Cosmic String Microlensing for WFIRST

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Introduction

Motivation

- Superstrings can yield information about the physical laws that governed the early universe, specifically the inflation epoch

Model for Cosmic Strings

- Superstrings are one-dimensional structures created at the end of the inflation era
- Interact only gravitationally which allow us to study them via gravitational microlensing
- Intercommutation between superstrings forms cosmic loops
- Loops radiate their length and rest mass in the way of gravitational waves
- The size of the loops scales with the size of the cosmic horizon
- Universe expansion slows down the motion of the loops which makes them behave like cold dark matter
- Models of cosmic loops predict that they fall into the potentials of the galaxies
- The following image is a simulation of the cosmic string network:

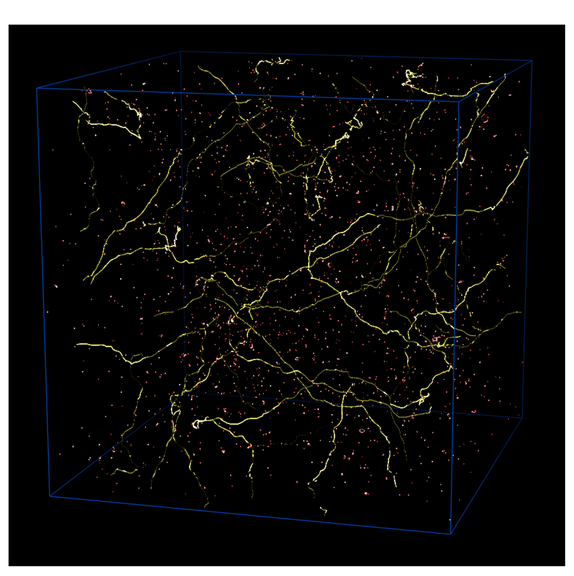

Image: Cambridge Cosmology

WFIRST Description

- The mission will study cosmological topics ranging from dark energy to exoplanets
- The microlensing survey will observe ten contiguous fields between galactic longitudes -0.5 and 1.8 and latitudes of -1 and -2.2
- There will be six 72-day seasons that will result in a total survey time of 0.98 years
- WFIRST will be sensitive to string tensions in the order of 10^{-15} to 10^{-12}

Image: WFIRST-AFTA 2015 Report

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Methods

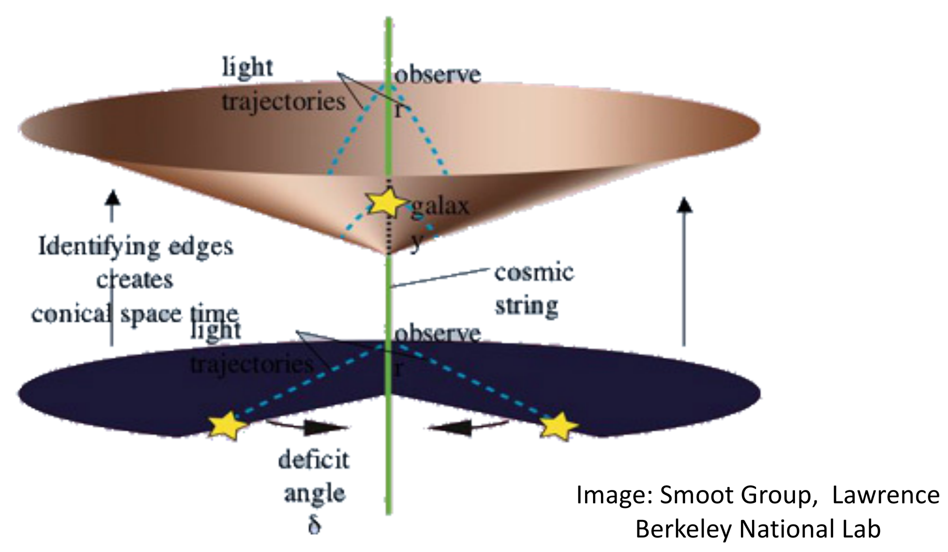


Image: Smoot Group, Lawrence Berkeley National Lab

Cosmic String Microlensing

- The string's positive energy and negative pressure leave spacetime flat
- The presence of the string creates a deficit angle $\delta = \frac{8\pi\mu G}{c^2}$ and a conical geometry
- When the observer, source and string are aligned, the photons of the source have multiple paths to travel

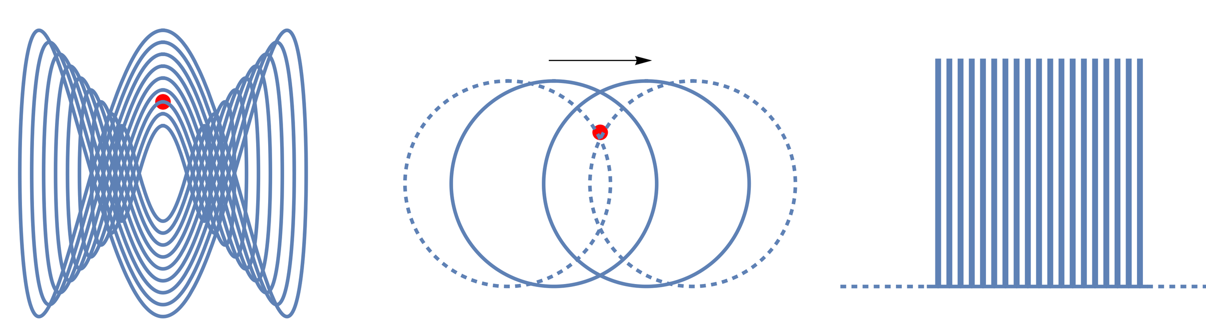


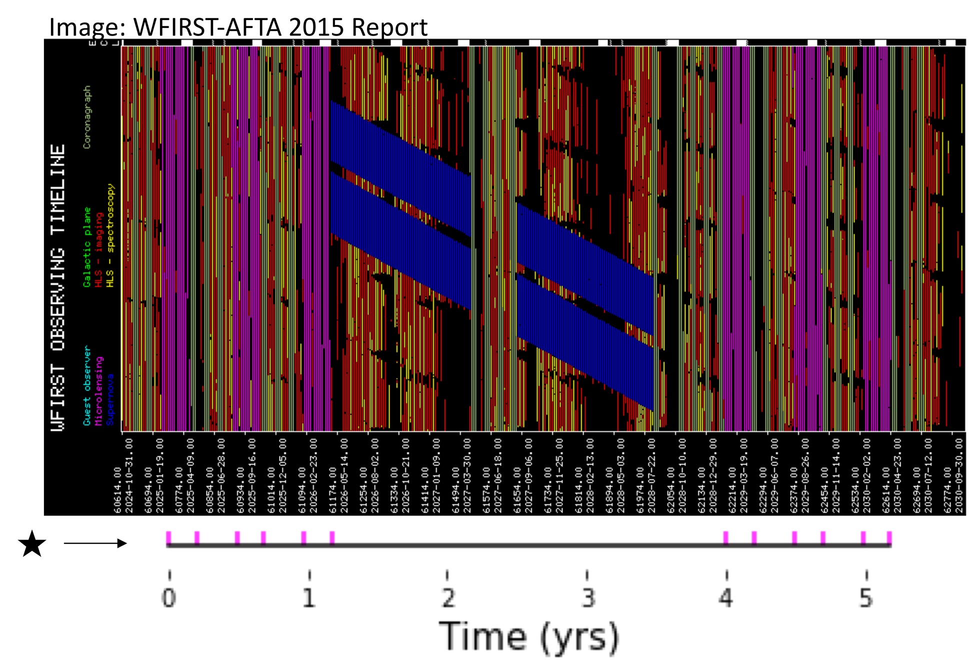
Figure 1 : Chernoff et al., 2019

- A microlensing event creates a digital signal in the light curve with a magnification close to 2

Observing Template

- A representation of the observing timeline of the microlensing survey
- The microlensing survey will observe in two filters, W149 (0.927–2.000μm) and Z087 (0.760–0.977 μm)
- Parameters considered are filter, exposure times, slew times, cadence and time between each of the 72-day seasons
- A visual representation of the accuracy of the template appears below the following image. Each vertical magenta line represents the surveying period calculated by the template (★)

Image: WFIRST-AFTA 2015 Report



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Microlensing Template

- A representation of a microlensing timeline
- A representative set of stars in the bulge that WFIRST might detect is used to simulate the conditions
- Parameters such as the speed of the earth, the speed and angle of the cosmic loop with respect to the line of sight are realized multiple times
- The variables of interest acquired from the previous set of parameters are represented in the following diagram:

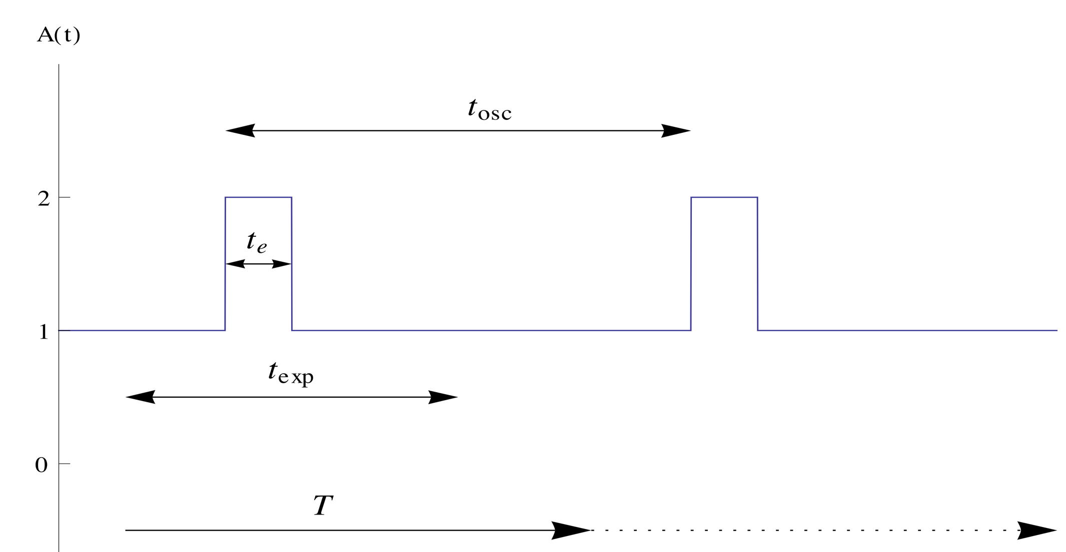
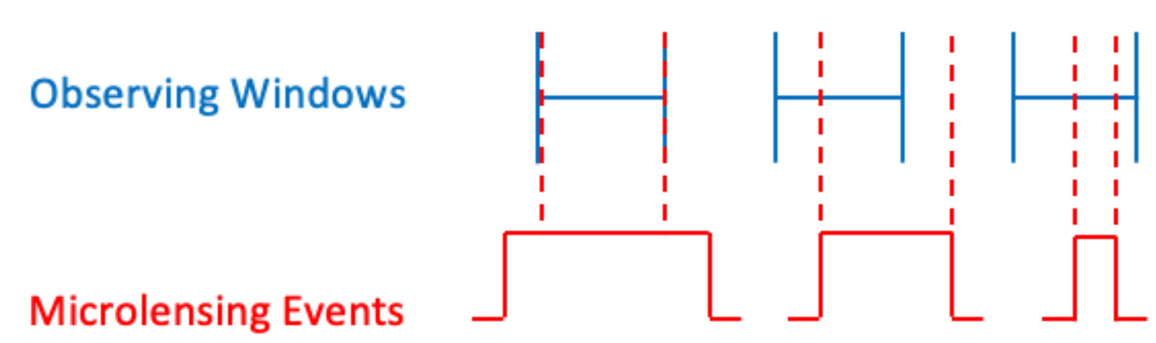


Figure 2 : Chernoff et al., 2019

- t_e = period during which the source is magnified
- t_{osc} = period of oscillations
- t_{cross} = time the string takes to cross the line of sight
- N_{rep} is an additional quantity that we are interested in and it is the number of times the source will be magnified by the same loop

Zipper Algorithm

- This is a conditional algorithm that compares both templates simultaneously in a complex routine
- The purpose of this zipper is to yield pseudo data that represents potentially detectable microlensing events



- The zipper algorithm yields the average flux per observing window
- Depending on the overlap between windows, we get values between 0 and 1 for the average flux

Associated Error

- Instrumental error for WFIRST depends on the magnitude of the source that is being magnified
- Associated error is added to the measurements from the zipper algorithm to obtain more realistic results

Future Prospects

- Establishing the most effective thresholds to reduce the number of false detections and dismissals

References

- Chernoff, D. et al., (2019), submitted to MNIRAS
- Chernoff, D. et al. (Work in Progress)
- Spergel, D. et al., (2015)