**STM V4.4:**

**Instructions:**

No need to touch Column 1,8;

Science WGs fill columns 2-5;

SH fills columns 6,7;

Red highlight means – needs to be completed

Fundamental Physics (Raphael)

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| **1. Science Goals** | **2. Science Objectives** | **Scientific Measurement Requirements** | | | **Instrument** | | **8. Mission Functional Requirements** |
| **3. Model Parameters** | **4. Physical Parameters** | **5. Observables** | **6. Functional Requirements** | **7. Projected Performance** |
| Explore how the universe began (inflation) | 1. Detect the energy scale at which inflation occurred if it is above 4x1015 GeV, or place an upper limit if it is below  (see Figure *TBD)* | Tensor-to-scalar ratio *r:*  σ(*r*) < 5x10-5 at *r* = *0*­  r<10-4 at 95% CL  (why not 1.5x10-5?) | CMB polarization B-mode power spectrum for modes 2<*l*<300 to cosmic variance limit, and CMB lensing power spectrum  for modes 2<*l*<1000 to cosmic variance limit | Linear polarization at frequencies 60<ν<300 GHz over the entire sky  (Raphael had starting at 20?) | 21 frequency bands between 20 and 800 GHz; fractional bandwidth of 25%  *(broad frequency necessary for foregrounds)*  Single mode angular resolution of 6.2’ at 155 GHz and remaining single mode to higher frequencies  *(resolution required for delensing and foregrounds)*  Combined instrument weight of 0.7 uK\*arcmin  *(sensitivity necessary for objectives)* | 21 frequency bands between 20 and 800 GHz; fractional bandwidth of 25%  7.6’ resolution at 150 GHz  Combined instrument weight of 0.5 uK\*arcmin | Sun-Earth L2 halo orbit  Mission life *4* yr  Full sky survey  Survey efficiency ≥*95*%  Downlink *150 Mbits/hour; 6 hour/day*  *TBD* Spinning/precessing  *TBD* Pointing accuracy  *TBD* Pointing stability  *TBD* Thermal  *TBD* Sun avoidance  *TBD* Launch vehicle compatibility |
| 2. Reject classes of potentials as the driving force of inflation  (see Figure *TBD)* | Spectral index *ns* and its derivative  σ(*ns*) < *0.0015*  σ(*nrun*) < *0.002* | CMB polarization B-mode power spectrum for modes 2<*l*<1000 to cosmic variance limit |

Fundamental Physics (Raphael) + reionization (Nick)

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| **1. Science Goals** | **2. Science Objectives** | **Scientific Measurement Requirements** | | | **Instrument** | | **8. Mission Functional Requirements** |
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| Discover how the universe works (Neutrino Mass and Neff) | 3. Determine the sum of neutrino masses, and distinguish between inverted and normal neutrino mass hierarchies (See Figure TBD) | Sum of Neutrino masses: σ(∑*m*ν*)* < *15* meV  (Using the lensing power spectrum, tau, and BAO from DESI; or independently using our cluster counts and LSST data) | CMB polarization B-mode power spectrum for modes 2<*l*<4000 to cosmic variance limit;  CMB intensity maps (to give Compton Y map from which we extract clusters) | Intensity and linear polarization at frequencies 60<ν<400 GHz over the entire sky | As above | As above | As above |
| 4. Detect departures from or tightly constrain the thermal history of the universe | Number of effective relativistic degrees of freedom  σ(Neff*)* < *0.03* | CMB temperature and E-mode polarization power spectra  2<*l*<4000  to cosmic variance limit | Intensity and linear polarization at frequencies 60 <ν<300 GHz over the entire sky |
| Explore how the universe evolved (reionization) | 5. Distinguish between models of the reionization epoch (see Figure *TBD*) | Depth to reionization τ:  σ(τ*)* < 0.002 | CMB polarization E-mode power spectrum for modes 2<*l*<20 to cosmic variance limit; T power spectrum and Compton Y maps. | Intensity and linear polarization at frequencies 60 <ν<300 GHz over the entire sky (role of intensity maps at high \ell to be clarified) | Frequency bands as above  *(broad frequency necessary for foregrounds)*  Resolution of 1 deg; (role of intensity maps at high \ell to be clarified)  Combined instrument weight of 0.7 uK\*arcmin  *(Perhaps can survive with less sensitivity)* |

Extragalactic Science (Nick)

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| **1. Science Goals** | **2. Science Objectives** | **Scientific Measurement Requirements** | | | **Instrument** | | **8. Mission Functional Requirements** |
| **3. Model Parameters** | **4. Physical Parameters** | **5. Observables** | **6. Functional Requirements** | **7. Projected Performance** |
| Explore how the universe evolved (galaxy formation, & feedback) | 6. Determine the role of energy injection due to feedback processes on galaxy formation and evolution | The baryon density and electron pressure radial profile of galaxy halos of mass  M>10^13.5 Msun/h | All sky CMB temperature and Compton Y maps | Temperature at frequencies 60<ν<400 GHz over the entire sky | Beam size of 2.5 arcmin at 385 GHz and increasing with single mode dependence to lower frequencies |  |  |

Galactic Science (Laura + Dave)

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| **1. Science Goals** | **2. Science Objectives** | **Scientific Measurement Requirements** | | | **Instrument** | | **8. Mission Functional Requirements** |
| **3. Model Parameters** | **4. Physical Parameters** | **5. Observables** | **6. Functional Requirements** | **7. Projected Performance** |
| Explore how the universe evolved (magnetic fields) | 7. Determine if magnetic fields are the dominant cause of low star formation efficiency in our Galaxy. | B - Magnetic Field strength as a function of spatial scale and density; Μa - Alfven Mach number (ratio of turbulent energy to magnetic energy); βp, Plasma beta (ratio of thermal energy to magnetic energy). | The turbulence power spectrum on scales ?? (from cores to diffuse cloud envelopes); Fractional polarization level; Correlations of fractional polarization and direction with hydrogen column density and temperature. | Linear polarization at ν = 799 GHz for galactic latitudes -20 <b<20  (to obtain maps of thousands of molecular clouds with <1pc resolution and <0.05 pc for the 10 nearest MCs.) | Frequency band at 799 GHz;  Angular resolution of 1 arcmin.  Sensitivity of 27.4 KJy/Sr | Frequency band at 799 GHz;  Angular resolution of 1 arcmin.  Sensitivity of 27.4 KJy/Sr | Same as above |
| 8. Determine whether the interstellar medium of our galaxy is unique by comparing the ratio of energy in magnetic field to turbulence to that in nearby galaxies. | B - Magnetic Field strength; Μa - Alfven Mach number | Magnetic field maps of nearby external galaxies (how many?); Levels of fractional polarization | Linear polarization at ν = 799 GHz to obtain maps of a statistically-significant set of external galaxies. |
| 9. Determine whether radiative torque is responsible for the alignment of dust grains with magnetic fields | Polarization spectra (fractional polarization as a function of wavelength) | This needs to be something like Tau\_radiative (a parameter that quantifies radiative torque) and A\_grain (a parameter that quantifies grain alignment). | Linear polarization maps in several frequency bands between 150 and 799 GHz for regions with high and low radiative flux | 10 frequency bands between 150 and 799 GHz;  To be completed |  |
| 10. Determine the variations in temperature and spectral index of polarized dust emission. | To be filled in | To be filled in | To be filled in |  |  |
| Explore how the universe evolved (magnetic fields) | 11. (needs more cooking)Is the level of magnetized turbulence consistent with observations of Cosmic Ray energy spectra? (why?) | B - Magnetic Field strength as a function of spatial scale; Μa - Alfven Mach number | Magnetic field maps of the diffuse ISM.  The turbulent power spectrum in regions of low intensity. | Linear polarization at frequencies > 300GHz over the entire sky, with <0.1 pc resolution for the edge of the local bubble (d~100pc). | Sensitivity: A\_v <0.1(need to convert to Jy/sr), < 4 arcmin resolution |  |  |

Legacy Science (Nick, Gianfranco)

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| Catalog | Impact | Science |
| 1. proto-clusters | Discover thousands (how many) of new proto-clusters selected homogeneously over the entire sky and in redshift.  Currently there are less than ?? identified (compared to heterogeneous samples of a few) | Explore how the universe evolved: Probe the earliest observable galaxy clusters to determine the initial stages of their formation and evolution |
| 2. Lensed Point sources | 3,000 highly magnified dusty sources.  Currently there are ?? sources found by the Planck satellite | Explore how the universe evolved: Learn about dark matter sub-structure in the lensing galaxies; probe star formation history in high-z dust enshrouded galaxies, a population in which star formation history can not be probed in any other way |
| 3. High-z galaxy clusters | Hundreds (200 or 800?) of virialized (opaque to the non-specialist, use a different word) clusters at z >2 | galaxy formation in dense environments at the peak of star formation for most cluster galaxies, ICM,… |
| 4. Polarized Point Sources | Detection of thousands(how many) of radio sources and dusty galaxies in polarization | Explore how the universe works: Measure the polarization properties of dusty and radio sources, and determine of their impact on CMB polarization science. |

Top of Form

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Shaul’s additional comments:

Please review the science column

Line #3 needs a thorough explanation