

AAS January 2010 Washington DC
Galaxies Near and (Very) Far

*Hubble observations of very
high-redshift galaxies:
looking back 13 billion years...*



Garth Illingworth, Rychard Bouwens
(University of California, Santa Cruz)
and the HUDF09 team

what we discovered

revealing galaxies 13 billion years ago

Hubble's new Wide Field Infra-Red Camera (WFC3/IR) has revealed galaxies 13 billion years ago (at redshift $z \sim 8$), just 600-700 million years from the big bang.

This is just 6 years after Hubble revealed $z \sim 6$ galaxies (900 million years after the big bang) using the Advanced Camera for Surveys (ACS)

what this tells us

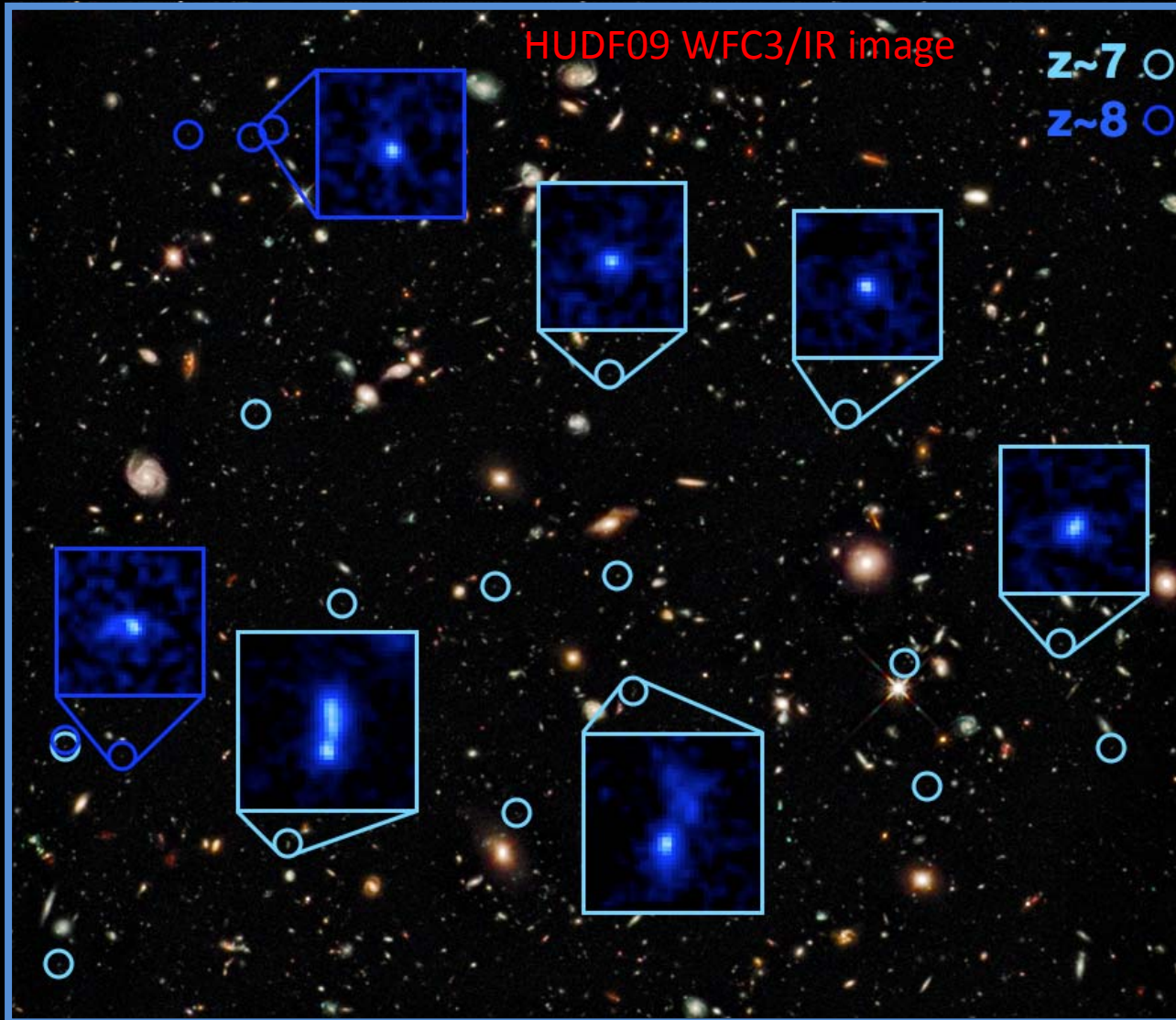
these redshift 7-8 galaxies are just 1/20 the size and <1% of the mass of the Milky Way, but are the seeds from which today's great galaxies grew

they have primordial characteristics – they are extremely blue in color and probably very deficient in the heavier elements

they are vigorously forming stars and growing through collisions/mergers during the “reionization” epoch

these galaxies were forming stars ~ 300 million years earlier, close to when the very first stars formed

Hubble is pushed to the limit to find these galaxies



examples of the 16 redshift $z \sim 7$ sources and 5 $z \sim 8$ galaxies we found in the HUDF with the WFC3/IR and the ACS.

(Bouwens et al and Oesch et al papers)

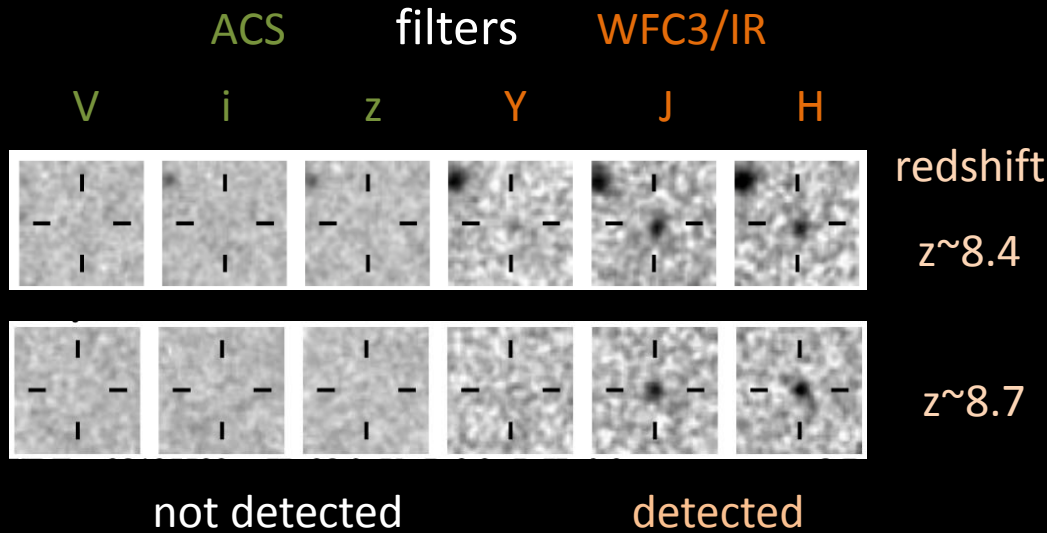
these galaxies are seen just 600-800 million years from the big bang

very competitive arena: three other teams have reported similar results at $z \sim 7-8$ (Bunker et al; McLure et al; Yan et al)

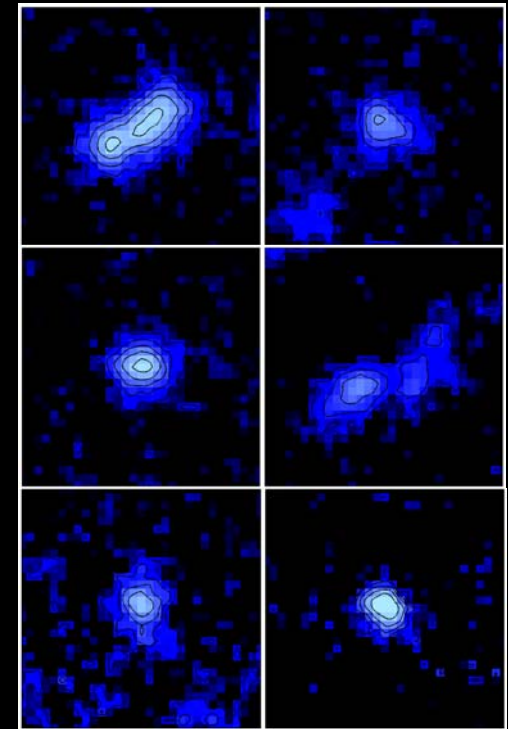
these galaxies are really faint

the highest redshift $z \sim 8$ galaxies

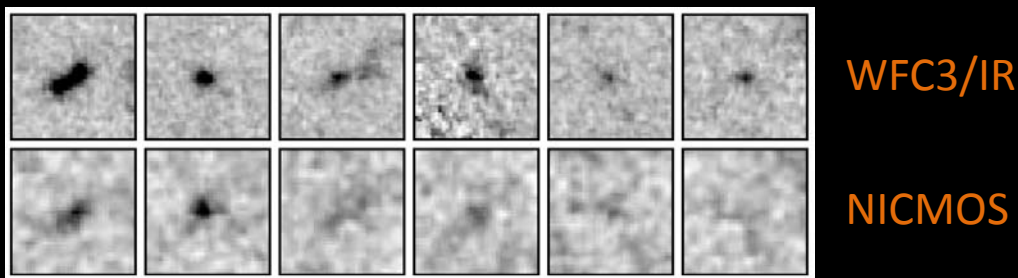
(Bouwens et al and Oesch et al papers)



redshift $z \sim 7$ galaxy images

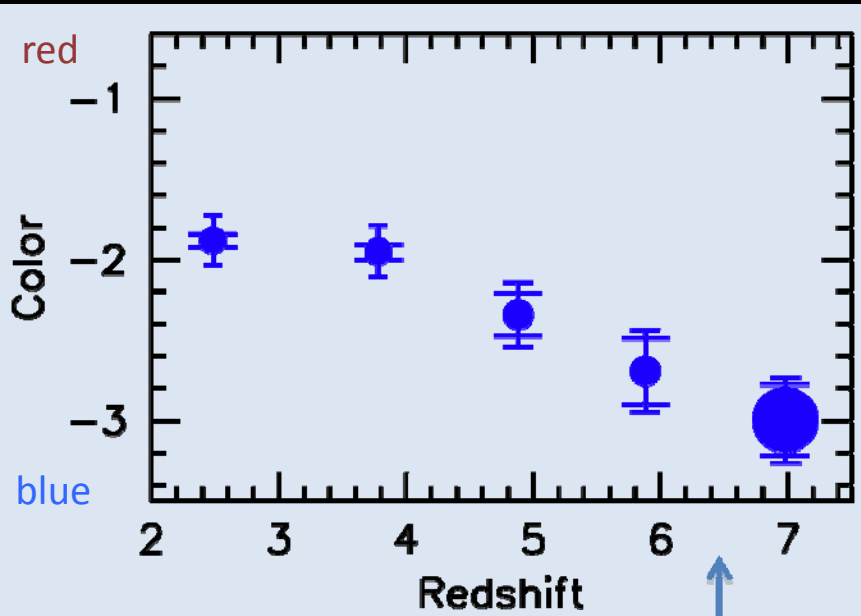


comparing the old and new Hubble infrared cameras



these early galaxies are small and very blue

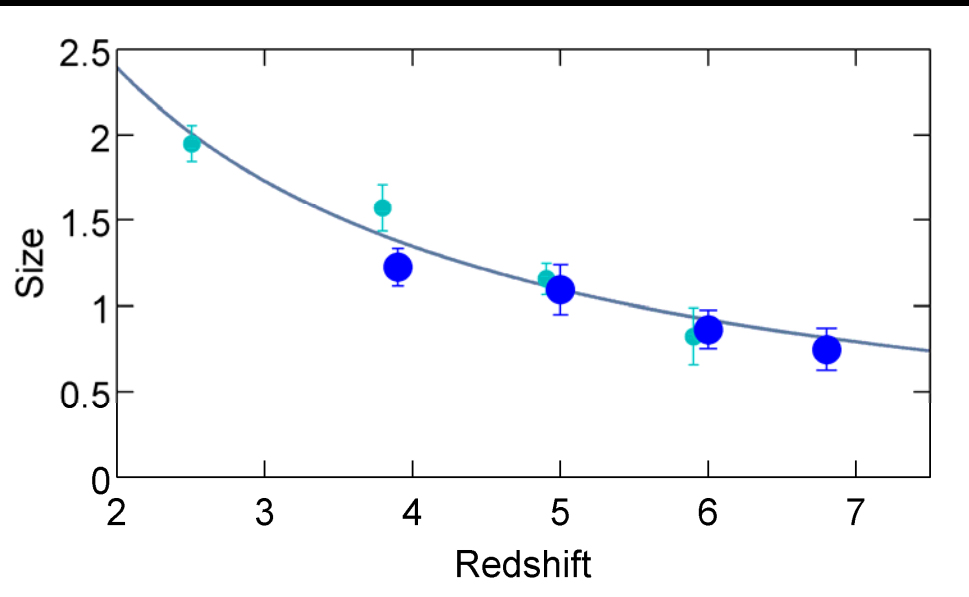
Bouwens/Illingworth et al paper



galaxies become very blue at early times – suggests that heavier elements are way less abundant than today

galaxies become very small at early times – 5% of Milky Way in size and <1% in mass – they are the seeds of today's great galaxies

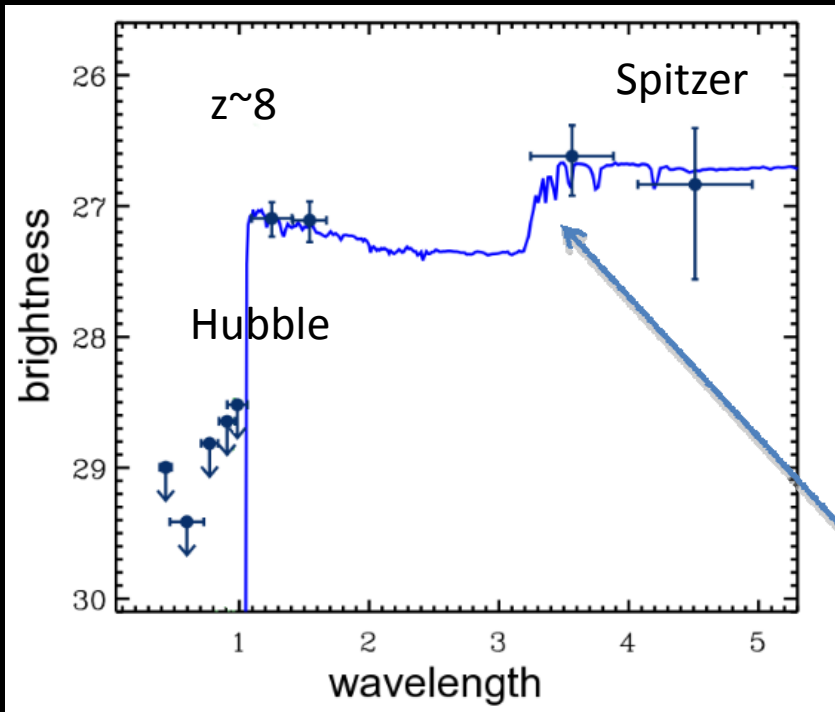
Oesch/Carollo et al paper



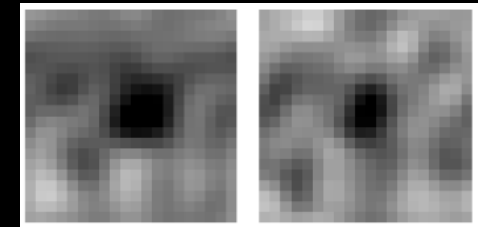
these galaxies formed stars much earlier

Hubble and Spitzer results combine to show us that $z \sim 8$ galaxies were already forming some stars about three hundred million years earlier (at $z > 10-11$) – close to the time of the first stars

some individual $z \sim 8$ Spitzer 3.6 μm images



$z \sim 8$ summed Spitzer images



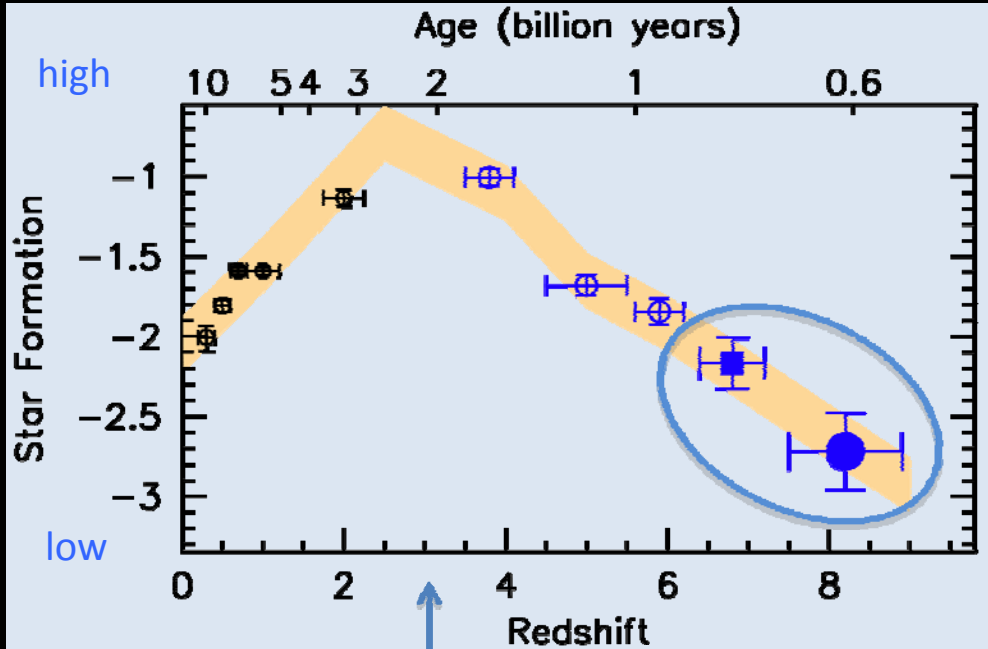
3.6 μm

4.5 μm

(Labbé/Gonzalez et al papers)

the blue line is fit to the data from a population of stars – the bump needed to fit the Spitzer data is what tells us that some stars in these $z \sim 8$ galaxies are 300 million years old!

galaxies formed stars and assembled smoothly over the first 2 billion years



the history of star formation in galaxies in the universe

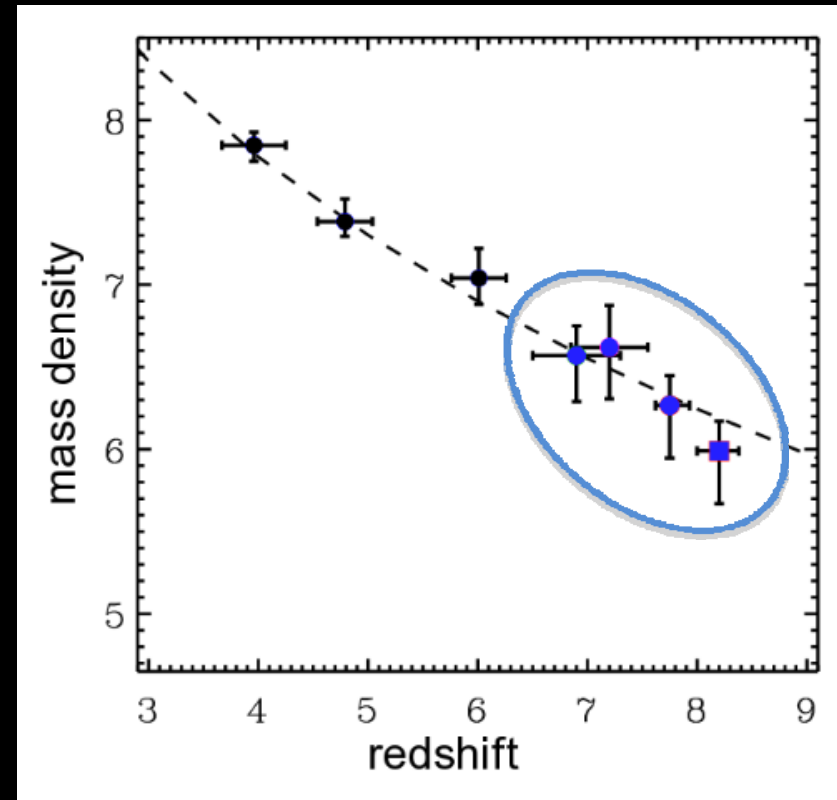
(Bouwens/Illingworth et al papers)



our new results

the history of the mass buildup in galaxies in the universe

(Labbé/Gonzalez et al papers)



what these new observations tell us

SUMMARY

Hubble's new Wide Field Infra-Red Camera (WFC3/IR) has revealed galaxies 13 billion years ago (at redshifts $z \sim 7$ and $z \sim 8$), just 600-800 million years from the big bang

these galaxies are just 1/20 the size and <1% of the mass of the Milky Way, but they are the seeds from which today's great galaxies grew

they have primordial characteristics – they are extremely blue in color and are probably very deficient in the heavier elements

they are vigorously forming stars and growing more and more massive through collisions/mergers

these galaxies were forming stars ~ 300 million years earlier, close to when the very first stars formed

these galaxies fall in the heart of the “reionization” epoch, but we still don't know if galaxies could have reionized the universe!!

CREDITS

the HUDF09 team

Credit (NASA/STScI press release):

NASA, ESA, G. Illingworth and R. Bouwens (University of California, Santa Cruz), and the HUDF09 Team.

These results are based on data from the Hubble WFC3/IR and ACS cameras obtained under proposal GO11563 by the HUDF09 team:

G. Illingworth (UCO/Lick Observatory; University of California, Santa Cruz)

R. Bouwens (UCO/Lick Observatory and Leiden University)

M. Carollo (Swiss Federal Institute of Technology, Zurich)

M. Franx (Leiden University)

I. Labbe (Carnegie Institution of Washington)

D. Magee (University of California, Santa Cruz)

P. Oesch (Swiss Federal Institute of Technology, Zurich)

M. Stiavelli (STScI)

M. Trenti (University of Colorado, Boulder)

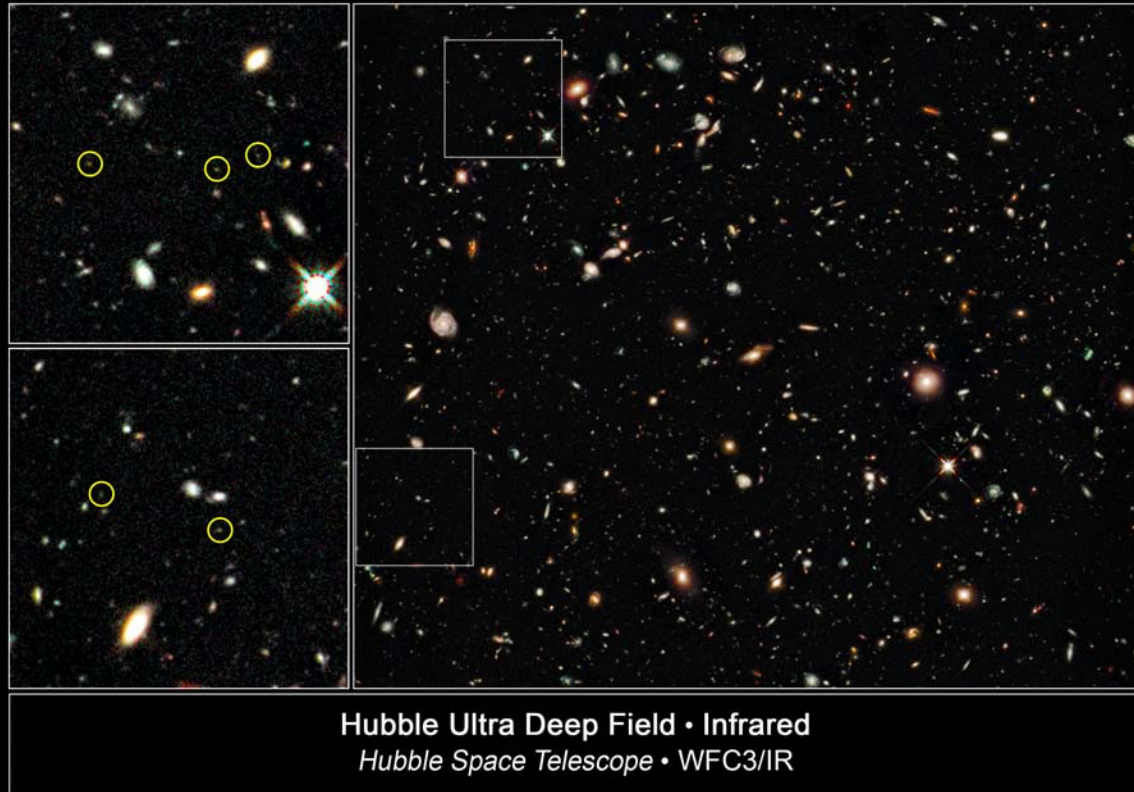
P. van Dokkum (Yale University)

for astro-ph links
to papers see:
firstgalaxies.org

redshift vs age

galaxies at $z \sim 8$

z redshift	millions of years since the big bang
2	3300
3	2200
4	1600
5	1200
6	950
7	750
8	650
9	550
10	500
11	400



NASA, ESA, G. Illingworth (UCO/Lick Observatory and University of California, Santa Cruz), and the HUDF09 Team STScI-PRC10-02