Pushing the Limits of Cosmology with Millimeter-Wave Spectrometers

Probes:

Galaxy Surveys

CMB

LIM

$z$

1100

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Outstanding Questions in Cosmology

Did **inflation** set the initial conditions that we see in the CMB?

What is the **dark matter**?

What is the **dark energy** causing the present-day acceleration?

Tensions, e.g. Hubble constant

Progress can be made by extending large-scale structure measurements to *higher redshift (distance)*

→ more volume (higher precision)
→ earlier times (probe different cosmological epochs)
“Line Intensity Mapping” (LIM): using low angular resolution observations of a spectral line to map a 3D volume (wavelength → redshift), without resolving individual sources.
Use a mm-wave spectrometer to identify redshift

Spectrum of a star-forming galaxy (continuum emission removed)

Ionized carbon fine-structure line [CII], C+
On-Chip Spectroscopy Enables Large Arrays

Space inside the telescope is at a premium.

Instead of using a diffraction grating (or Fabry-Perot or Fourier Transform Spectrometer), print a spectrometer on a silicon wafer.

Compare one spectrometer:

- **TIME grating**
  - 32 x 23 x 1 cm
  - $\sim 736 \text{ cm}^3$

- **SuperSpec**
  - 3.6 x 5.7 x 0.05 cm
  - $\sim 1 \text{ cm}^3$

Could pack orders of magnitude more spectrometers in a given volume!
SuperSpec: A Filter-Bank Spectrometer Printed on Silicon

Kovacs & Zmuidzinas 2010
SPT-SLIM: the South Pole Telescope
Summertime Line Intensity Mapper

Just funded through Fermilab LDRD!

**LIM pathfinder** using on-chip spectrometers

Observe in 2022/2023 Austral summer season (SPT-3G remains in place)

Anticipate $5\sigma$ detection of LIM signal
Summary

Millimeter-wave line intensity mapping detects galaxies through far-IR emission lines, and will probe inflation, dark matter, and dark energy beyond the redshift reach of traditional galaxy surveys.

On-chip spectrometers will enable filled focal planes with orders of magnitude more detectors than current instruments.

SPT-SLIM will demonstrate LIM with on-chip spectrometers in 2 years!