# Cosmic Origins Program Analysis Group: Update, Status Report

Dominic Benford, COPAG Chief Scientist
Michael Garcia, COPAG Executive Secretary
Christopher Martin, former COPAG Chair
COPAG Executive Committee

Outline

1. COPAG composition and recent activities
2. All-encompassing Science Goal?
3. Update on Sept 2012 & Jan 2013 workshops
4. Open issues and way forward

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# COPAG Executive Committee

COPAG Chair
TBA

Ken Sembach
StScI
11/10-11/13

Julianne Dalcanton
UWash
10/11-10/14

Paul Goldsmith
JPL
11/10-11/13

Chuck Lillie

11/10-11/13

Mike Garcia
Executive Secretary

Jon Gardner
GSFC
11/10-11/13

Lynne Hillenbrand
Caltech
10/11-10/14

James Lowenthal
Smith College
3/12-3/15

Paul Scowen
ASU
12/11-12/14

David Leisawitz
GSFC
10/11-10/14

Dominic Benford
Ex Officio

Susan Neff
Ex Officio

# Executive Committee

- A Cosmic Origins “Dear Colleague” letter will be issued during the summer to replace some of the original COPAG EC members.
- In consultation with the COPAG Chair, the AP Division Director, and the approval by the ApS Chair, new appointments will be issued for the EC before November 2013.



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# COPAG: What Has Worked

- Most of the current Executive Committee(EC) is interested, active and pushing issues
- Regular (usually) EC telecons to discuss issues
- Very animated and interesting Community meetings at STScI and at AAS
- Technology prioritization; great and very detailed input to Program Office
- Efforts in attempting to unify science drivers: Cosmogony (more on this later...)
- UV/Visible RFI#1 – 33 great responses



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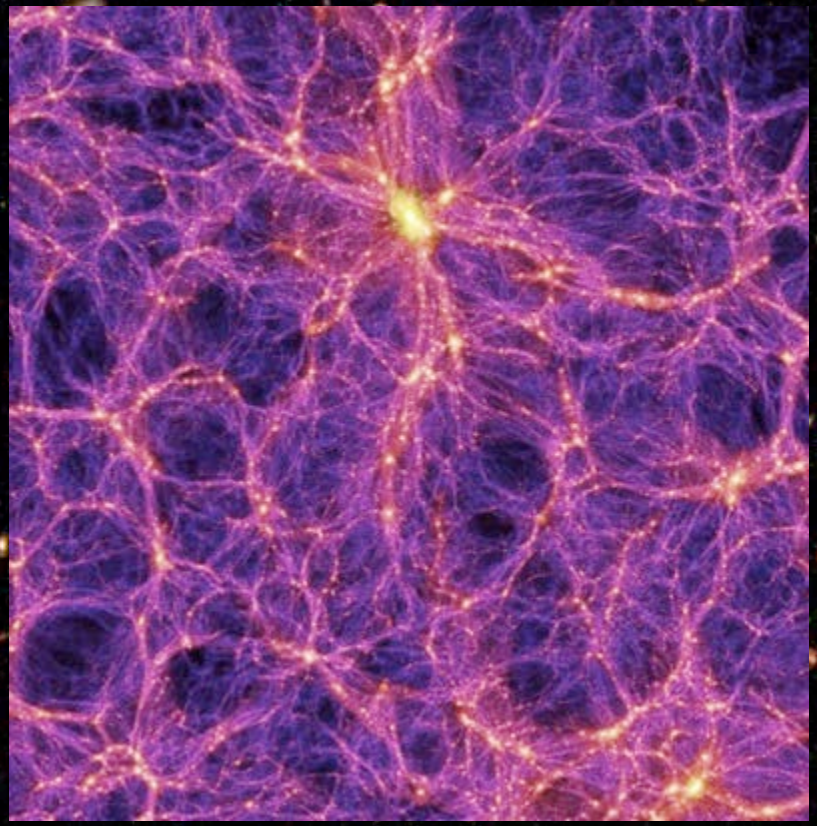
# 2012 Tasks/SAGs

- SAG1: Science Goals, Objectives, Requirements for Cosmic Origins missions. Where are science thresholds and how do they link with mission class / aperture size?
- SAG2: Determine technology focus areas for a monolithic 4m Aperture UV/Optical/NIR mission with Internal Coronograph for Exoplanet Imaging
- SAG3: Determine technology focus areas for a segmented 8 m Aperture UV/Optical/NIR mission with External Occulter for Exoplanet Imaging
- SAG4: Determine technology focus areas for future Far IR Instruments
- SAG5: What is the scientific case for a set of linked probes and corresponding technology requirements?

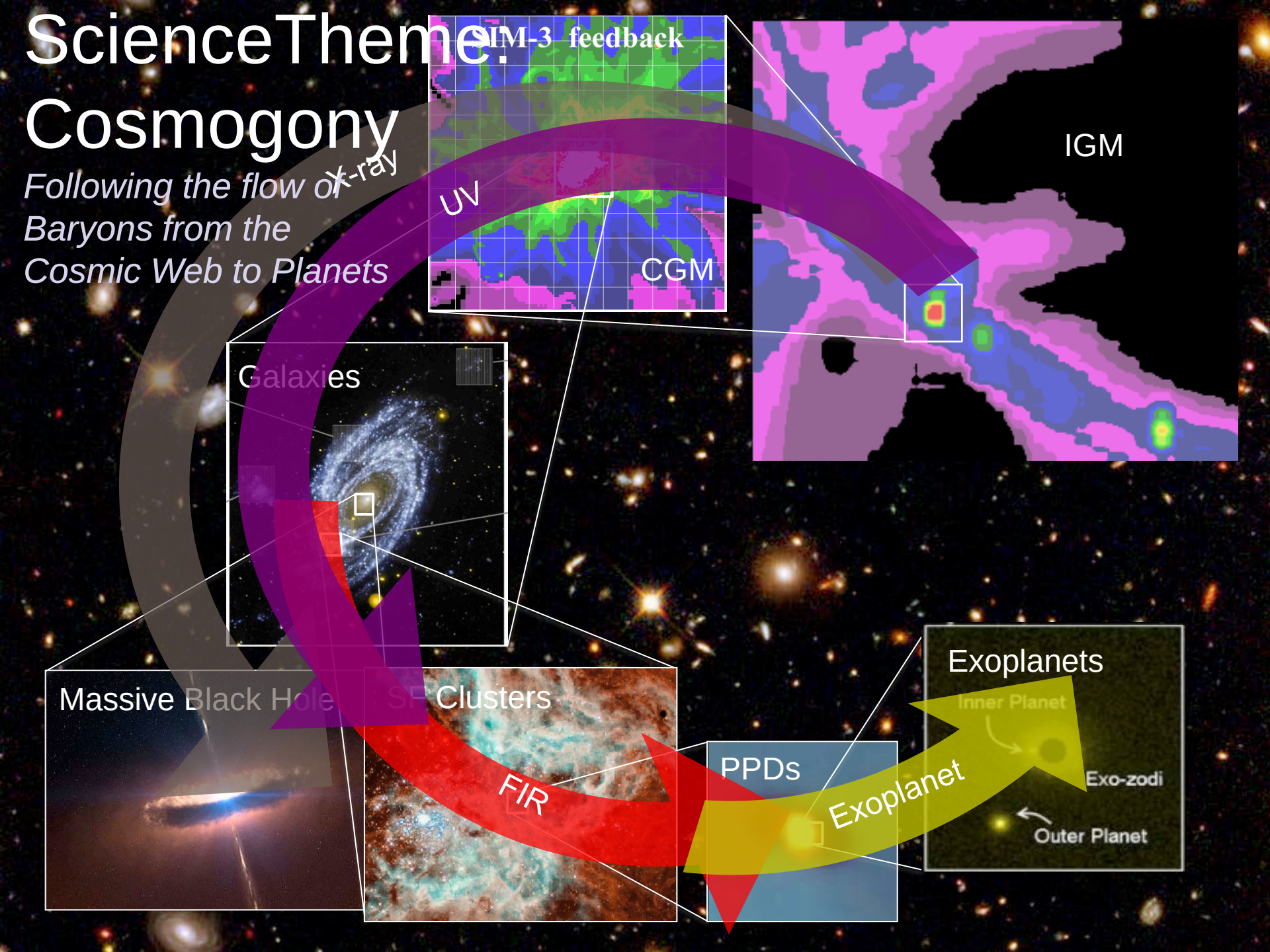
# Cosmogony

*Following the flow of matter from the Cosmic Web to Planets*



# ScienceTheme: Cosmogony

*Following the flow of Baryons from the Cosmic Web to Planets*



# Updates from Sept 2012 & Jan 2013 Workshops

UV RFIs 1 and possible 2

Technology priorities and SAT program

Mid-decadal process

Path to Astro2020

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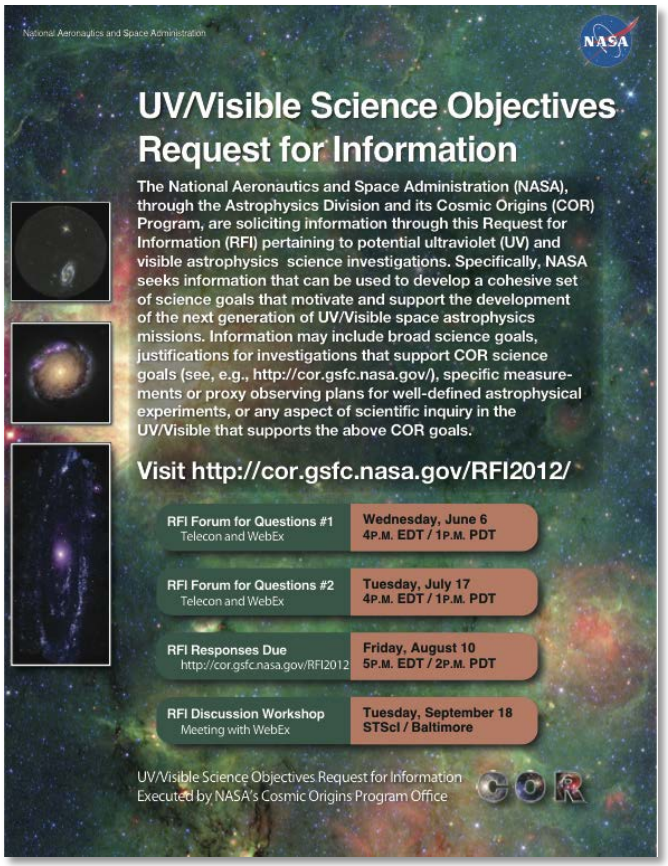
# UV/Visible Science Request For Information (Community Input)




Responses August 2012 (34 compliant)

Workshop September 2012 (50+ attend)

Provided representative, not comprehensive, view of important COR UV/Vis science.

222 individual respondents!

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# Imaging Mission Classes

| Diam | UV RFI Imaging Science Topic | Band | Resol | FOV |
|---|---|---|---|---|
| 1-2 m | Stellar Physics with UVO Spectropolarimetry | 117-870nm | <0.01” | 2” |
| | The Magellanic Clouds Survey | 200-1000nm | <0.1” | 10’x10’ |
| | Conditions for Life in the Local Universe | 100-300nm | <0.1” | ? |
| | The Role of Dwarf Galaxies in Reionization | 100-630nm | 1” | 10’ |
| | Project Lyman: 11 Gyrs of Metagalactic Ionizing Background Evolution | 95-400nm | 0.25” | 0.5 sq. deg |
| | Solar System Science Objectives w/ UVO Space Observatory | UV-IR | 0.05” | <50” |
| | CASTOR: a widefield UVO Survey Telescope | 150-550nm | 0.15” | 0.67 sq. deg. |
| 2.4 m | Galaxy Assembly and SMBH/AGN Growth | 200-1000nm | <0.04” | 15’x15’ |
| | Understanding Global Galactic Star Formation | 250-950nm | 0.02” | >15’x15’ |
| | Near-Field Cosmology and Galactic Evolution Using Globular Clusters in Nearby Galaxies | 200-550nm | 0.05” | 20’x20’ |
| | Extragalactic Lyman-alpha Experiments in the Nearby Universe | 122-350nm | 0.05” | 0.1 sq. deg. |
| 4 m | Exoplanet Science of Nearby Stars on a UVO Astrophysics Mission | 500-800nm | Diff. Limit | 1” |
| 8 m | The History of Star Formation in Galaxies | 300-900nm | Diff. Limit | 3’x3’ |
| | The Crucial Role of High Spatial Resolution, High Sensitivity UV Observations to Galaxy Evolution Studies | 110-600nm | 0.007” | 30’x30’ |
| | Seeking Behind the Anthropic Principle | 90-320nm | 0.01” | 3’ |
| | AGN & their role in Galaxy Formation & Evolution | 120-300nm | <0.0001” | 4mas |


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# Spectroscopic Mission Classes

| Diam | UV RFI Spectroscopic Science Topic | Band | R | MOS |
|---|---|---|---|---|
| 1-2 m | Science from IGM/CGM Emission Mapping | 100-400nm | 1000-5000 | Y |
| | Project Lyman: 11 Gyrs of Metagal. Ionizing Background Evolution | 95-400nm | Few 1000s | Y |
| | Extragalactic Lyman alpha in nearby universe | 122-350nm | 100-5000 | |
| | UV spectroscopic time-domain studies of AGN | 110-300nm | >600 | |
| | A UVOIR spectroscopic sky survey to understand galaxy evolution | 200-1700nm | 400-1000 | Y |
| | CASTOR: a widefield UVO Survey Telescope | 150-550nm | 100-700 | |
| 2.4 m | The origin of elements heavier than Iron | 190-305nm | 60,000 | Y |
| | Magellenic Clouds Survey | 200-1000nm | 30,000 | |
| | Near-Field Cosmology and Galactic Evolution Using Globular Clusters in Nearby Galaxies | 200-550nm | 3000 | Y |
| | Galaxy Assembly and SMBH/AGN-growth | 200-1000nm | Few 100s | |
| | From proto-planetary disks to extrasolar planets: understanding the life cycle of circumstellar gas with UV spectroscopy | 92-180nm<br>120-400nm | 150,000<br>3000 | Y |
| | Solar system science objectives with next UVO space observatory | UV-IR | 2500 | |
| 4 m | How do molecules and dust form in massive interactive winds | 300-700nm | 10,000 | Y |
| | Conditions for life in the local universe | 100-300nm | 100,000 | |
| | The Baryon census in a Multiphase IGM | <100nm+ | 100,000 | |
| | Unique astrophysics in the Lyman UV | 92-200nm | 50,000 | Y |
| 8 m | Massive stars: Key to solving the cosmic puzzle | 92-900nm | 6000 | |
| | QSO absorption lines in Far UV: gold mine for galaxy evolution | 100nm+ | ~COS | |
| | Seeking the Anthropic Principle | 90-320nm | 1000 | |
| | Active Galactic Nuclei and their role in Galaxy Formation & Evolution | 120-300nm | 500 | |

# UV Imaging Science

| Parameter | Enabled | Not Enabled | Best Bang for Buck? |
|---|---|---|---|
| **Waveband:** | | | |
| **≥ 92nm** | 18 | 0 | |
| **≥ 115nm** | 11 | 5 | ✓ |
| **≥ 250nm** | 4 | 13 | |
| **Resolution:** | | | |
| **≥ 1 mas** | 13 | 3 | |
| **≥ 10 mas** | 12 | 4 | ✓ |
| **≥ 50 mas** | 8 | 8 | |
| **Aperture:** | | | |
| **1-2m** | 7 | 10 | |
| **2.4m** | 11 | 6 | ✓ |
| **4m** | 12 | 5 | |
| **8m+** | 16 | 1 | |
| **FoV:** | | | |
| **1 arcmin** | 5 | 12 | |
| **10 arcmin** | 11 | 6 | ✓ |
| **30 arcmin** | 15 | 2 | |

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# UV Spectroscopic Science

| Parameter | Enabled | Not Enabled | Best Bang for Buck? |
|---|---|---|---|
| **Waveband:** | | | |
| **≥ 92nm** | 22 | 2 | ✓ |
| **≥ 115nm** | 13 | 11 | |
| **≥ 250nm** | 2 | 22 | |
| **Spectral Resolution:** | | | |
| **R=1000** | 9 | 15 | |
| **R=10,000** | 16 | 8 | |
| **R=40,000** | 18 | 6 | ✓ |
| **Aperture:** | | | |
| **1-2m** | 6 | 18 | |
| **2.4m** | 12 | 12 | |
| **4m** | 16 | 8 | ✓ |
| **8m+** | 20 | 4 | |
| **MOS:** | 8 | N/A | |

A 2.4m UV/Visible telescope with 10 arc-min FOV and MOS is highly competive: HST?

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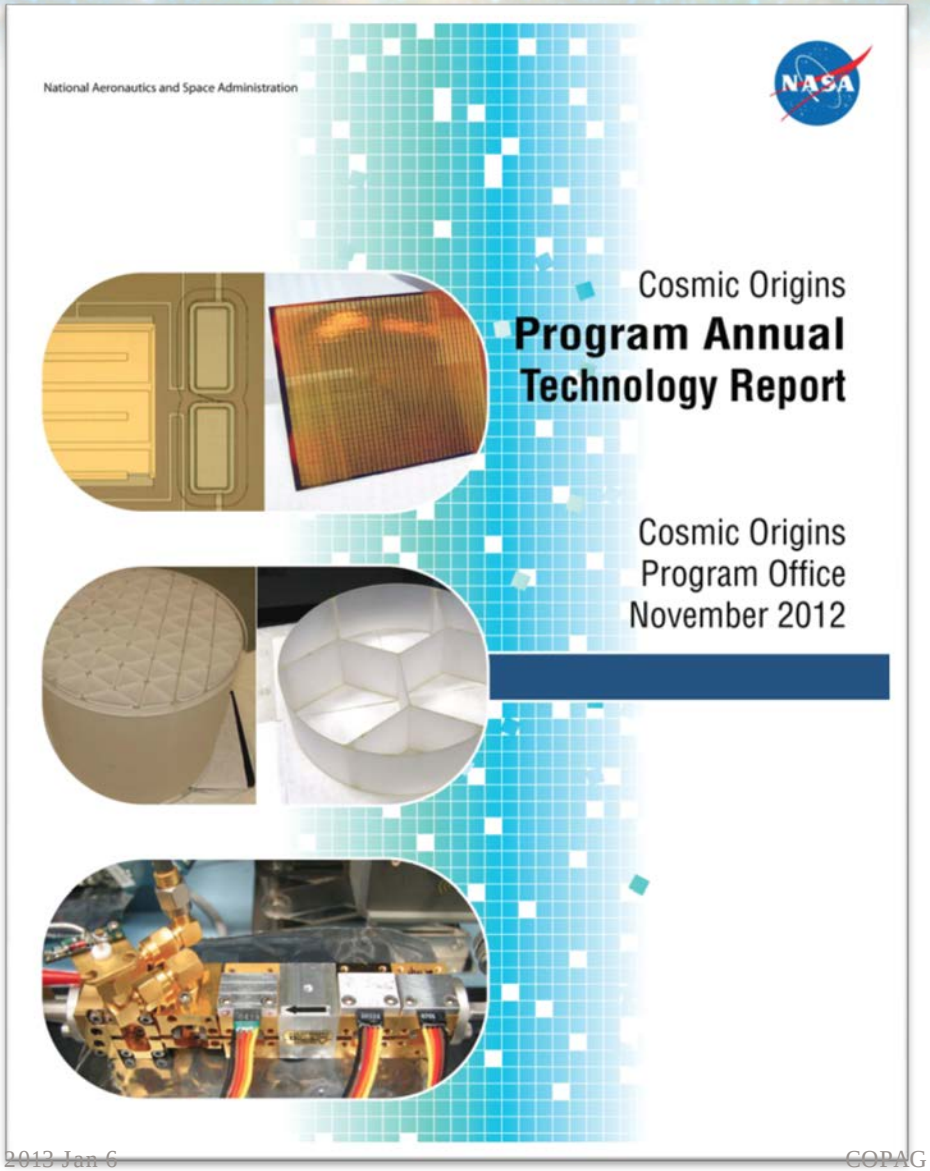
# PATR




- Contains status of COR-funded technology developments
- Provides new technology needs prioritization.
- Available online! http://cor.gsfc.nasa.gov

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# COR Technology Needs Priorities from 2012 PATR

| COR Technology Needs Prioritization | |
|---|---|
| High QE, large format UV detectors | **Priority 1.** Contains technology needs that the TMB has determined to be of the highest interest to the Cosmic Origins program and recommends that they **should** be invested in first, when funding is available |
| Photon counting UV large-format detectors | |
| High Reflectivity UV coatings | |
| Ultralow-noise Far-IR direct detectors | |
| Very large format, low noise Optical/IR detector arrays | **Priority 2:** Contains technology needs that the TMB feels are worthy of pursuit and **would** be invested in, if funding allows |
| Large, low-cost, light-weight precision mirrors for Ultra-Stable Large Aperture UV/Optical Telescopes | |
| Large format, low noise Far-IR direct detectors | |
| Photon counting Optical/IR detector arrays | |
| Heterodyne Far-IR receiver arrays | |
| High efficiency cryocoolers | **Priority 3:** Contains technologiy needs that are deemed to be supportive of COR objectives but, for various reasons, do not warrant investment at the present, although they **could** be invested in, if significant additional funding is available |
| High efficiency UV multi-object spectrometers | |
| Large, cryogenic far-IR telescopes | |
| High Performance Sub-Kelvin Coolers | |
| Deployable light-weight precision mirrors for future Very Large Aperture UV/Optical Telescopes | |
| Interferometry for far-IR telescopes | |


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# COR Top Priorities

- High-QE, large-format UV detectors – QE (>70%), large-format (>2k × 2k) detectors for operation at 100–400 nm or broader .
- Photon-counting, large-format UV detectors – For spectroscopy, high QE (>50%), very low-noise ($<10^{-7}$ ct/pixel/s), large-format (>2k × 2k) photon-counting detectors for operation at 100–400 nm or broader .
- UV coatings –high reflectivity, high uniformity, and wide bandpasses, operating from visible to wavelengths below 100 nm .
- Ultra-low-noise far-IR direct detectors – For spectroscopy at wavelengths between ~30 μm and ~300 μm;
  NEP ≈ $3 \times 10^{-21}$ W/√Hz arrayable in a close-packed configuration in at least one direction

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# Technology Priorities & Strategic Astrophysics Technology Program

- COPAG agrees that in general CO Program Office technology priorities reflect community consensus
- COPAG will continue to refine technology priorities based on
  - ✓ Prior technology development results
  - ✓ Revised science, mission concepts, and associated needs (input from community email list)
  - ✓ New technology developments
    - ➢ Example: UVOIR spectrometer multiplexing technology
      - Digital Micromirror Devices (TRL3)
      - Microshutter arrays (TRL7)
- COPAG will continue to monitor NASA Cosmic Origins program to ensure that community priorities continue to be reflected

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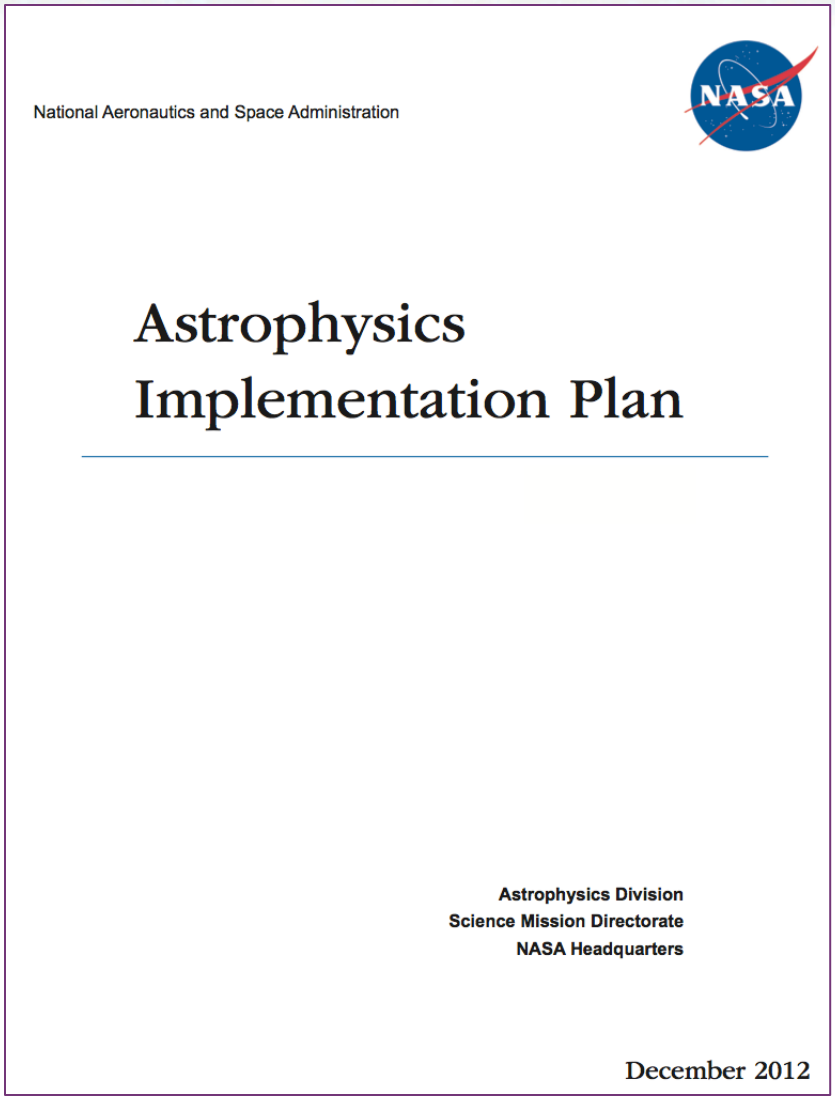
# Implementation Plan




- *"Astrophysics Implementation Plan* has been prepared by the Astrophysics Division of NASA's Science Mission Directorate… to respond to the decadal survey recommendations within the current budgetary constraints."
- For COR, only present mission-related effort is to conduct mission trade studies envisioned to inform technology investment decisions during latter half of decade

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# NASA Planned Mission Concept Activity in this Decade

| Strategic Mission Concepts | Derived from Recommendation | Status of Studies | Candidate Plan(s) for Future Mission |
|---|---|---|---|
| WFIRST: Large Strategic Mission (DRM1) | Large 1st : WFIRST | Completed in 2012 | Large mission for mid-decade |
| WFIRST: Probe-size Strategic Mission (DRM2) | Large 1st : WFIRST | Completed in 2012 | Probe for mid-decade |
| Use of 2.4m telescope assets to advance science of WFIRST | Large 1st : WFIRST (Medium 1: New Worlds Technology) | Started in 2012 | Large mission for mid-decade |
| Gravitational Wave missions to advance science of LISA | Large 3rd : LISA Technology | Completed in 2012 | Large mission for next decade; international partnership |
| X-ray missions to advance the science of IXO | Large 4th : IXO Technology | Completed in 2012; under consideration for study in 2014 | Probe for mid-decade; Large mission for next; international partnership |
| Exoplanet probes to advance the science of a planet characterization and imaging mission | Medium 1st : New Worlds Technology | Planned for 2013; SDT opportunity just announced | Probe for mid-decade; large mission for next decade |
| Cosmic Microwave Background Polarization Probe | Medium 2nd : Inflation Probe Technology | Study under consideration for study in 2015 | Probe or large mission for next decade |
| Science + technology drivers for a UV/Visible mission | Small: (Definition of) a future UV- optical space capability | Started in 2012 | Probe or large mission for next decade |

# Updates from Sept 2012 & Jan 2013 Workshops

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# Path to Astro2020

- No COR mission (except WFIRST) in mid-decadal process
- Possible Community Directions:
  - Option 1: Community proposes many competing approaches to Astro2020, grass roots, DS decides
  - Option 2: Community converges on 1 concept
  - Option 3: Community converges on a small set of options (e.g., Probes, 4 m mono, 8 m segmented)
- *What is the process for the community to "self-organize" to make the decision & converge on best option?*
- Possible first steps:
  - Workshop to address Community Decision to make it or agree on process to make it
  - Form new SAG: *Cosmic Origins Community Strategy to Prepare for Astro2020*

# COPAG: Issues to Resolve

- **New COPAG Chair** – important for the overall dynamics of the group
- **Replacing EC Members** at the end of 2013 (established in November 2010).
- **Planning community workshops** (technology, mission concepts) for Summer 2013
- **Direction/Terms of Reference for SAGs** (clear product, clear end game)
- **Consolidate future missions concepts** in UV/Visible and Far-IR science areas for next decade
- **Compelling Technology Development Plan** (TDP) for the rest of this decade; community input
- **Prepare for Decadal UV/Visible follow-on to HST,** re: Astro2010



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# Backup

# Updates from Sept 2012 & Jan 2013 Workshops

## Science Goals for Cosmic Origins

# Science Goals

- **Goal 1:** Characterize the growth of large-scale baryonic structures in the intergalactic medium
- **Goal 2:** Observe and explain the assembly of galaxies over cosmic time
- **Goal 3:** Trace and understand the flows of baryons between galaxies and the intergalactic medium
- **Goal 4:** Trace and understand the cycles of matter and energy within galaxies
- **Goal 5:** Measure and explain the history of star formation in galaxies over time
- **Goal 6:** Determine how the conditions for habitability arise during planetary system formation

# Updates from Sept 2012 & Jan 2013 Workshops

## New Science of Cosmic Dawn

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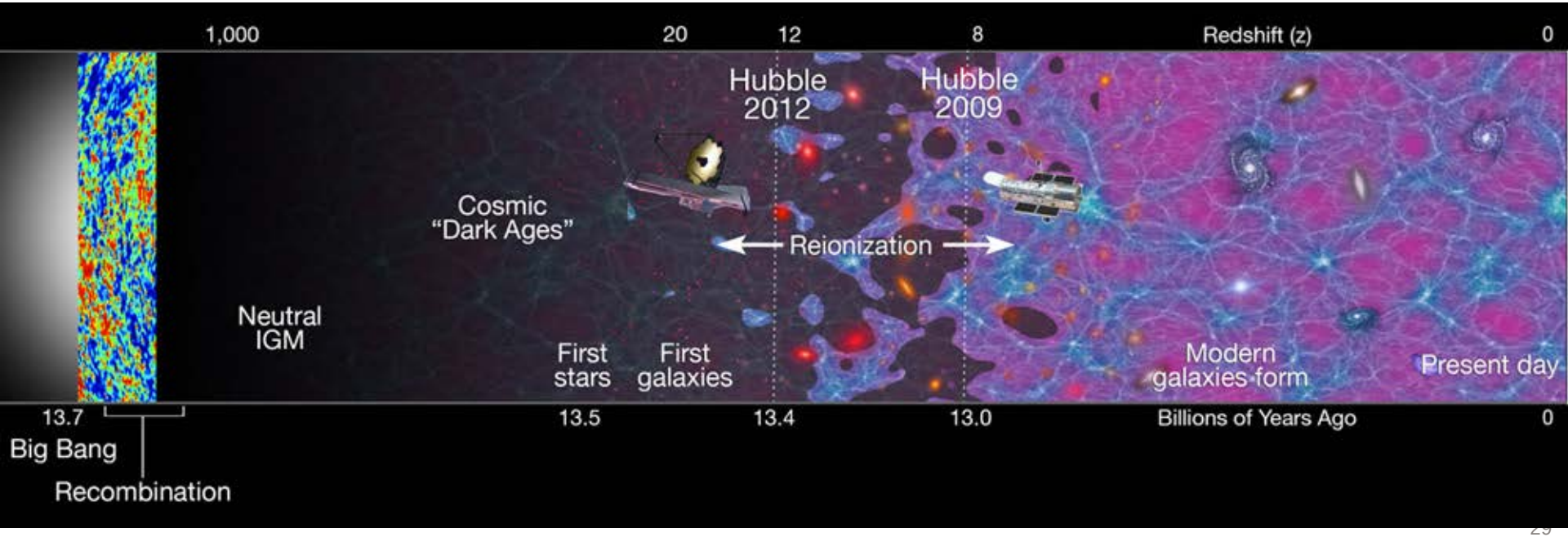
# Cosmic Dawn

- HI 21 cm $z$~10-40+ to probe pre-galaxy era!
- Low frequency radio band, moon-shadow
- May form form new SAG to explore



# Updates from Sept 2012 & Jan 2013 Workshops

## Science-Driven Technology Flowdown

# Example: Measurement → UV Detector Requirements

| UV Detector Property | UV High Resolution/High Contrast Imaging | UV Wide Field Imaging | UV High Resolution Spectroscopy | UV Multi-Object Spectroscopy | UV Integral Field Spectroscopy | Current Performance |
|---|---|---|---|---|---|---|
| QE | Moderate | Moderate | High-Very High | High | High-Very High | Low-Very Low |
| Format: Number of Pixels | Very High | Very High | High-Very High | High-Very High | High-Very High | High |
| Photon-counting | XX | X | XXX | XX | XXX | YES |
| Equivalent background | Low | Moderate | Very Low | Low-Very Low | Very Low | Moderate |
| Dynamic Range | High | High | Moderate | Moderate | Moderate | Moderate |
| Radiation Tolerance | Moderate | Moderate | Moderate | Moderate | Moderate | High |
| Time Resolution | Low | Low | Low | Low | Low | High |
| Out of Band Rejection | High | High | Moderate | Moderate | Moderate | High |