



COSMIC DAWN: EARLY RESULTS  
FROM THE HUBBLE ULTRA DEEP FIELD  
September 23, 2004

# MAJOR SOURCES OF THE COSMIC REIONIZING BACKGROUND AT $z \sim 6$

Haojing Yan

SIRTf Science Center, California Institute of Technology

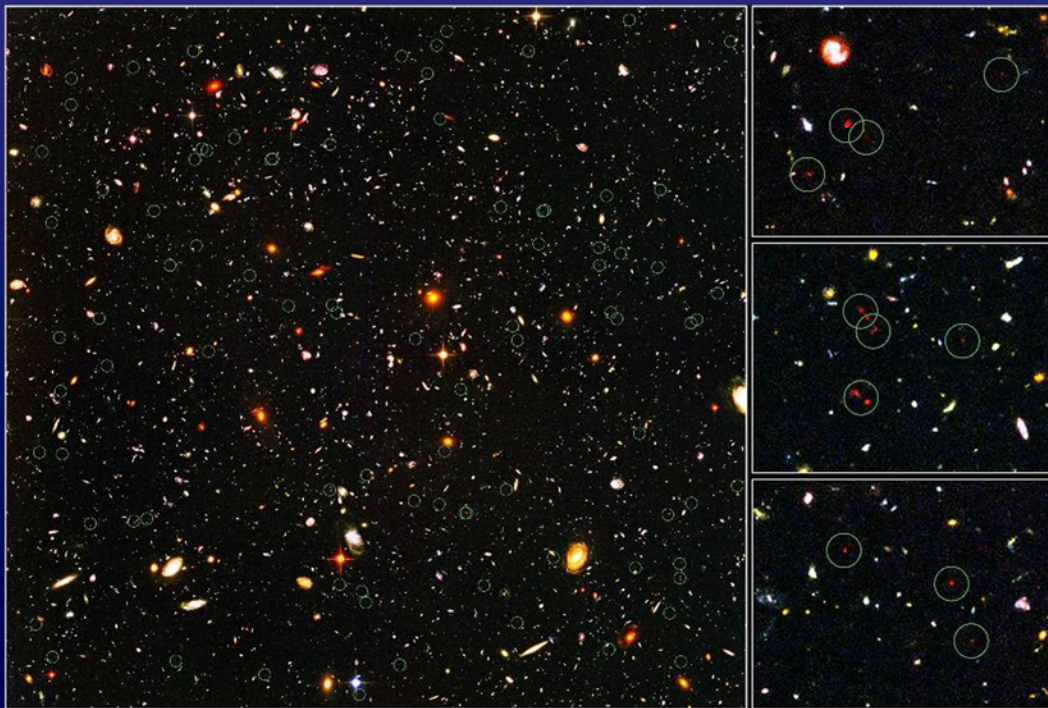
Rogier Windhorst

Department of Physics and Astronomy,  
Arizona State University

*Yan and Windhorst: Cosmic Reionizing Background at  $z \sim 6$*

# COSMIC DAWN: EARLY RESULTS FROM THE HUBBLE ULTRA DEEP FIELD

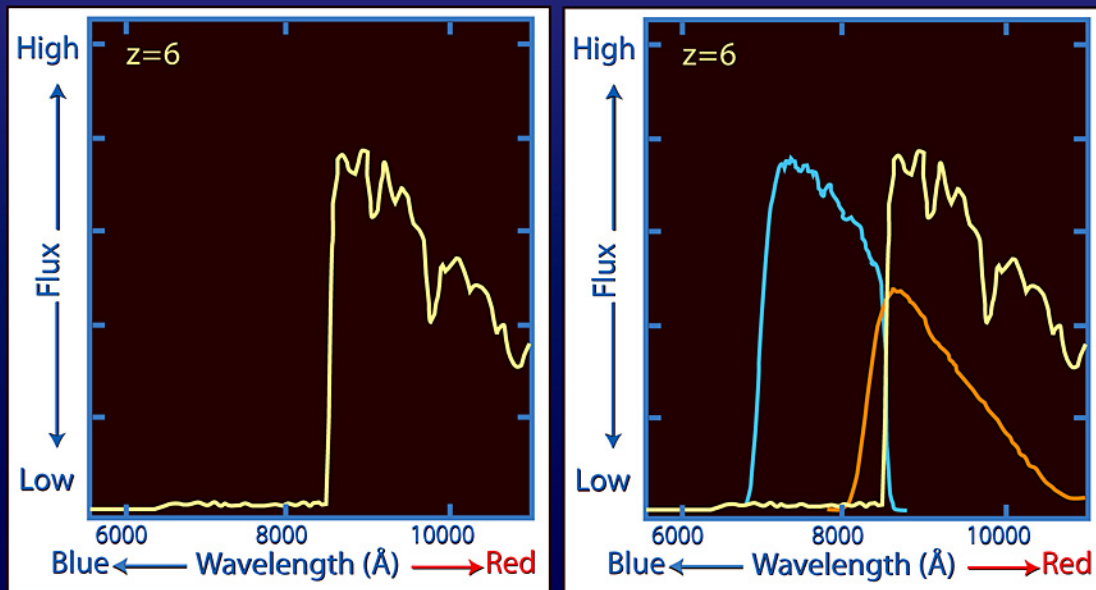
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*Up to 108 redshift 6 candidates are seen.*

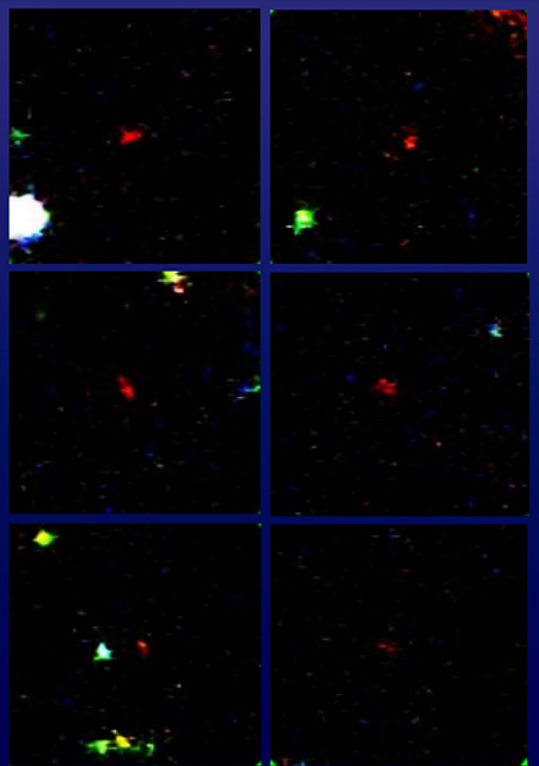
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Galaxies at  $z \sim 6$  have rather a unique color.



*Yan and Windhorst: Cosmic Reionizing Background at  $z \sim 6$*

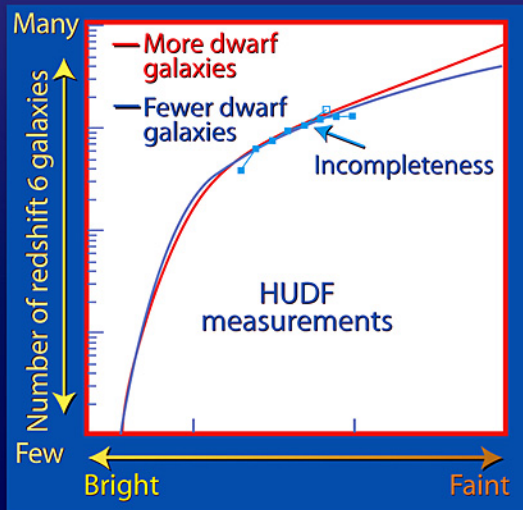
By pushing to the very limit of the HUDF, we can begin to address how many dwarf galaxies there were at the epoch when the reionization ended.





## To see what is currently unseen :

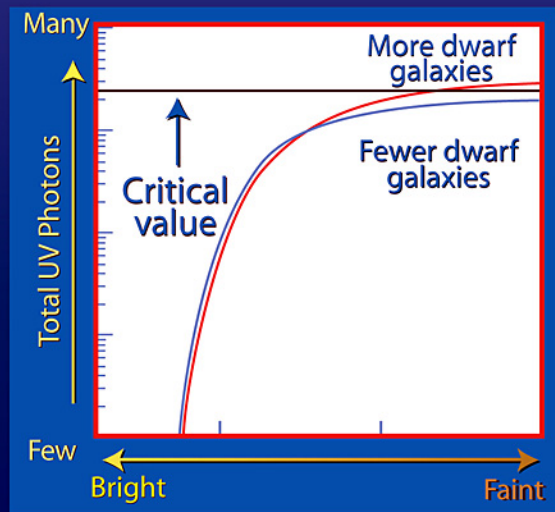
- Rule of Nature: Noise prevents us from finding all objects close to the detection limit.
- We carefully modeled the fraction of faint objects missed by the HUDF, and so estimated how quickly the number of dwarf galaxies increases at fainter fluxes — a very steep slope!
- This is a like a cosmic “stock market chart” but with very few large corporations and numerous “mom-and-pop stores.”



## Dwarf galaxies have done it!

If their numbers indeed increased this quickly at fainter fluxes, dwarf galaxies collectively could have generated enough UV light to finish reionization.

This includes the extrapolated light from even fainter dwarf galaxies at redshift 6 that are still below the HUDF detection limit.



## Conclusions:

- Luminous (giant) galaxies alone cannot finish reionization. All groups agree on this.
- Faint dwarf galaxies that we now start to see see with the HUDF could have contributed most of the reionizing UV photons.
- We do not seem to need new classes of reionizing sources of unknown nature. The entire ensemble of faint star-forming galaxies seems sufficient.

Conclusions are subject to several possible uncertainties:

- Clumping of the intergalactic gas
- Ultraviolet photon escape fraction
- Metal content of the dwarf galaxies
- Distribution of dwarf galaxies' stellar mass