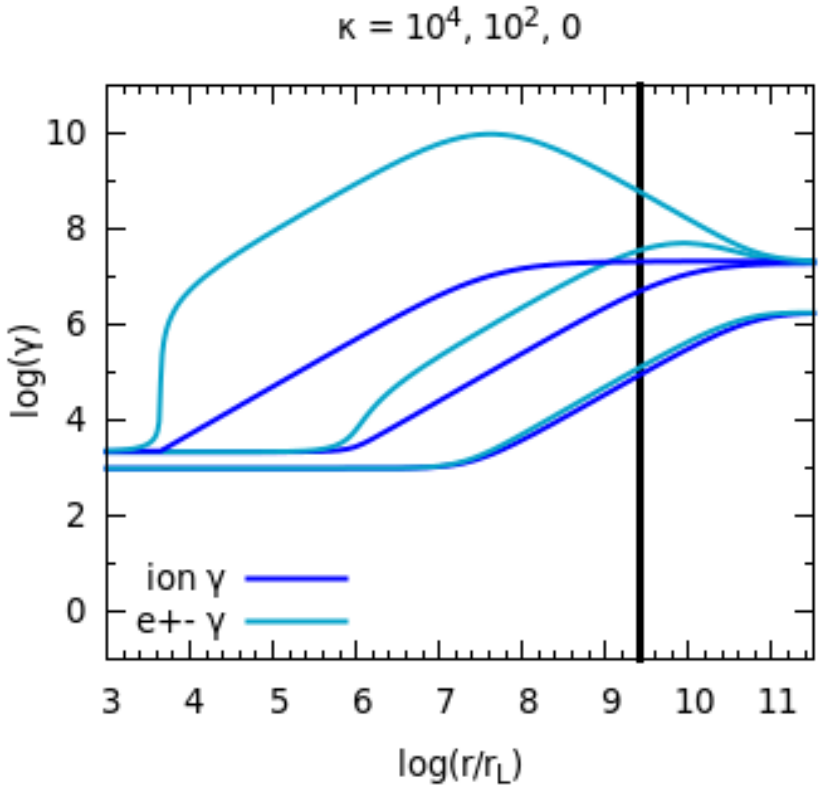
- $\kappa \gg 1000$: pairs dominate, protons achieve same Lorentz factor.



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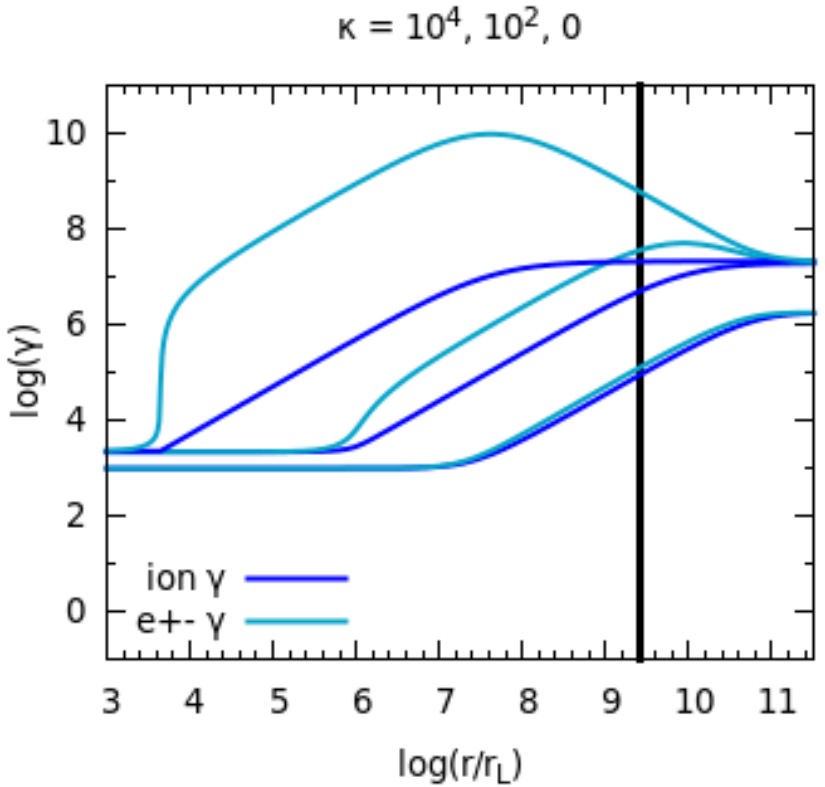

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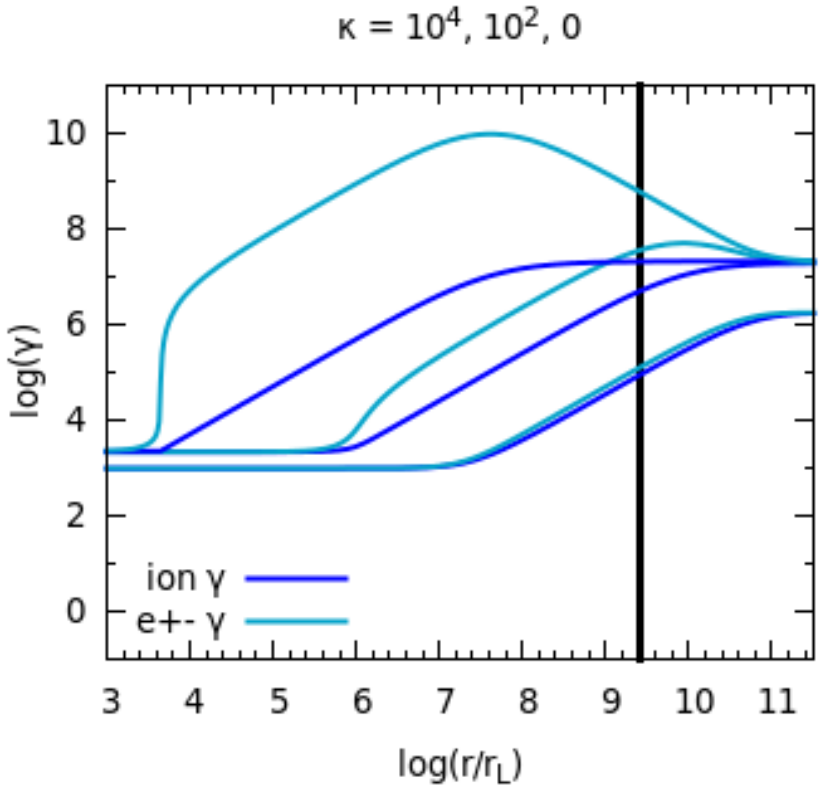

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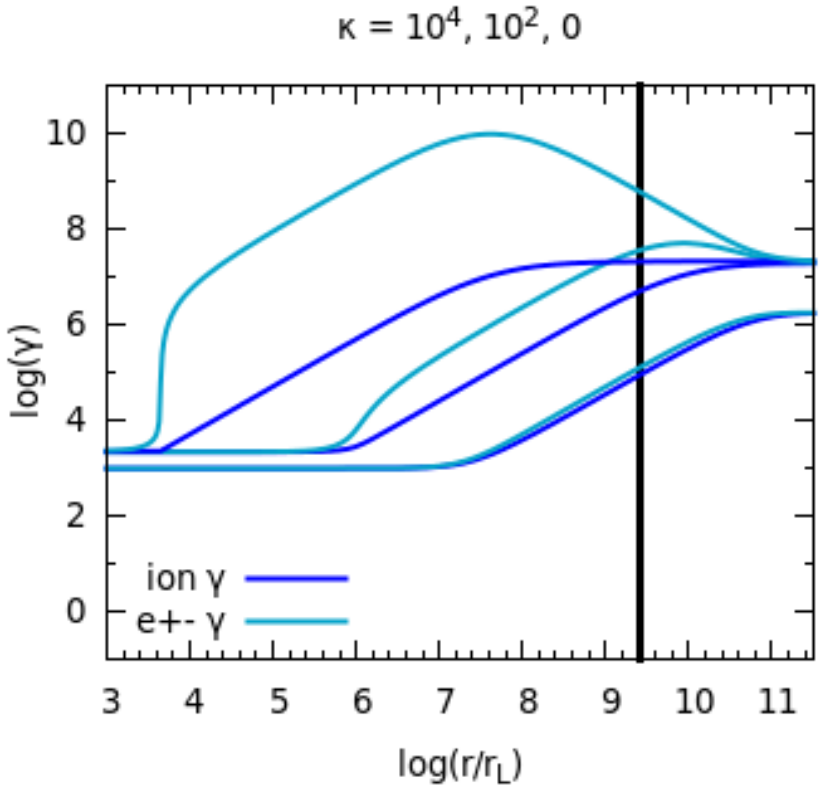
- Opening angle of the electron beam $\gg$ proton beam.



A mechanism for UHECRs?

For ions injected with the GJ charge-density:

$$\gamma_{\rm max} \approx Z a_{\rm L} m_{\rm e} / \left[2 \left(A m_{\rm p} + Z m_{\rm e} \left(1 + 2\kappa \right) \right) \right]$$

so need $Z a_{\rm L} \gtrsim 10^{13}$ for a 10^{19}eV accelerator.

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- similar powers are emitted in each species if the wind terminates during the acceleration phase,
- the acceleration is radial, not caused by a drift in latitude,
- because of this, the Hillas limit, expressed as $E < Za_{\rm L} m_{\rm e} c^2$, could, in principle, be exceeded if very few particles ($<$ GJ density) are injected. However, perturbation theory ("reconnection fields" $\ll$ regular field) breaks down in this regime.