Cosmic Origins Program Analysis Group: Status Report

Christopher Martin, Chair
COPAG Executive Committee

Outline

1. COPAG composition and activities
2. Science Goals
3. Mission/Technology Requirements
4. Burning Issues
5. Requests to Astrophysics Subcommittee

Astrophysics Subcommittee Meeting August 30-31, 2012

1. COPAG Composition and Activities

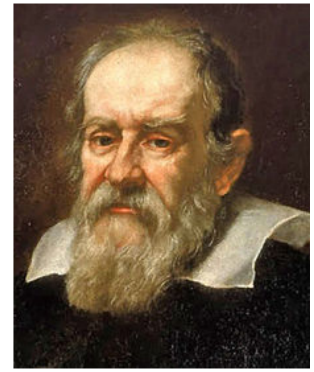
COPAG Executive Committee


Chris Martin
Caltech (Chair)


Ken Sembach
StScI


Julianne Dalcanton
UWash


Paul Goldsmith
JPL


Chuck Lillie


Jon Gardner
GSFC


Lynne Hillenbrand
Caltech


James Lowenthal
Smith College


Paul Scowen
ASU


David Leisawitz
GSFC

COPAG Activities 2011- 2012

- Community meeting -- Jan 2011 AAS
- Bi-weekly telecons
- COPAG Web site (2 now)
- AAS Exploder
- Provide inputs to NRC/NASA Technology Roadmap Process
- Joint COPAG/ExoPAG Meeting -- 26 April 2011
- Community meeting – May 2011 AAS
- Fall community workshop – Sept 22-23, 2011 – StScI
- Draft Technology Assessment → ApS (Oct 19, 2011)
- Winter community workshop – Jan 8, 2012 – AAS Austin
- Cosmic Origins Newsletter
- Attending PhysPAG meeting DC Aug 14, 2012
- Supporting NASA CO Program Office RFI Process
- Workshop at StScI 21 Sept 2012: UVO RFI, Science Objectives, Probes, NRO Telescopes

2012 Tasks/SAGs

- SAG1: Science Goals, Objectives, Requirements for Cosmic Origins missions. Where are science thresholds and how do they link with Probe vs. Flagship class and 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 [to be modified]: What is the scientific case for a set of linked probes and corresponding technology requirements? Can this be accomplished with one NRO telescope?
- SAG6 [to be approved]: Develop a plan for community costing transparency, training, ownership, and effecting systemic change.

Blue: active investigations. Program office RFI process.

Red: to be approved

Black: reported out in Technology Assessment 2011. Roadmaps in process. Assess progress on yearly basis.

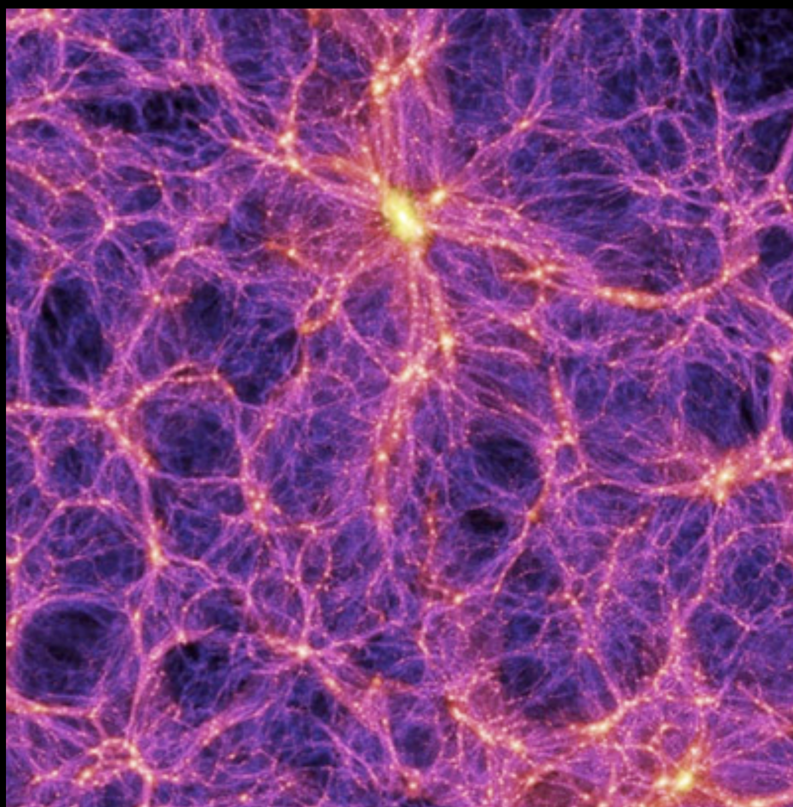
COPAG Communication

- Input to Cosmic Origins Newsletter
- email list
- AAS Exploder — 3 PAG reports, 2-4 per year?
- Suggestions!?

2. Developing a Single, Coherent Science Story

Cosmogony

Following the flow of matter from the Cosmic Web to Planets



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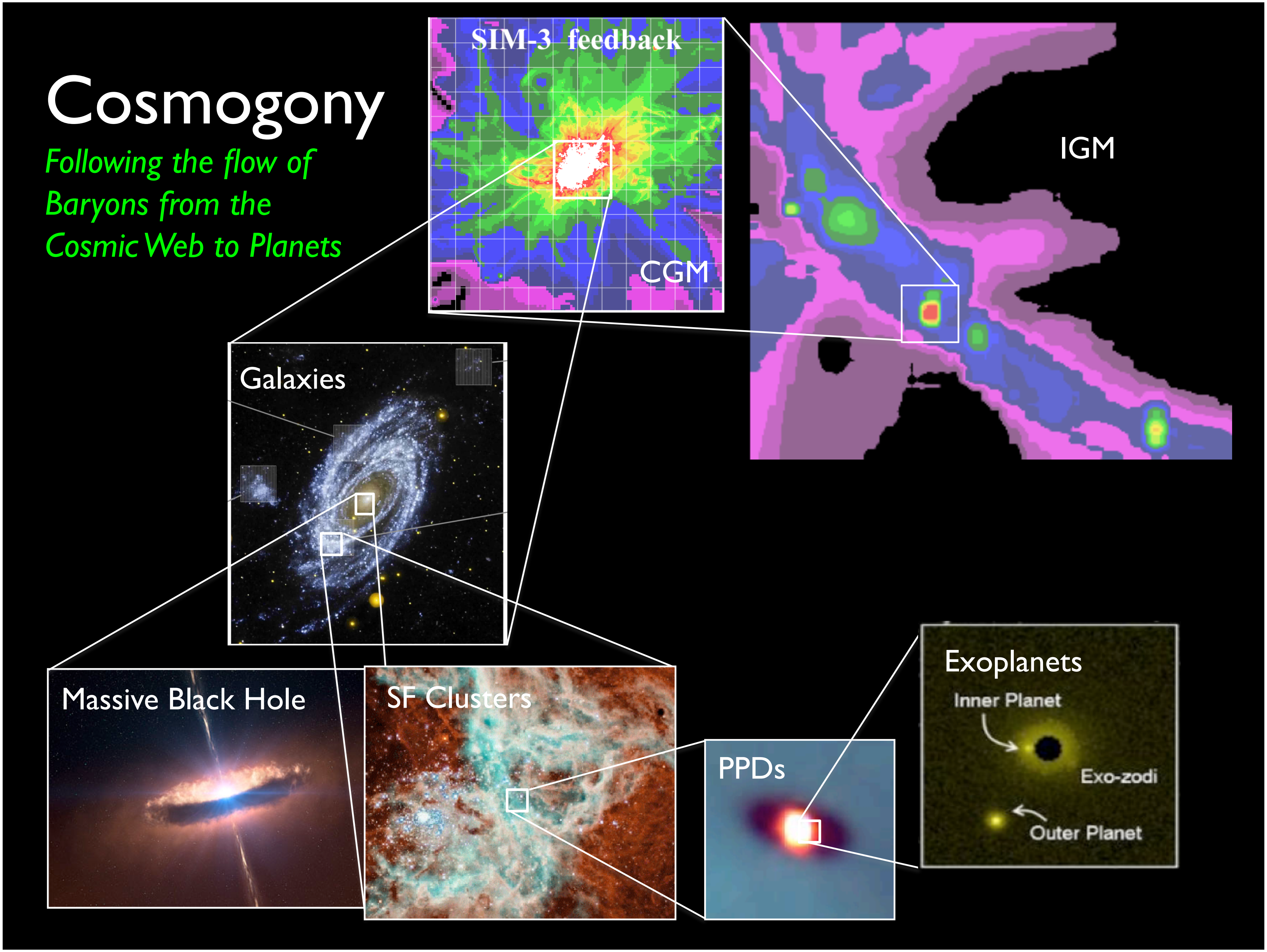
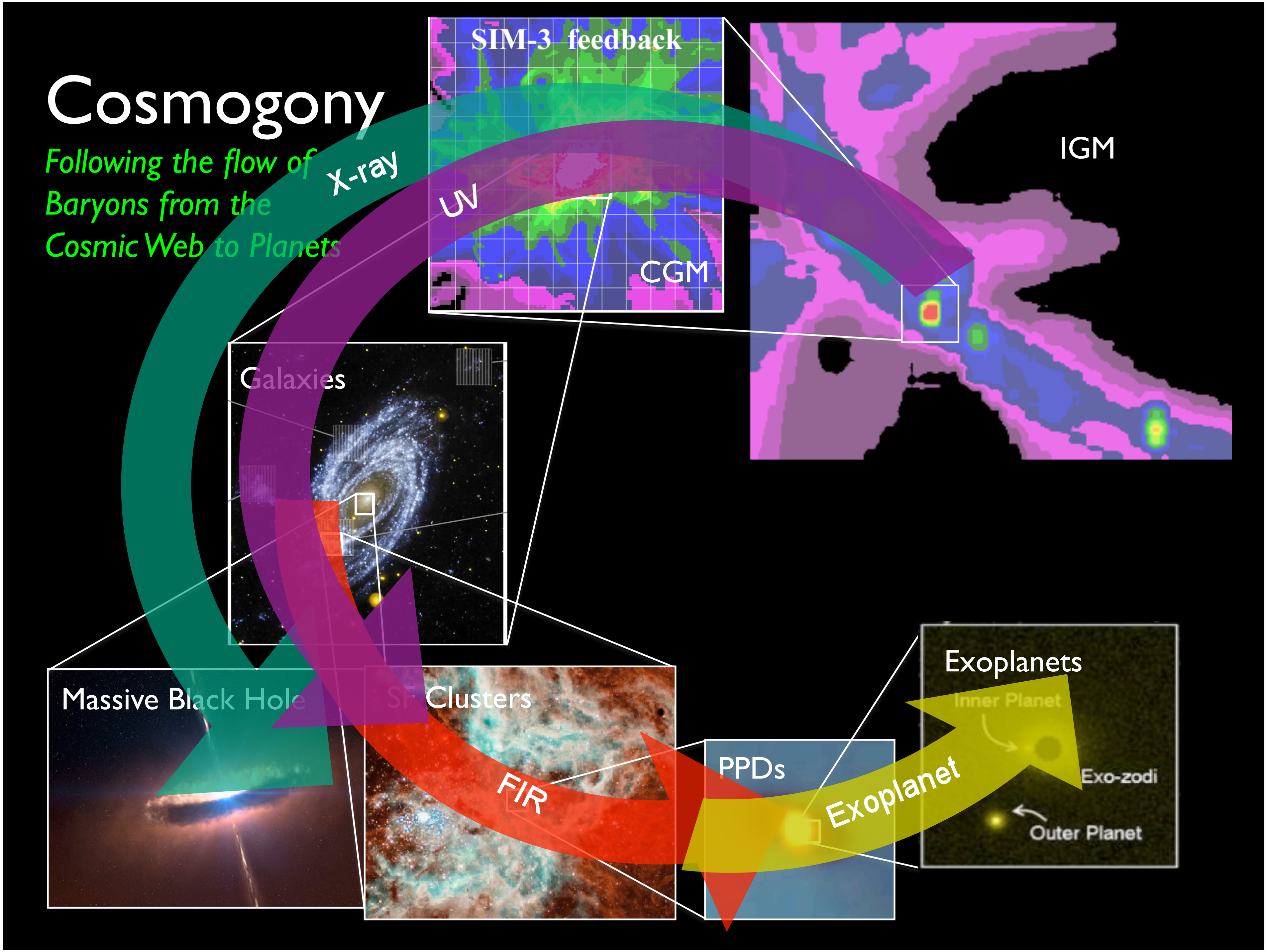

Cosmogony
Following the flow of Baryons from the Cosmic Web to Planets
SIM-3 feedback
CGM
IGM
Galaxies
Massive Black Hole
SF Clusters
PPDs
Exoplanets
Inner Planet
Exo-zodi
Outer Planet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UV
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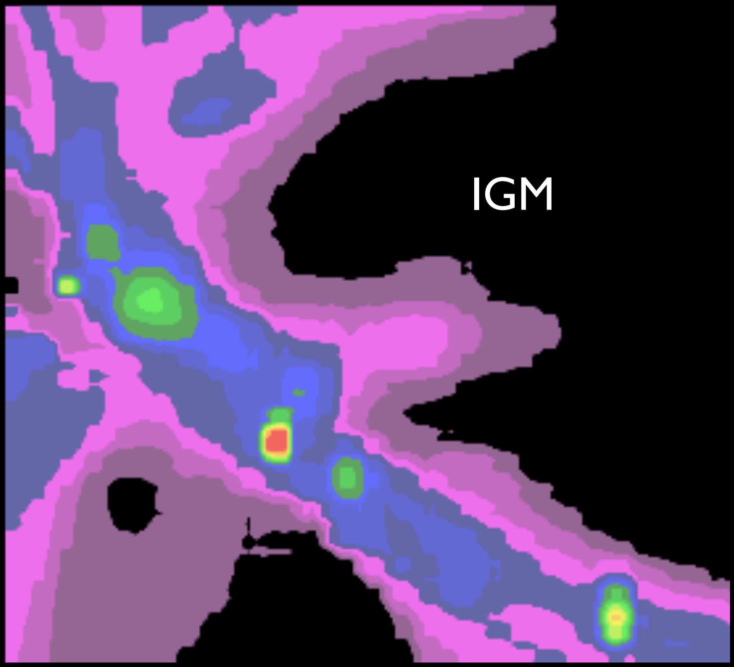
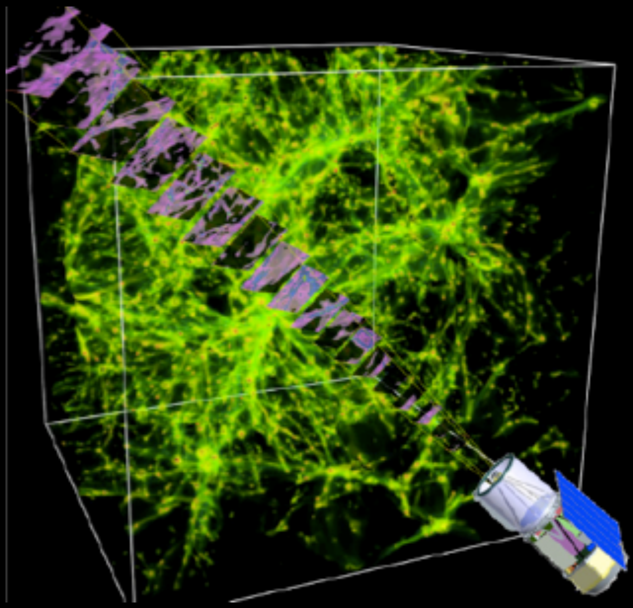
Cosmogony

Following the flow of Baryons from the Cosmic Web to Planets

IGM (δ~1-100)

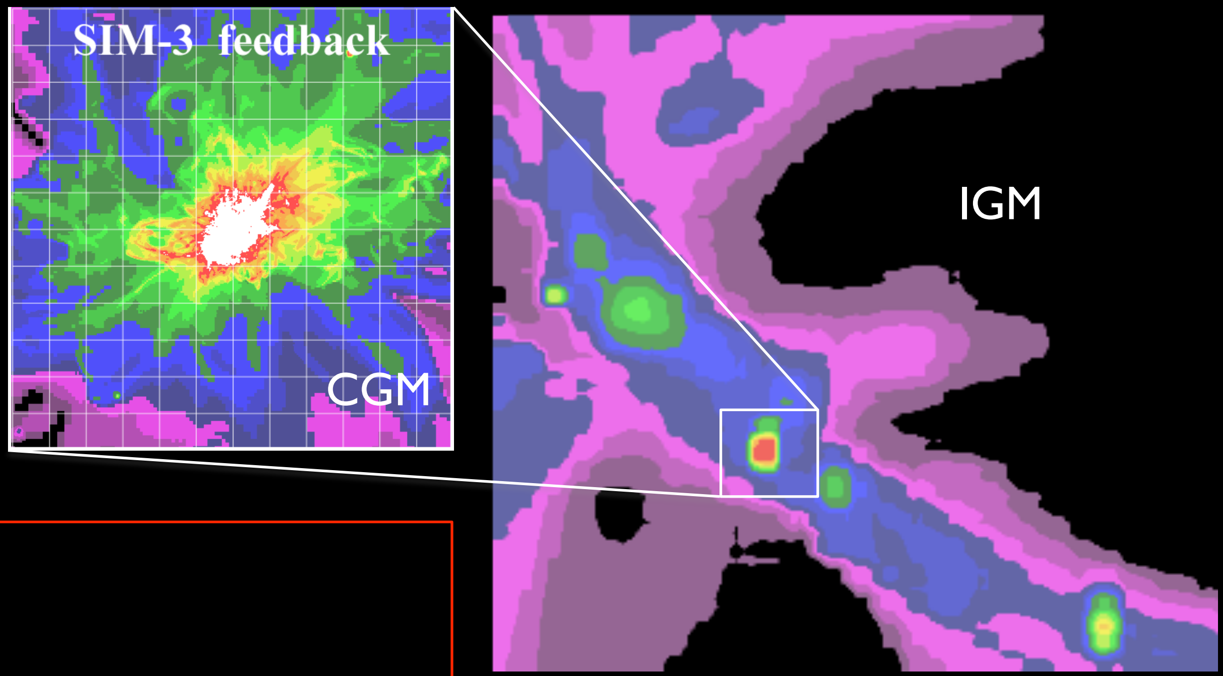
- *Where are the baryons?*
- *How does gas flow from the IGM to the CGM to galaxies?*
- *How is the IGM affected by the evolution of galaxies and massive black holes over time?*
- *Does the IGM trace dark matter?*





Cosmogony

Following the flow of Baryons from the Cosmic Web to Planets

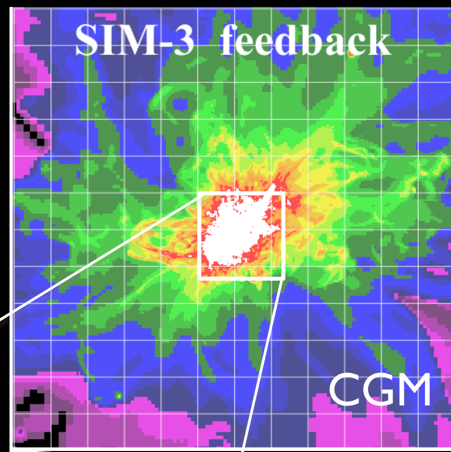


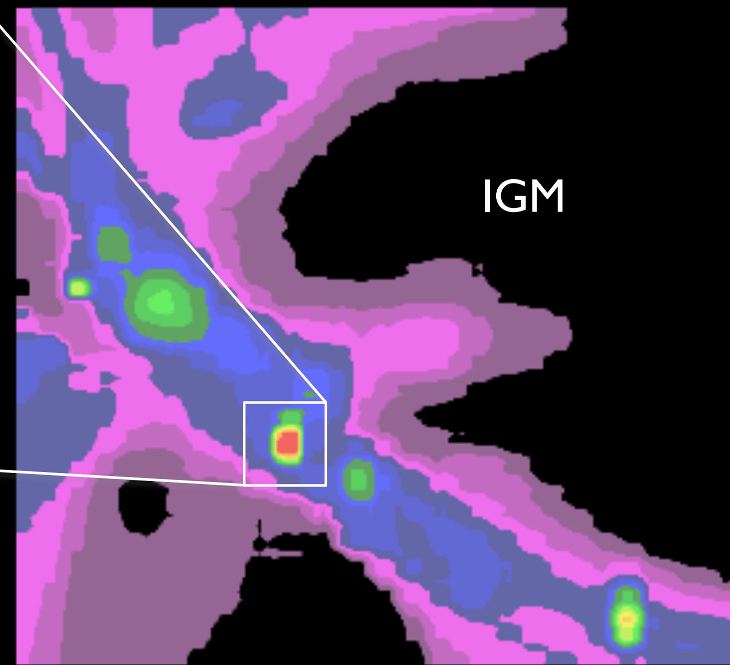
CGM (δ~10^2-10^4)

- *What are the flows of matter and energy in the circumgalactic medium?*
- *How do baryons cycle in and out of galaxies?*
- *What is in the circum-galactic medium?*
- *How are galaxies fed? How do galaxies acquire their gas across cosmic time?*
- *How does galaxy feedback work?*
- *How are the chemical elements dispersed & distributed in the circumgalactic & intergalactic media?*
- *Where are the baryons?*

Cosmogony

Following the flow of Baryons from the Cosmic Web to Planets



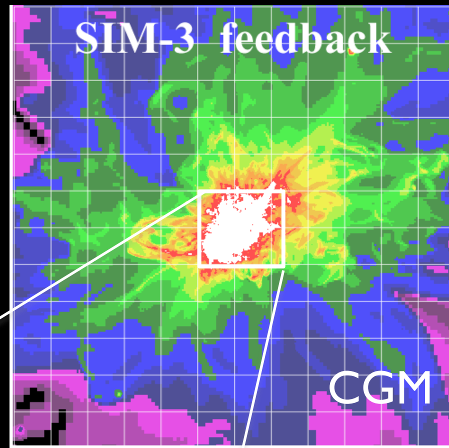


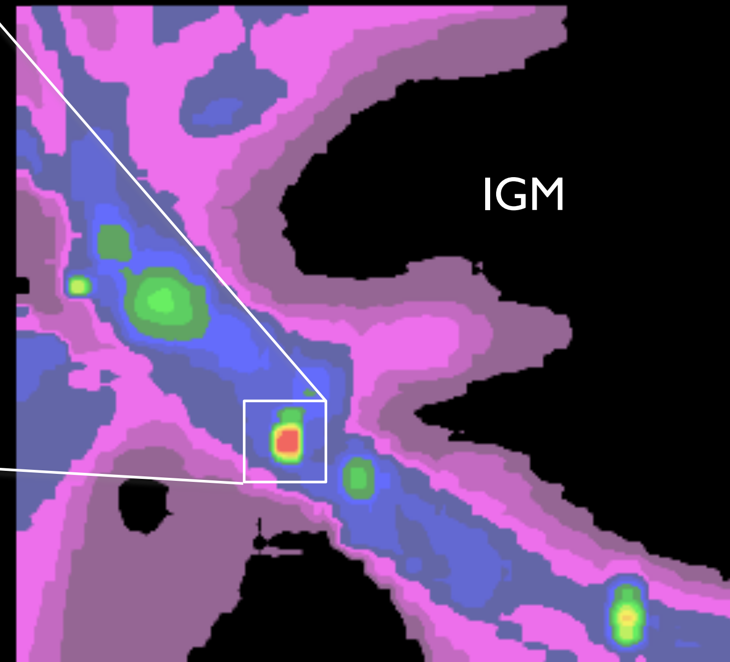
Galaxies (δ~10^4-10^8)

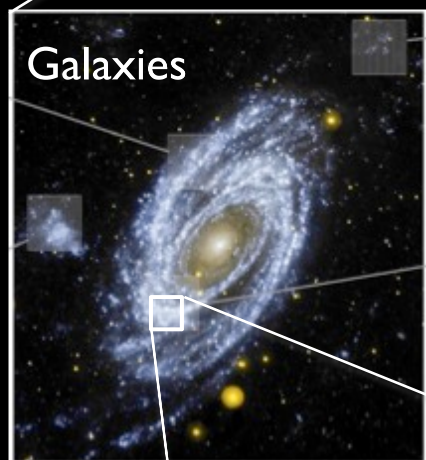
- *How do galaxies build up their stellar component over cosmic time?*
- *What processes regulate the conversion of gas into stars inside galaxies?*
- *How are the chemical elements dispersed and distributed in galaxies?*
- *What is the fossil record of galaxy assembly over cosmic time?*

Cosmogony

Following the flow of Baryons from the Cosmic Web to Planets





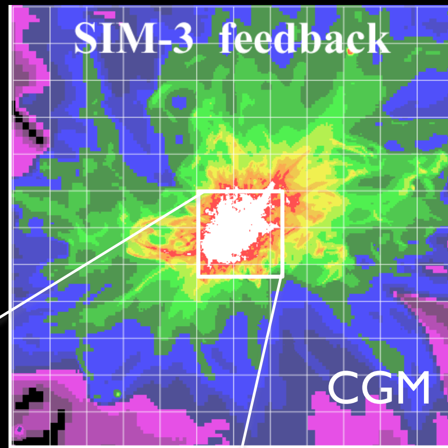


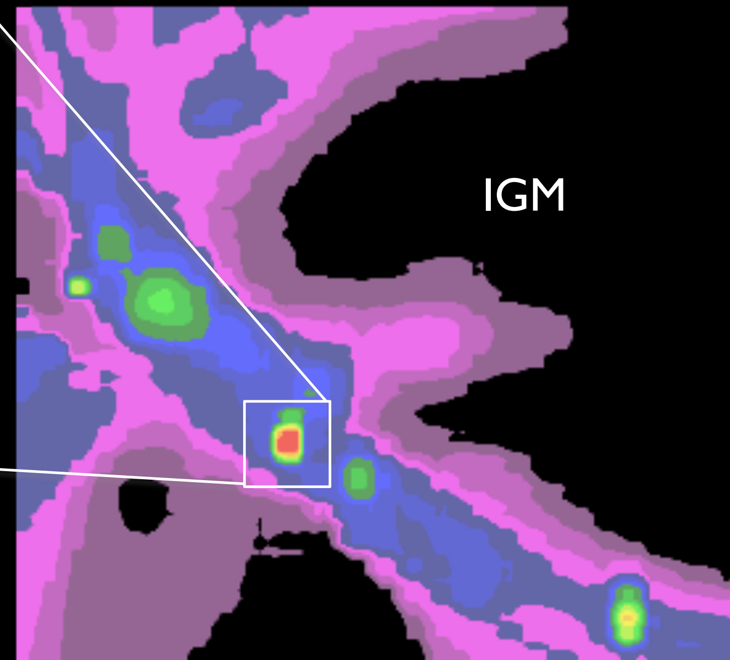
Clusters/GMCs (δ~10^8-10^{10})

- *Ηοω δο σταρσ φορμ?*
- *Ηοω δοεσ γασ φλοω ιντο ανδ χοντρολ σταρ φορματιον?*
- *Ηοω δοεσ φεεδβαχκ χοντρολ σταρ φορματιον?*

Cosmogony

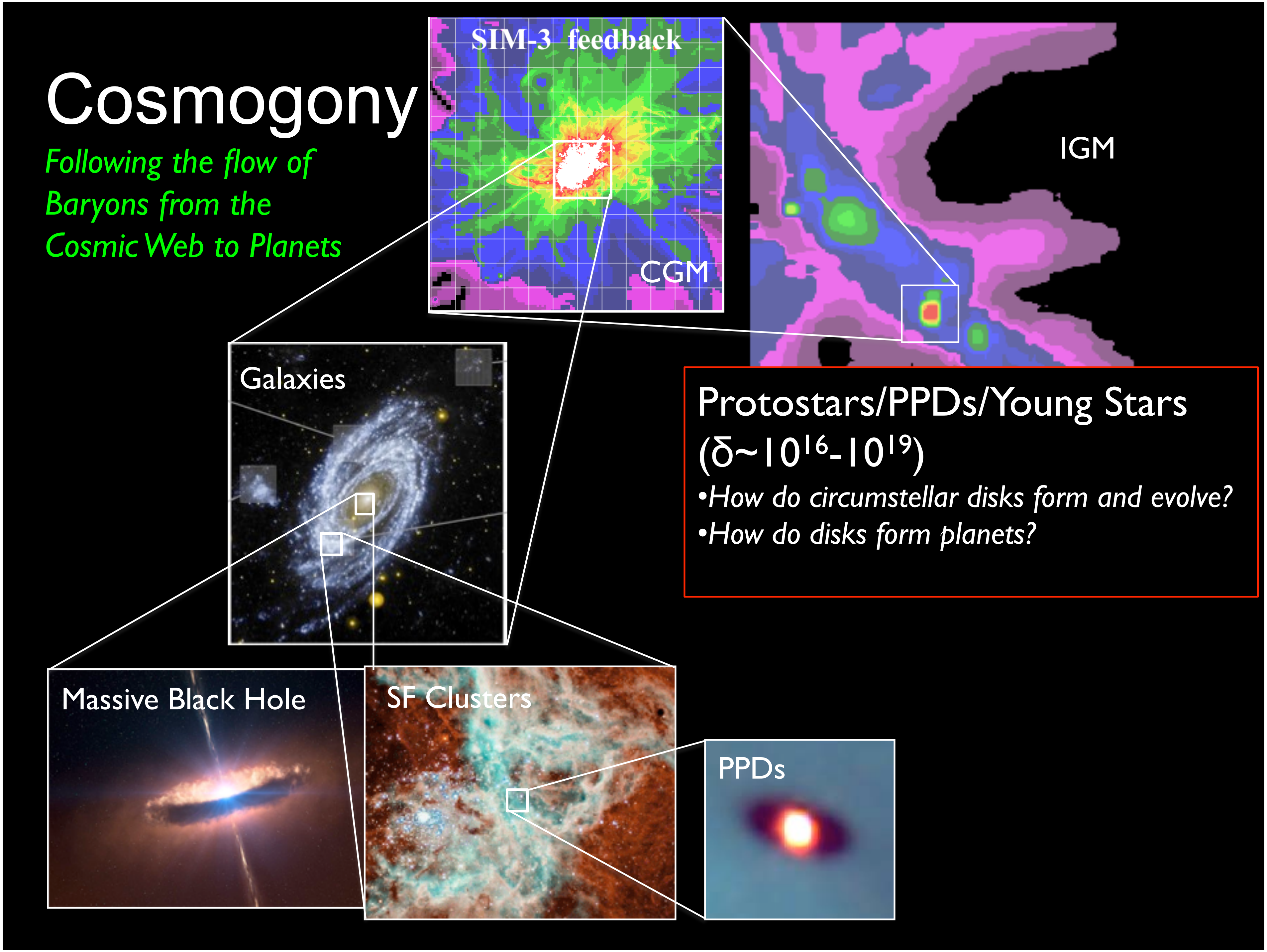
Following the flow of Baryons from the Cosmic Web to Planets





Central Black Holes ($\delta \sim 10^{29}$)

- *Ηοω δο βλαχκ ηολεσ γροω, ραδιατε, ανδ ινφλυενχε τηειρ συρρουνδινγσ?*
- *Ηοω δοεσ α βλαχκ ηολε σηαπε τηε εϖολυτιον οφ χοσμιχ στρυχτυρε?*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CGM
IGM
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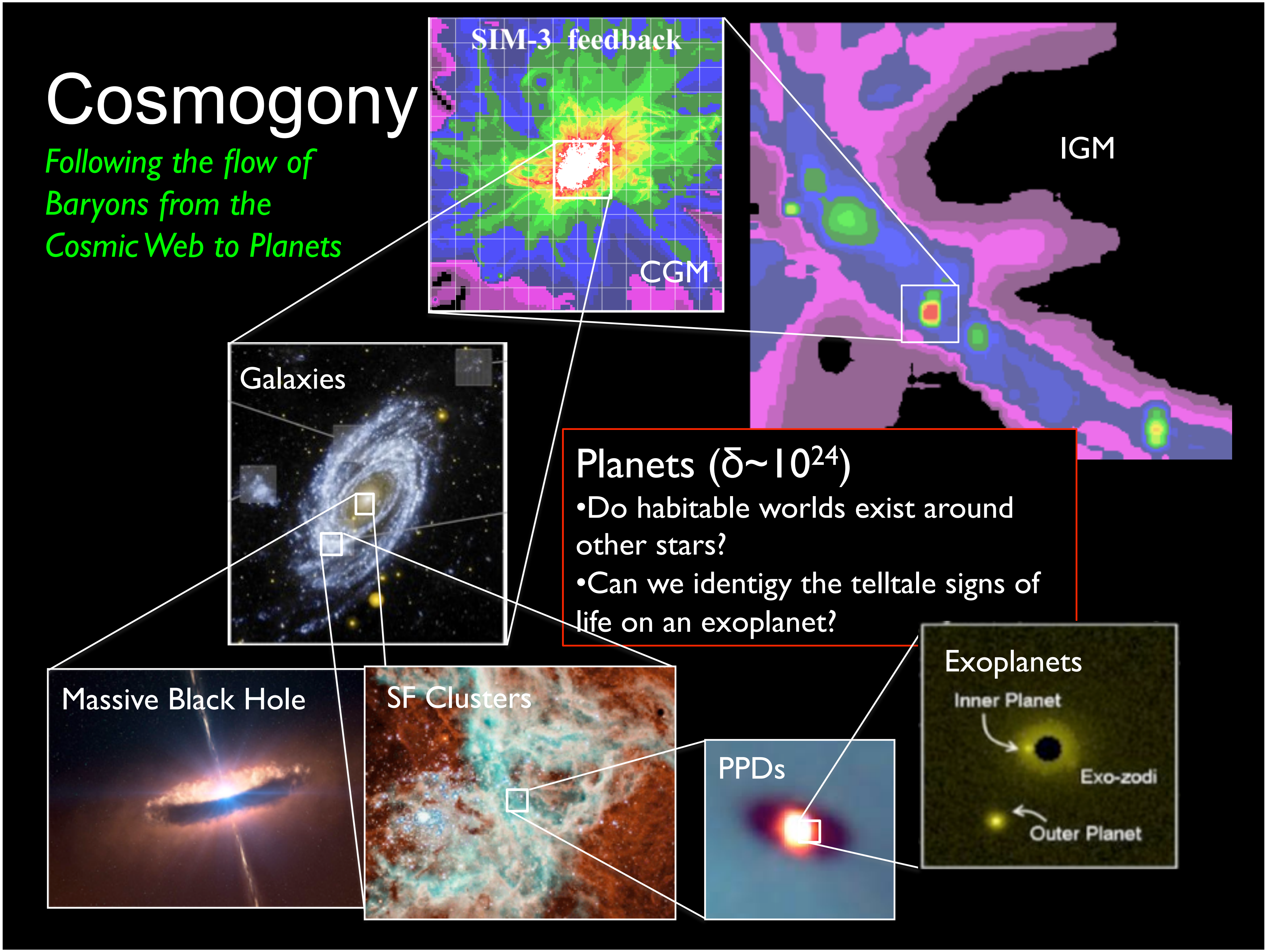
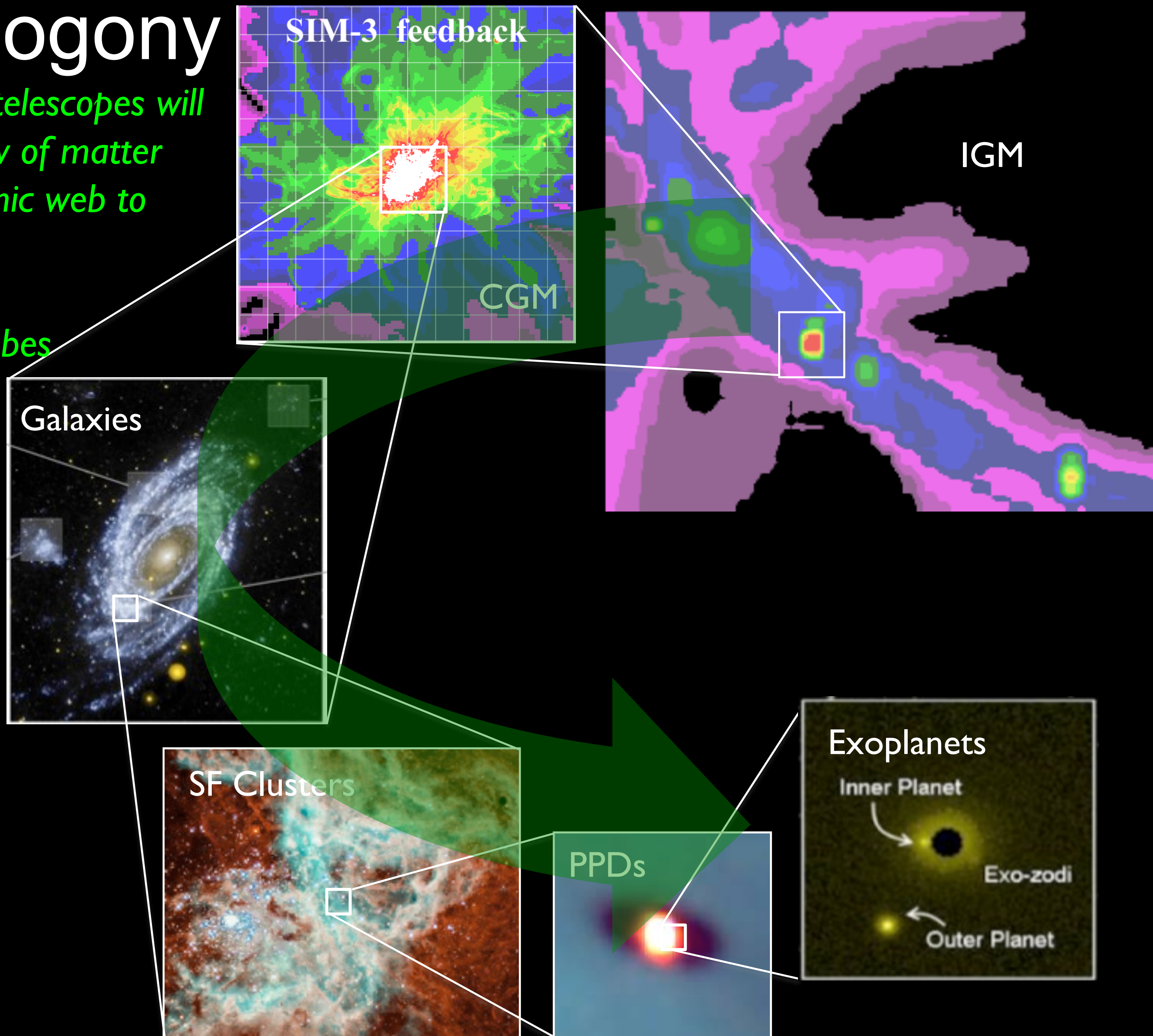
SF Clusters
PPDs
Protostars/PPDs/Young Stars
(δ~10^16-10^19)
•How do circumstellar disks form and evolve?
•How do disks form planets?


Cosmogony
Following the flow of Baryons from the Cosmic Web to Planets
SIM-3 feedback
CGM
IGM
Galaxies
Planets (δ~10^24)
•Do habitable worlds exist around other stars?
•Can we identigy the telltale signs of life on an exoplanet?
Massive Black Hole
SF Clusters
PPDs
Exoplanets
Inner Planet
Exo-zodi
Outer Planet

Cosmogony

A large UVO telescopes will follow the flow of matter from the cosmic web to planets.

A set of 3 probes may also be able to make significant progress



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

3. Translating This into Science Measurement Objectives & Technology Requirements

Science Measurement Objectives

- **Objective 1:** Characterize the spatial distribution of IGM absorption lines using background QSOs and galaxies through high resolution UV spectroscopy
- **Objective 2:** High angular resolution UVO imaging and imaging spectroscopy of forming galaxies and galaxy systems
- **Objective 3:** High angular resolution photometry of individual stars in a representative sample of galaxies
- **Objective 4:** UV Imaging spectroscopy of star formation regions, galaxies, CGM and IGM
- **Objective 5:** Multiobject UV spectroscopy of galaxies, CGM, CQM
- **Objective 6:** Wide field UV/optical photometry of star formation regions in nearby galaxies
- **Objective 7:** UV/optical imaging spectroscopy of protostars and Protoplanetary disks
- **Objective 8:** Far IR/sub-mm imaging and spectroscopy of forming galaxies
- **Objective 9:** Far IR/sub-mm imaging and spectroscopy of star formation regions
- **Objective 10:** Far IR/sub-mm imaging interferometric spectroscopy of SFRs, protostars, PPDs

Astro 2010 Science Questions → Cosmic Origins Measurements

	O	OUV		UV			FIR		
COSMOLOGY & FUNDAMENTAL PHYSICS	HCI/S	HRI	WFI	HRS	MOS	IFS	SPICA	10m	IF
HOW DID THE UNIVERSE BEGIN?									
WHY IS THE UNIVERSE ACCELERATING?			*X*		*X*				
WHAT IS DARK MATTER?		*X*	*X*						
WHAT ARE THE PROPERTIES OF NEUTRINOS?									
GALAXIES ACROSS COSMIC TIME									
HOW DO COSMIC STRUCTURES FORM & EVOLVE?		X	X	X	X	X	X	X	X
HOW DO BARYONS CYCLE IN & OUT OF GALAXIES, AND WHAT DO THEY DO WHILE THEY ARE THERE?		X	X	X	X	X	X	X	X
HOW DO BLACK HOLES GROW, RADIATE, AND INFLUENCE THEIR SURROUNDINGS?		X	X	X	X	X	X	X	X
WHAT WERE THE FIRST OBJECTS TO LIGHT UP THE UNIVERSE AND WHEN DID THEY DO IT?					X	X	X	X	
GALACTIC NEIGHBORHOOD									
WHAT ARE THE FLOWS OF MATTER & ENERGY IN THE CIRCUMGALACTIC MEDIUM?		X	X	X	X	X	X	X	X
WHAT CONTROLS THE MASS-ENERGY-CHEMICAL CYCLES WITHIN GALAXIES?		X	X		X	X	X	X	X
WHAT IS THE FOSSIL RECORD OF GALAXY ASSEMBLY FROM THE FIRST STARS TO THE PRESENT?		X	X	X	X		X	X	X
WHAT ARE THE CONNECTIONS BETWEEN DARK AND LUMINOUS MATTER?					X	X			
PLANETARY SYSTEMS & STAR FORMATION									
HOW DO STARS FORM?		X	X	X	X	X	X	X	X
HOW DO CIRCUMSTELLAR DISKS EVOLVE & FORM PLANETARY SYSTEMS?	X	X	X	X	X?	X	X	X	X
HOW DIVERSE ARE PLANETARY SYSTEMS?	X								X
DO HABITABLE WORLDS EXIST AROUND OTHER STARS,& CAN WE IDENTIFY THE TELLTALE SIGNS OF LIFE ON AN EXOPLANET?	X						X	X	X
STARS AND STELLAR EVOLUTION									
HOW DO ROTATION & MAGNETIC FIELDS AFFECT STARS?			X	X	X				
WHAT ARE THE PROGENITORS OF TYPE Ia SUPERNOVAE			X	X	X				
HOW DO THE LIVES OF MASSIVE STARS END?			X			X	X	X	X
WHAT CONTROLS THE MASS, RADIUS, AND SPIN OF COMPACT STELLAR REMNANTS?		X							

Science Measurement Requirements *(sample)*

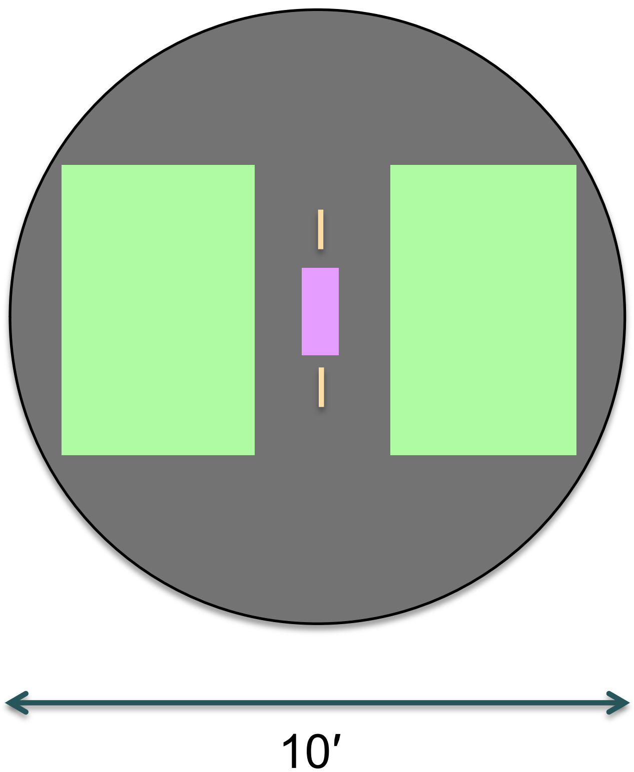
- **M1** Reach a flux limit of FFF for a surface density of YYY QSOs/AGN/sq. deg with S/N=SSS over lam=WWW for NNN QSOs with resolution RRR
- **M2** Reach a flux limit of FFF for a surface density of YYY galaxies/sq. deg with S/N=SSS over lam=WWW for NNN galaxies with resolution RRR
- **M3** Imaging: Achieve a resolution of XXX arcsec and a sensitivity of FFF in each XXX x XXX arcsec^2 pixel for NNN galaxies in bands WWW
- **M4** Imaging spectroscopy: Achieve a angular resolution of XXX arcsec and a sensitivity of FFF in each XXX x XXX arcsec^2 pixel at R=RRR for NNN galaxies over wavelength range WWW
- **M5** Imaging: Achieve a resolution of XXX arcsec and a sensitivity of FFF mag for a total field of view of OOO deg^2 over the mission in bands WWW
- **M6** Galaxies: Achieve a angular resolution of XXX arcsec and a sensitivity of FFF in each XXX x XXX arcsec^2 pixel at R=RRR over wavelength range WWW for a NNN galaxies ranging from AAA-BBB arcsec in diameter

Science Measurement Requirements

(linked to objectives)

	MEASUREMENT REQUIREMENTS	O1	O2	O3	O4	O5	O6	O7	O8	O9	O10
M1	Reach a flux limit of FFF for a surface density of YYY QSOs/AGN/sq. deg with S/N=SSS over lam=WWW for NNN QSOs with resolution RRR	x									
M2	Reach a flux limit of FFF for a surface density of YYY galaxies/sq. deg with S/N=SSS over lam=WWW for NNN galaxies with resolution RRR	x									
M3	Imaging: Achieve a resolution of XXX arcsec and a sensitivity of FFF in each XXX x XXX arcsec^2 pixel for NNN galaxies in bands WWW		x								
M4	Imaging spectroscopy: Achieve a angular resolution of XXX arcsec and a sensitivity of FFF in each XXX x XXX arcsec^2 pixel at R=RRR for NNN galaxies over wavelength range WWW		x								
M5	Imaging: Achieve a resolution of XXX arcsec and a sensitivity of FFF mag for a total field of view of OOO deg^2 over the mission in bands WWW			x							
M6	Galaxies: Achieve a angular resolution of XXX arcsec and a sensitivity of FFF in each XXX x XXX arcsec^2 pixel at R=RRR over wavelength range WWW for a NNN galaxies ranging from AAA-BBB arcsec in diameter				x						
M7	CGM: Achieve a angular resolution of XXX arcsec and a sensitivity of FFF LU in each XXX x XXX arcsec^2 pixel at R=RRR over wavelength range WWW for a NNN CGMs (galaxy halos) ranging from AAA-BBB arcsec in diameter				x						
M8	CQM: Achieve a angular resolution of XXX arcsec and a sensitivity of FFF LU in each XXX x XXX arcsec^2 pixel at R=RRR over wavelength range WWW for a NNN CQMs (QSO halos) ranging from AAA-BBB arcsec in diameter				x						
M9	IGM: Achieve a angular resolution of XXX arcsec and a sensitivity of FFF LU in each XXX x XXX arcsec^2 pixel at R=RRR over wavelength range WWW for a NNN CGMs (galaxy halos) ranging from AAA-BBB arcsec in diameter				x						
M10	Galaxies: Achieve a angular resolution of XXX arcsec and a sensitivity of FFF mag in each XXX x XXX arcsec^2 pixel at R=RRR over wavelength range WWW for a NNN galaxies ranging from AAA-BBB arcsec in diameter					x					
M11	CGM: Achieve a angular resolution of XXX arcsec and a sensitivity of FFF LU in each XXX x XXX arcsec^2 pixel at R=RRR over wavelength range WWW for a NNN CGMs (galaxy halos) ranging from AAA-BBB arcsec in diameter					x					
M12	Imaging: Achieve a resolution of XXX arcsec and a sensitivity of FFF mag for a total field of view of OOO deg^2 over the mission in bands WWW						x				
M13	PS/PSD: Achieve a angular resolution of XXX arcsec and a sensitivity of FFF mag in each XXX x XXX arcsec^2 pixel at R=RRR over wavelength range WWW for a NNN PS/PSDs ranging from AAA-BBB arcsec in diameter							x			
M14	FIR measurements								x		
M15	FIR measurements									x	
M16	FIR measurements										x

Probe (2.4 m) – Spectroscopic Focus (Notional)

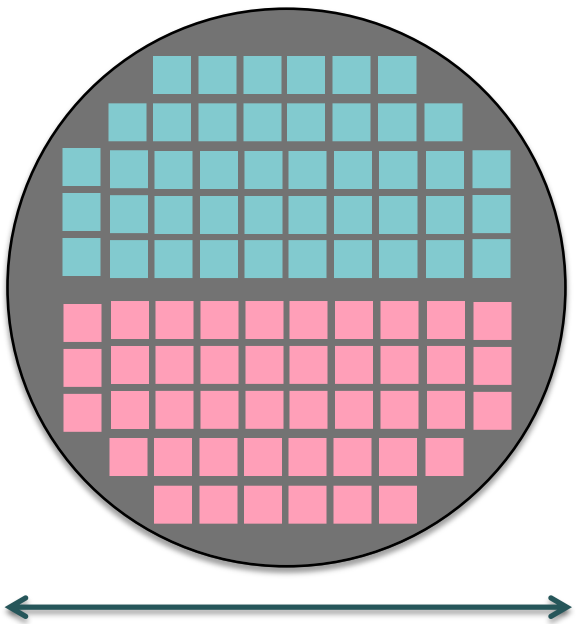


- Integral Field Spectroscopy
  - 1200-3000Å, R~3000
  - 1" x 1" spaxels
  - 2' x 2' field of view
  - A_{eff}~4,000 cm^2 (COS x 10)
  - $A_{eff}\Omega$~8 x 10^7 arcsec^2 cm^2 (COS x 5000)

- Multi-object Spectroscopy
  - 1200-3000Å, R~2000-4000
  - 4' x 8' field of view
  - A_{eff}~4,000 cm^2 (COS x 10)
  - $A_{eff}\Omega$~3 x 10^8 arcsec^2 cm^2 (COS x 100,000

- High Resolution Spectroscopy
  - 1000-3000Å, R~30,000
  - Long-slit mode
  - A_{eff}~10,000 cm^2 (COS x 10)

Probe (2.4 m) – Imaging Focus (Notional)



- UV Imager
  - 4 bands? 1100Å, 1500Å, 2200Å, 2600Å
  - Field of view: 1° x 0.5°
  - A_{eff}~8,000 cm^2
  - $A_{eff}\Omega$ ~ 600 x UVIS ~ 75 x GALEX
  - Grism: R~1000-2000

- Optical imager
  - Multiple Bands
  - Field of view: 1° x 0.5°
  - A_{eff}~10,000 cm^2
  - $A_{eff}\Omega$ ~ 250 x UVIS
  - Grism

Mission Requirements

- Next Generation UV Technology
  1. High QE, Large format, Low noise UV photon-counting detectors
  2. High reflectivity coatings 1000-3000Å
  3. High efficiency, low scatter gratings
  4. Multiplexing technology
- Cost
  - **Early investment:** Serious investments in technology must be made up front.
  - **Cost ownership & consistency:** Cost must be treated like other technical requirements and understood in detail to be optimized and controlled by scientist-builders.
  - **Break cost paradigm:** Mission cost paradigm MUST be broken at ~1B$ scale.

Enhancement of Science Impact of Next Generation UV Technologies

Technology	Implementation Approaches	Potential impacts	Mission Enabling Factor
1) Single Photon counting UV Detector	BSMCPs + GaN Photocathodes AR+DD+EMCCDs	Major increase in QE for large format, low background, versatile detectors	5-10*
2) Next Generation UV Coatings	Atomic Layer Deposition	• High reflectivity coatings —> high performance instruments+telescopes • Broad-band coatings —> 100-120 nm coverage: key UV range • Ultra-uniform coatings —> Joint Exoplanet/UV astrophysics mission	3‡
3) Next Generation Diffractive optics	Electron beam lithographic patterning	• Arbitrary groove profile and shape • High performance spectrographs • High efficiency • Low scatter • Wide-field, multi-object, high efficiency spectrographs	2-4§
Total Improvement Factor	Data grasp ($A_{eff} \times N_{objects}$) factor	20-250	
	Aperture reduction factor (linear): F_A	2-4	
	Cost reduction factor: F_A^2	4-16 (e.g., 10B$ → 600M-2.5B$)	

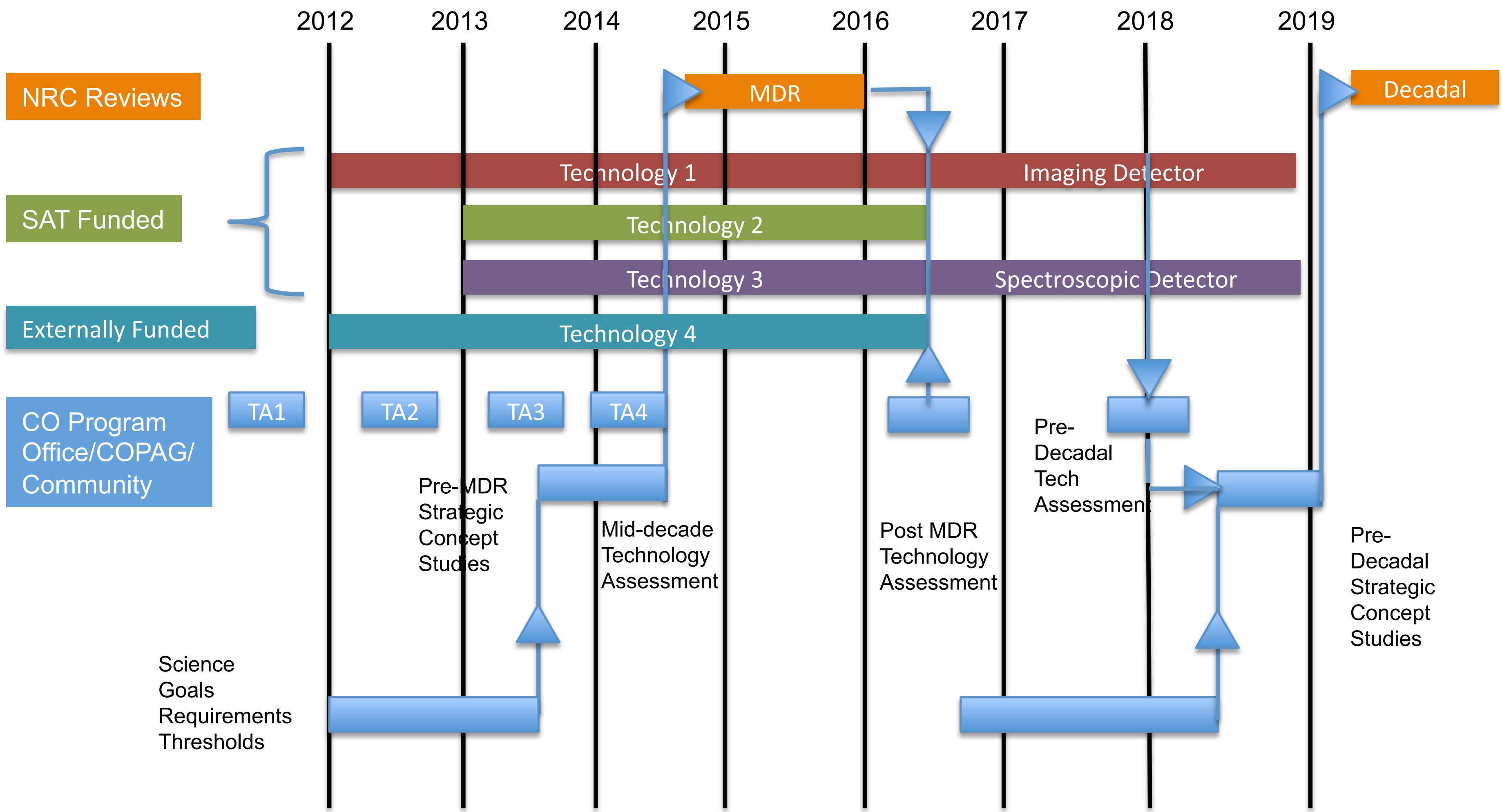
Detector Requirement Definitions

UV DETECTOR PROPERTY	Very Low	Low	Moderate / X	High / XX	Very High / XXX
QE	>5%	>15%	>30%	>50%	>70%
Format: Number of Pixels	100 x 100 10^4	300 x 300 10^5	10^3 X 10^3 10^6	$(3000)^2$ 10^7	$(10,000)^2$ 10^8
Photon-counting		Not important	Important	Very Important	Critical
Equivalent background [ct cm^{-2} s^{-1}]	0.01	0.1	1.0	10	100
Dynamic Range [ct/s]	$10^{-3}:10^0$	$10^{-3}:10^1$	$10^{-3}:10^2$	$10^{-3}:10^3$	$10^{-3}:10^5$
Radiation Tolerance		1 kRad	10 kRad	100 kRad	1000 kRad
Time Resolution	None	1000 s	1 s	1 msec	1 usec
Out of Band Rejection [including	1	10^{-1}	10^{-2}	10^{-3}	10^{-4}

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

UV Detector Roadmap
(notional)



4. Burning Issues

Burning Issue #1: Probes vs. Flagships

- The Problem
  - Flagships take so long they can become obsolete before launch, and cannot sustain a vibrant community nor respond to current science
  - The richness and synergy of the Great Observatory program will never be repeated.
- The Solution
  - Can a compelling case be made for a program of (linked?) probes in the intermediate term?
  - Example: Cosmogeny Probes
    - Probe 1: Wide field UV/Optical Imaging & Spectroscopy
    - Probe 2: X-ray spectroscopy
    - Probe 3: Far IR Probe
    - Probe 4: Exoplanet Probe
- Issues:
  - Again, we need to understand costs and science/$.
  - Can multiple communities join together to push a combined program?

Burning Issue #2: NRO Telescopes

- 3 candidate missions: WFIRST-2.4, Exoplanet-2.4, UVO-2.4
- Could Exoplanet and UVO be combined?
- Can costs be managed in such a way to break the telescope aperture cost curve and therefore stay within the Probe-class cost point?
- Or can additional funds be applied to such a mission outside of NASA astrophysics?

Burning Issue #3: How Do Take Ownership of Costs and if Possible Change the Cost Paradigm?

- The Problem
  - Not understanding real costs is while discussing missions and science is like not understanding gravity while discussing cosmology and astrophysics.
  - We have reached a point where flagship missions can only occur once per 20-30 years.
  - More modest missions using existing technology are now flagships (e.g., WFIRST).
- The Solution
  - In order to discuss, compare, and refine future Origins missions we must have common, agreed upon, cost estimating tools.
  - We must have, as community, some ownership over mission cost.
  - *We must incentivize cost efficiency and change cost growth paradigm*
- But: NASA centers and aerospace companies are *not incentivized* to make cost estimation a transparent and level process.
  - NASA HQ must take lead to change this

5. Requests to Astrophysics Subcommittee

- Approve general direction of activities
- Approve modification of Probe SAG to consider NRO telescopes
- Approve Cost SAG