The (false) colors indicate the temperature of the universe 400,000 years after the big bang: average temp 3 K
Oscillations in the CMB
Fundamentals and overtones

Fundamental

Overtones (timbre)
Oscillations in the CMB

Angular scale

Location of peaks (size/geometry)

Height of peaks (materials)
Newest observations of the oldest light

**Standard cosmological model parameter estimates**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Omega_b h^2$</td>
<td>$0.02233 \pm 0.00015$</td>
</tr>
<tr>
<td>$\Omega_c h^2$</td>
<td>$0.1198 \pm 0.0012$</td>
</tr>
<tr>
<td>$100\theta_{MC}$</td>
<td>$1.04089 \pm 0.00031$</td>
</tr>
<tr>
<td>$\tau$</td>
<td>$0.0540 \pm 0.0074$</td>
</tr>
<tr>
<td>$\ln(10^{10} A_s)$</td>
<td>$3.043 \pm 0.014$</td>
</tr>
<tr>
<td>$n_s$</td>
<td>$0.9652 \pm 0.0042$</td>
</tr>
<tr>
<td>$r_{0.002}$</td>
<td>$&lt; 0.065$</td>
</tr>
</tbody>
</table>

**Planck 2018**

**Material content**

**Geometry/expansion**

**First stars?**

**Inflation**
The Swarthmore Cosmology Group

Theoretical physics/astrophysics research

Third/fourth-year: take my cosmology seminar (P137, T 1-4)

Preference to students with some programming experience

**Semester** and summer opportunities

Over the summer will work in pairs

Will most likely go to national conference winter/spring