**STM V4:**

**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

Page 2 – Fundamental Physics

Page 3 - Extragalactic

Fundamental Physics (Raphael)

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| **1. Science Goals** | **2. Science Objectives** | **Scientific Measurement Requirements** | | | **Instrument** | | **Mission Functional Requirements** |
|  |  | **Model Parameters** | **Physical Parameters** | **Observables** | **Functional Requirements** | **Projected Performance** |
| Explore how the universe began (inflation) | 1. Detect the energy scale at which inflation occurred if it is above xx, or place an upper limit if it is below that level  (see Figure *TBD)* | Tensor-to-scalar ratio *r:* σ(*r*) < *TBD* at *r* = *TBD* ­ | CMB polarization B-mode power spectrum for modes 2<*l*<300 to cosmic variance limit | Linear polarization at frequencies 60<ν<300 GHz over the entire sky | 21 frequency bands between 20 and 800 GHz; fractional bandwidth of 25%  *(broad frequency necessary for foregrounds)*  7.6’ resolution at 150 GHz  *(resolution required for foregrounds)*  Combined instrument weight of 0.5 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*) < *TBD*  (LK/FR insert) < *TBD* | CMB polarization B-mode power spectrum for modes 2<*l*<1000 to cosmic variance limit |

Fundamental Physics (Raphael) + History of Star Formation (Nick)

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| *Discover how the universe works (Neff, dark matter, dark energy)* | 3. Determine the sum of neutrino masses.  Distinguish between inverted and normal neutrino mass hierarchies (See Figure TBD) | Sum of Neutrino masses: σ(∑*m*ν*)* < *15* meV  (Constraints using the power spectrum rely on tau and forthcoming DESI data; constraint using cluster counts relies on resolution) | CMB polarization B-mode power spectrum for modes 2<*l*<1000 to cosmic variance limit, and all sky polarization map  (to give Compton Y map from which we extract clusters) | Linear polarization at frequencies 60<ν<400 GHz over the entire sky | As above | As above | As above |
| Explore how the universe evolved (reionization) | 4. 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 | Intensity and linear polarization at frequencies 60 <ν<300 GHz over the entire sky  (does this require intensity as well?) |

Extragalactic Science

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| **1. Science Goals** | **2. Science Objectives** | **Scientific Measurement Requirements** | | | **Instrument** | | **Mission Functional Requirements** |
| **Model Parameters** | **Physical Parameters** | **Observables** | **Functional Requirements** | **Projected Performance** |
| Explore how the universe evolved (galaxy formation, & feedback) | 5. Determine the role of energy injection due to feedback processes on galaxy formation and evolution  (Nick’s text: that impact the distributions of dark and baryonic matter in the Universe) | The baryon density and thermal energy profile of halos of mass  M>10^13.5 Msun/h  (Nick’s text: to a few percent out to z < 2 on scales inside the virial radius) | All sky CMB intensity and Y maps (what do you mean by intensity and Y? do you need the absolute intensity?)  (need resolution for clusters) | Intensity and at frequencies 60<ν<400 GHz over the entire sky |  |  |  |

Galactic Science

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| **1. Science Goals** | **2. Science Objectives** | **Scientific Measurement Requirements** | | | **Instrument** | | **Mission Functional Requirements** |
|  |  | **Model Parameters** | **Physical Parameters** | **Observables** | **Functional Requirements** | **Projected Performance** |
| Explore how the universe evolved (magnetic fields) | 6. Determine if magnetic fields are the dominant cause of star formation repression in the Galaxy. | Magnetic Field strength B as a function of scale and density; Alfven Mach number (ratio of turbulent energy to magnetic energy) 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 *atomic hydrogen* column density and temperature. | Linear polarization at for ν > 300GHz over the entire sky (to obtain maps of thousands of molecular clouds with <1pc resolution and <0.05pc for the 10 nearest MCs. *(need to say how many vectors per cloud?)* | Bands between 300 and 800 GHz  Angular resolution: 1 arcmin.  Sensitivity: 27,400 Jy/Sr (9090 microK) at 799 GHz; 7,570 Jy/Sr (147 microK) at 555 GHz. |  |  |
| 7. How energetic are magnetic fields compared to turbulence in the ISM of nearby galaxies. (why? isn’t this the same as as above?) | Magnetic Field strength, B. Alfven Mach number. | Magnetic field maps of nearby external galaxies. Fractional polarization levels, magnetic field direction. | Linear polarization at frequencies > 300GHz over the entire sky to obtain maps of a statistically-significant set of external galaxies. | Angular resolution ~ 1 arcmin |
| 8. Is the level of magnetized turbulence consistent with observations of Cosmic Ray energy spectra? (why?) | Magnetic Field strength B as a function of scale.  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 |  |  |
| 9. Determine whether radiative Torques responsible for the alignment of dust grains with magnetic fields? (why?) Determine the variations in temperature and spectral index of polarized dust emission. | Polarization spectra (fractional polarization as a function of wavelength) | Multi-frequency, high S/N polarization maps of both diffuse ISM and molecular clouds. | Linear polarization at many frequencies 150 GHz-799 GHz over the entire sky | Combination of number of bands and angular resolution? |  |  |
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