Characteristic	Ground	Balloon	Space
Sky coverage	Partial from single site	Partial from single flight	Full
Frequency coverage	70 GHz inaccessible[a]; $\nu \geq 300$ GHz unusable otherwise, limited atmospheric windows	70 GHz inaccessible[a] otherwise, almost unlimited	Unrestricted
Angular resolution at 150 GHz[b]	1.5' with 6 m telescope	6' with 1.5 m telescope	6' with 1.5 m telescope
Detector Noise	$\geq$ *xx* microK rt(s);	$\geq$ *xx* microK rt(s)	*xx* microK rt(s)
Integration time	Unlimited	Weeks to a Month	Continuous, for years.
Accessibility, repairability	Good	None. Multiple flights possible.	None.

[a] 70 GHz is the frequency at which Galactic emissions are expected to have a minimum for sky coverage of $\sim$50% or more.
[b] We give representative approximate telescope aperture values. Significantly larger apertures for balloons and in space result in higher mass, volume, and cost.

Table 3: Relative characteristics of ground, balloon, and space platforms for experiments in the CMB bands.

or impossible. Thanks to its high sensitivity, it will detect in polarization both populations over a substantial flux density range, determining directly, for the first time, number counts in polarized flux density.

Mm/sub-mm polarimetry of radio sources provides unique information on the magnetic field configuration (geometry and degree of order) in the innermost, unresolved regions of the jets, close to the active nucleus. Polarimetry of dusty galaxies as a function of their inclination is informative on the structure and on the ordering of their large-scale magnetic fields.

2.4 Complementarity with Other Surveys and with Sub-Orbital Measurements

2.4.1 Complementarity with Astrophysical Surveys in the 2020s

PICO has strong complementarity with forthcoming surveys. Here we summarize areas of synergy that have been mentioned in a number of earlier sections.

There is no known way to achieve any cosmological constraint on the sum of the neutrino mass $\sigma(\sum m_\nu) < 25\,\text{meV}$ without improving *Planck*'s measurement of the optical depth τ. In particular, this applies to all methods that rely on comparing low-redshift structures with the amplitude of the CMB at high redshift, such as galaxy clustering, weak lensing, or cluster counts. PICO therefore complements all efforts that probe the late time structure of the Universe; combining PICO with these low-redshift observations extends the scientific reach of all these experiments well beyond what they could achieve on their own.

Reconstructing the CMB lensing convergence on very large angular scales, $L_\kappa < 20$, requires exquisite control of systematic uncertainties over a large sky fraction, with sufficient angular resolution to perform the lensing reconstruction, and with breadth in frequency band to robustly separate Galactic emissions (see Section 2.5). PICO will provide these, complementing ground-based CMB lensing reconstructions that typically observe a smaller sky fraction, with a smaller number of frequency bands, and without access to the largest angular scales. As discussed in page **??**, PICO will robustly measure the lensing signal with a power spectrum SNR larger than 10 *per mode* on very large scales. Such high-significance CMB lensing measurements on the very largest scales will be useful when combined with measurements of galaxy clustering, from example from LSST, to search for local primordial non-Gaussianity via its scale-dependent effect on galaxy bias; see Section **??**. While such a measurement would ultimately be limited by limitations of the LSST data on the very largest scales, space based observations of galaxy clustering with Euclid or SPHEREx may enable further improvements.

what about wfirst? jwst? DESI? CIB?

2.4.2 Complementarity with Sub-Orbital Measurements

Since the first CMB measurements, more than 50 years ago, important observations have been made from the ground, from balloons, and from space. Each of the CMB satellites flown to date

- COBE, WMAP, and *Planck*- has relied crucially on technologies and techniques that were first proved on ground and balloon flights, making these also crucial to the success of PICO. The phenomenal success of, and the immense science outcomes produced by, past space missions is a direct consequence of their relative advantages, as listed in Table 3. In every respect, with the exception of integration time exceeding several years, space has the advantage. These advantages used to come with higher relative costs. However, with the advent of massive ground-based experiments this balance shifts; the costs for a CMB experiment planned for the next decade are squarely within the cost window of this Probe. We can thus point to the following general guidelines for the next decade.

When the entire sky is needed, as for fluctuations on the largest angular scales, space is by far the most suitable platform, and for the search for the IGW signal it is absolutely necessary. When broad frequency coverage is needed, space will very likely be required to reach the ultimate limits set by astronomical foregrounds. As Figures 1 and 14 demonstrate Galactic emission overwhelm the IGW signal on the largest angular scales, and they are dominant even at high ℓ potentially limiting the process of delensing that is necessary for reaching levels of $r \lesssim 0.001$. The stability offered in space can not be matched on any other platform and translates to superb control of systematic uncertainties. There is a broad consensus within the CMB community that for levels of $r \lesssim 0.001$ the challenges in the measurement are the ability to control systematic uncertainties and to remove Galactic emissions; modern focal plane arrays, like the one employed by PICO have ample raw sensitivity. The PICO r goal of 10^{-4} is beyond the reach of ground observations. However, for science requiring higher angular resolution, such as observations of galaxy clusters with ~ 1 arcmin resolution at 150 GHz, the ground has a clear advantage. An appropriately large aperture on the ground will also provide high resolution information at lower frequencies, which may be important for separating Galactic emissions at high ℓ. A recommended plan for the next decade is therefore to pursue a space mission, and complement it with an aggressive ground program that will overlap in ℓ space, and will add science at the highest angular resolution, beyond the reach of a space mission.

Balloon observations have been exceedingly valuable in the past. They co-lead discoveries of the temperature anisotropy and polarization, provided proving grounds for the technologies enabling the success of COBE, WMAP and *Planck*, and trained the scientists that then led NASA's space missions. There are specific areas for which balloon missions can continue to play an important role, despite their inherently limited observing time. Balloon payload can access frequency bands above 280 GHz; currently there are no plans for any ground program to conduct observations at higher frequencies. These frequency bands will provide important, and perhaps critical information about polarized emission by Galactic dust, a foreground that is currently known to limit knowledge of the CMB signals. With flights above 99% of the atmosphere, balloon-borne observations are free from the noise induced by atmospheric turbulence, making them good platforms for observations of the low ℓ multipoles, and for characterizing foregrounds on these very large angular scales. And balloon-platforms continue to be an excellent arena for training the scientists of tomorrow.

2.5 Signal Separation

Component separation? Signal separation? Foreground removal? need to be consistent. Diffuse Milky Way emissions dominate the sky's polarized intensity on the largest angular scales; see Figure 14. also reference to Figure 1? Even in the cleanest, smaller patches of the sky, far from the