Gravitational lensing and SASIR

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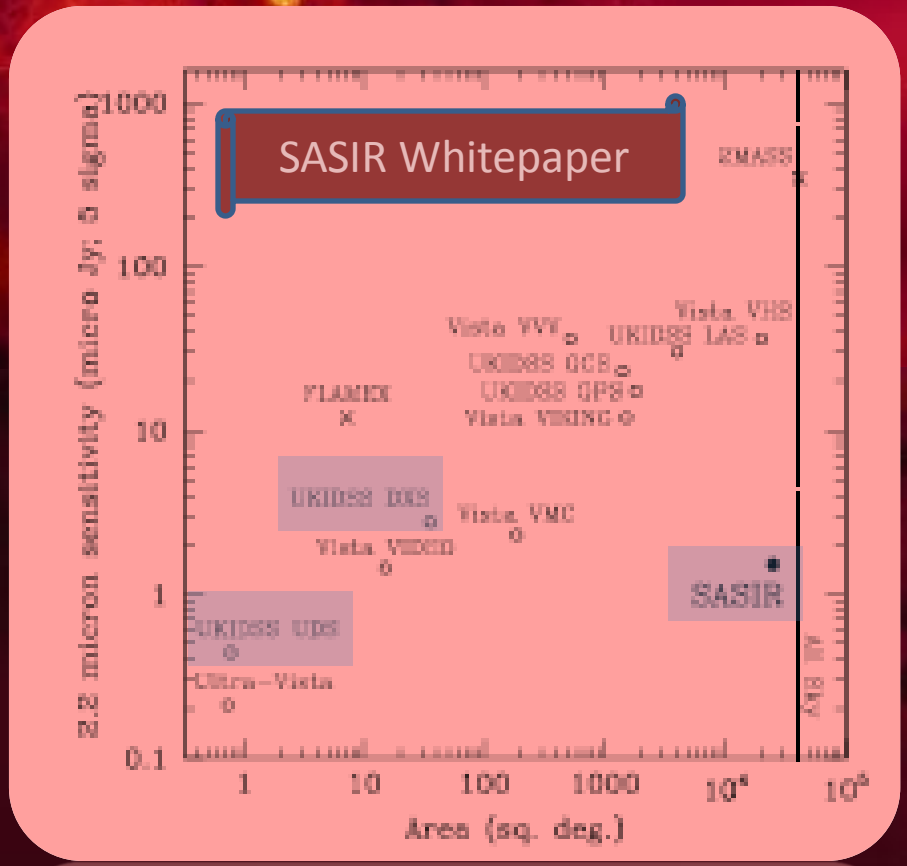
UKIRT Infrared Deep Sky Survey Headline science goals

- To find the nearest and faintest sub-stellar objects
- To discover Pop II brown dwarfs, if they exist
- To determine the substellar mass function
- **To break the z=7 quasar barrier**
- **To determine the epoch of reionization**
- To construct a galaxy catalogue at z=1 as large as the SDSS catalogue
- To measure the growth of structure and bias from z=3 to the present day
- To determine the epoch of spheroid formation
- To clarify the relationship between quasars, ULIRGs, and galaxy formation
- To map the Milky Way through the dust, to several kpc
- To increase the number of known Young Stellar Objects by an order of magnitude, including rare types such as FU Orionis stars
- ***(Transneptunian planets?)***

Lawrence, A., et al. 2007, MNRAS, 379, 1599

UKIDSS components

- Large Area Survey
- Galactic Plane Survey
- Galactic Clusters Survey
- Deep Extragalactic Survey
  - z = 1 - 1.5 galaxies
  - J < 22.3; K < 21; J-K=1.5-1.8
- Ultra Deep Survey
  - Giant ellipticals z = 3
  - J-H ~ 2; H-K ~ 1
  - J < 24.8; H < 23.8; K < 22.8
  - Subaru/XMM-Newton Deep Field



Quasars at z > 7

- Current quasar surveys (SDSS, 2dF) show
  - Strong evolution of luminous quasar number density
  - Strong clustering of luminous quasars
  - Existence of billion solar mass BHs at **z**~6
  - Emergence of Gunn-Peterson effect indicates the end of reionization epoch by **z**~6 (Fan et al. 2002, AJ, 123, 1247)
- A wide-field infrared quasar survey will
  - Probe the evolution of faint quasars and the evolution of UV background at high-z
  - Reveal the evolution of first luminous quasars in the Universe
  - **Map the history of reionization at z >7** (Importance of the Y band; Warren, S., & Hewett, P. 2002. in A New Era in Cosmology 283, WFCAM, UKIDSS, and z = 7 Quasars, 369)
  - Relation between quasar activity and galaxy formation

Yesterday: Xavier Prochaska – The static sky

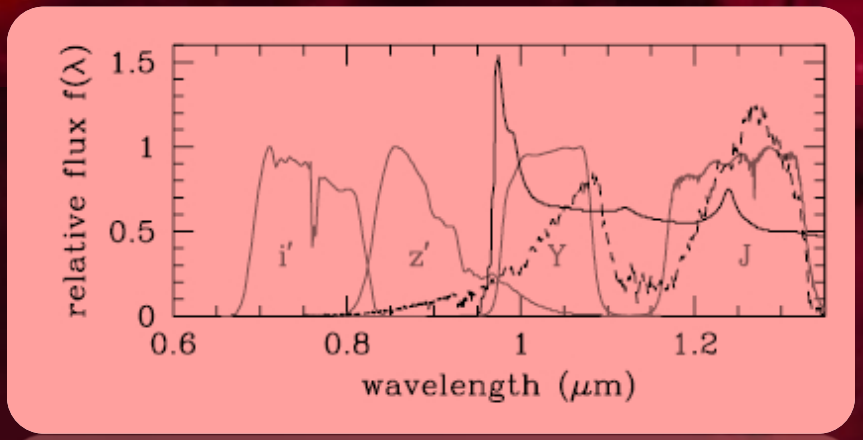
Today: Takamitsu Miyaji – X-ray & SASIR

Tomorrow: Bob Becker – Reddened quasars

- - - Brown dwarf

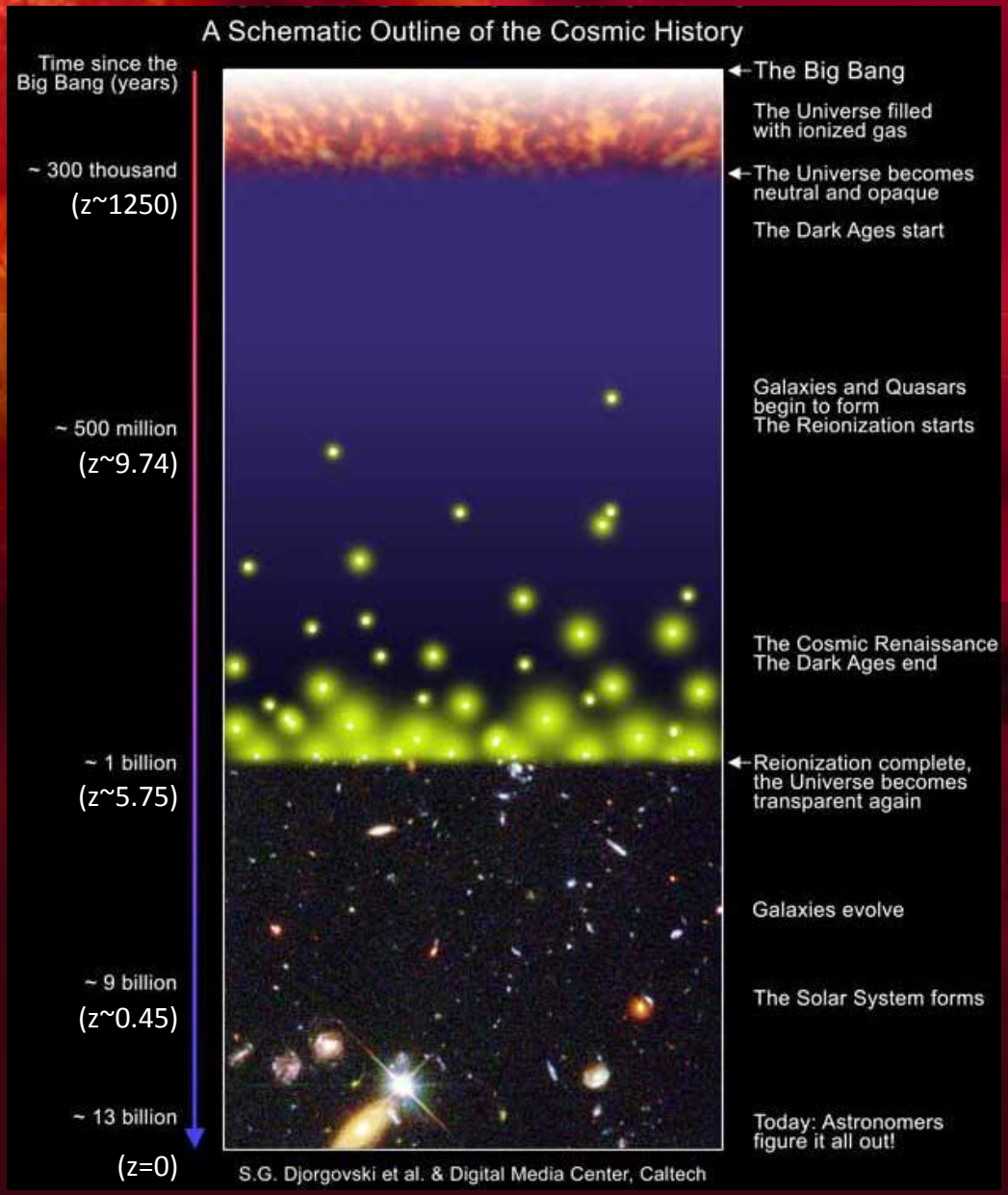
---- Quasar at z=7

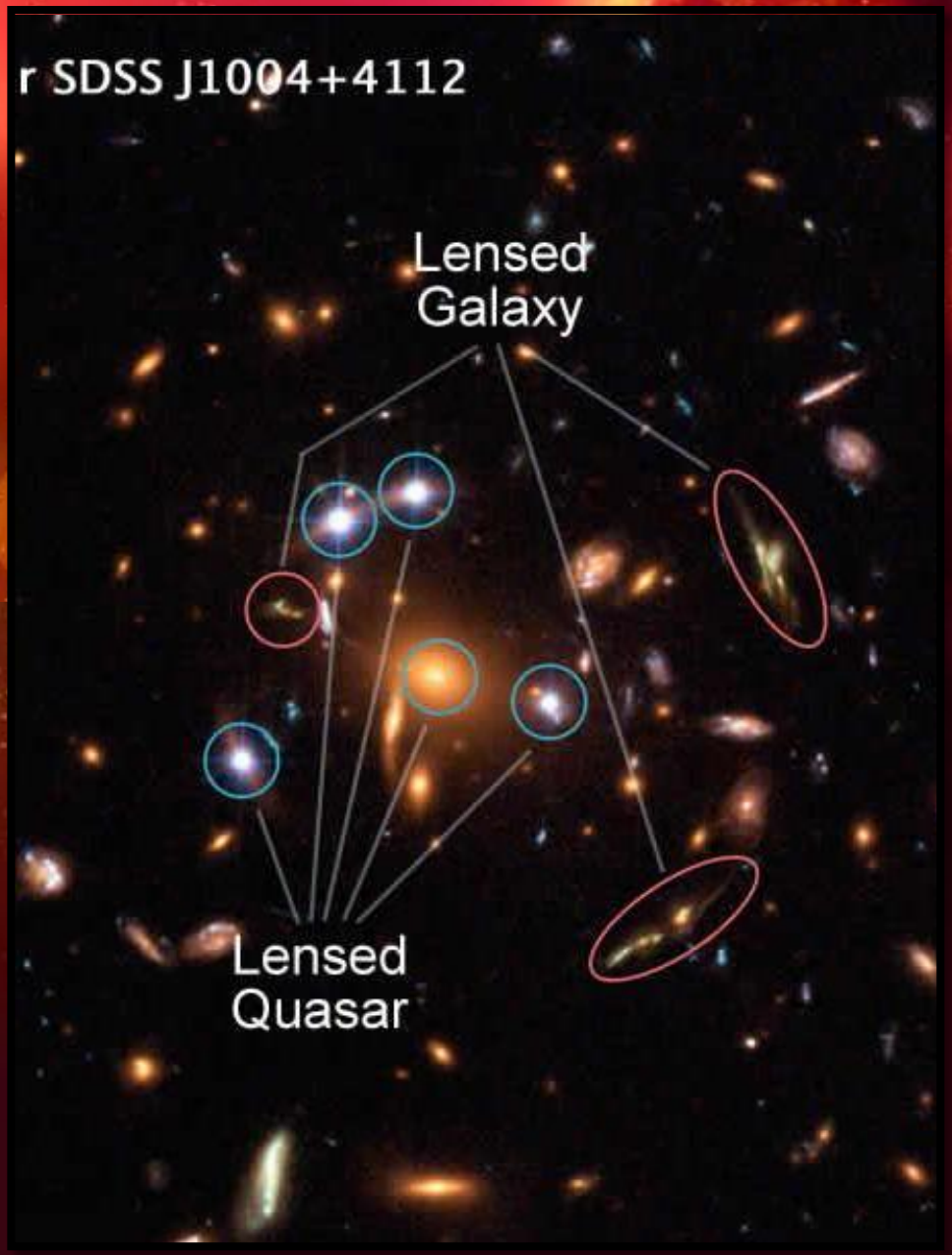
Lawrence, A., et al. 2007, MNRAS, 379, 1599

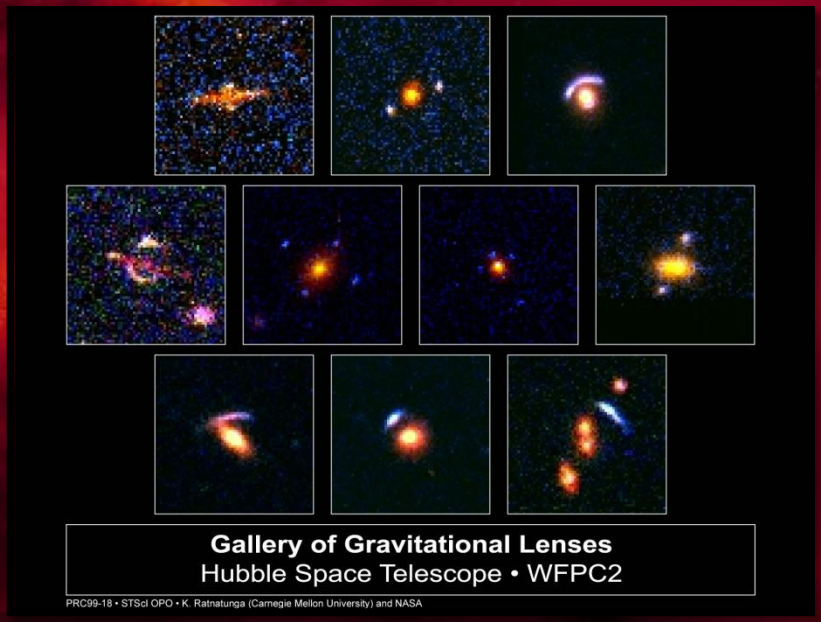


Cosmic history

- Observations of the Gunn-Peterson trough in z~6 quasars as indication of the end of reionization epoch
  - Fan et al. 2002, AJ, 123, 1247
- A search of LAE candidates in the Subaru Deep Field indicates that the reionization may have not been completed at z=6.5
  - Kashikawa et al. 2006, ApJ, 648, 7
- WMAP data suggest that the universe was ionized out to z~10
  - Page et al. 2007, ApJS, 170, 335



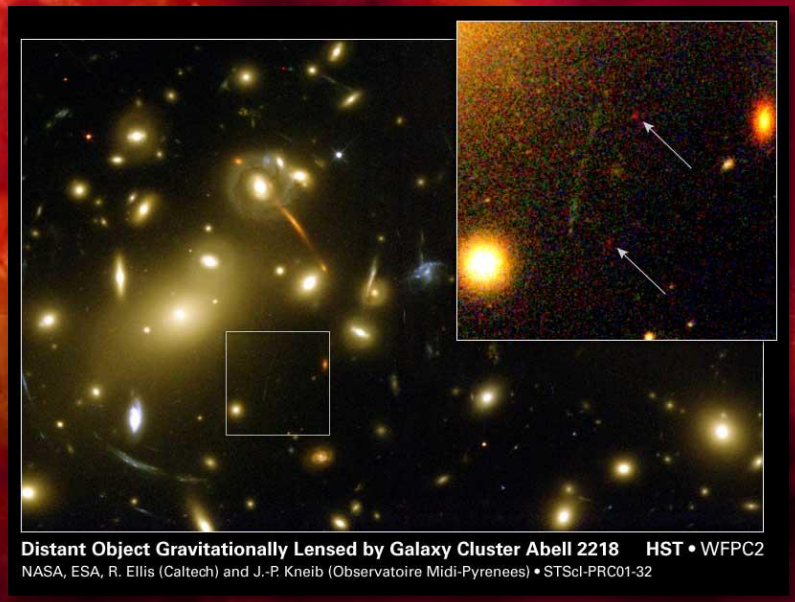




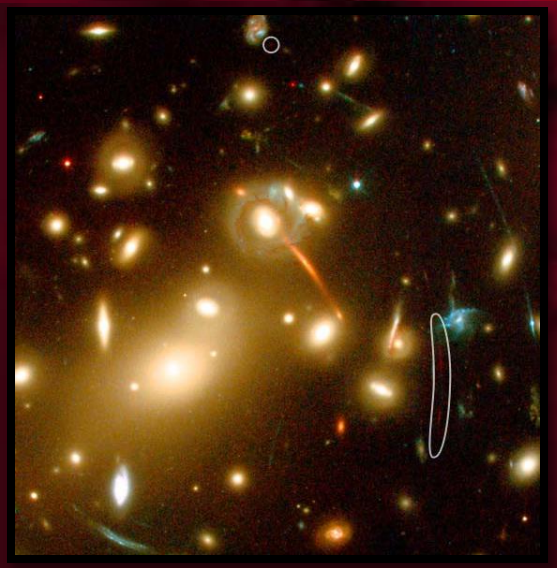
- Why may be important Gravitational Lensing for high-redshift quasars?
  - Luminosity bias
  - Evolution of AGN Lum. Func.
  - Young AGNs may be dimmer
- Were to look
  - Galaxies
  - Clusters

Galaxies at z > 7

- Using GL as telescopes
  - Santos, M. R. et al. 2004, ApJ, 606, 683
  - Richard, J., et al. 2006, A&A, 456, 861
- Photometric redshifts
  - Optical – NIR synergy
- Ly$_\alpha$ relatively easy
  - But flux uncertain
    - Reionization incomplete
- Hα from space
  - Not absorbed by IGM
  - No resonant trapping/dust absorption
  - JWST

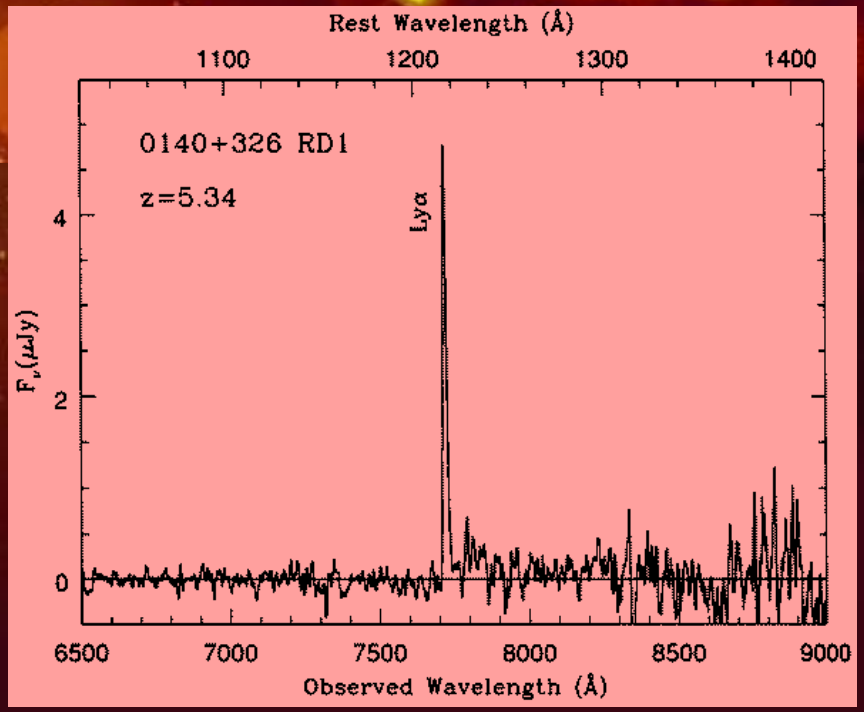


- Galaxies at z~7 in Abell 2218
  - Ellis & Kneib
- Clusters at z ~ 1
  - Adam Stanford talk
- Open questions
  - M/L evolution
  - IMF
  - Pop III
  - Metallicity

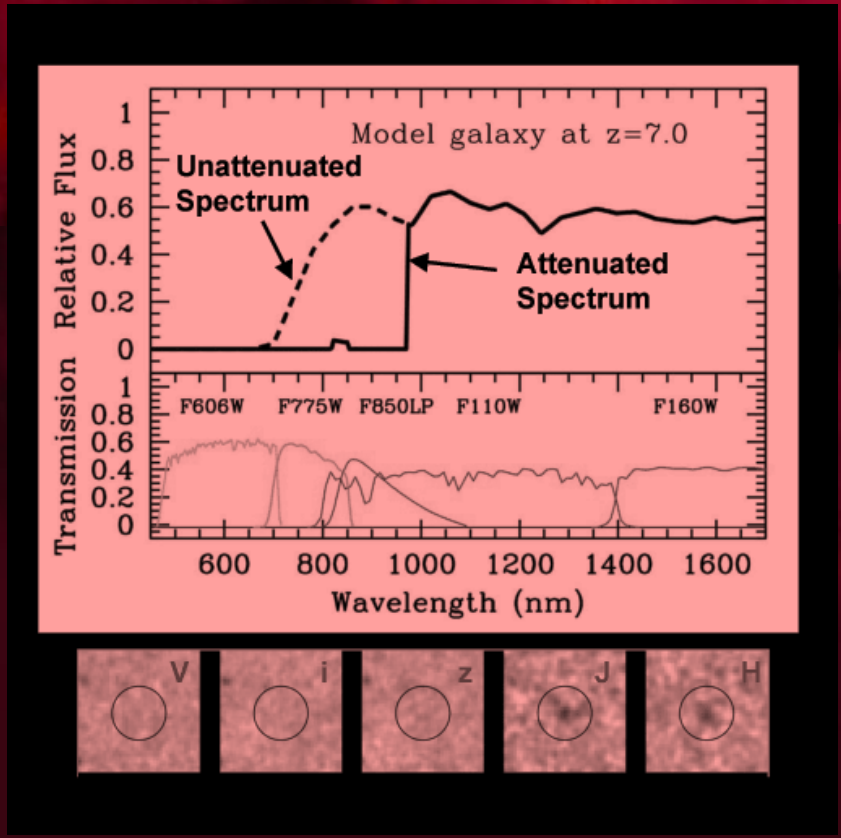


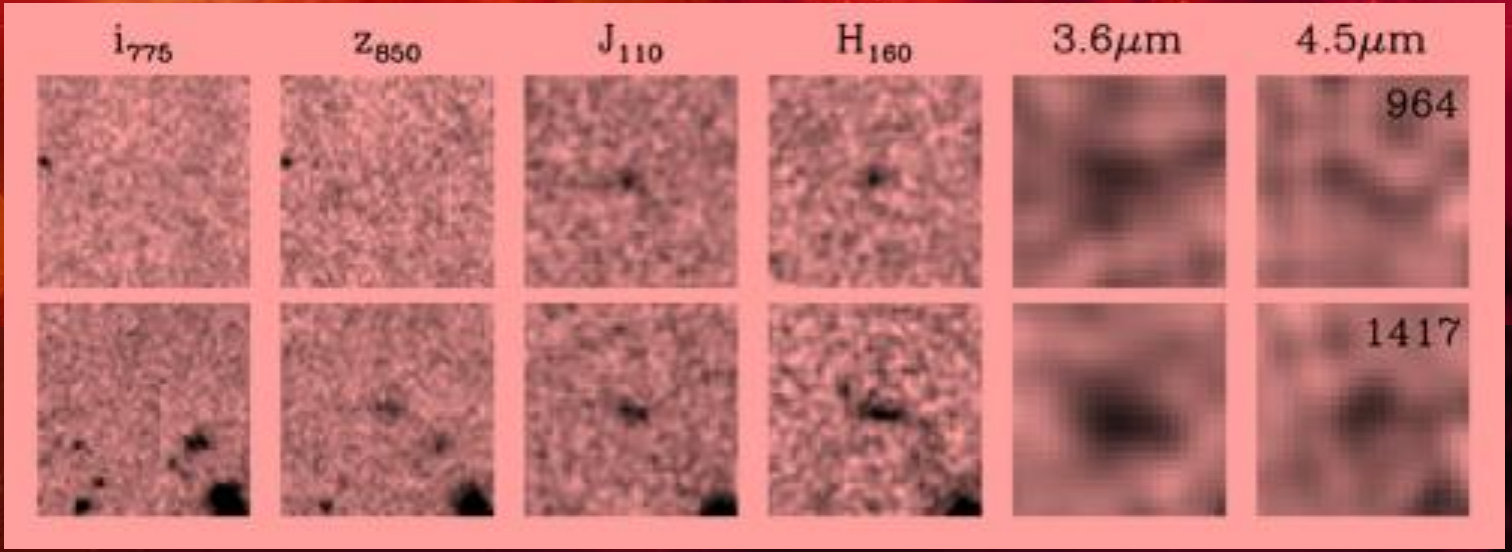
High redshift galaxies

Lyman Alpha Emitters



Lyman Break Galaxies



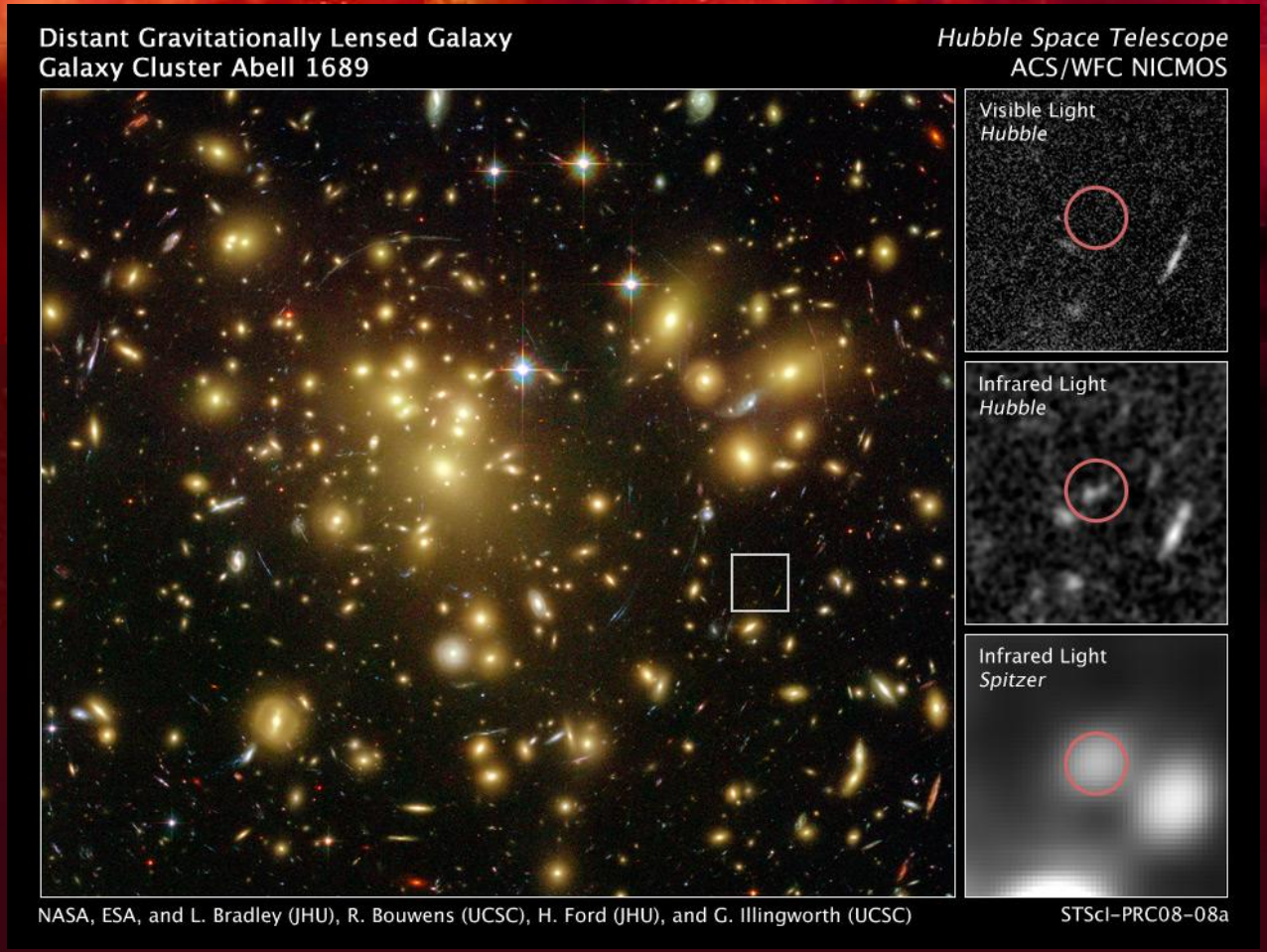


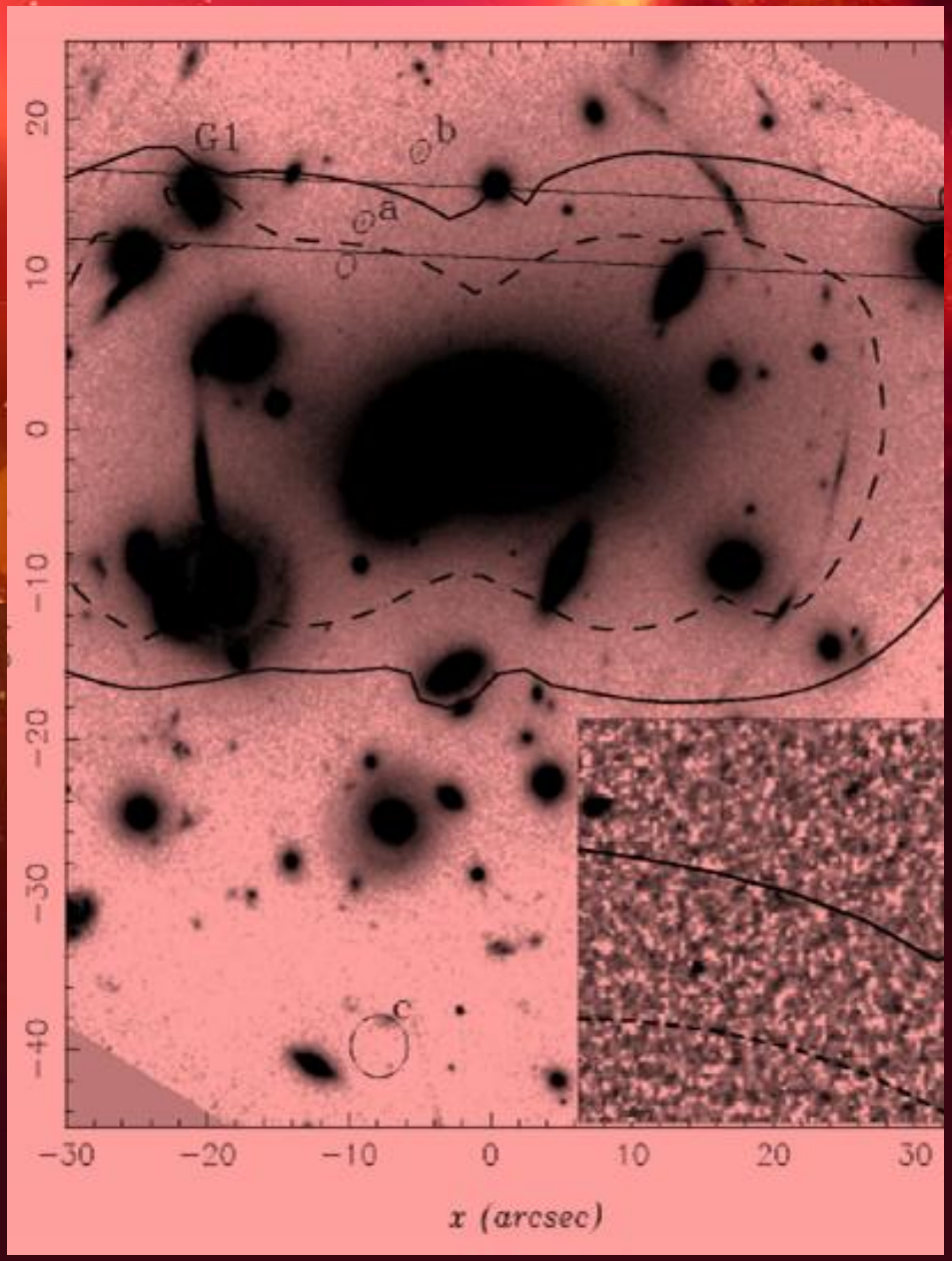
Two z~7 LBG galaxies wit Spitzer IRAC imaging in the HST Ultra Deep Field

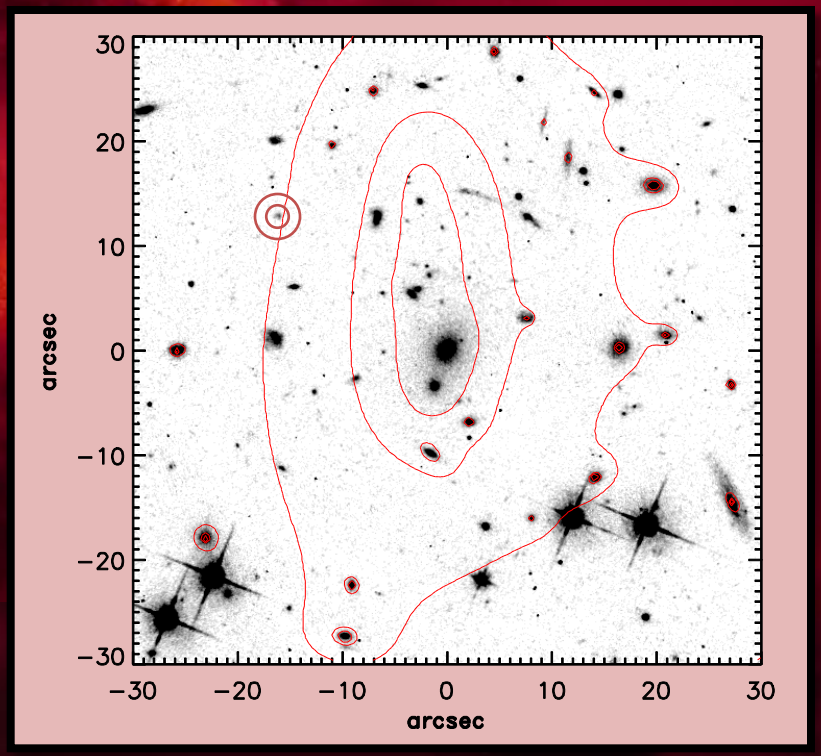
Labbé, I., Bouwens, R., Illingworth, G. D., & Franx, M. 2006, ApJ, 649, L67

9.3 magnification LBG at z~7.6

Bradley, L. D., et al. 2008, ApJ, 678, 647





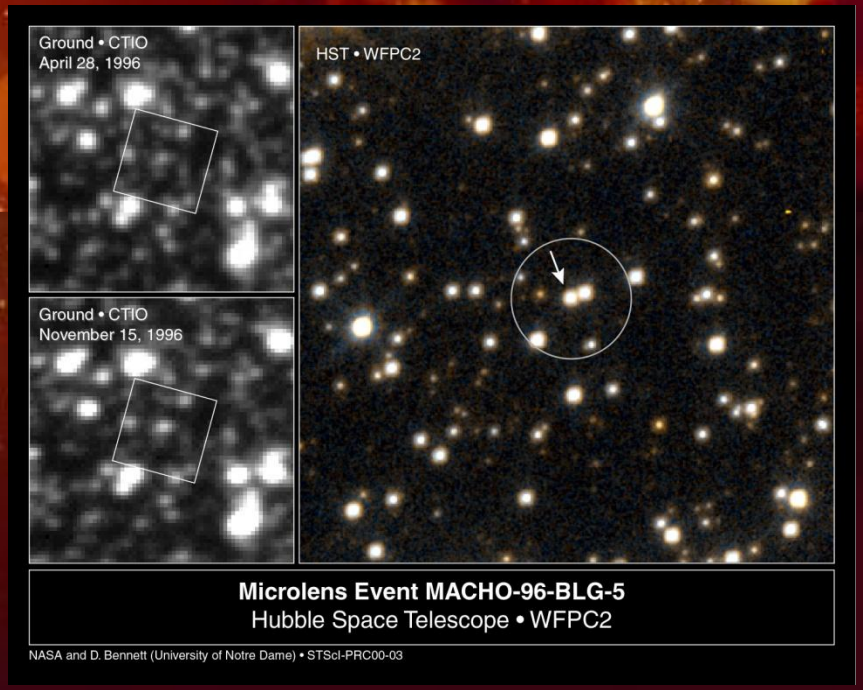


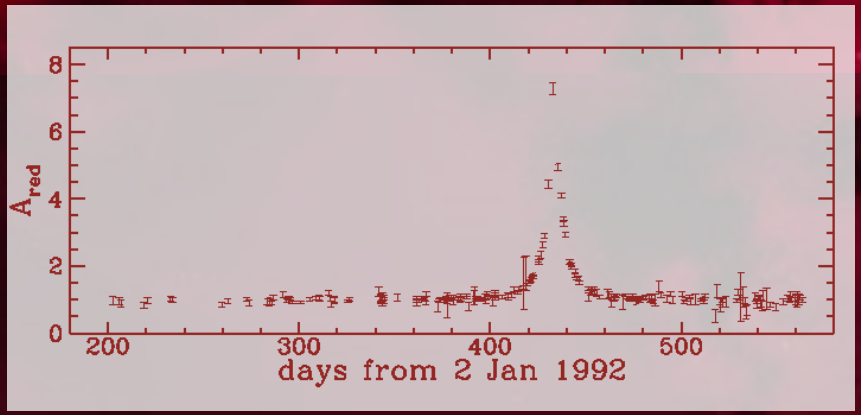
- UP: Counterpart candidates
  - Verdugo, T., de Diego, J. A., & Limousin, M. 2007, Astrophysical Journal, 664, 702
- LEFT: Search of High-z galaxies
  - Ellis, R., Santos, M. R., Kneib, J.-P., & Kuijken, K. 2001, ApJ, 560, L119

SASIR – GTC – LMT…

SASIR	GTC – LMT…
Catalogue cross correlation	X-Ray, UV, Optical (OTELO)
Clusters at z > 0.5	Deep fields
High-z candidates	Redshift confirmation
David Hughes talk	LMT Redshift Receiver
	CO lines at z > 3
High-z gravitational lensing	Lens model in the optical
Weak lens statistics	Mass distribution
Search around critical lines	Identify critical lines
More GL systems	
Larger redshifts	
Radial arcs	

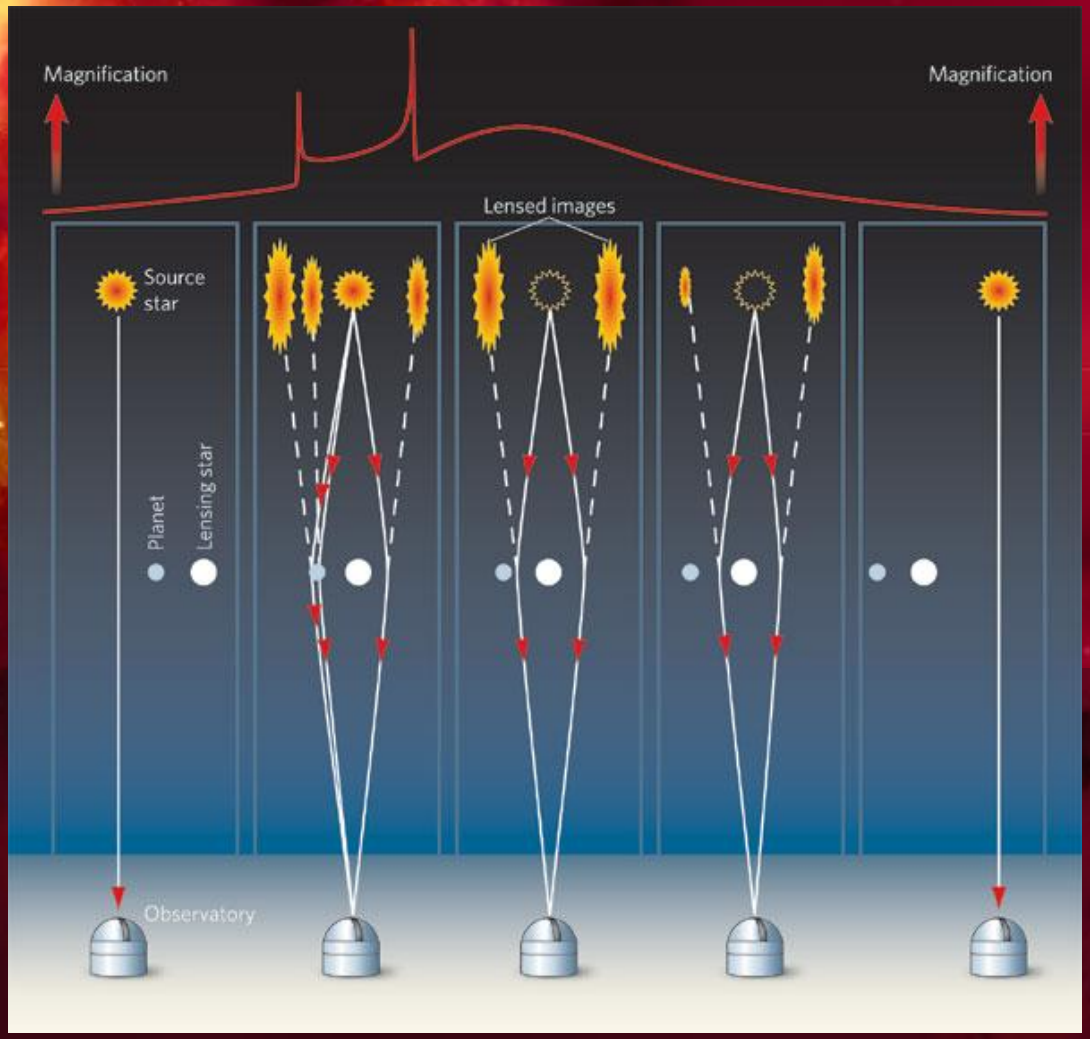
MACHOs

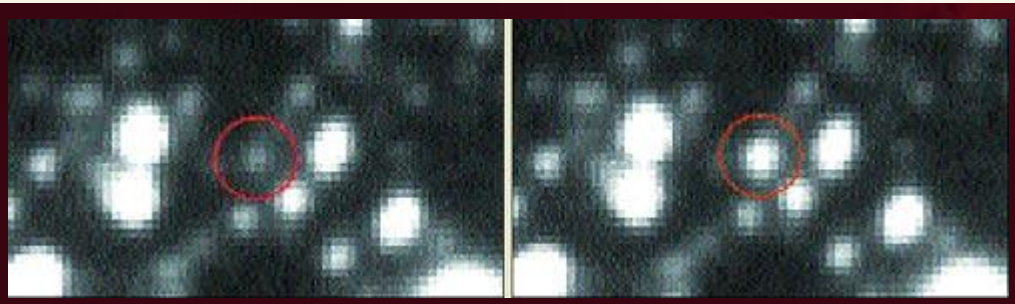

Ground • CTIO
April 28, 1996
Ground • CTIO
November 15, 1996
HST • WFPC2
Microlens Event MACHO-96-BLG-5
Hubble Space Telescope • WFPC2
NASA and D. Bennett (University of Notre Dame) • STScI-PRC00-03


A_red
0
2
4
6
8
200
300
400
500
days from 2 Jan 1992

Extrasolar planet

- 1.3 m Warsaw telescope at the Las Campanas Observatory in Chile
  - 0.06 $M_\odot$ for the star
  - 3.3 $M_\oplus$ for the planet





Bennett, D.P., et al. 2008, arXiv:0806.0025