The Hubble Wide Field Camera 3 Early Release Science (ERS) images
Rogier Windhorst (ASU) & the WFC3 Science Oversight Committee

Thanks to the work of many at NASA, including the SM4 Shuttle astronauts:

- Hubble has a new panchromatic Wide Field Camera 3 with unprecedented high UV–blue and near-IR throughput, field-size, and resolution!


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see posters by Ashcraft et al. (463.28), Cohen+ (463.23), Hathi+ (463.37), McCarthy+ (338.03), Rutkowski+ (463.35), Ryan+ (463.30), Straughn+ (463.25), Tamura+ (432.12), Yan+ (463.04); Windhorst+ (463.27).

See also 8x20 ft color poster in Exhibit Hall C downstairs.
The Early Release Science images in the GOODS CDF-South field:
10 filters with HST/WFC3 & ACS reaching $AB = 26.5-27.0$ mag (10-$\sigma$) over 40 arcmin$^2$ at 0.07–0.15” FWHM from 0.2–1.7 $\mu$m (UV-UBVizYJH).
Some science results of the Wide Field Camera Early Release Science data

Galaxy structure at the peak of the merging epoch ($z \sim 1–2$) is very rich: some resemble the cosmological parameters $H_0$, $\Omega$, $\rho_o$, $w$, and $\Lambda$, resp.

Panchromatic WFC3 ERS images of early-type galaxies with nuclear star-forming rings, bars, weak AGN, or other interesting nuclear structure. (Rutkowski et al. 2010; 463.35). “Red and dead” galaxies aren’t dead!
Early-type ERS galaxies at redshifts $0.4 \lesssim z \lesssim 0.8$: Red and relatively featureless in the optical, but considerable (extended) emission in the UV (Rutkowski et al. 2010; 463.35). “Red and dead” galaxies aren’t dead!

$z=2.368$:

$z=2.975$:

Lyman break galaxies at the peak of cosmic star-formation ($z \sim 1-3$; Hathi 463.37)
ERS 10-band redshift estimates accurate to $\sim 4\%$ with small systematic errors (Cohen et al.; 463.23), resulting in a reliable redshift distribution.

- Reliable masses of faint galaxies to AB=26.5 mag, accurately tracing the process of galaxy assembly: downsizing and merging.
- WFC3 can trace young & old stars in galaxies over $\lesssim 13$ billion years.

Details in posters by Ashcraft et al. (# 463.28), Cohen$^+$ (463.23), Hathi$^+$ (463.37), McCarthy$^+$ (338.03), Rutkowski$^+$ (463.35), Ryan$^+$ (463.30), Straughn$^+$ (463.25), Yan$^+$ (463.04), Windhorst$^+$ (463.27).


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CONCLUSIONS

- The panchromatic WFC3 (0.2–2 µm) opens significant new parameter space for discoveries at redshifts $z \lesssim 0–9$:
  - ERS shows WFC3’s new panchromatic capabilities on galaxies at $z \lesssim 0–7$
  - The HUDF (Illingworth’s talk) shows WFC3’s capabilities at $z \lesssim 7–9$
  - WFC3 is an essential pathfinder at $z \lesssim 8$ for JWST (0.7–29 µm) at $z \gtrsim 9$
REFERENCES & URLs to WFC3 POSTERS, TALKS at AAS MEETING.

www.asu.edu/clas/hst/www/wfc3ers/  [WFC3 related work at ASU]
www.asu.edu/clas/hst/www/ahah/    [Hubble at Hyperspeed Java–tool]

Ashcraft, T., et al. 2010, AAS 215, 463.28
Cohen, S. H., et al. 2010, AAS 215, 463.23
McCarthy, P. J., et al. 2010, AAS 215, 338.03
Rutkowski, M. J., et al. 2010, AAS 215, 463.35
Ryan, R. E., Jr., et al. 2010, AAS 215, 463.30
Straughn, A. N., et al. 2010, AAS 215, 463.25
Yan, H., et al. 2010, AAS 215, 463.04
HUDF i-drops: faint galaxies at z ≃ 6 (Yan & Windhorst 2004), most spectroscopically confirmed at z ≃ 6 to AB ≤ 27.0 mag (Malhotra et al. 2005).
Update of Yan et al. 2009 (astro.0910.0077) HUDF with WFC3 ERS data:
- $z=7$ LF more firm (see Illingworth), $z=8$ LF improved, $z=9.5$ UL’s still stand!
Assume only 33% of the J-drops are real and at $z \gtrsim 9$. Together with the HUDF and ERS upper limits to $AB \lesssim 28$ mag, the $z \sim 9$ LF is still steep!

- Need JWST to measure $z \gtrsim 9$ LF, and see if it’s fundamentally different from the $z \lesssim 8$ LFs. Does a pop-III driven IMF cause a power-law LF?
- Objects at $z \gtrsim 9$ are rare, since volume element is small and the LF evolves.
- WFC3 will cover $z \lesssim 9$, but only JWST can see First Light at $z \gtrsim 10$. 
Implications of the (2008) 5-year WMAP results on JWST science:

HST/WFC3 $z \lesssim 7$ ←− $z \approx 8$–25

The year-5 WMAP data provided much better foreground removal (Dunkley et al. 2009; Komatsu et al. 2009)

⇒ First Light & Reionization occurred between these extremes:

- (1) Universal & instantaneous at $z \approx 10.8 \pm 1.4$, or, more likely:
- (2) Inhomogeneous & drawn out: starting at $z \gtrsim 20$, peaking at $z \approx 11$, ending at $z \approx 7$. The implications for HST and JWST are:

- HST/ACS has covered $z \lesssim 6$, and WFC3 is now covering $z \lesssim 7$–9.
- For First Light & Reionization, JWST will sample $z \approx 8$ to $z \approx 15$–20. (JWST will cover $\lambda = 0.7$–29 µm, with its diffraction limit at 2.0 µm).
After the dark ages started at $z \lesssim 1000$, Hydrogen and Helium were reionized:

- Dwarf galaxies (??) reionized Hydrogen at $z \approx 7–20$.
- The hard-UV light of Quasars reionized Helium at redshifts $z \lesssim 3$. 
At the end of reionization, dwarfs had beaten the Giants, but ...
What comes around, goes around ...