Cosmic Strings and the 21cm Signal at Cosmic Dawn

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(Based on 1810.03219 and 1902.08282)

Institut Spatial de McGill

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Outline

- String Refresher

- Cosmic String Cusps

- (Normal) Cosmic Strings and 21-cm Emission

- Superconducting Cosmic Strings

Cosmic String Refresher

- Can form at cosmological P.T.s
- Core consists of exotic particles coupled to the standard model
- Probe of fundamental physics from the top down!
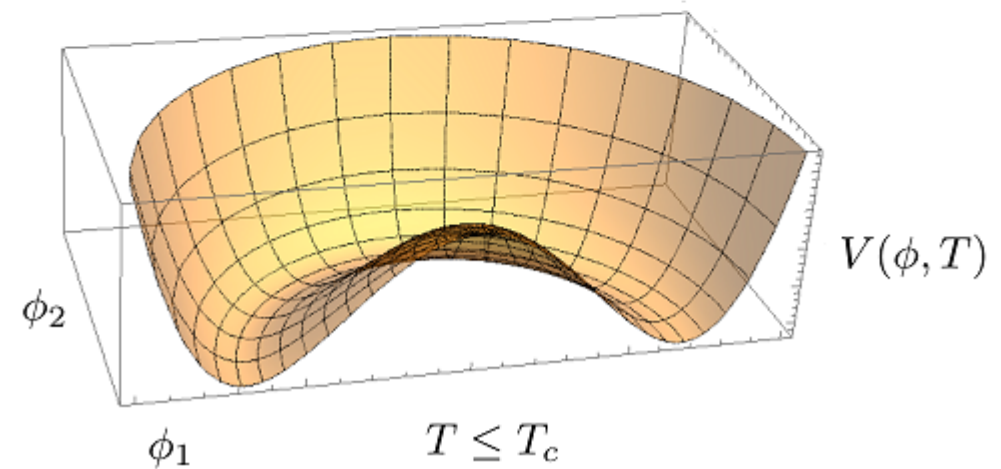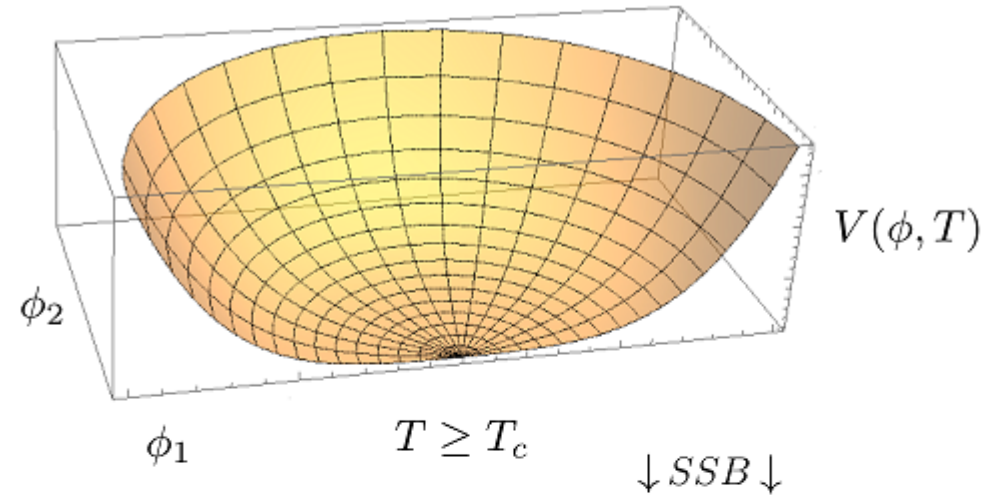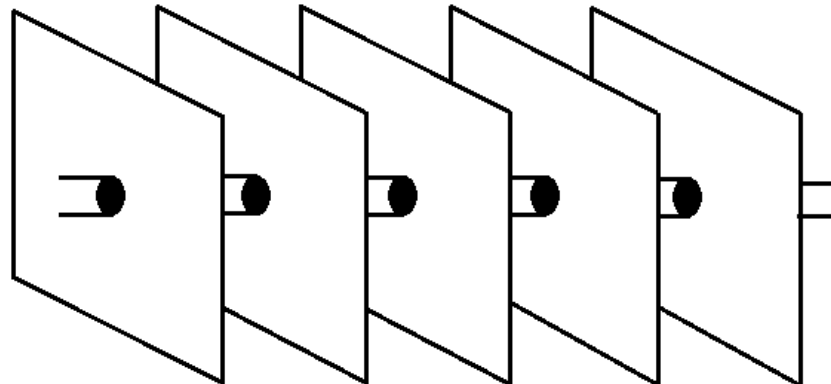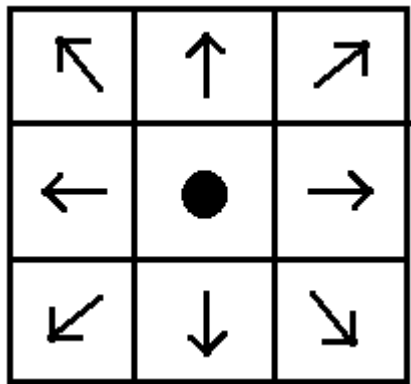
Background String Network

- If strings are allowed, they arrange themselves into loops and long segments

- Long strings follow a scaling solution, likely that loops do too!

- Only one parameter, $G\mu$ determines all observables in the theory
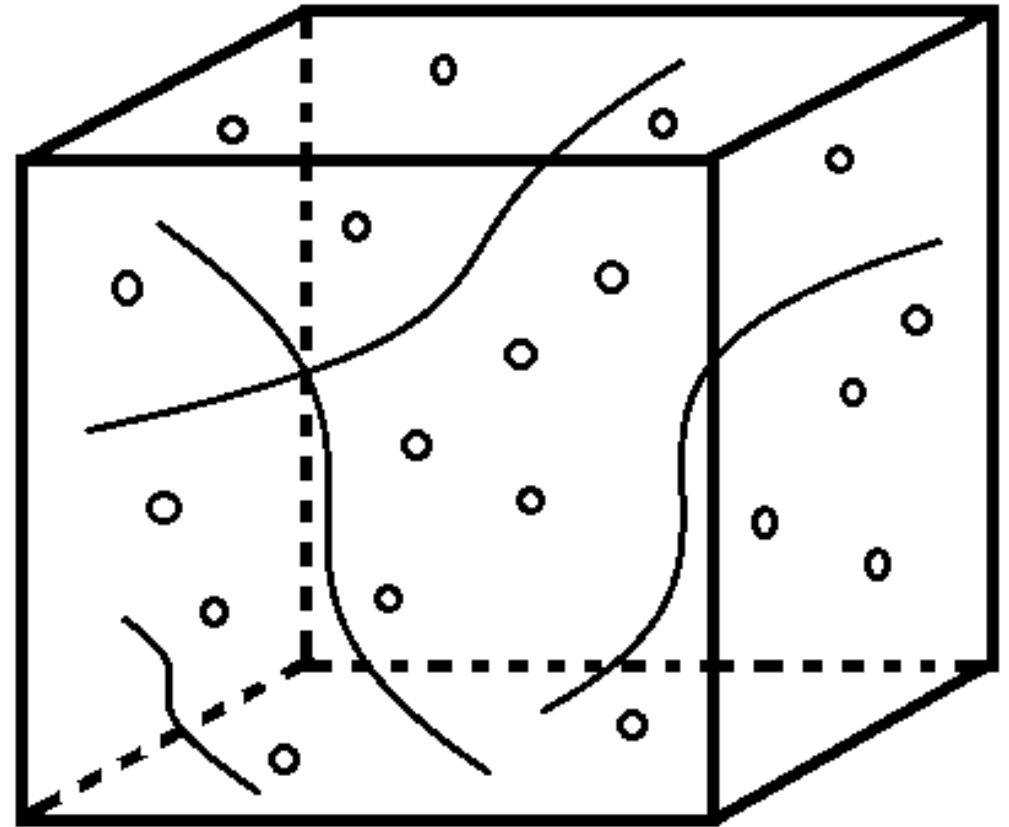
Background String Network

- Loops decay to gravitational waves (stochastic background expected)

- PTA constraints $G\mu < 10^{-11}$

- Possible to get a photon spectrum with these parameter values?
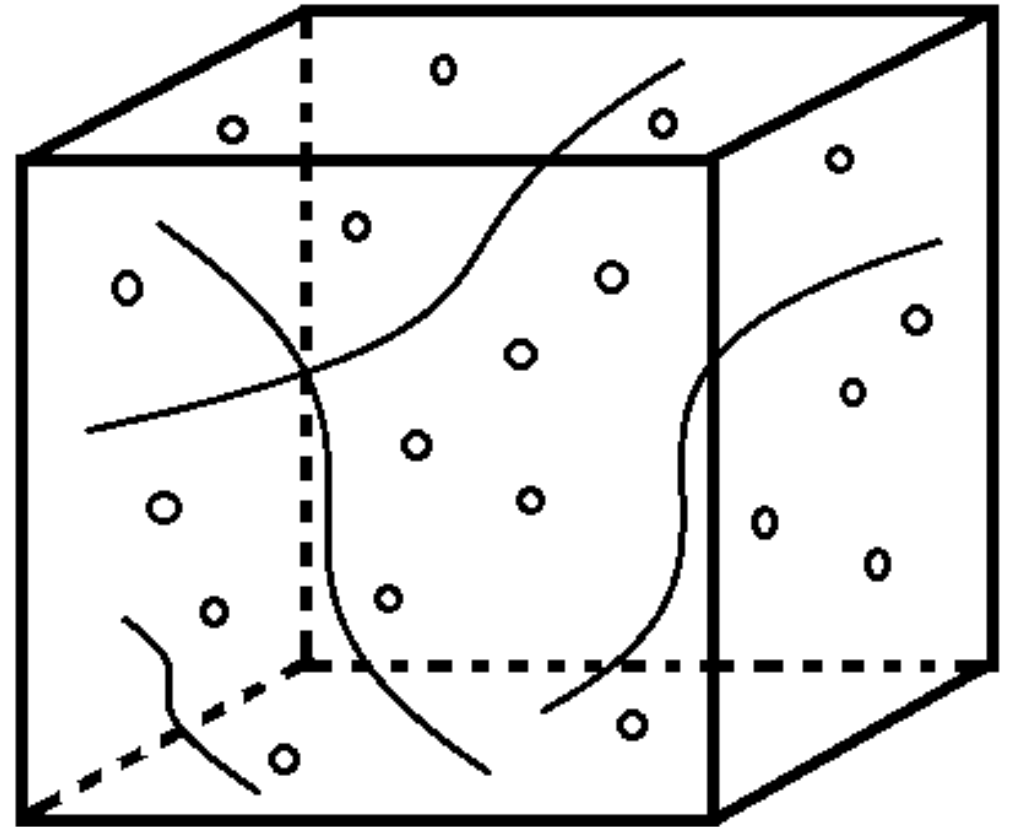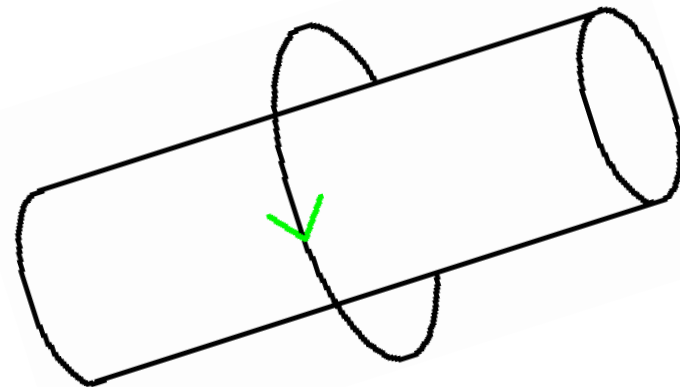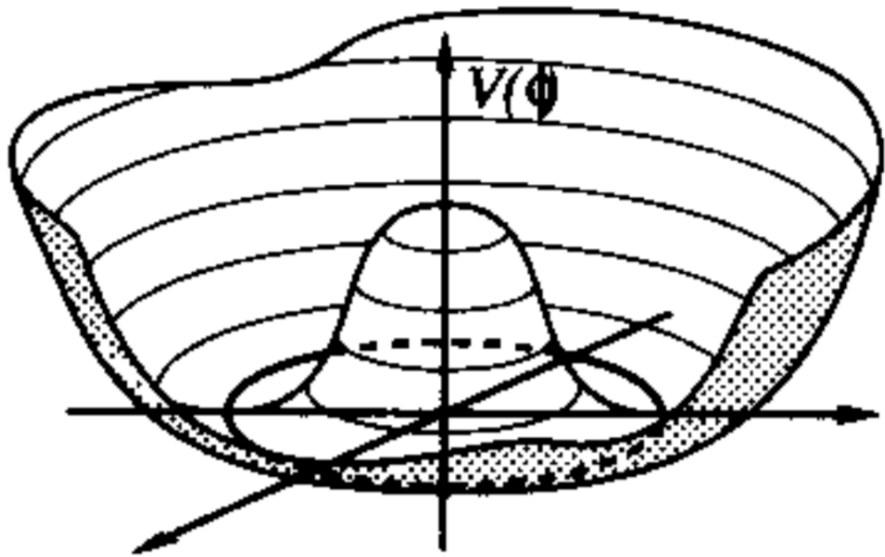
Objective

- To source a radio background from this underlying skeleton of cosmic strings (motivated by EDGES/ARCADE-2)

- Concerned with comparing to amplitude of signal detected by EDGES
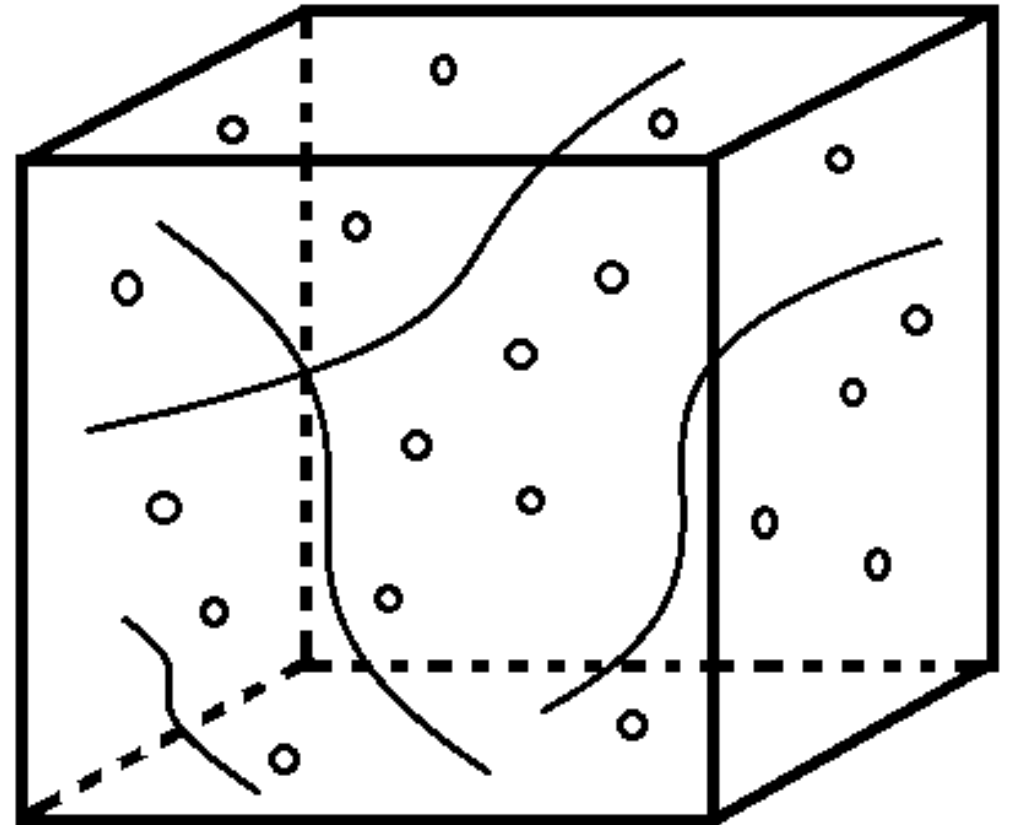
Cosmic String Cusps

- Formation of strings come with intrinsic winding in field space

- Notion of antistring is a string with opposite winding orientation

- Analysis of EoM yield naively luminal points

- In the region of such points, cusp-like features generically form

- Locally looks like string-antistring configuration: annihilation!
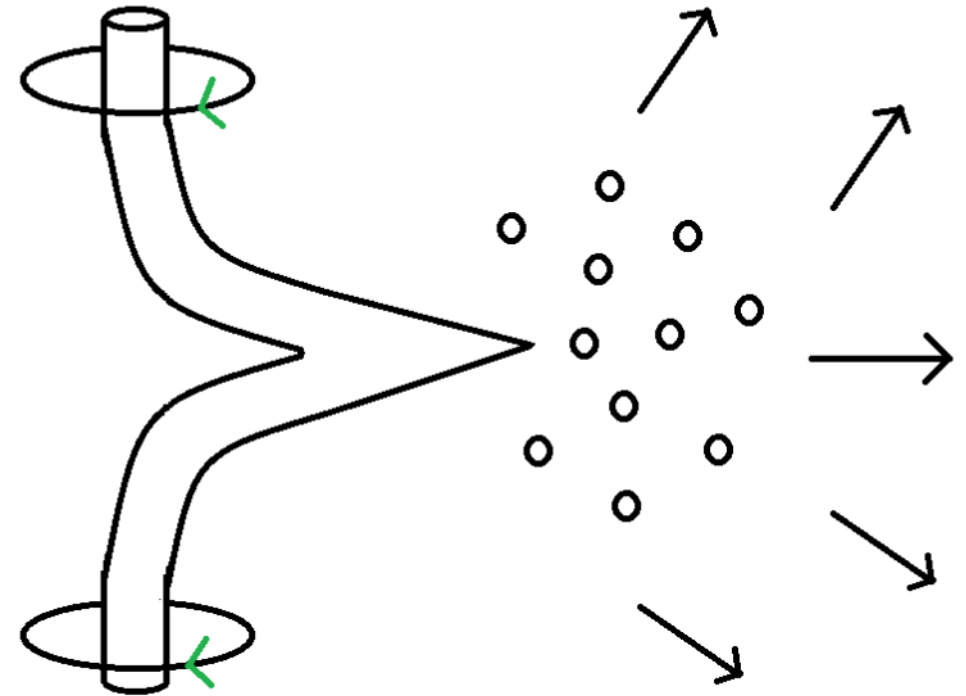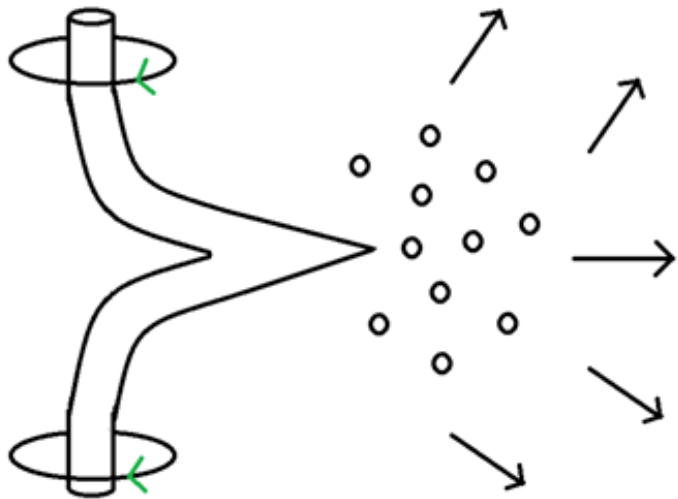
Cosmic String Cusps

- Annihilation creates exotic particles
(scalars and gauge fields of old symmetry)

- Natural coupling to the standard model

- Decay to standard model gauge fields
occurs rapidly (photons!)
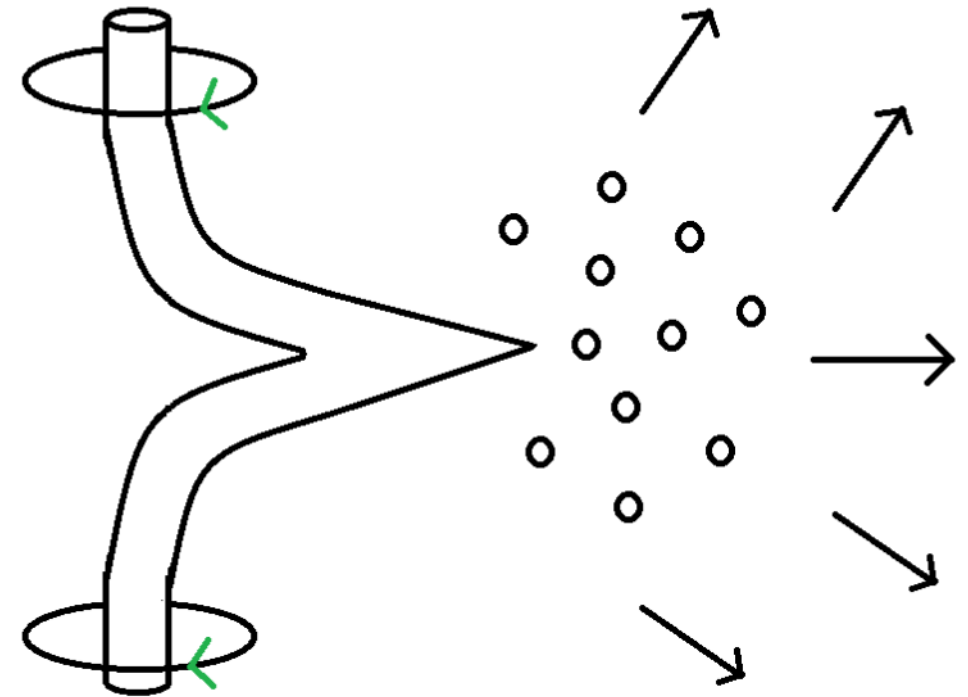
Decay Path
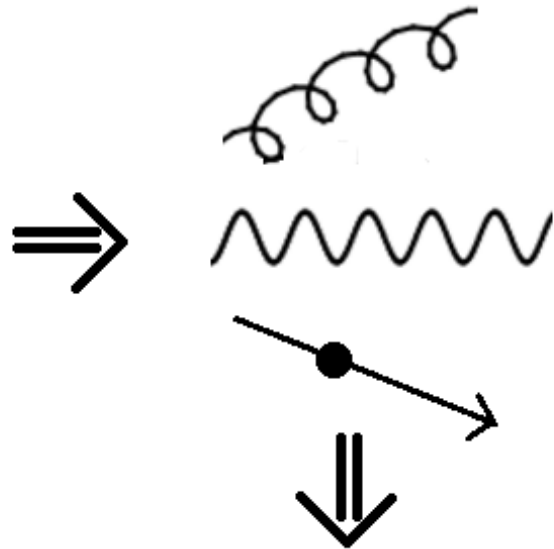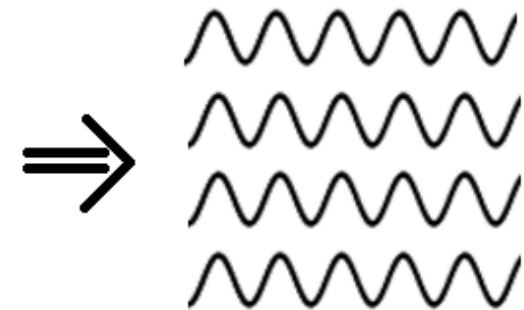
Should be easy to get a spectrum…
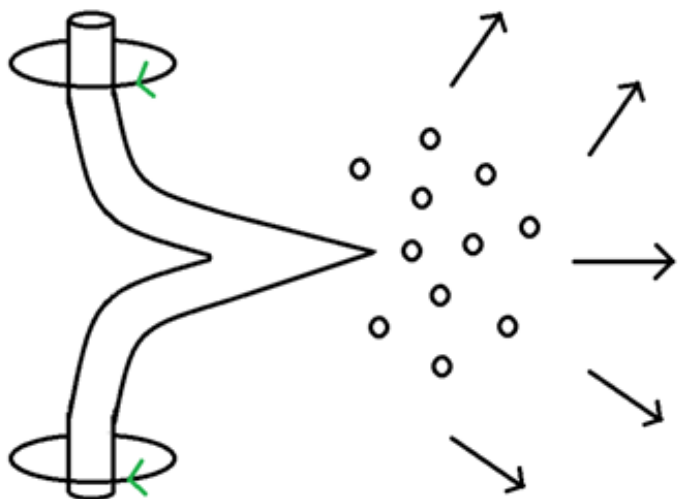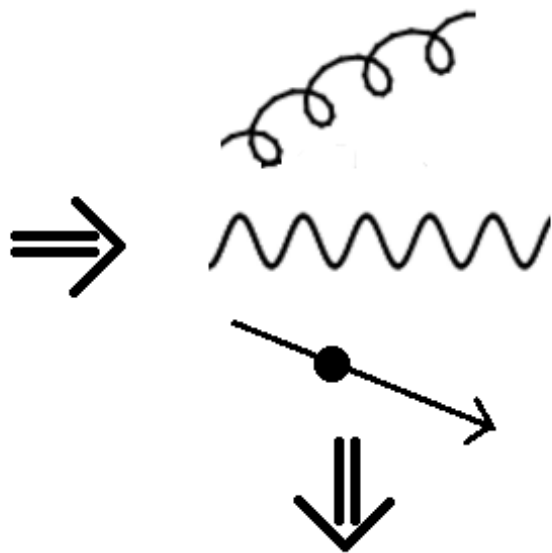
Decay Path

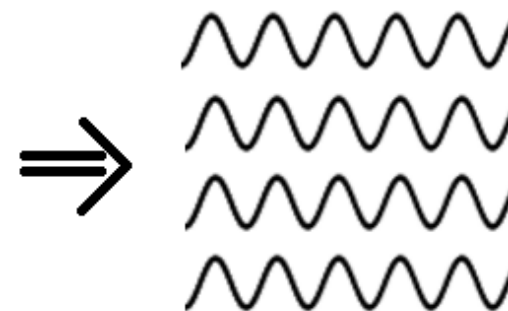Should be easy to get a spectrum...

Cusp Annihilates to Exotic Particles

Decay to SM Gauge Bosons

Direct Photon Production
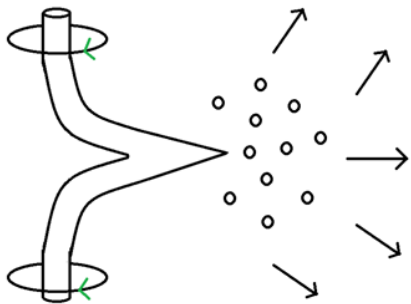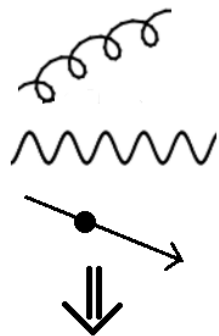
Too few photons!

Decay Path

How about this setup?
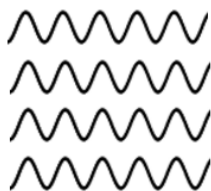
Decay Path

Cusp Annihilates to Exotic Particles
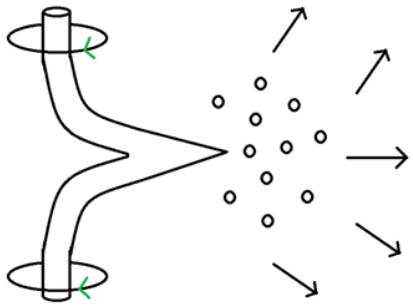
Decay to SM Gauge Bosons

Direct Photon Production

How about this setup?

Photons too high energy!
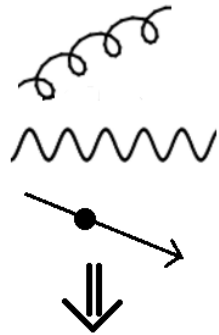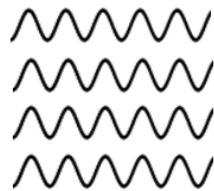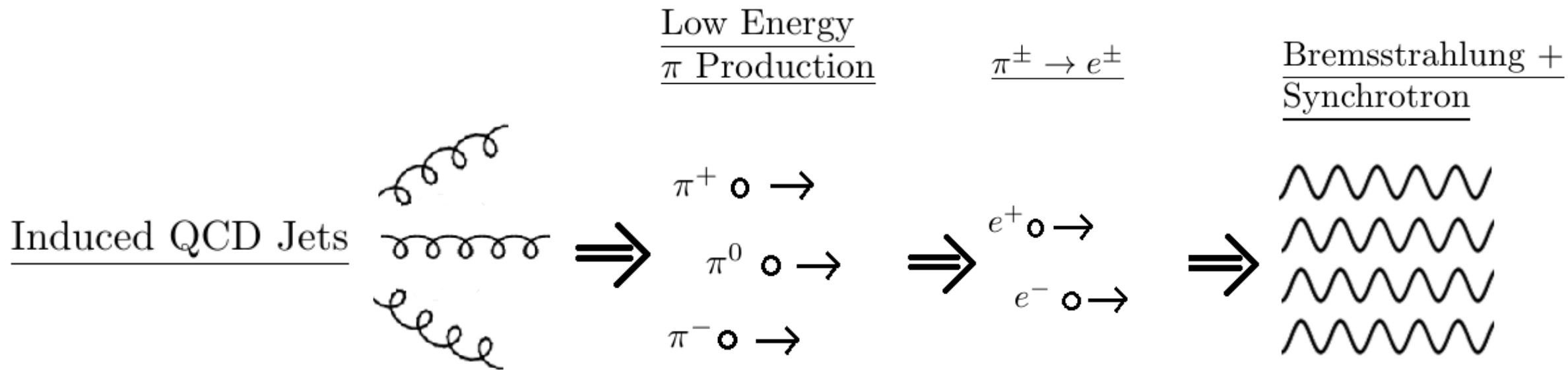
Low Energy π Production

Induced QCD Jets

π^+ o $\rightarrow$

π^0 o $\rightarrow$

π^- o $\rightarrow$

$\pi^0 \rightarrow 2\gamma$
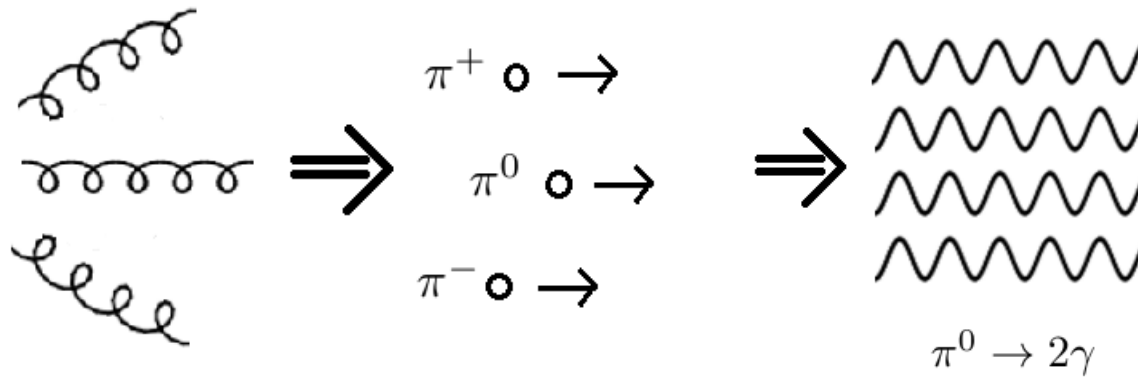
Decay Path

Start with the QCD jets

Constraints and Predictions

This gives us a (convoluted) way to get 21-cm photons, however the effect is very small

$$\frac{\delta T_b}{\delta T_b^{CMB}} \sim 1 + \mathcal{O}(10^{-4})$$

Induced QCD Jets $\Longrightarrow$ $\underline{\text{Low Energy}}$ $\underline{\pi \text{ Production}}$

$\pi^+ \circ \rightarrow$

$\pi^0 \circ \rightarrow$

$\pi^- \circ \rightarrow$

$\Longrightarrow$ $\underline{\pi^\pm \rightarrow e^\pm}$

$e^+ \circ \rightarrow$

$e^- \circ \rightarrow$

$\Longrightarrow$ $\underline{\text{Bremsstrahlung} +}$ $\underline{\text{Synchrotron}}$
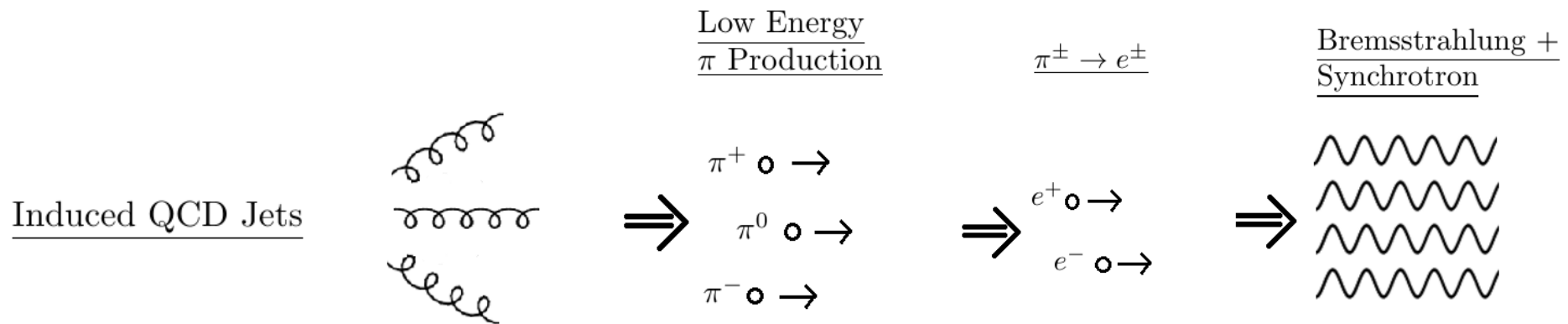
Superconducting Cosmic Strings

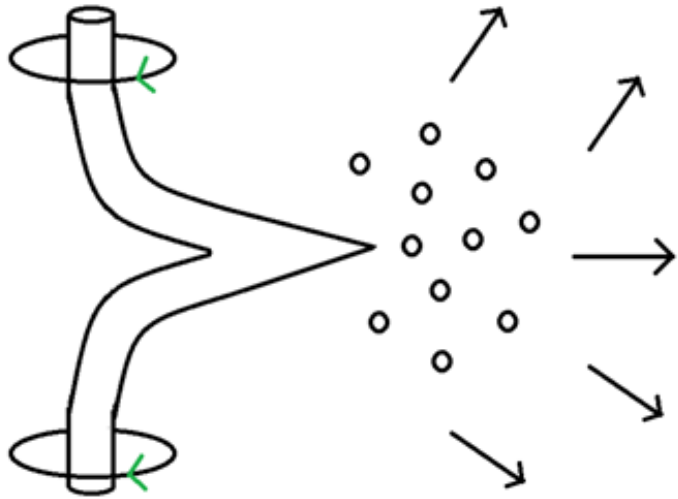- Possible to construct strings with an electric current (parameter space expands to $G\mu$ x Current)

- Decay now proceeds by either EM radiation off cusps, or gravitational waves

- Direct coupling to photons makes production of 21cm radiation very simple
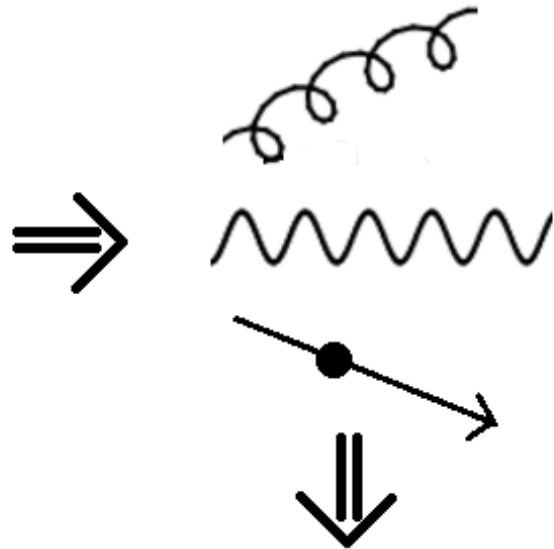
Now it IS easy to get a spectrum...

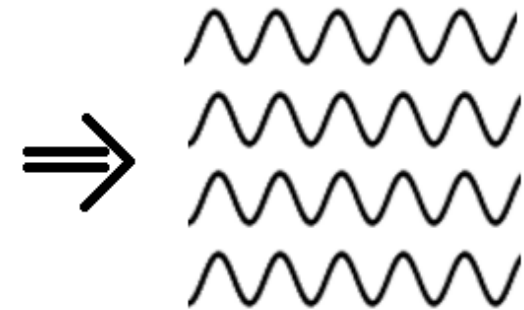Cusp Annihilates to Exotic Particles

Decay to SM Gauge Bosons

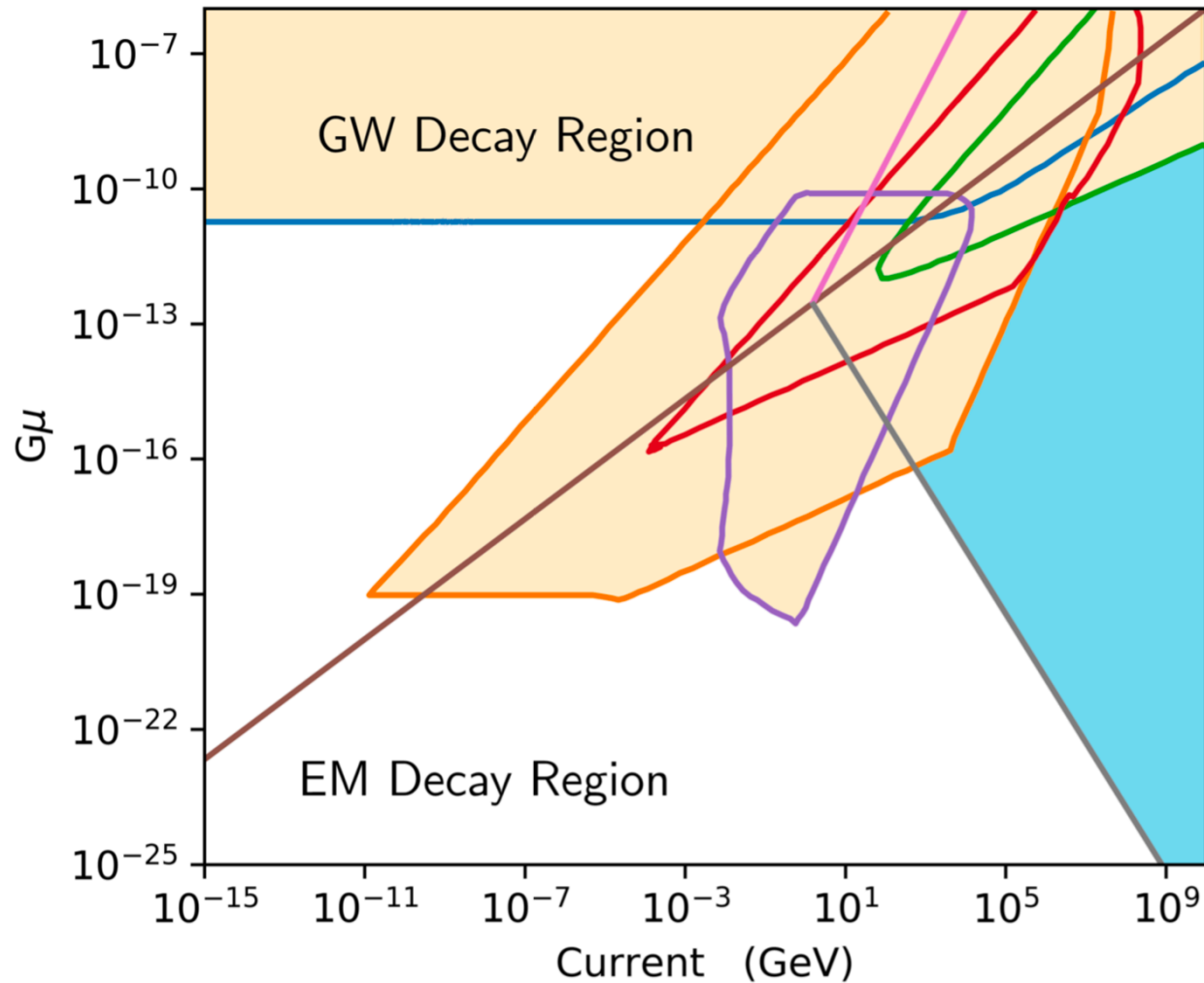Direct Photon Production

Plenty of photons!
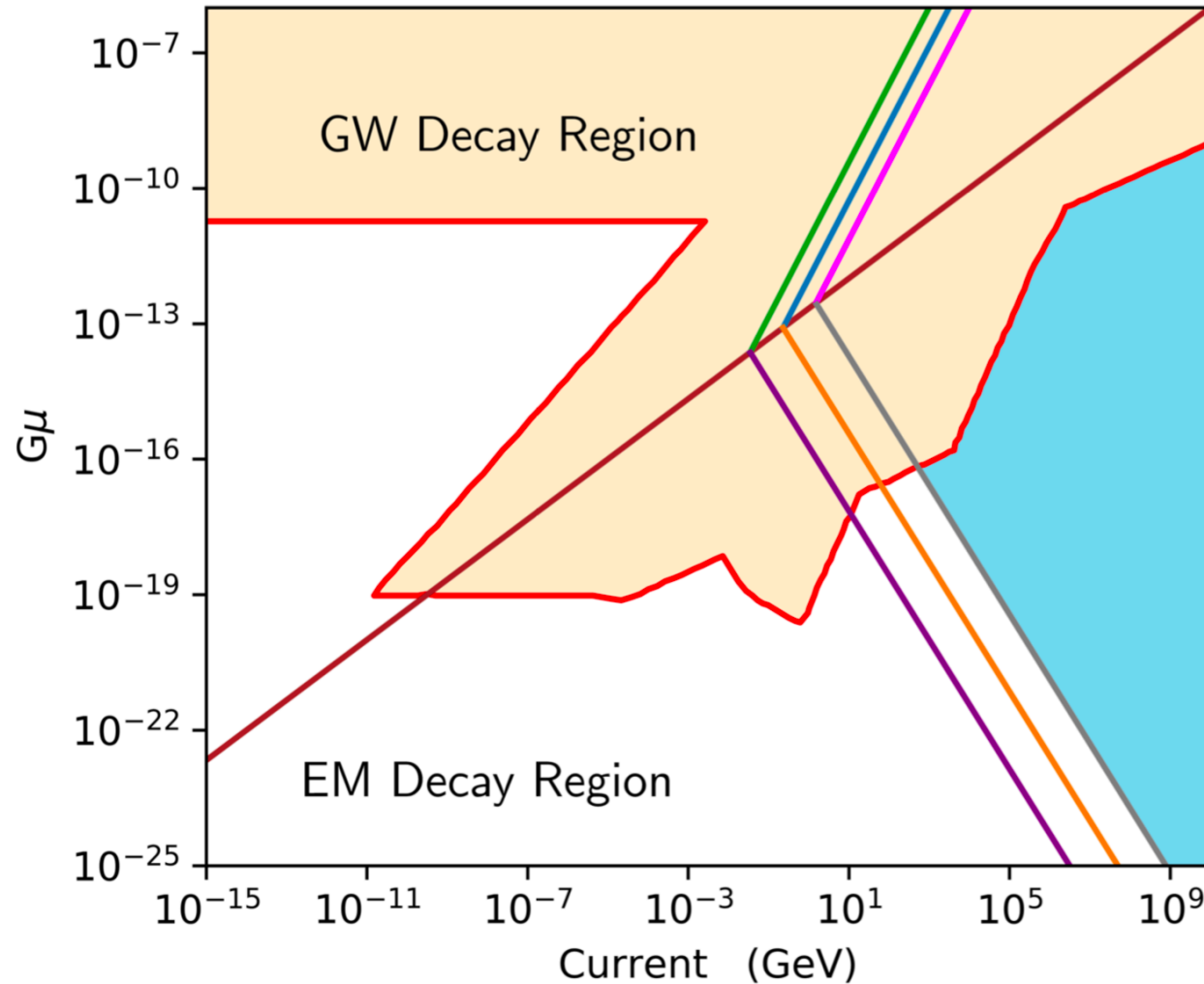
Constraints and Predictions

$$\mathcal{R} = \frac{d\rho^{21}/dE}{d\rho^{CMB}/dE}$$

$$\frac{\delta T_b}{\delta T_{CMB}} \approx 1 + \mathcal{R}$$

Constraints and Predictions

$$\mathcal{R} = \frac{d\rho^{21}/dE}{d\rho^{CMB}/dE}$$

$$\frac{\delta T_b}{\delta T_{CMB}} \approx 1 + \mathcal{R}$$

Conclusions

- Cusp emission from cosmic strings can source a radio background between recombination and reionization

- (Normal) cosmic strings produce a negligible effect on the brightness temperature at reionization

- Superconducting strings, however, have a large region of parameter space that can produce a significant signal, and is a potential resolution of the EDGES anomaly