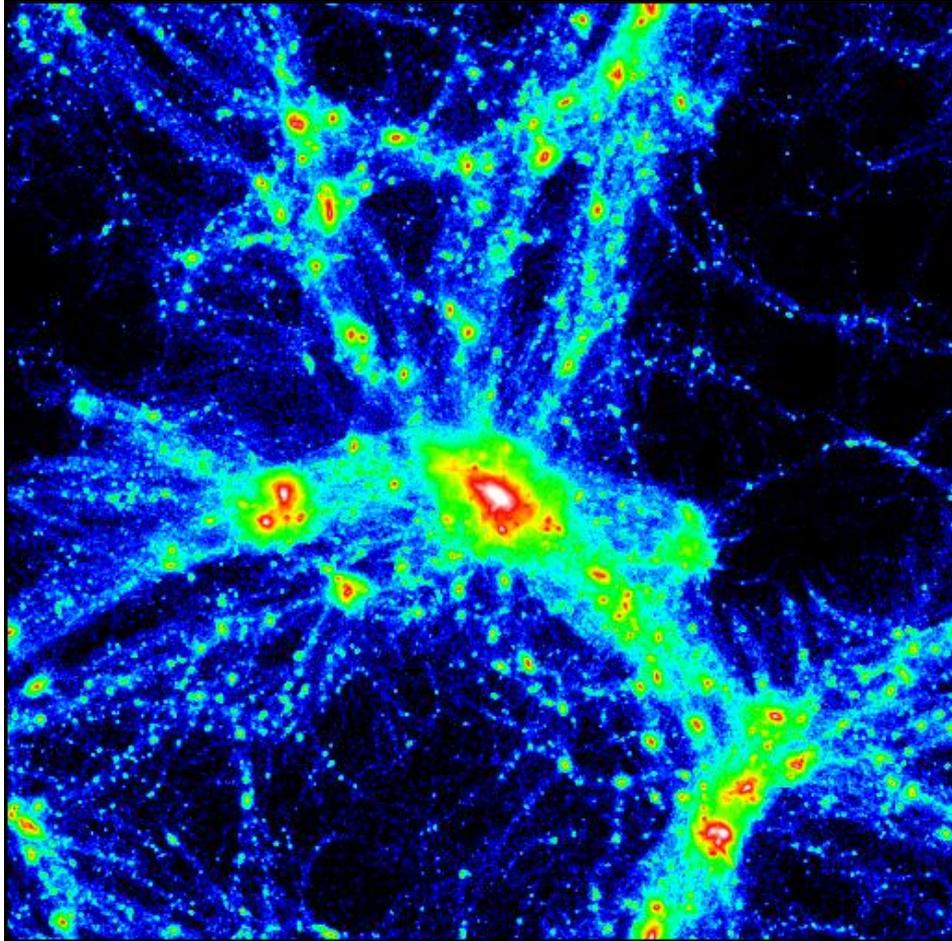


# Gas in the Cosmos: Prospects for the Next Decade



# The Big Picture

- The great majority of the baryons in the universe are in the form of gas
- Galaxies, stars, planets and black holes all form from this gas
- These are all components in a complex cosmic ecosystem
- Observations of gas will play a dominant role in understanding our cosmic origins

# Gas & “New Worlds, New Horizons”

## Science Questions Ripe for Answering

- How do stars form?
- How do circumstellar disks evolve and form planetary systems?
- What controls the mass-energy-chemical cycles within galaxies?
- What are the flows of matter and energy in the circumgalactic medium?
- How do baryons cycle in and out of galaxies and what do they do while they are there?
- How do black holes grow, radiate, and influence their surroundings?

# Question: How do stars form?

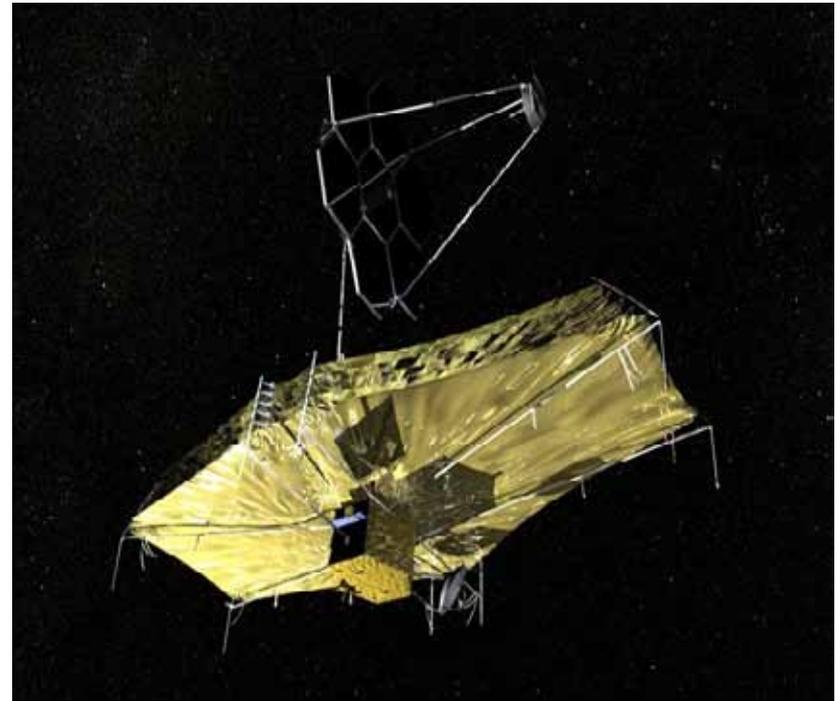
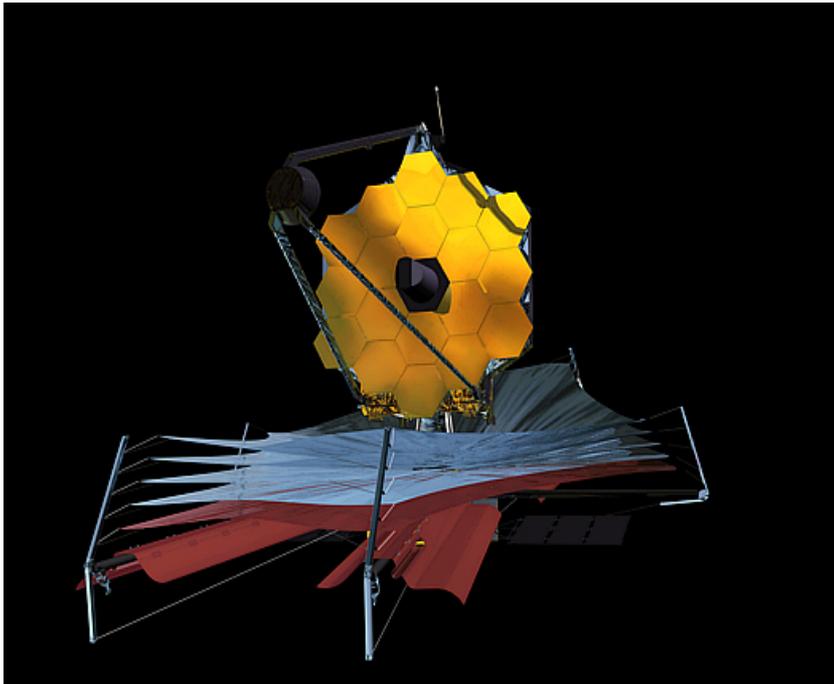
What determines the star formation efficiencies in molecular clouds?

What determines the properties of pre-stellar cores?

What is the origin of the stellar initial mass function?

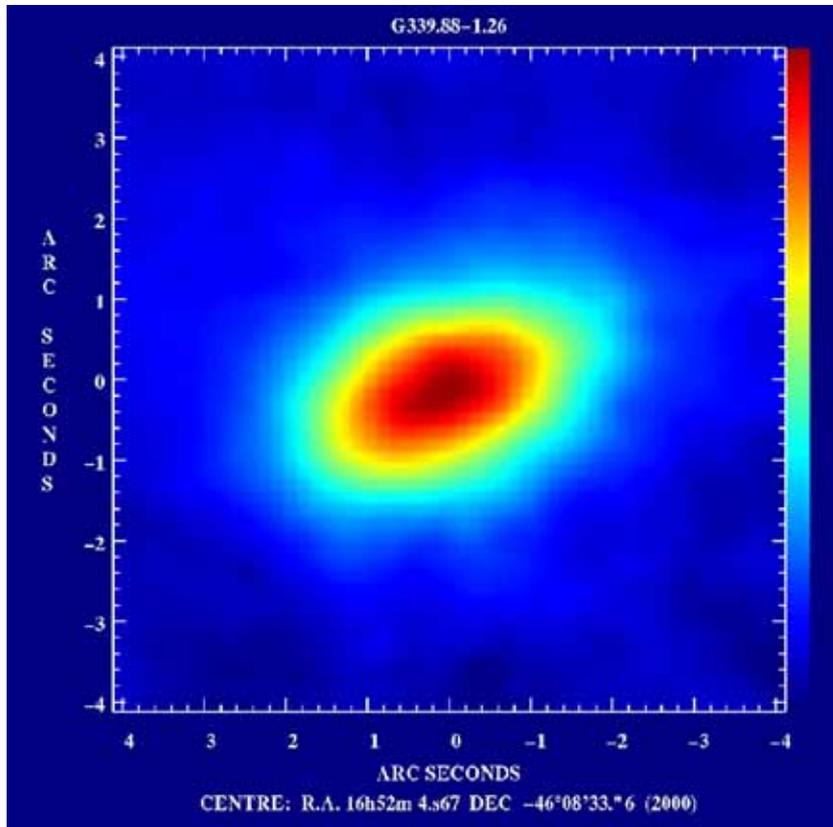


# Future Facilities



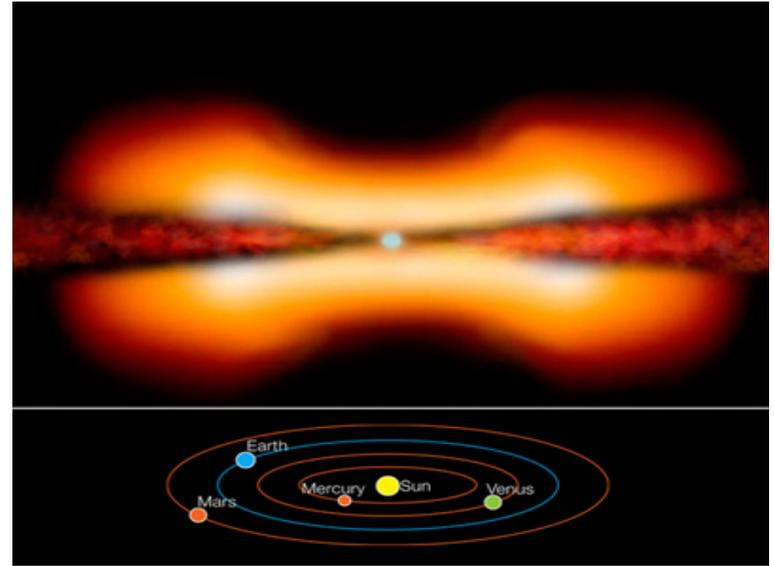
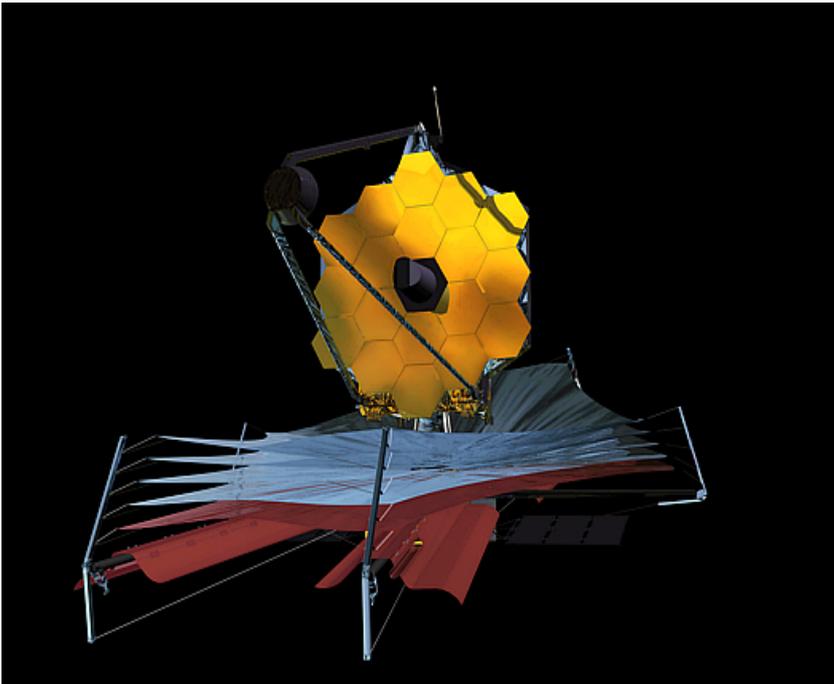
- Near-IR imaging and near- and mid-IR spectroscopy of star-forming regions with JWST to determine the IMF and measure the physical properties & dynamics of giant molecular clouds
- Large (~10 kilo-pixel) bolometer array cameras on a large sub-mm/far-IR telescope to determine SFRs, star-formation efficiencies, core properties, etc.

# Question: How do circumstellar disks evolve & form planetary systems?



- What is the nature of the star-forming environment?
- How do giant planets accrete from and interact with disks?

# Future Facilities



The Young Stellar Object MWC 297 (Artist View)

ESO PR Photo 36a/05 (November 24, 2005)



- JWST for NIR imaging and spectroscopy on scales of  $\sim 10$  au for  $\sim$ one thousand nearest disks
- Stretch goal – interferometer to get to 1 au scales in MIR ( $\sim 10$  mas)
- High spectral resolution in the FIR and sub-mm to determine the density, thermal, and chemical properties

# Question: **What controls the mass-energy-chemical cycles within galaxies?**

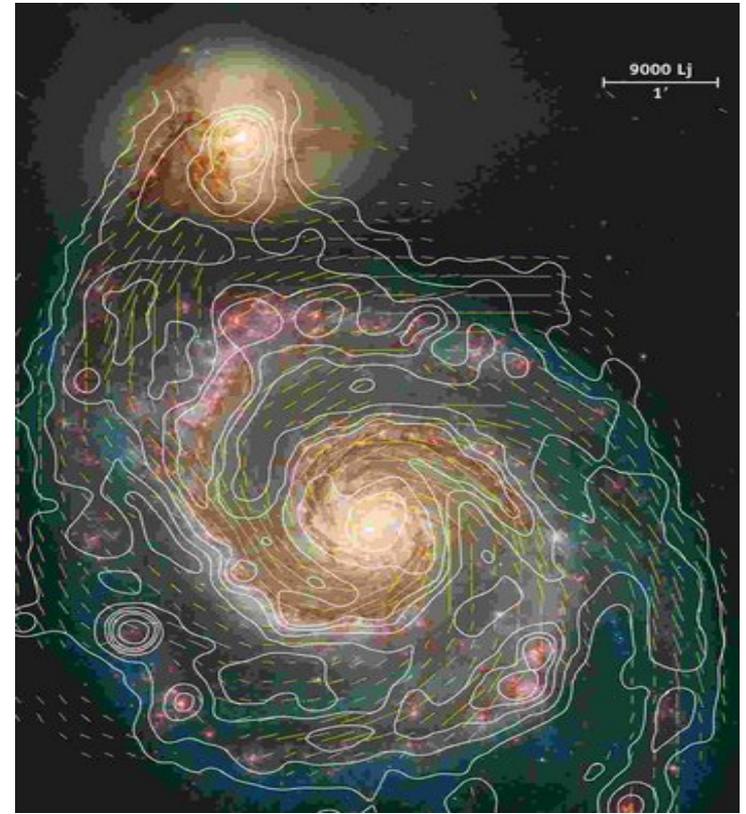
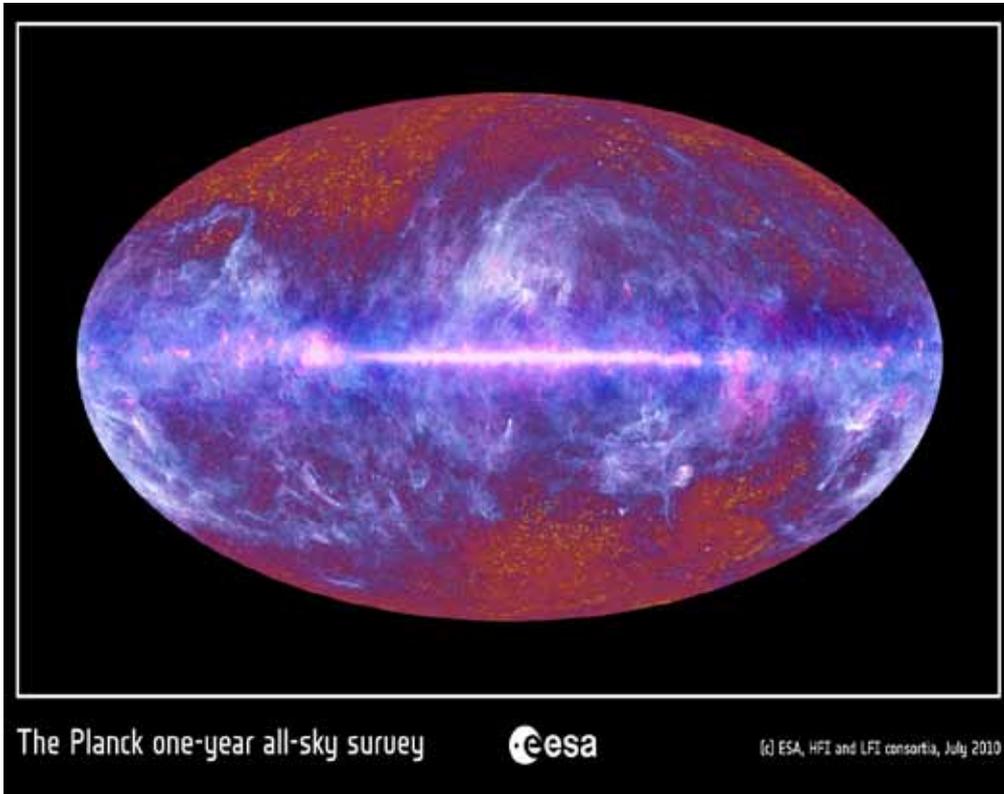
What processes regulate the conversion of gas into stars inside galaxies? How do galaxies build up their stellar component over cosmic time?

How are the chemical elements dispersed and distributed in galaxies?

What determines the multi-phase nature of the interstellar medium, including the magnetic field?



# Future Facilities



- Multi-pixel arrays in FIR and sub-mm to map molecular gas and dust in nearby galaxies. FIR polarimetry to probe the B-field
- FUV-optimized 4-8m telescope for absorption-line spectra of MW ISM and halo (sightlines to stars & QSOs)
- FUV imaging spectroscopy of diffuse warm gas in ISM and halo

**Question: 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?

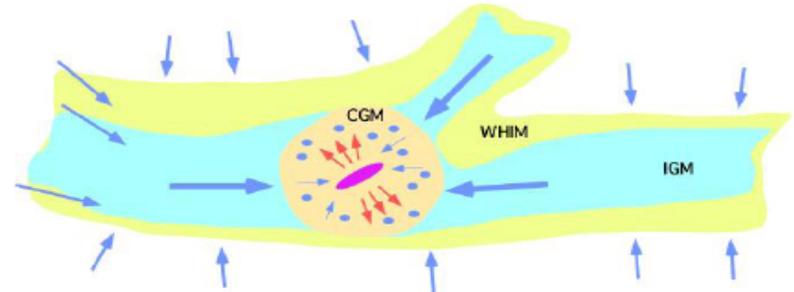
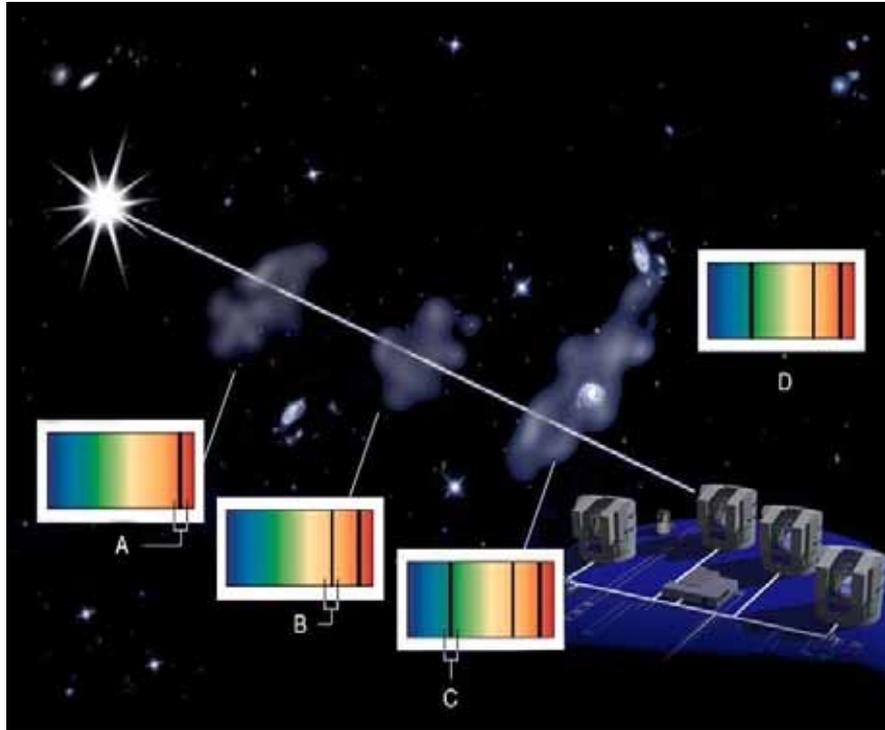
How does galaxy feedback work?

How are the chemical elements dispersed & distributed in the circumgalactic & intergalactic media?

Where are the baryons?



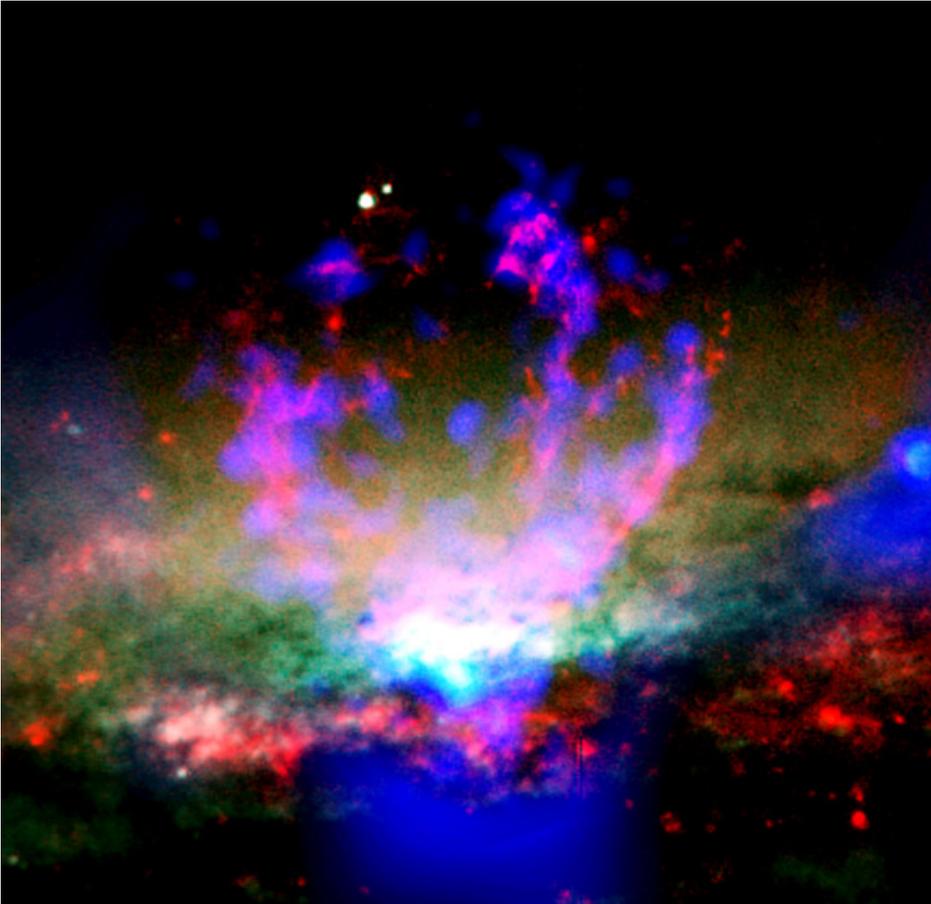
# Future Facilities



Property	Component			
	Cosmic Web	Web/Halos	Dark Halos	Galaxies
Baryon & structure tracer	IGM fuel	WHIM baryons metals	CGM infall winds metals	XUV disk gal. winds, SF
$\delta$	1-100	1-100	$10^2-10^5$	$>10^6$
Size [Mpc]	0.3-30	1-30	0.1-0.3	0.03-0.1
T[K]	$10^4-10^5$	$10^5-10^7$	$10^4-10^6$	
QSO absorption	$L\alpha$ forest	OVI, broad $L\alpha$	Ly limit Metal lines	Damped $L\alpha$
Emission	Photon pumping (PP)	Collisional excitation (CE), PP	CE, PP, $L\alpha$ fluorescence	UV cont CE from feed-back
Intensity [LU]	1-100	1-100	$10^2-10^4$	

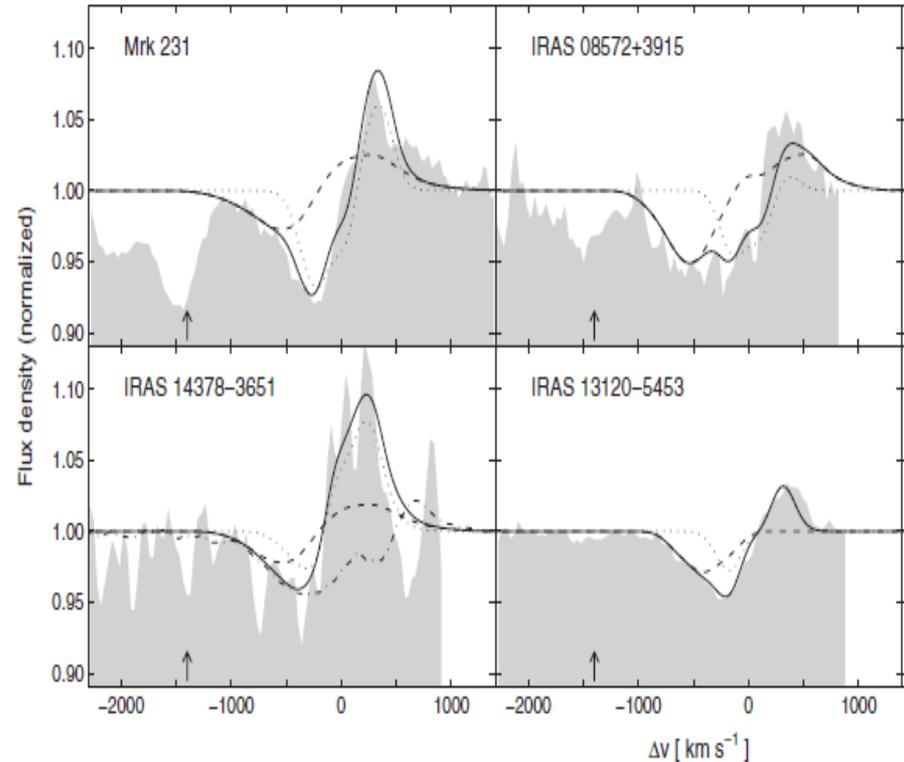
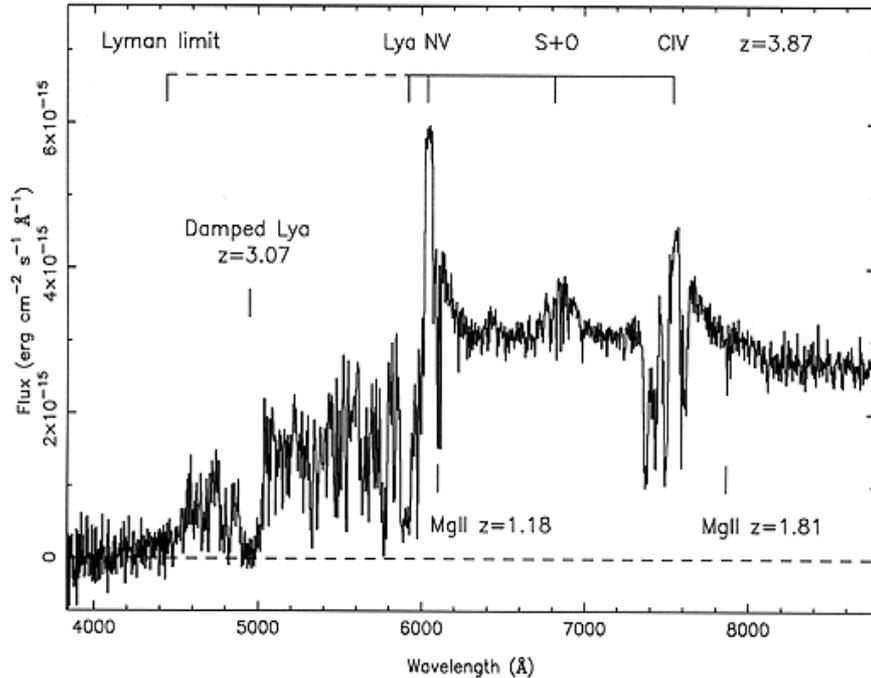
- An FUV-optimized 4m to 8m telescope for absorption-line spectroscopy of QSOs sightlines through galaxy halos. Reach  $\sim 100$  nm (to reach OVI). Probe thousands of sightlines.
- FUV imaging spectroscopy to map out the CGM and IGM line emission in the 100 to 200 nm range

**Question: How do black holes grow, radiate, and influence their surroundings?**



How does a black hole shape the evolution of cosmic structure?

# Future Facilities



- An FUV-optimized 4m to 8m telescope for absorption-line spectroscopy of nearby bright AGN and their environment to determine the sizes, and the mass and energy outflow rates in warm phase
- FIR spectroscopy to determine the mass and energy outflow rates in the molecular phase

# Summary

- Understanding our cosmic origins without understanding the gas is like trying to understand a forest without understanding the soil, the air, or the water. We couldn't see the forest for the trees....
- UV, IR, and sub-mm observations from space will all play a critical role, given the right technology and the right resources