Title: Gravitational Bursts from Unstable Cosmic Strings

Date: Jun 06, 2008 09:30 AM

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Abstract: We compute the GW signature of a meta-stable cosmic string network. Such networks arise in a large class of brane inflation models.

The Bursts and The Beads

(gravitational bursts from monopoles on strings)

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Based on:
ArXiv:0806.xxxx (with Louis Leblond and Xavier Siemens)

PASCOS
Perimeter Institute
June 6th, 2008

Outline

- Motivation for Cosmic Strings
  - Brane Inflation
  - Detectable!
- Generic Instability
  - Motivation
  - Effects
- Cosmological Evolution
  - Boltzmann Eq. and Scaling
  - World Sheet Picture
- GW Signature
  - Bursts
  - Stochastic

Why Cosmic Strings?

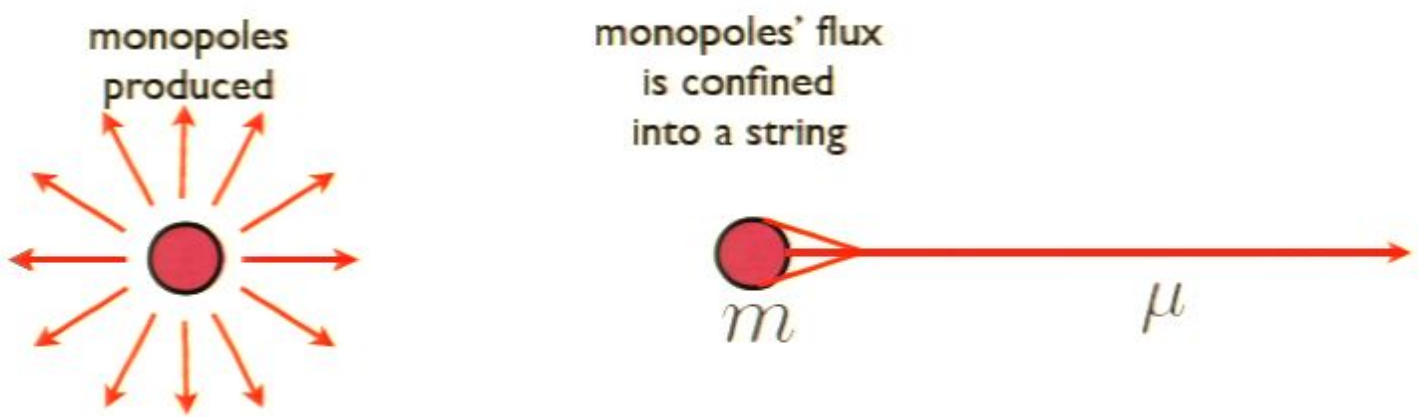
- Many (not all) Brane Inflationary scenarios predict their existence, e.g. KKLMMT
- Detectability
  - High tension: lensing, Kaiser-Stebbins
  - Low tension: LIGO/LISA (Stochastic GW, Cusp-GW bursts) B-Mode CMB
  - Extra low tension: LIGO/LISA(Monopole-GW Bursts), Pulsar Timing (perhaps)

Why monopoles?

Copeland, Myers, Polchinski, Martin, Guth, Vilenkin

- Generic instability of cosmic superstrings
- Pattern of Symmetry Breaking: Monopoles, then Strings.

$$G \to H \times U(1) \to H$$

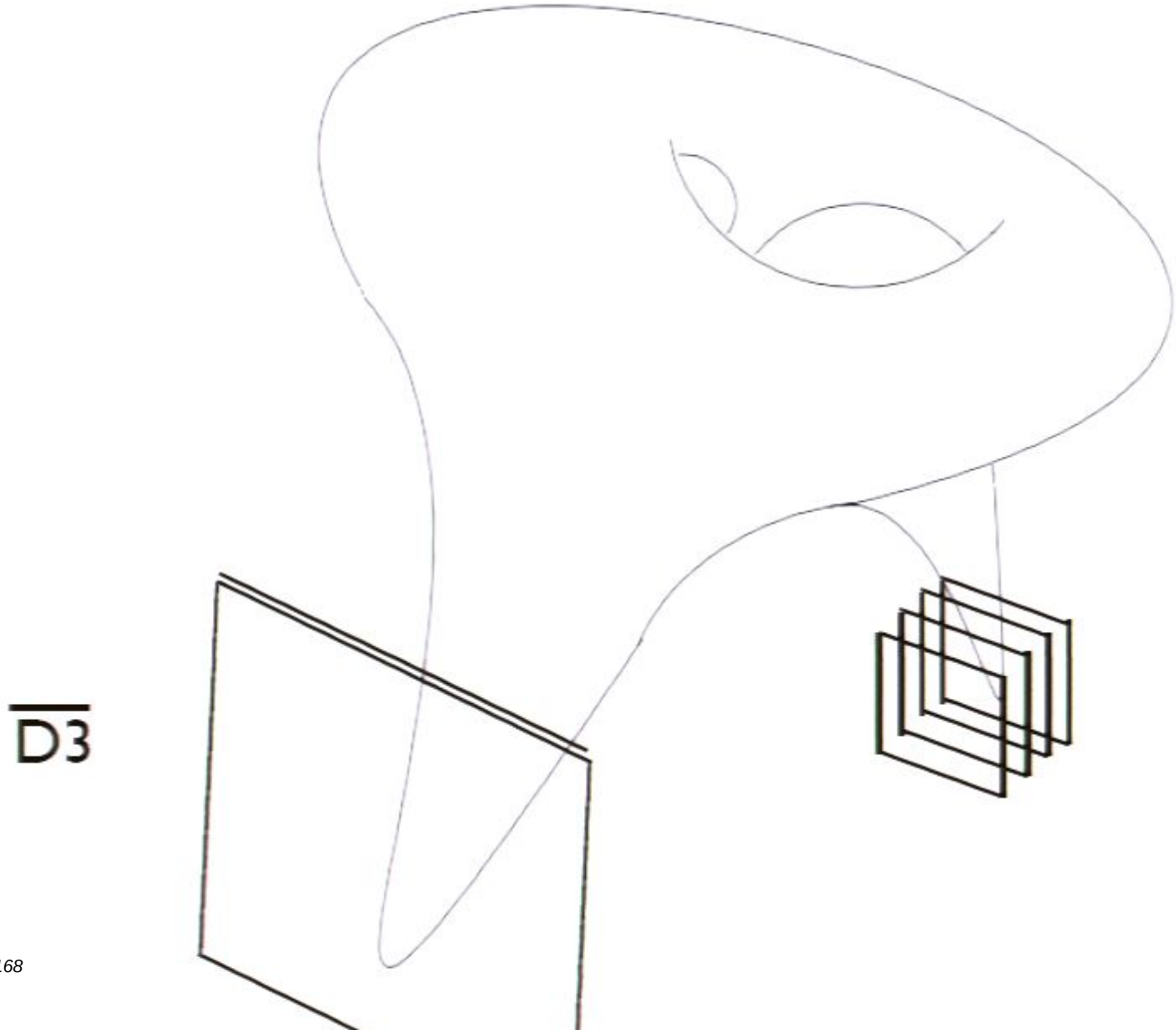


Corollary: Strings can Break

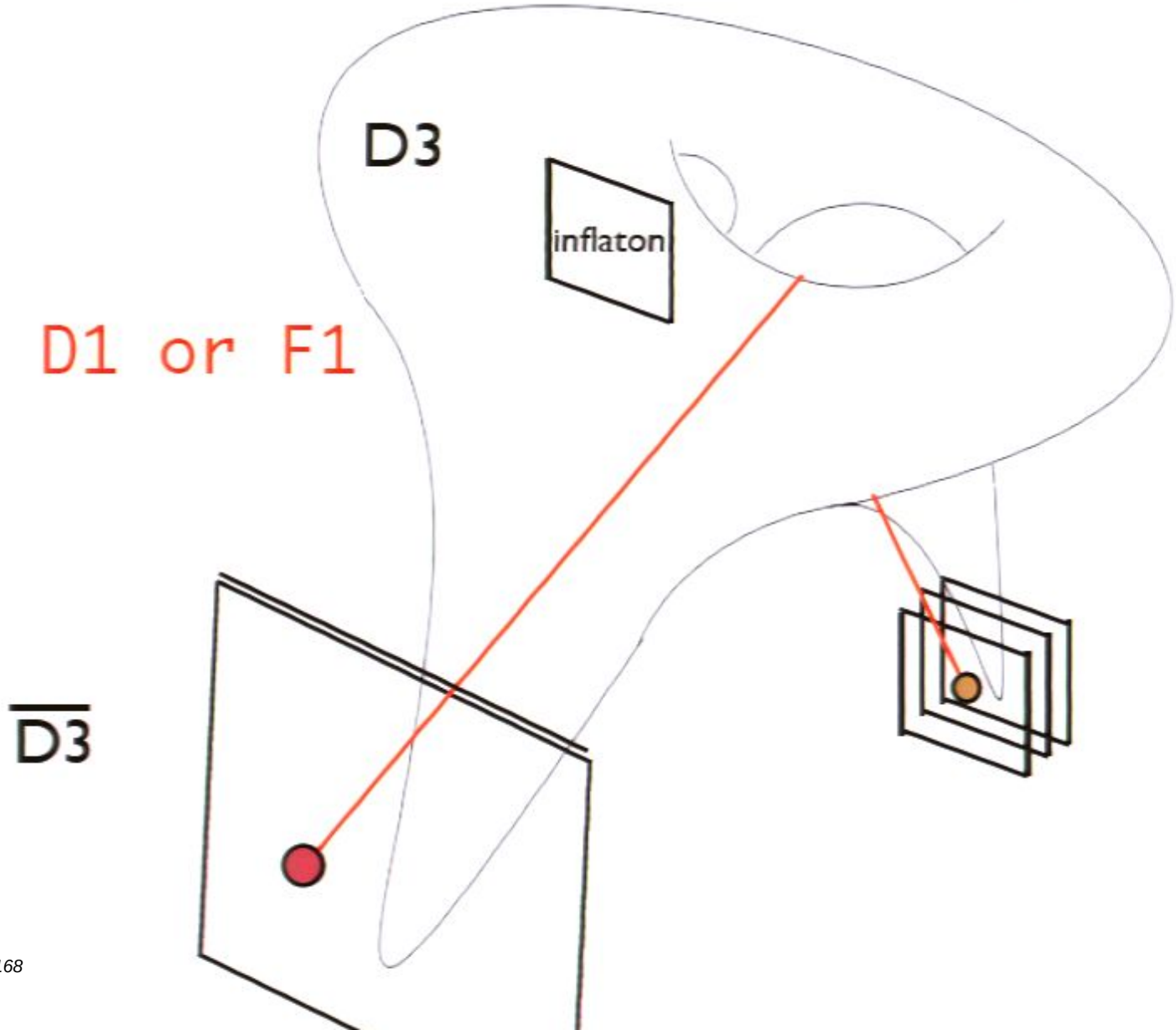
$$\Gamma_2 = \frac{\mu}{2\pi} \exp\left(-\frac{\pi m^2}{\mu}\right)$$

via Schwinger pair production

IIB Flux Compactification w/ $\overline{D3}$



Spectrum contains monopoles (but they're inflated away)



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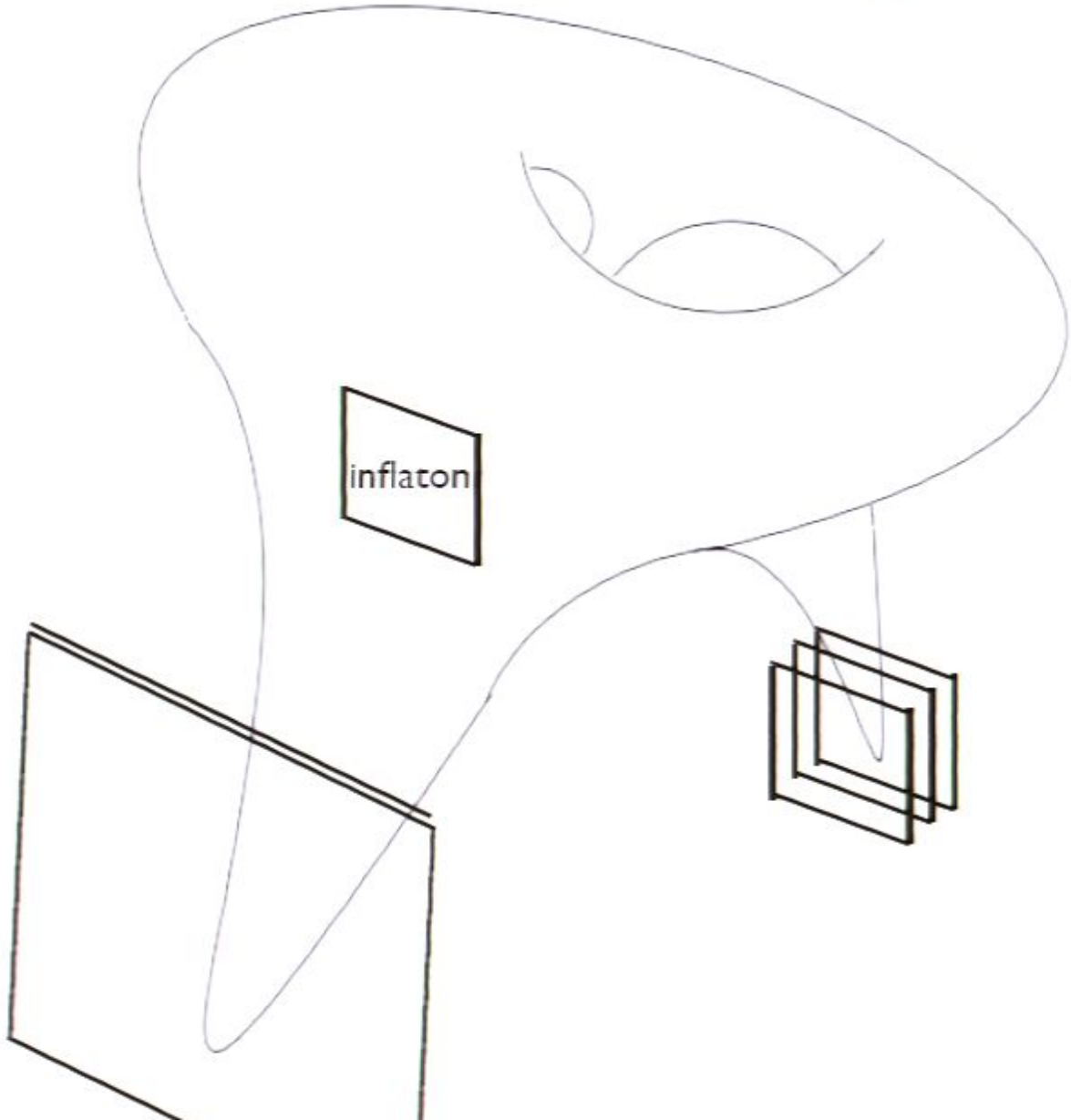

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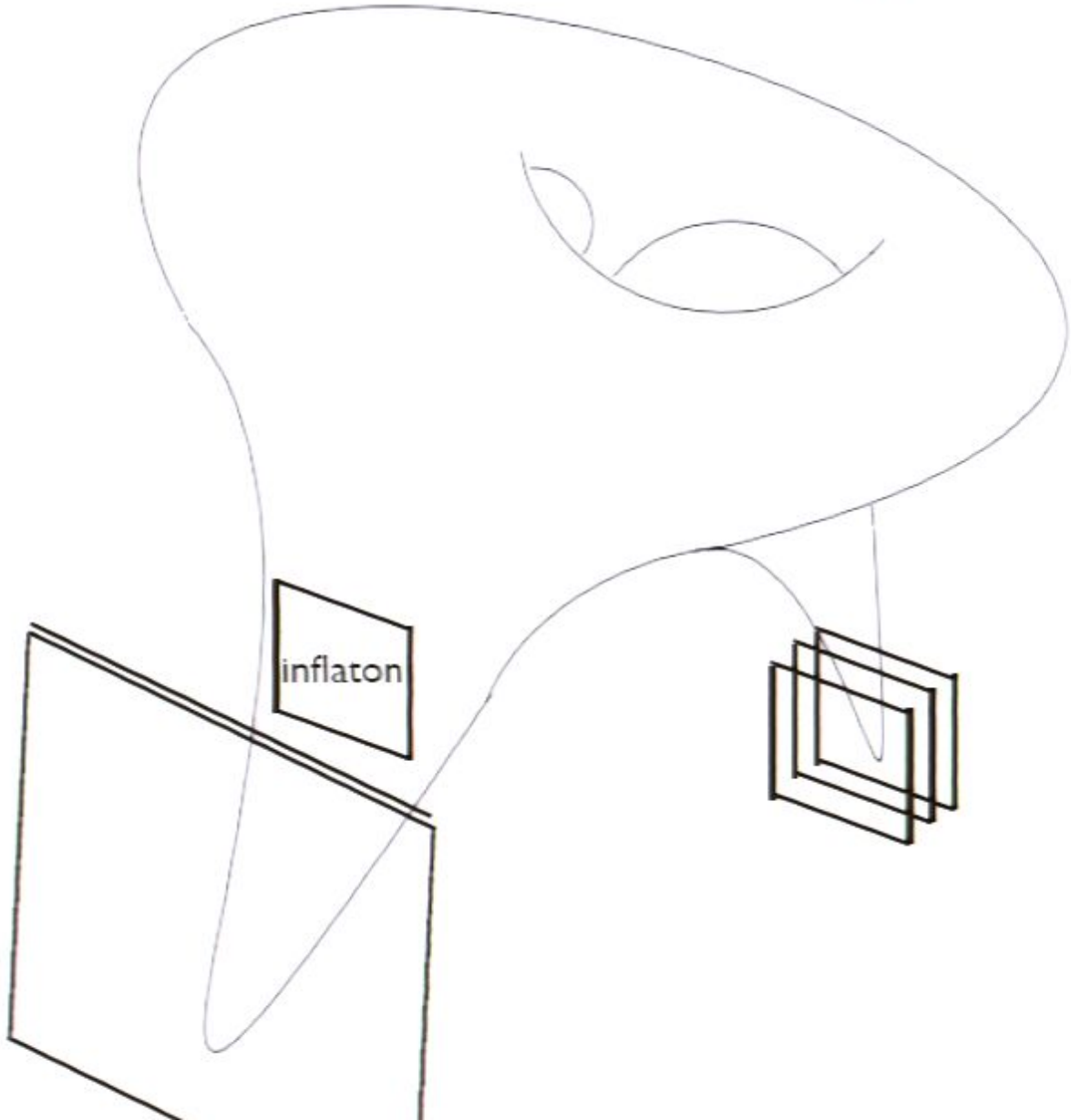
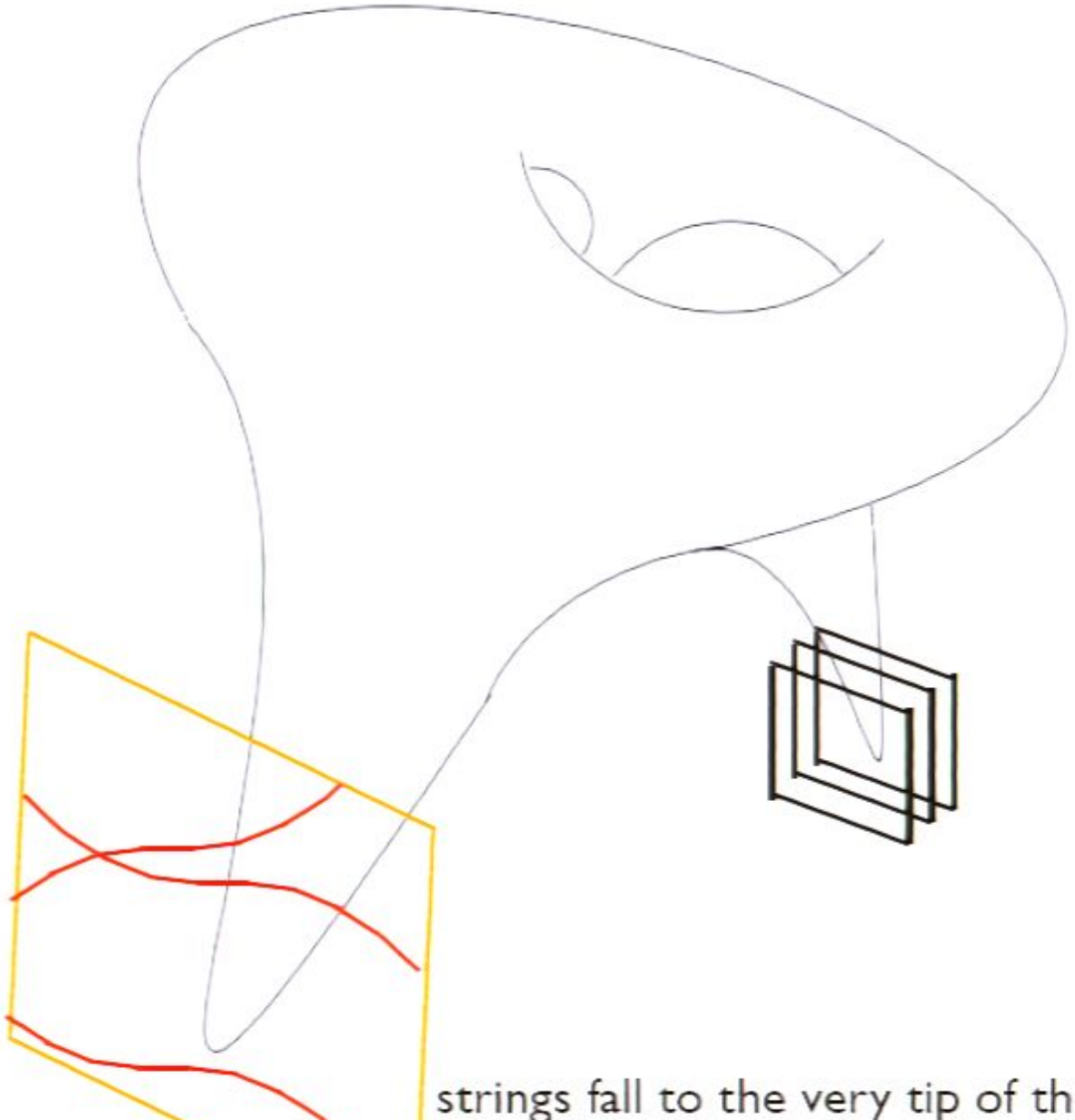


Cosmic Strings are Produced via Kibble Mechanism

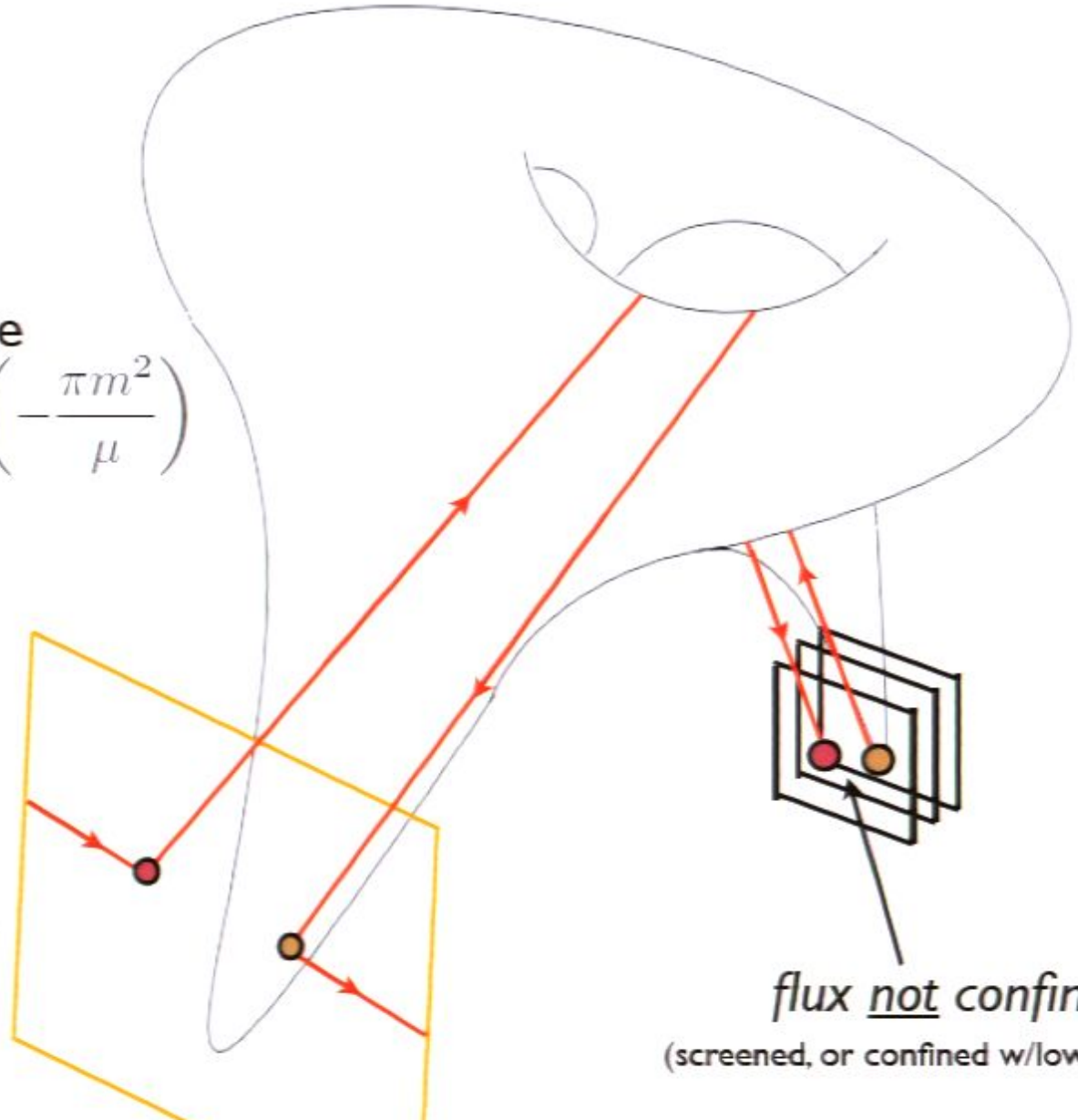


strings fall to the very tip of the throat

Cosmic Strings Break via Monopole Pair Production

Breakage Rate

$$\Gamma_2 = \frac{\mu}{2\pi} \exp\left(-\frac{\pi m^2}{\mu}\right)$$



monopoles neutral under all light fields

flux <u>not</u> confined

(screened, or confined w/lower tension)

GW Radiation

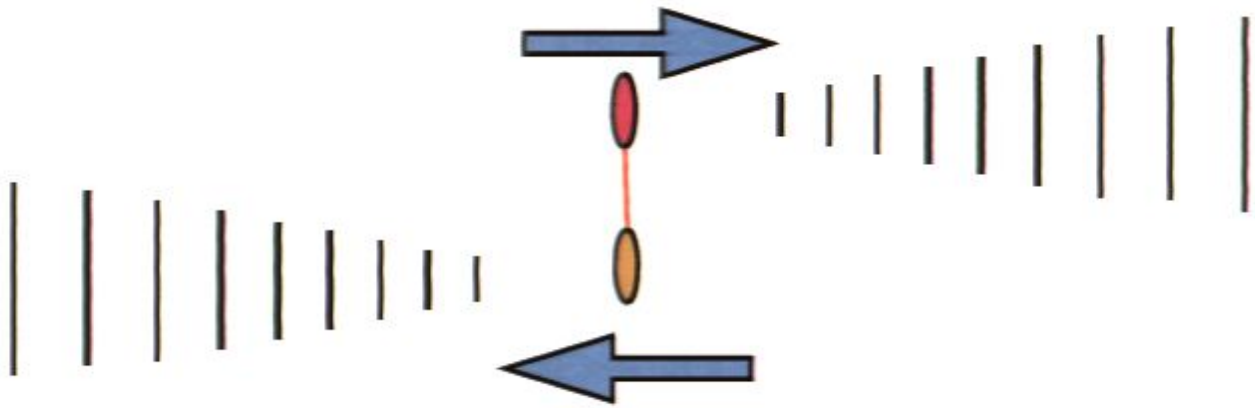
monopoles are accelerated over *extremely* long distances

Also contributes to stochastic GW background

Vilenkin, Martin

Highly focused GW Burst

monopoles are *ultra ultra* relativistic !!!
with a changing acceleration



$$\gamma = 1/\sqrt{1-v^2} \lesssim \mu/Hm$$

γ can be Hubble length in string units!

Cosmological Evolution
of Cosmic Strings

$$\rho_{cs} \sim 1/a^2$$ inert strings

$$\rho_{cs} \sim 1/t^2$$ actual strings

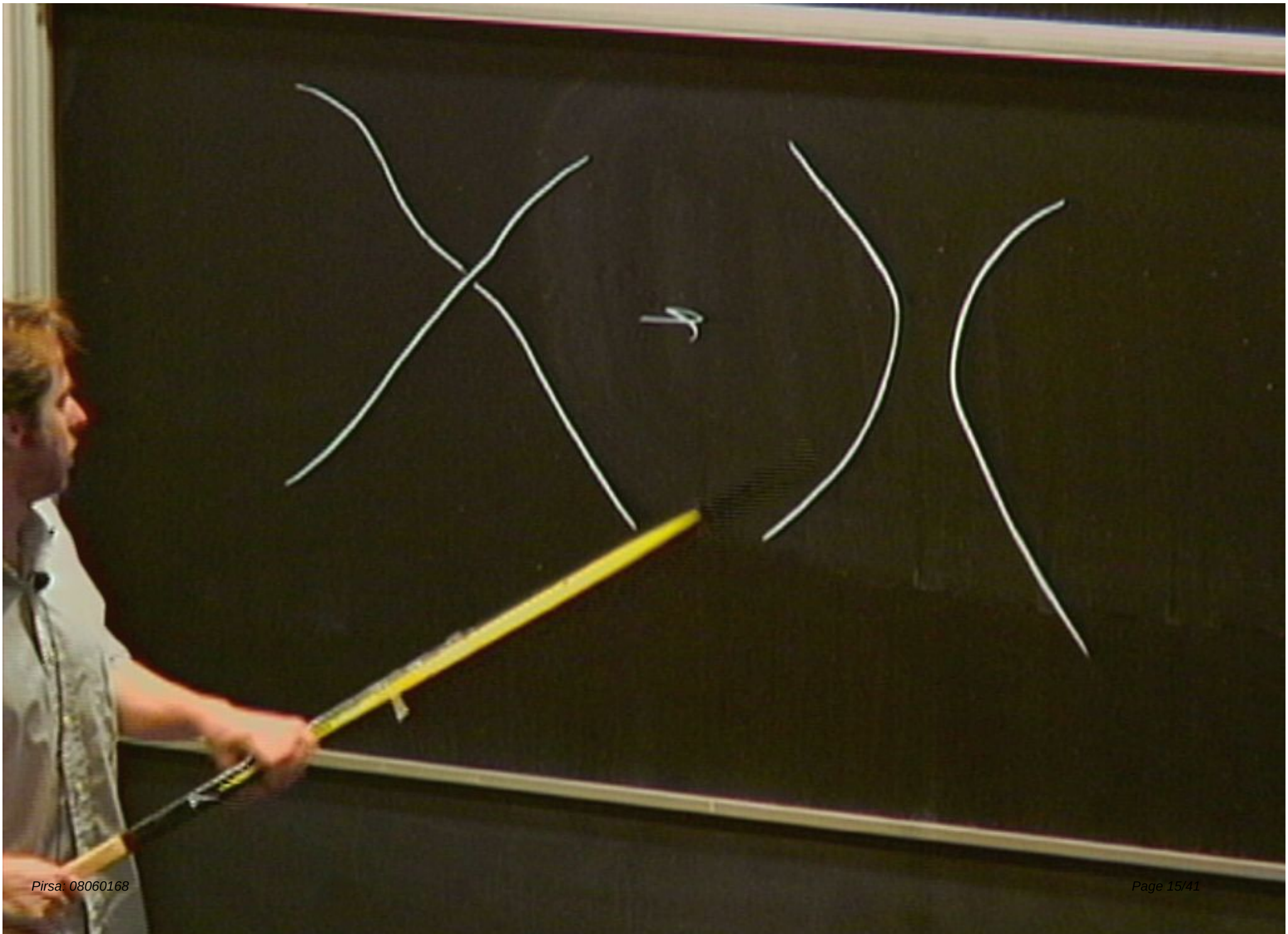
$$\Rightarrow \quad \rho_{cs} \sim \begin{cases} 1/a^4 & \text{radiation era} \\ 1/a^3 & \text{matter era} \end{cases}$$

Mechanism: String collisions (intercommutation) generates small scale wiggles on the strings. These cause the strings to quickly lose energy via production of small loops.

wiggles $\Rightarrow$ loops

more string $\Rightarrow$ more collisions $\Rightarrow$ more loop production.

$\Rightarrow$ Stable Scaling Solution



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Cosmological Evolution

of String Segments

number density
(per unit length)

$$\frac{\partial n(l,t)}{\partial t} = -\frac{\partial}{\partial l}\left(\dot{l} n(l,t)\right) - 3\frac{\dot{a}}{a} n(l,t) + g$$

$l := E/\mu$

$$g = g_{loop} + g_{ic} + g_{break}$$

$$g_{break} dl = \Gamma_2 \left(2\int_l^\infty n(l',t)dl' - ln(l,t)\right) dl$$

$$g_{ic} dl = \Gamma_2^{ic} \left(\frac{1}{2}\int_{l/2}^\infty n(l',t)dl' - ln(l,t)\right) dl$$

$$g_{loop} = (\text{difficult})$$

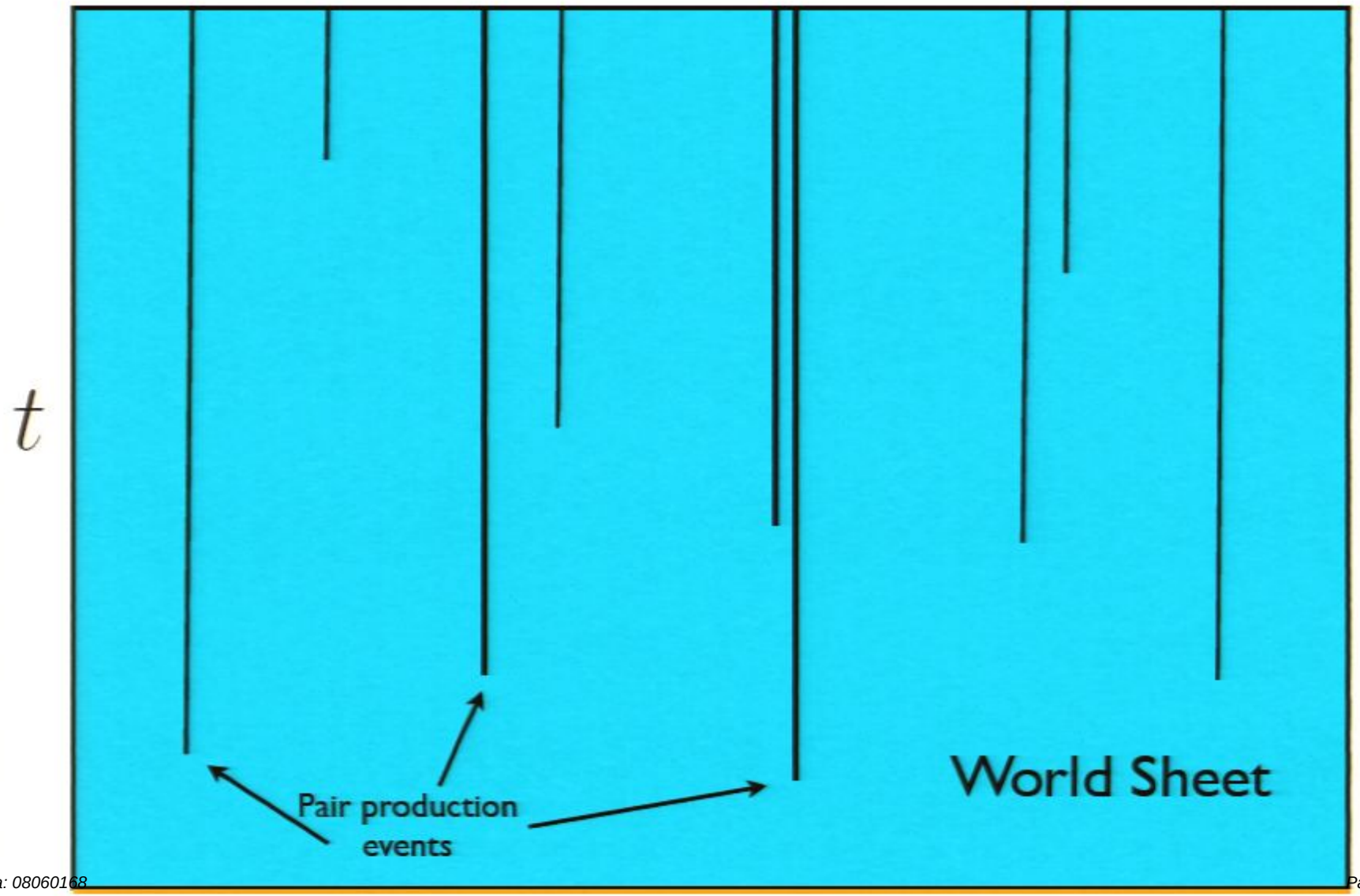
related

But we can use scaling!

$$\subseteq \dot{l}$$

number density: easy derivation of $n(l,t)$

$$P_k(A) = \frac{(A\Gamma_2)^k e^{-A\Gamma_2}}{k!} \quad \Rightarrow \quad P(l,t) = \mathrm{e}^{-\Gamma_2 l t}\Gamma_2 t dl$$



number density (per unit length)

$$P_k(A) = \frac{(A\Gamma_2)^k e^{-A\Gamma_2}}{k!} \qquad \rho_{cs}(t) \sim \mu/t^2$$

$$\Rightarrow \; n(l,t) \sim \Gamma_2^2 \mathrm{e}^{-\Gamma_2 l t}$$

Boltzmann Equation Solution:

$$n(l,t) = 4\Gamma_2^2 \mathrm{e}^{-2\Gamma_2 l t}$$

worldsheet method not too bad...

Gravitational Wave Signature

- Because monopoles are ultra relativistic, bursts are extremely intense. Thus strings with no measurable kink/cusp bursts can still yield a strong burst signature
- The scaling solution of cosmic strings remains robust, and allows for a tremendous signal over certain parameter ranges.

Damour, Vilenkin, Hogan, Siemens, Creighton, Maor, Majumder, Cannon, Reed

details

$$h(f,\gamma,r) \approx \frac{G\mu}{r}\frac{\gamma^2}{f^2}$$ Strain (+ polarization)

$$\theta \approx 1/\gamma$$ Beam width

$$n(l,t)$$ Number density

$\Rightarrow$ LIGO detection event rate

results (preliminary)

$m^2 \lesssim 50\mu \quad \Rightarrow$ LIGO off the chart!

Strong constraints on m
even for extremely light strings!

Bottom Line: Many models
(even those with extremely light strings)
are ruled out.

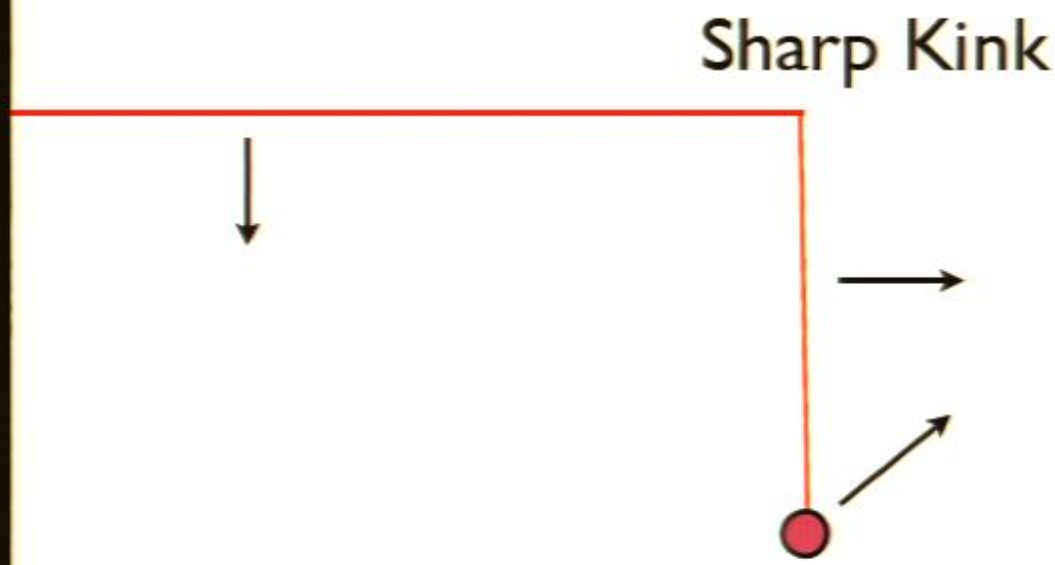
Interesting Possibilities

- Kinks and small scale wiggles lead to bursts, too (extreme gamma factor is robust)
- Oscillation smoothens strings, after rapid loop production
- String segments become dynamical upon Horizon Crossing
  - Coherence to Burst & Stochastic spectra!
  - Does any of this survive intercommutation of segments?

$\Rightarrow$

$$g_{ic}dl = \Gamma_2^{ic}\left(\frac{1}{2}\int_{l/2}^{\infty} n(l',t)dl' - ln(l,t)\right)dl$$

Kink-Monopole scattering



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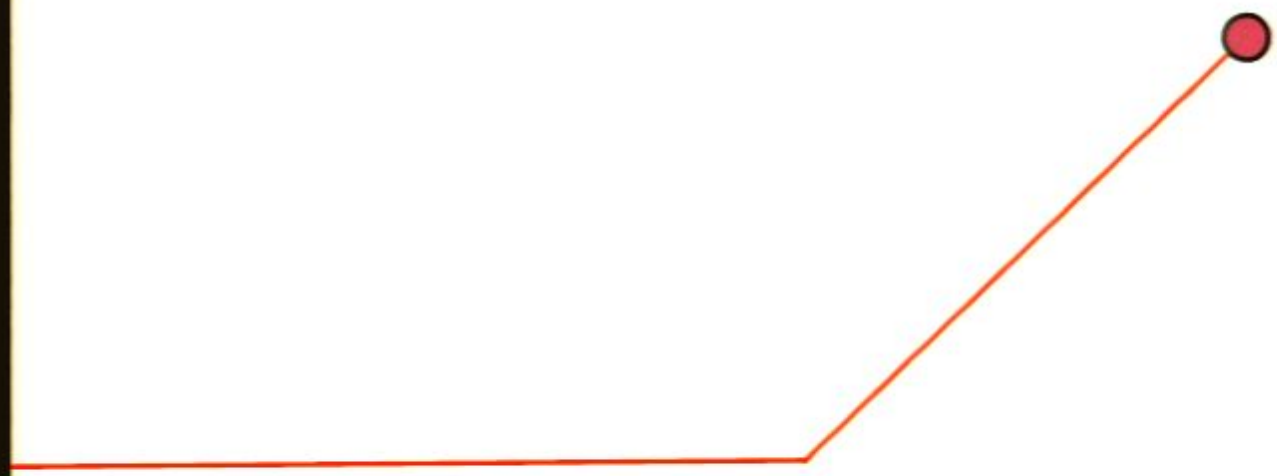
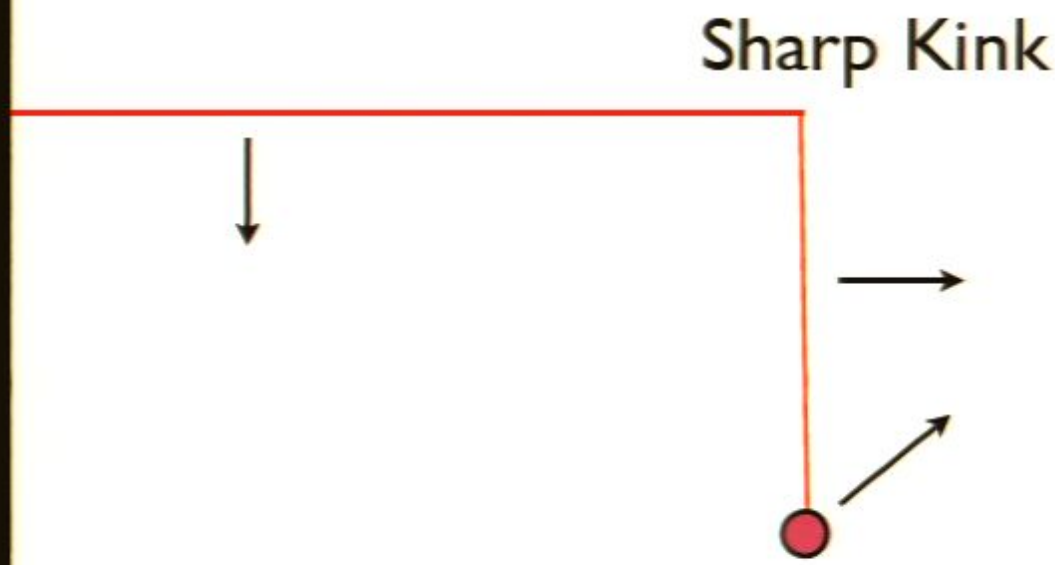


Mild Kink

Kink-Monopole scattering

Kink-Monopole scattering

Kink-Monopole scattering



Kink-Monopole scattering

Monopoles air-condition string segments

- Monopoles heat up the wiggles & Kinks when collapsing (like Compton scattering)
- String radiates more loops
- Monopoles cool string upon re-expansion

Conclusion

- Monopoles are a generic instability of a cosmic string network
- Ultra relativistic nature gives a strong signal even for light strings (i.e. constrains m^2/μ)
- Exponential sensitivity to monopole mass makes detectability highly model dependent
- Coherence and A/C effect make Monopole Burst Signature striking and unique

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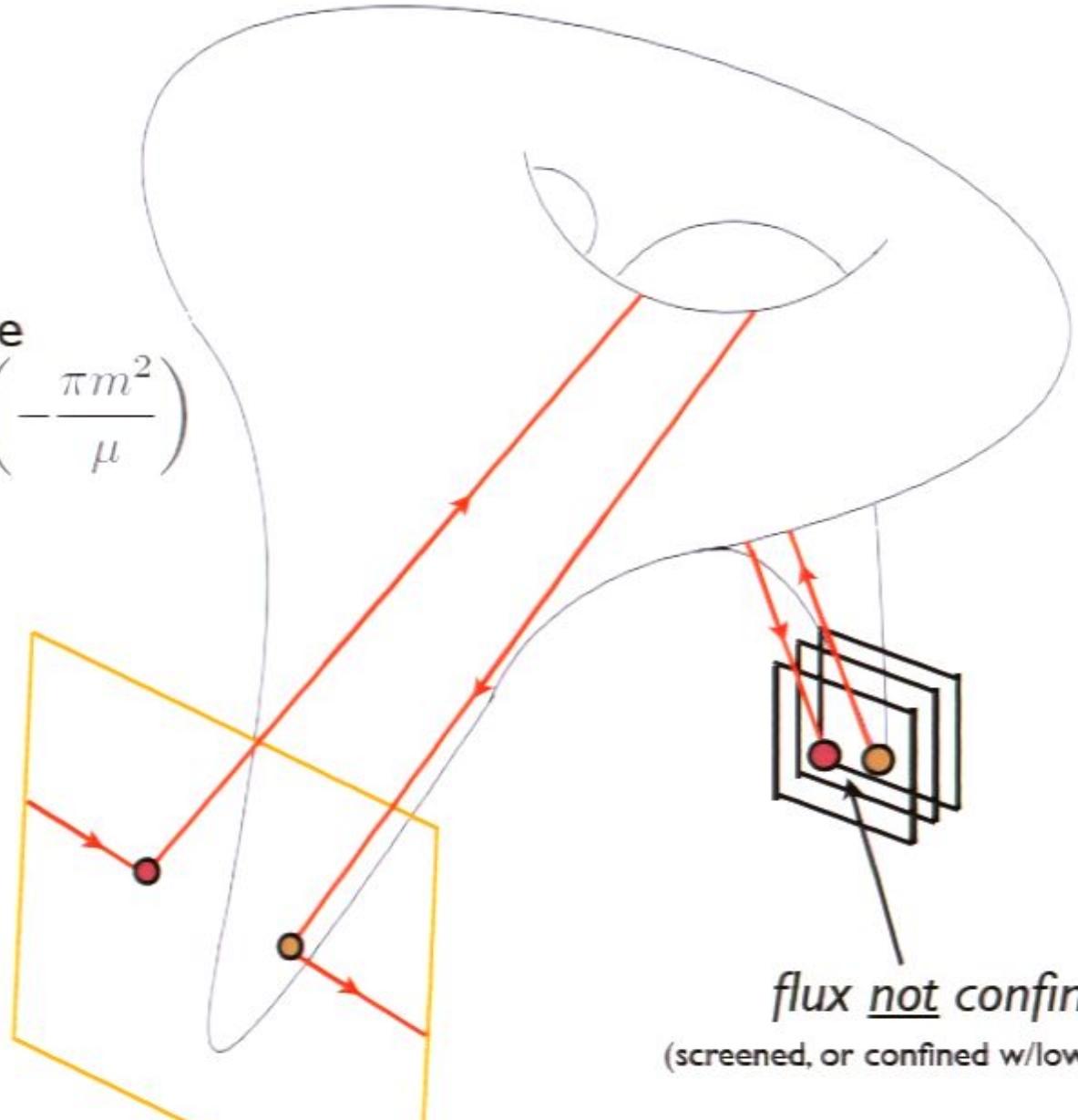

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No Signal

VGA-1