Light superconducting strings in our galaxy

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511 KeV gamma rays

Observation: 511 KeV gamma rays from Milky Way center.

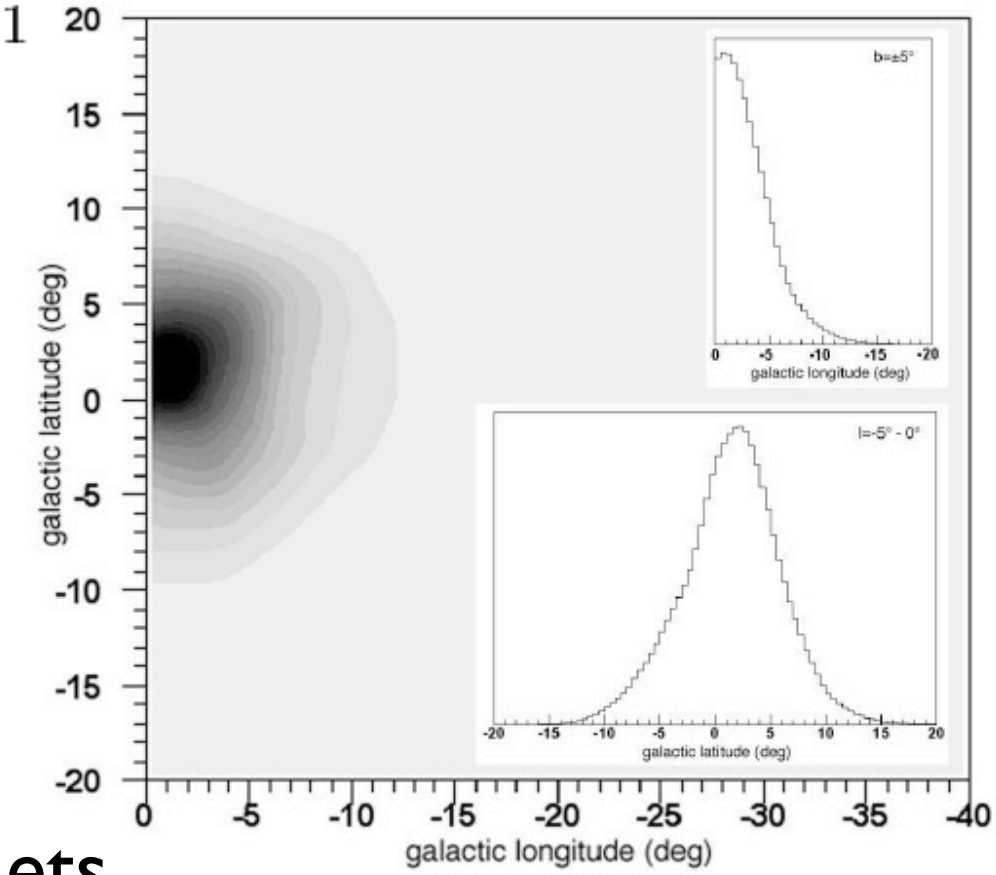
Flux: $9.9^{+4.7}_{-2.1} \times 10^{-4}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$

Astrophysical scenarios:

neutron stars, black holes,
supernovae, hypernovae,
gamma ray bursts, ...

Other scenarios:

dark matter annihilation,
color superconducting droplets...



Jean et al; Knoedsleder et al

511 KeV: explanations

Astrophysical scenarios proceed by producing radioactive nuclei/antineutrons in an energetic explosion that then decay by positron emission. Other radioactive decay signals must also be present. There is considerable uncertainty in SN/HN rates, and a suppressed signal from the disk is hard to explain.

Dark matter annihilation/decay strongly constrained by bremsstrahlung and inflight annihilation. Mass of DM particle has to be less than 3 MeV.

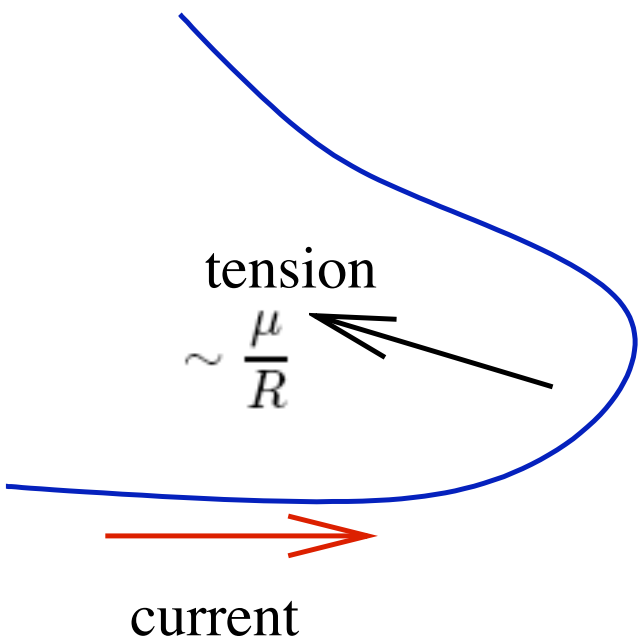
Beacom et. al.

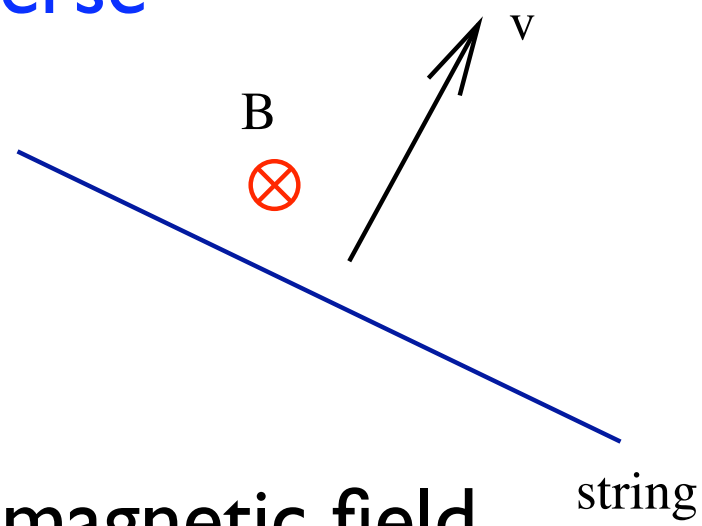
Low energy, diffuse source needed in the bulge (but not the disk).

Superconducting strings

Zero modes: Caroli, de Gennes & Matricon; Jackiw & Rossi
Superconducting cosmic strings: Witten

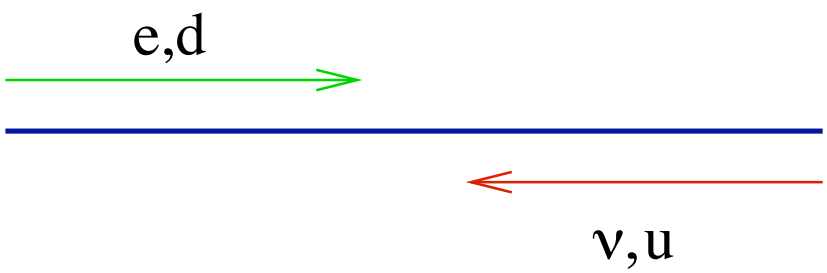
Superconducting strings are predicted in many particles physics models and would have been formed in the early universe





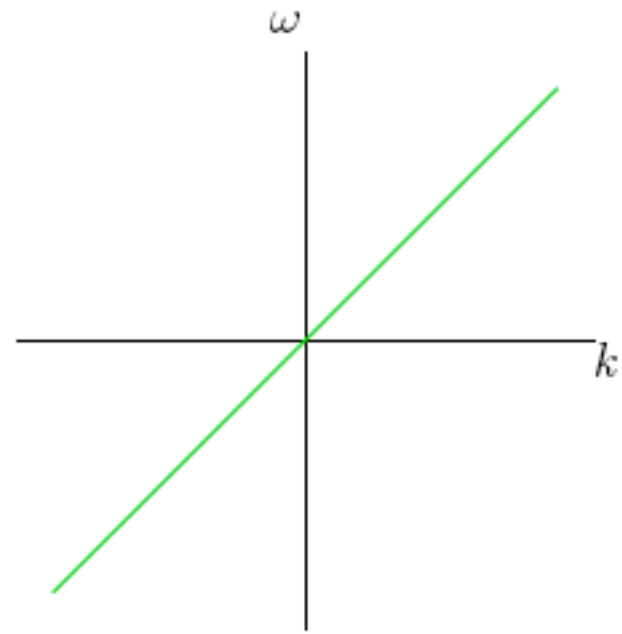
Motion in magnetic field, generates currents via Faraday's law.

Particles on the string



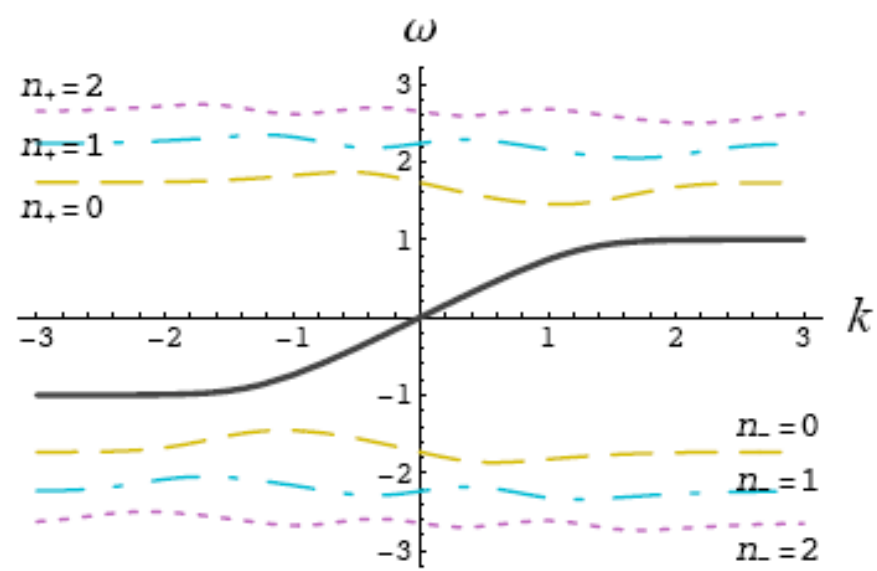
No external magnetic field:

$$\omega_k^0 = +k$$



In external magnetic field:

$$\omega_k = m_f \tanh\left(\frac{k}{k_*}\right)$$

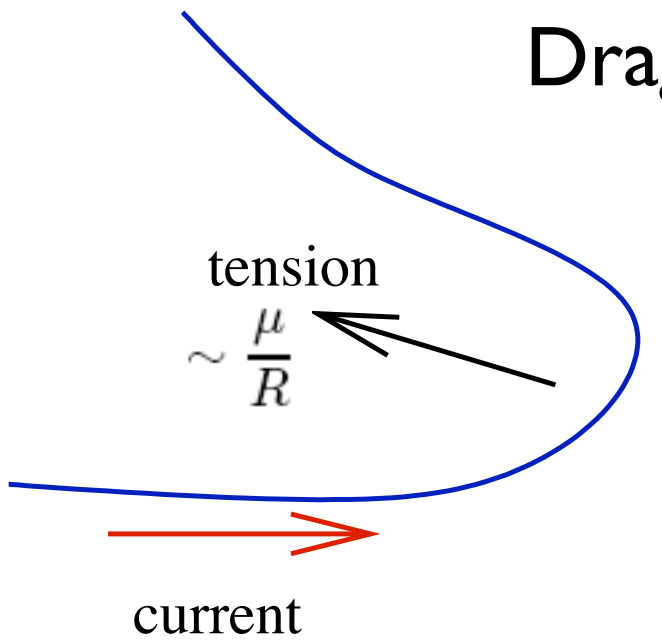


Ferrer, Mathur, Vachaspati & Starkman

Strings in a plasma

Chudnovsky, Field, Spergel & Vilenkin

String+plasma behaves like a solid cylinder.



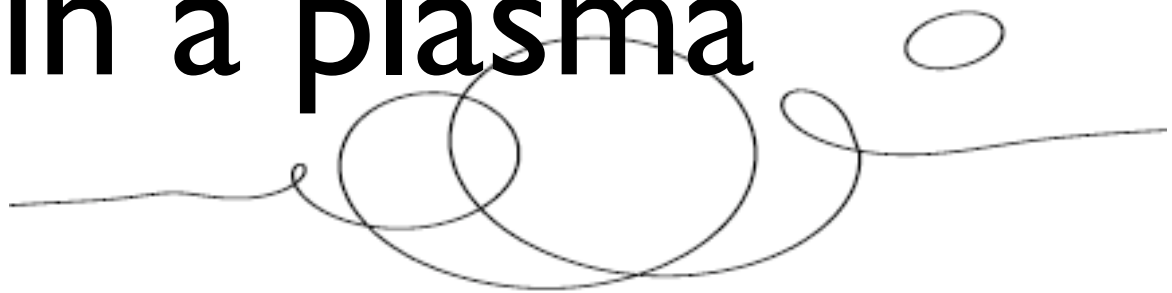
Drag force on cylinder:

$$F_d \sim \rho v_{\rm rel}^2 r_s \sim \sqrt{\rho} v_{\rm rel} J$$

Terminal velocity:

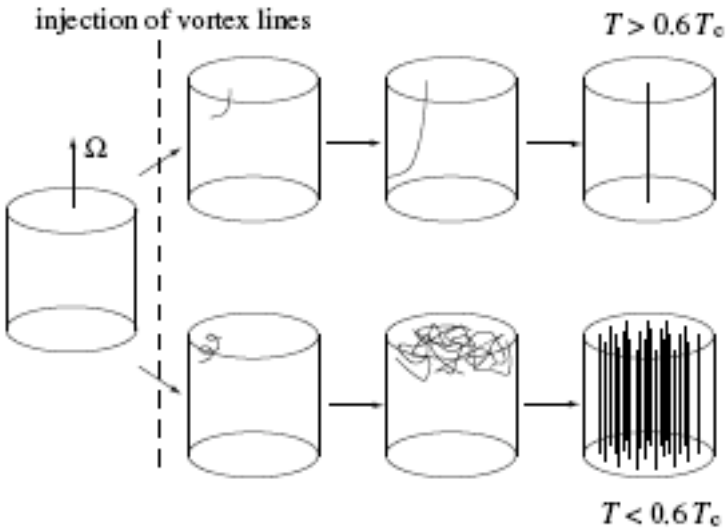
$$v_{\rm term} \sim \frac{\mu}{\sqrt{\rho} J R}$$

Strings in a plasma



Motion of plasma drags strings and turbulence produces a tangle of strings.

Helium-3 experiments (Helsinki)

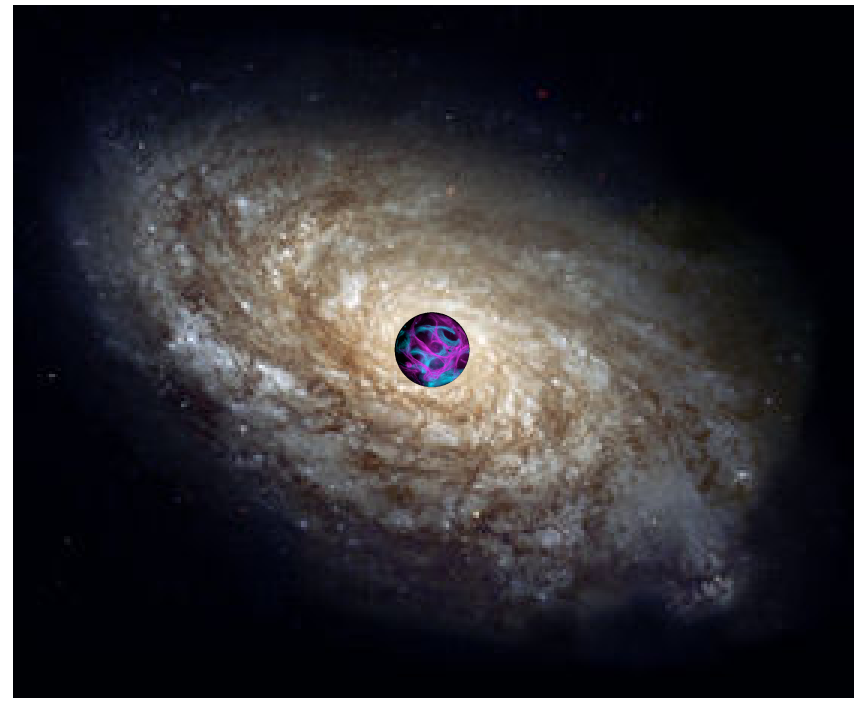


A. Finne et al

Tangle properties

Motion of galactic plasma drags strings and galactic turbulence produces a tangle of strings.

Ostriker, Thompson & Witten
Chudnovsky & Vilenkin



Take string energy scale: 1 TeV

String curvature scale:

$$R_* \sim 5 \cdot 10^{15} \mathrm{cm}$$

String energy density:

$$\rho \sim 4 \cdot 10^{-36} \mathrm{g/cm}^3$$

Superconducting strings and 511 KeV

Ferrer & Vachaspati

As current builds up, charge carriers (e.g. positrons) leak off string, into ambient medium.

*Positrons leak off *at mass threshold*.*

Ferrer, Mathur, Vachaspati & Starkman

$$\frac{dN_+}{dt} \sim 10^{42} \kappa^{7/5} B_3 l_{100}^{-3} \mu_1^{-7/5} \rho_{\rm gc}^{7/10} \left(v_{l_6} l_{100}\right)^{12/5} \ {\rm s}^{-1}$$

Easily gives observed flux of positrons: $9.9^{+4.7}_{-2.1} \times 10^{-4} \ {\rm cm}^{-2}{\rm s}^{-1}$

Predictions

511 KeV flux proportional to B.

B weaker in disk:

Flux from disk $\sim 10^{-6}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$

Sagittarius a bit further away too:

Flux from Sagittarius $\sim 10^{-7}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$

Predicted fluxes from disk and Sagittarius are much smaller than MeV dark matter predictions.

Flux works out only for light (1 TeV) strings.

Future missions

To test astrophysical scenarios:

Better angular resolution to test for point sources.

Good energy resolution to search for other lines.

To test string scenario:

Search for signal from disk and Sagittarius.

Look for signatures due to emission of other particles from strings (e.g. antiprotons).

Conclusions

- 511 KeV gamma emission may be explained by light superconducting strings
- positron flux tracks galactic magnetic field
- other tests include flux of 511 KeV from Sagittarius, galactic disk
- antiproton flux also predicted

Starkman & Vachaspati

- strings must be light (order 1 TeV scale)