SAND2014-16413D

Micropinch Plasma Concepts for Creation of Low Kappa Distribution Plasmas

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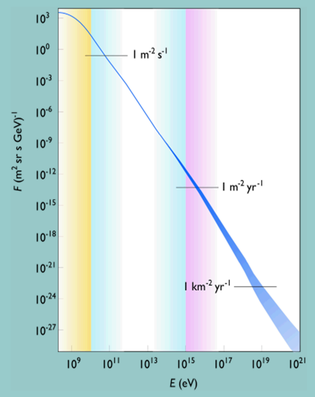
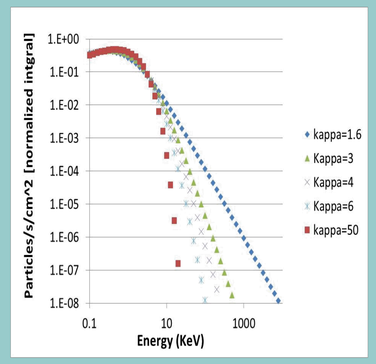
What is the Challenge?

Historically x ray production and neutron yields in small pinch machines (<10kJ) are consistent with highly non-thermal velocity distribution functions. These velocity distributions can be modeled with kappa distributions or power law functions. A distinguishing feature of low kappa plasmas is particles whose peak kinetic energy can be many times the applied voltage. We illustrate how small machines (Joule to kJ) may be used to create low kappa plasmas in order to understand this interesting regime and to study these plasmas as a source of non-thermal particles. We argue for performing these experiments on a small scale in high rate machines to more quickly understand the underlying physics. We illustrate with old experimental results and modeling how these plasmas create the distributions and how the work relates to basic physics in astrophysical plasmas.



An example of a cosmic ray spectrum.
Swordy, S.P., 2001, Space Science Reviews 99(1-4): 85.

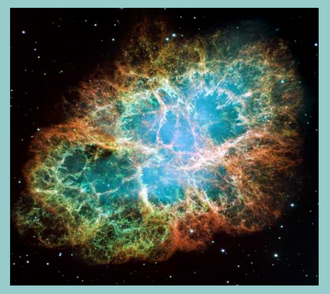


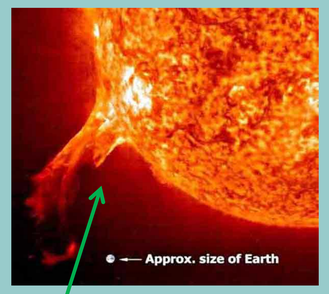
Kappa distribution Note the large number of orders of magnitude difference between the Maxwellian and a kappa distribution. The distributions fit to various portions of the heliosheath and other space plasmas.

By using the kappa temperature $k_B T_\kappa$ and introducing particle energy $E = (1/2)mv^2$, we can convert $f_\kappa(v)$ into the density distribution $F_\kappa(E)$ (cm^{-3} keV^{-1}) as

$$F_\kappa(E) = \frac{2N_\kappa\sqrt{E}}{\sqrt{\pi(k_B T_\kappa)^3}} \frac{\Gamma(\kappa+1)}{(\kappa-3/2)^{3/2}\Gamma(\kappa-1/2)} \times \left[1+\frac{E}{k_B T_\kappa(\kappa-3/2)}\right]^{-(\kappa+1)} \quad (2)$$

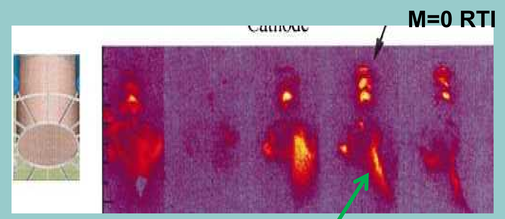
What is the Physics? Instabilities, particularly Rayleigh-Taylor, appear to involve large amounts of mass. See Crab Nebula.





Not all of this is RTI (see solar flare)

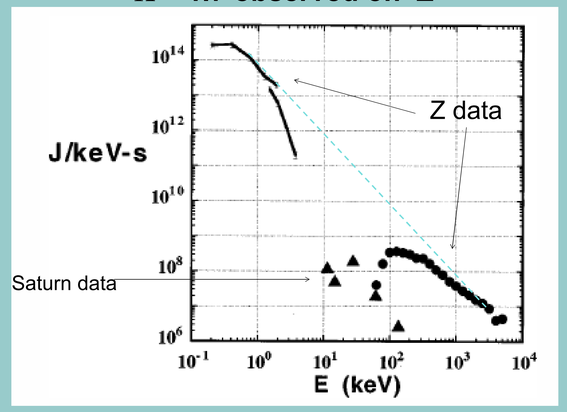
Kappa Distribution and other Plasma Dynamics Is Accessible for Study in Laboratory Plasmas

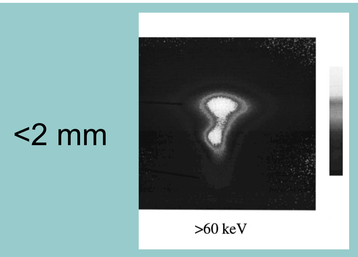


Jet Plasma Similar to Solar Flare

Framing Camera Image of Soft x ray Emission from the SNL Z machine. From Left. Cad image of target prior to firing, time integrated frame, 3-frames in order until last image 5 ns apart.

K ~ 1.7 observed on 'Z'



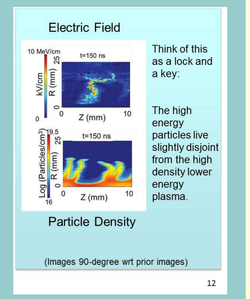


<2 mm

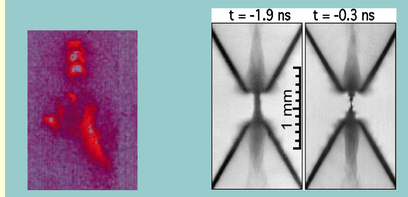
'Z' machine hard x ray image from foam target

We Propose to Build High Data Rate, Small Devices, to Study Plasma Dynamics

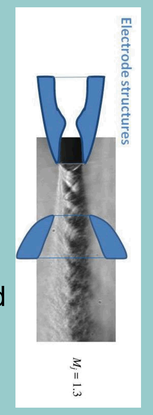
Using Repetitively operated
High pressure controlled nozzles
Densities above 10^{17}/cc density in novel micro gas puff configurations to study non thermal effects



Access traditional and novel Gas Configurations with New Concepts



MEMs Valve And Nozzle set



Why?

Basic Science **Rocket Thruster**

Accelerators
- efficient devices for many GeV/m

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