A → Ω Probe(s)

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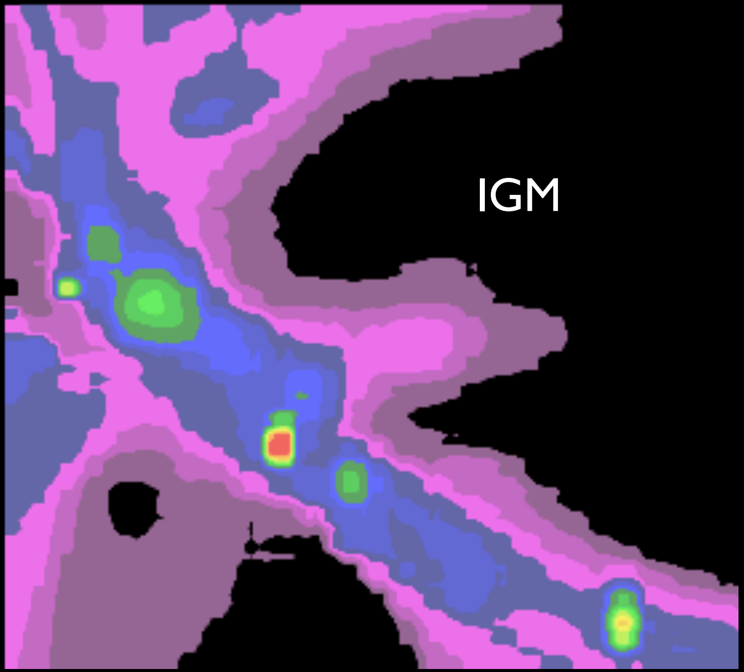
Wisdom

- “Do or do not... there is no try.”
- “Size matters not, ... Look at me. Judge me by size, do you? ”

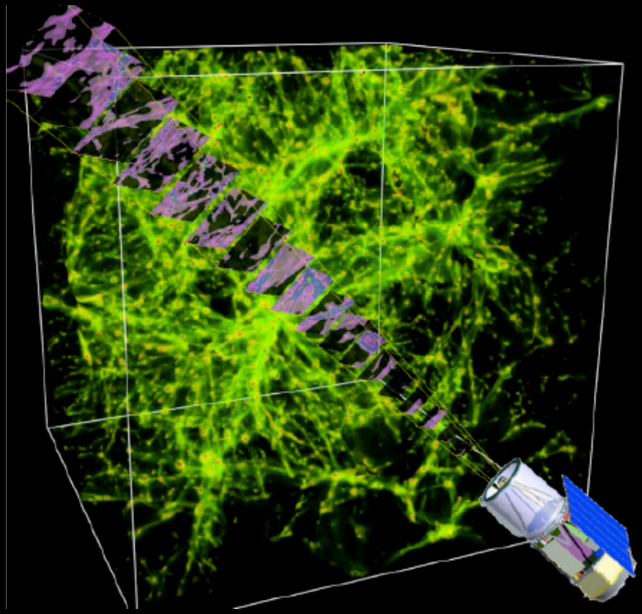
A → Ω

Following the flow of Baryons from the Cosmic Web to Planets



IGM (δ~1-100)

- High Resolution UV Absorption Spectroscopy (Multi-object? Tomography?)
- Mod Resolution UV Emission Integral Field Spectroscopy (IFS)
- Mod Resolution Multi-Object-Spectroscopy (MOS)



A → Ω

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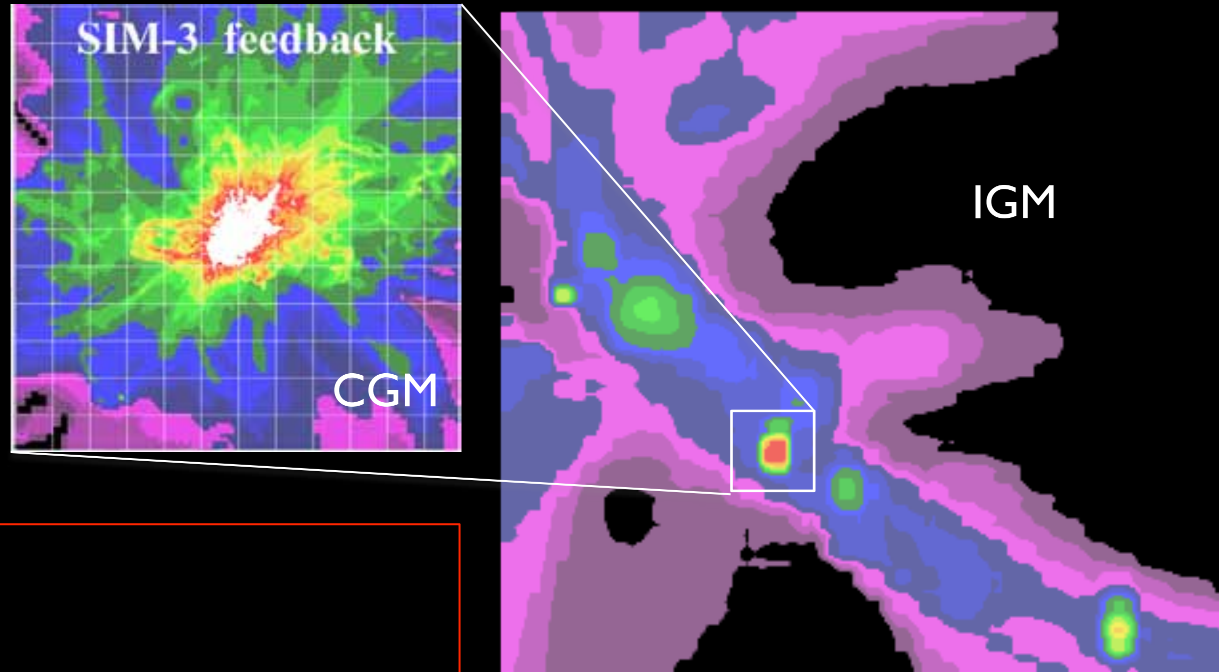
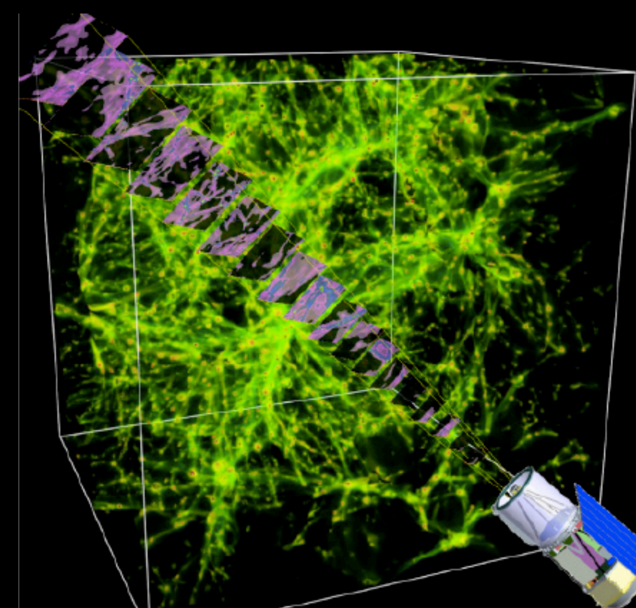


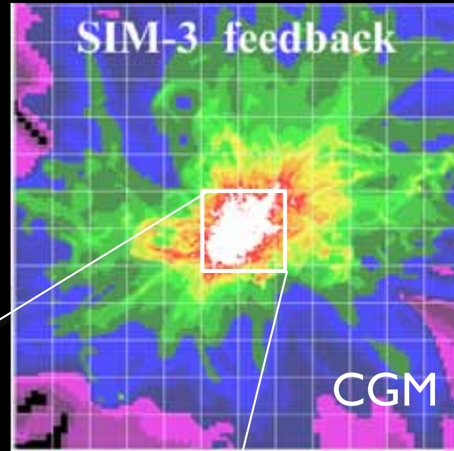
CGM ($\delta \sim 10^2 - 10^4$)

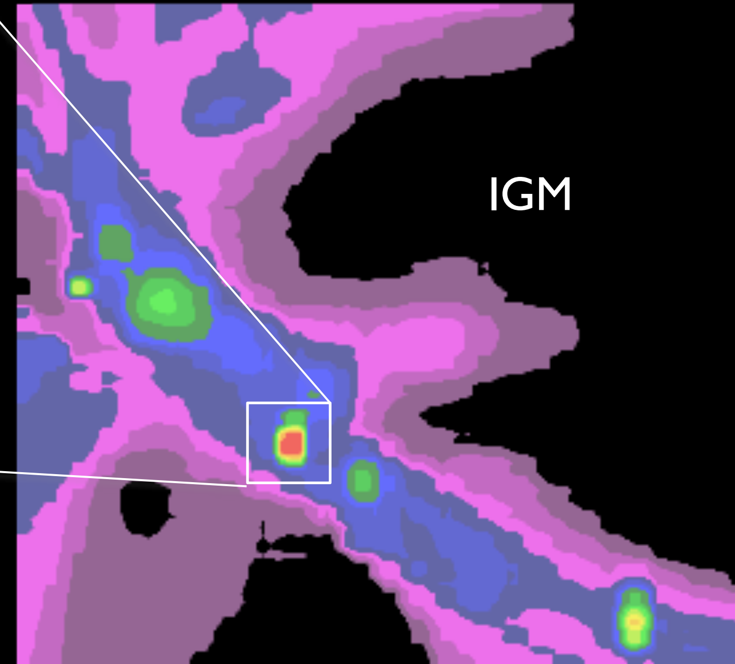
- High Resolution UV Absorption Spectroscopy (Multi-object? Tomography)
- Mod Resolution UV Emission Integral Field Spectroscopy (IFS)
- Mod Resolution Multi-Spectroscopy



A → Ω

Following the flow of Baryons from the Cosmic Web to Planets



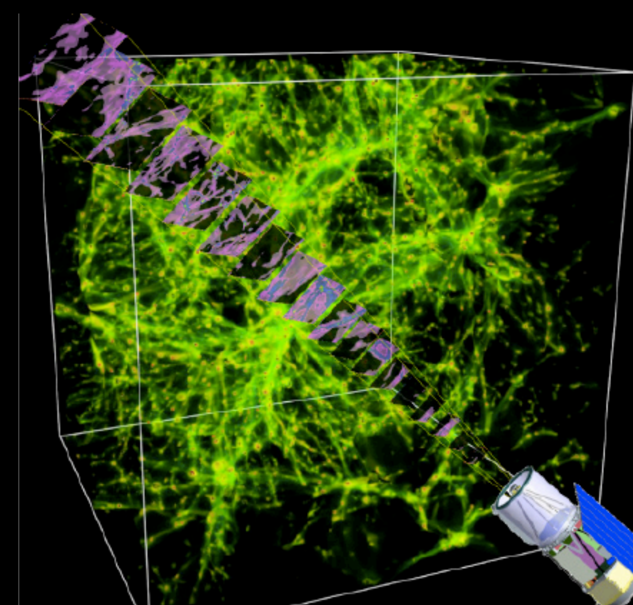


Galaxies (δ~10^4-10^8)

Mod-High Resolution UV Emission IFS

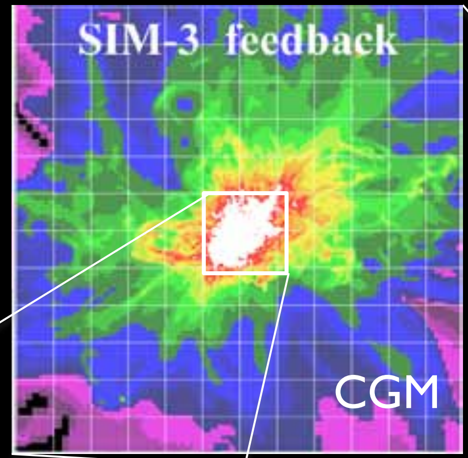
Mod Resolution Multi-Object Spectroscopy

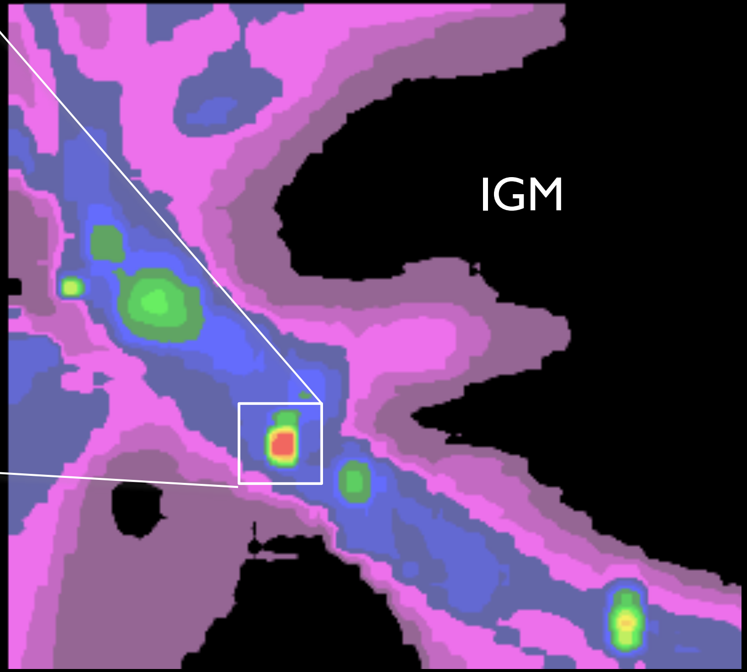
Wide field UV/Optical Imaging

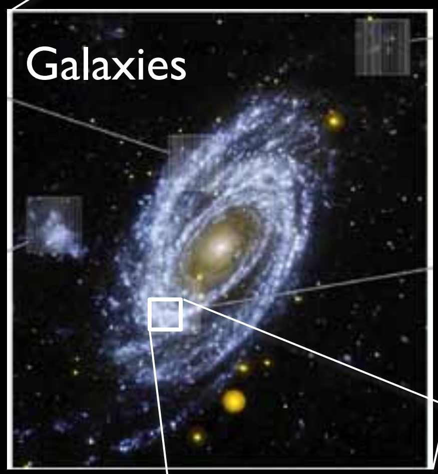


A → Ω

Following the flow of Baryons from the Cosmic Web to Planets





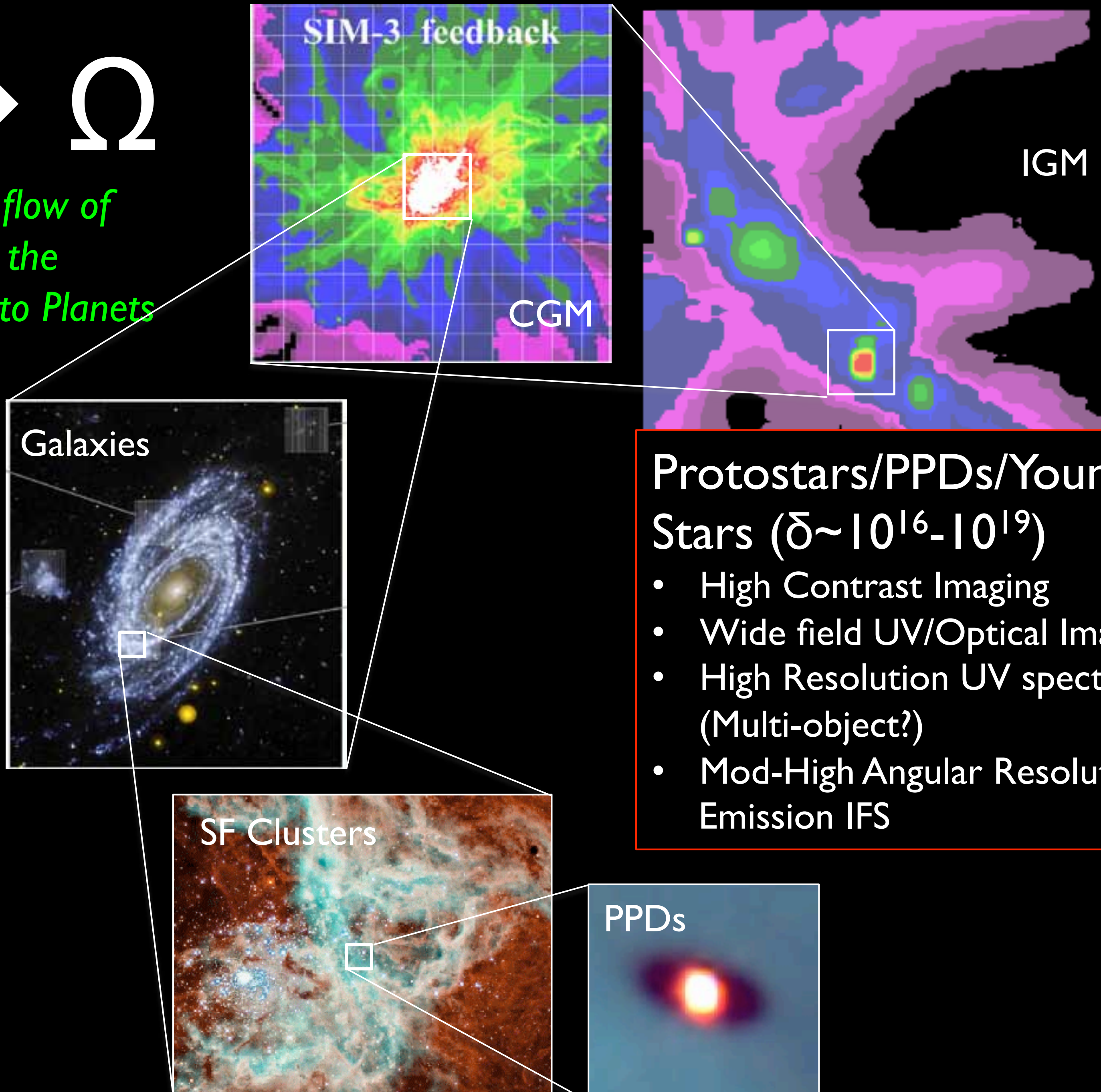


Clusters/GMCs ($\delta \sim 10^8$-10^{10})

- Wide field UV/Optical Imaging
- Mod-High Resolution UV Emission IFS
- Mod Resolution UV Multi-Object Spectroscopy

A → Ω

Following the flow of Baryons from the Cosmic Web to Planets

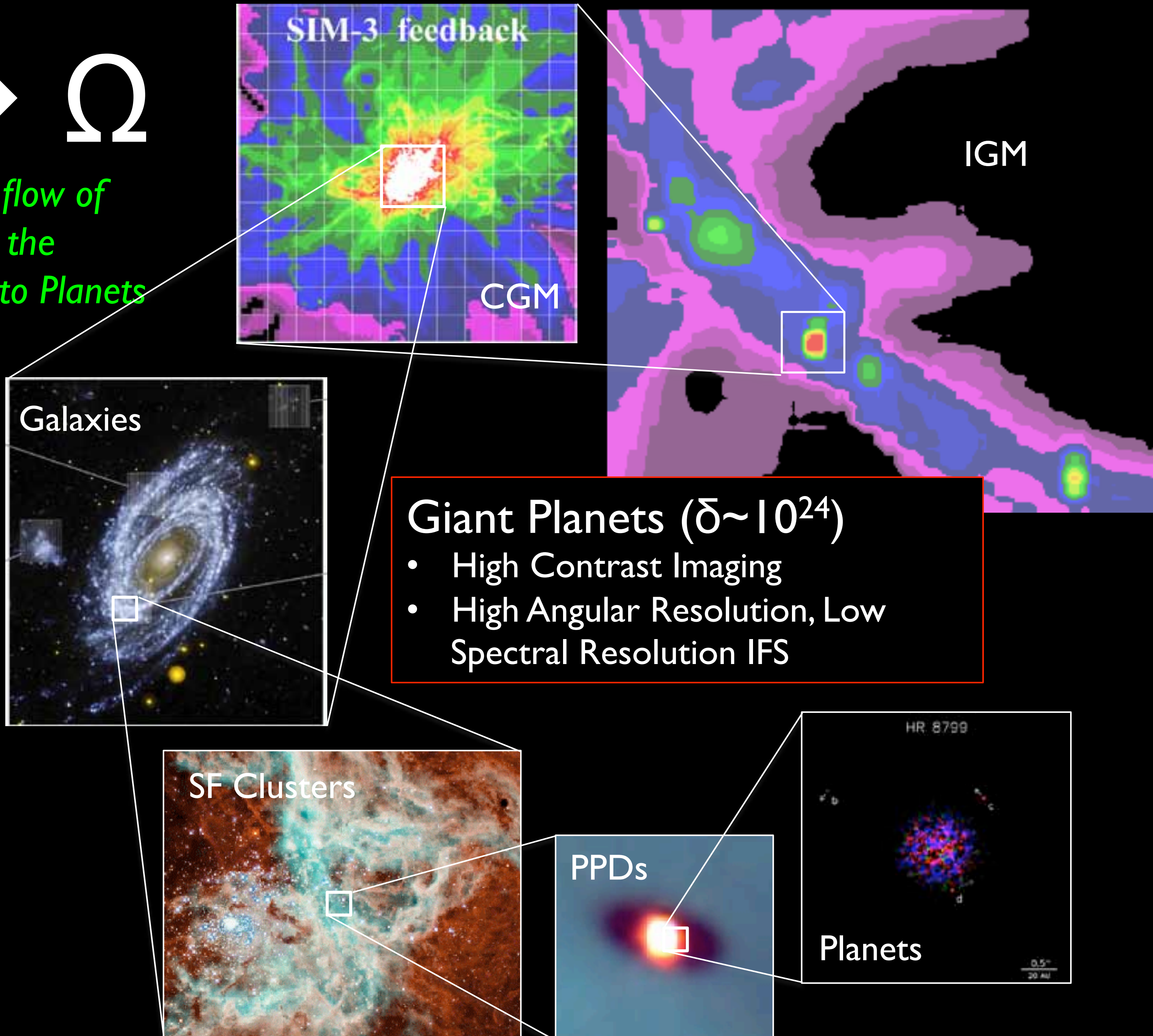


Protostars/PPDs/Young Stars ($\delta \sim 10^{16}$-10^{19})

- High Contrast Imaging
- Wide field UV/Optical Imaging
- High Resolution UV spectroscopy (Multi-object?)
- Mod-High Angular Resolution UV Emission IFS

A → Ω

Following the flow of Baryons from the Cosmic Web to Planets



Probe 1 -- Alpha

- Wide-field
  - ~1.5 m
  - Wide-field UVO imaging
  - Massively multi-object UV Spectroscopy
    - low, medium, high R?
  - Wide-field UV Integral Field Spectrograph

- Science
  - IGM/CGM emission/ absorption, tomograph?
  - Galaxy gas, star formation history, feedback
  - Star Formation Region gas physics, PDRs
  - Protoplanetary Disk gas physics
  - General astrophysics
- Technology Demonstration
  - High efficiency UV coatings, detectors
  - Highly multiplexed UV

Probe 2 -- Omega

- Narrow-field
  - ~1.5 m
  - Dedicated O/UV
  - High resolution imaging
  - High contrast imaging
  - High resolution/contrast imaging spectroscopy
- Science
  - Physics of star formation
  - Proto-planetary disk structure
  - Giant planets imaging & characterization
  - AGN formation, evolution, & feedback
- Technology demonstration
  - High-contrast imaging
  - UV compatibility
  - Starshade?

Spectroscopy Requirements

Spectrograph Requirement	Current Technology	Technology Requirement
Field of View	1 grating → single object	Wide field of view
Imaging or Multiobject	single object	Integral field unit Multiobject capability
# of reflections	COS → 1 STIS → 3-4	3 reflection spectrographs high R coatings
Gratings	holographic aberration correcting 35-40% efficiency	anamorphic arbitrary groove function near theoretical limits
Spectral resolution	1000-30,000	3000 → 50,000

Detector Requirements

Detector Requirement	**Technology Status**	**Technology Requirement**
QE	5-10%	50-80%
Background (Read noise + Dark Noise + Spurious Noise)	~0.1-1 ct/s/cm^2	<0.1 ct/s/cm^2
# of pixels	~4 x 10^6	4 * (10-100)^2 * 2000 ~ 10^6 - 10^8
Photon counting	MCPs – yes CCDs – no	UV imaging – yes UV spectroscopy – YES!!
Red rejection (instrument system)	10^{-3} – 10^{-5} photocathode, filters, spectroscopy	10^{-3} – 10^{-4}
Time resolution	microsecond	0.1-1000 sec for aspect reconstruction
Dynamic range	<100 ct/s	10^{-3} – 10^7 ct/s (imaging)

Technology Roadmapping

Christopher Martin

Chair

COPAG Executive Commitee

Technology Categories

- Telescopes/mirrors
- Structures
- Detectors
- Coatings
- Multiplexing: microshutter arrays, micromirror arrays, integral field units
- Instrumentation optics (Gratings, optical surfaces, spectrometers, etc.)
- Other: electronics, cryogenics, thermal, telemetry

Technology Figures of Merit

- 1. Current and projected (2020, assuming funding as specified below) performance.
  - e.g., for detectors: QE vs. wavelength, internal/dark noise, photon-counting capability, number of pixels/formats/scaleability, energy resolution, dynamic range.
- 2. Implementation and operational issues/risks:
  - e.g., for detectors requirements for cooling, high voltage, required materials/process improvements, red leak/out of band response.
- 3. Cost/time to TRL-6 and leverage:
  - What is the current TRL level, what NASA funding and time is required to reach TRL6,
  - What is the degree of difficulty of these developments
    - for example using the DOD Degree of Difficulty scale
  - What non-NASA astrophysics division resources can be brought to bear to leverage the development>
    - significant industrial involvement and prior investments, cross-division, cross-agency, private-sector investments and applications, existing infrastructure and institutional investment
- 4. Relevance to and impact on possible future missions:
  - Large 4-8 m UVOIR general astrophysics missions, Far IR/Sub mm missions
  - Joint Exoplanet imaging missions & required compatibility technologies

Technology Readiness Level

- TRL 1. Basic principles observed and reported.
- TRL 2. Technology concept and/or application formulated.
- TRL 3. Analytical and experimental critical function and/or characteristic proof-of-concept completed.
- TRL 4. Component and/or breadboard validated in laboratory environment.
- TRL 5. Component and/or breadboard validated in relevant environment.
- TRL 6. System/subsystem model or prototype demonstrated in a relevant environment (ground or space).
- TRL 7. System prototype demonstrated in a space environment.
- TRL 8. Actual system completed and “flight-qualified” through test and demonstration (ground or flight).
- TRL 9. Actual system “flight-proven” through successful mission operations.

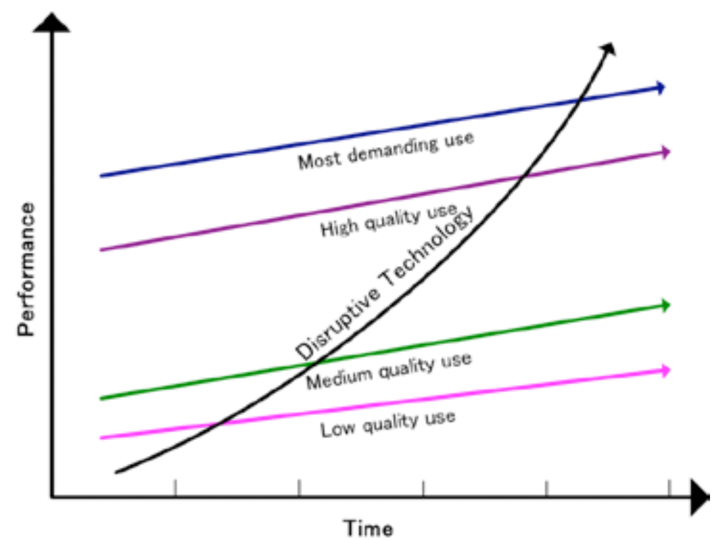
DOD Degree of Difficulty

- **I. Very low degree of difficulty** anticipated in achieving research and development (R&D) objectives for this technology; only a single, short-duration technological approach needed to be assured of a high probability of success in achieving technical objectives in later systems applications.
- **II. Moderate degree of difficulty** anticipated in achieving R&D objectives for this technology; a single technological approach needed; conducted early to allow an alternate approach to be pursued to be assured of a high probability of success in achieving technical objectives in later systems applications.
- **III. High degree of difficulty** anticipated in achieving R&D objectives for this technology; two technological approaches needed; conducted early to allow an alternate subsystem approach to be pursued to be assured of a high probability of success in achieving technical objectives in later systems applications.
- **IV. Very high degree of difficulty** anticipated in achieving R&D objectives for this technology; multiple technological approaches needed; conducted early to allow an alternate system concept to be pursued to be assured of a high probability of success in achieving technical objectives in later systems applications.
- **V.** The degree of difficulty anticipated in achieving R&D objectives for this technology is so high that a **fundamental breakthrough in physics, chemistry**, and so on is needed; basic research in key areas needed before system concepts can be refined.

Disruptive Innovation

- Ingredients
  - Questioning
  - Experimenting
  - Observing
  - Associating
    - linking concepts from diverse fields
  - Networking
    - to search for new ideas

- Examples
  - e-Book (p-Book)
  - digital cameras (film)
  - PC (mainframe)



see UNBOXED, Steve Lohr, Sunday 8/28/11 NYT

The Business Model

- 2 Strategies
  - Entrepreneurial
    - Decisions/rankings made by peer review panels
    - PI vs. PI
    - Natural selection
      - (or species extinction)
  - Collective/collaborative
    - Community speaks with one voice
    - Self-organized
    - e.g., Decadal Surveys

Exoplanets, Dark Energy

Mira

Mira

COSMOLOGY & FUNDAMENTAL PHYSICS	CO	PCOS	Exo	IFS
HOW DID THE UNIVERSE BEGIN?		X		
WHY IS THE UNIVERSE ACCELERATING?		X		
WHAT IS DARK MATTER?		X		
WHAT ARE THE PROPERTIES OF NEUTRINOS?		X		
GALAXIES ACROSS COSMIC TIME				
HOW DO COSMIC STRUCTURES FORM & EVOLVE?	X			
HOW DO BARYONS CYCLE IN & OUT OF GALAXIES, AND WHAT DO THEY DO WHILE THEY ARE THERE?	X			
HOW DO BLACK HOLES GROW, RADIATE, AND INFLUENCE THEIR SURROUNDINGS?	X	X		
WHAT WERE THE FIRST OBJECTS TO LIGHT UP THE UNIVERSE AND WHEN DID THEY DO IT?	X			
GALACTIC NEIGHBORHOOD				
WHAT ARE THE FLOWS OF MATTER & ENERGY IN THE CIRCUMGALACTIC MEDIUM?	X			
WHAT CONTROLS THE MASS-ENERGY-CHEMICAL CYCLES WITHIN GALAXIES?	X			
WHAT IS THE FOSSIL RECORD OF GALAXY ASSEMBLY FROM THE FIRST STARS TO THE PRESENT?	X			
WHAT ARE THE CONNECTIONS BETWEEN DARK AND LUMINOUS MATTER?	X			

PLANETARY SYSTEMS & STAR FORMATION	CO	PCOS	Exo	
HOW DO STARS FORM?	X		X	
HOW DO CIRCUMSTELLAR DISKS EVOLVE & FORM PLANETARY SYSTEMS?	X		X	
HOW DIVERSE ARE PLANETARY SYSTEMS?			X	
DO HABITABLE WORLDS EXIST AROUND OTHER STARS,& CAN WE IDENTIFY THE TELLTALE SIGNS OF LIFE ON AN EXOPLANET?			X	
STARS AND STELLAR EVOLUTION				
HOW DO ROTATION & MAGNETIC FIELDS AFFECT STARS?	X	X		
WHAT ARE THE PROGENITORS OF TYPE Ia SUPERNOVAE	X	X		
HOW DO THE LIVES OF MASSIVE STARS END?	X	X		
WHAT CONTROLS THE MASS, RADIUS, AND SPIN OF COMPACT STELLAR REMNANTS?		X		