Cosmology with Objects from the Hamburg QSO Surveys

- QSOs sufficiently bright for high resolution spectroscopy (UVES/VLT, Keck, HST)

- The first generation(s) of stars in the Galaxy (stellar archaeology)

Two different ways to look back into the history of the Universe

Both require Wide Angle Surveys because of the intrinsic rareness of suitable objects.

Hamburg QSO Surveys

1. HS with Hamburg Schmidt telescope on Calar Alto (Spain)
   1983 - 1999
   13 600 deg^2 (567 Schmidt fields)
   Resolution: ~ 50 Å

2. HES (Hamburg/ESO Survey)
   ESO-Schmidt La Silla (Chile)
   1990 - 2000
   9 000 deg^2 (380 Schmidt fields) Resolution: 15 Å

Digitization of all plates in Hamburg (PDS 1010 G)
Development of automated search and classification of all objects (several 10^6 spectra)

Quasars and Cosmology

Bright, high-redshift QSOs are ideal background light sources

for the investigation matter on the line of sight
(diffuse or compact)

- **Intergalactic matter at early epochs**
- **HeII reionization**
- **D/H**
- **Gravitational lenses**
- **Variation of Funda-mental constants**

The discovery of HeII reionization of the Universe at z $\simeq$ 3 in HE 2347-4342

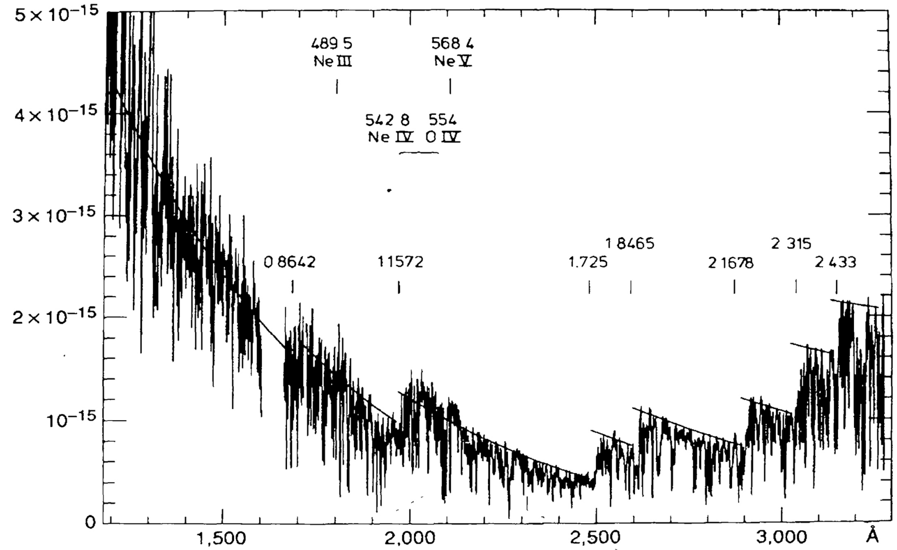
The detection of HeII 303.8 Å with HST requires z > 2.8

<u>However:</u> 1) Only 5% of the sky is transparent to z = 3 due to intervening hydrogen, mainly in form of Lyman limit systems

2) For HST (Ø = 2.4 m) QSOs have to be bright in the UV with fluxes above 2 10(-15) The number of suitable QSOs is ≤ 100 The aim

' 1990 was to find the predicted 1 or 2 suitable QSOs using our all sky QSO survey.

A survey of suitable bright QSOs with IUE led in 1995 to the discovery of HE 2347-4342 as a suitable target fo HST.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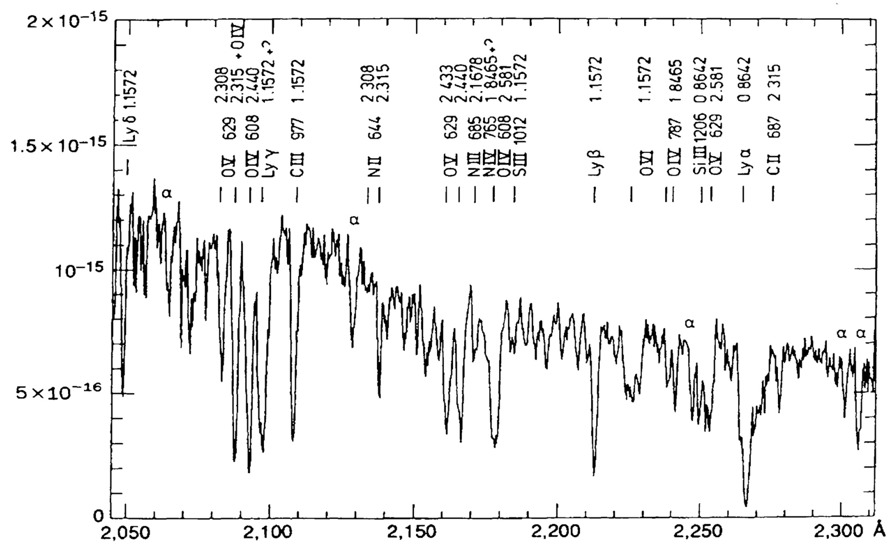
1 8465
2 1678
2 315
2 433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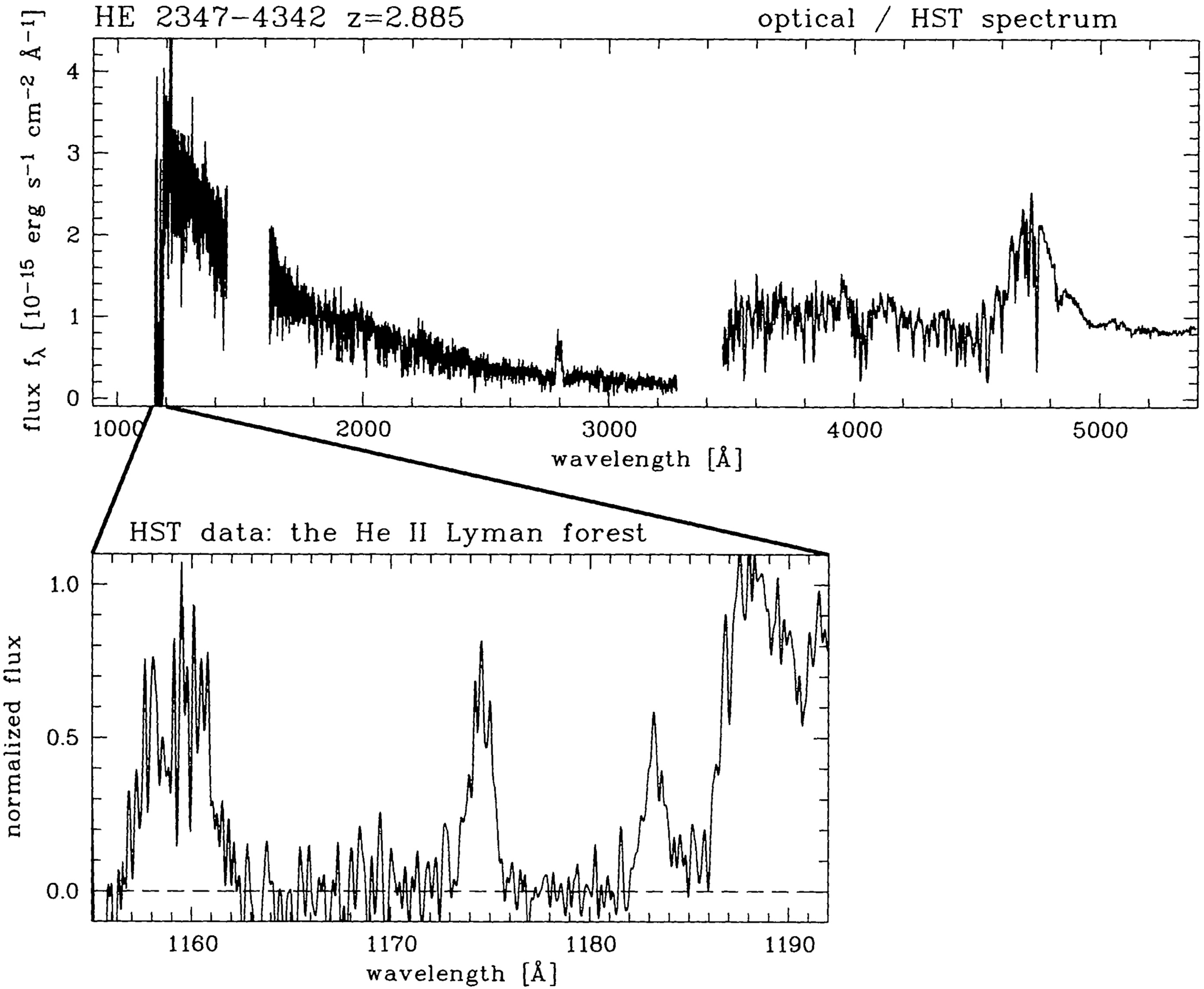
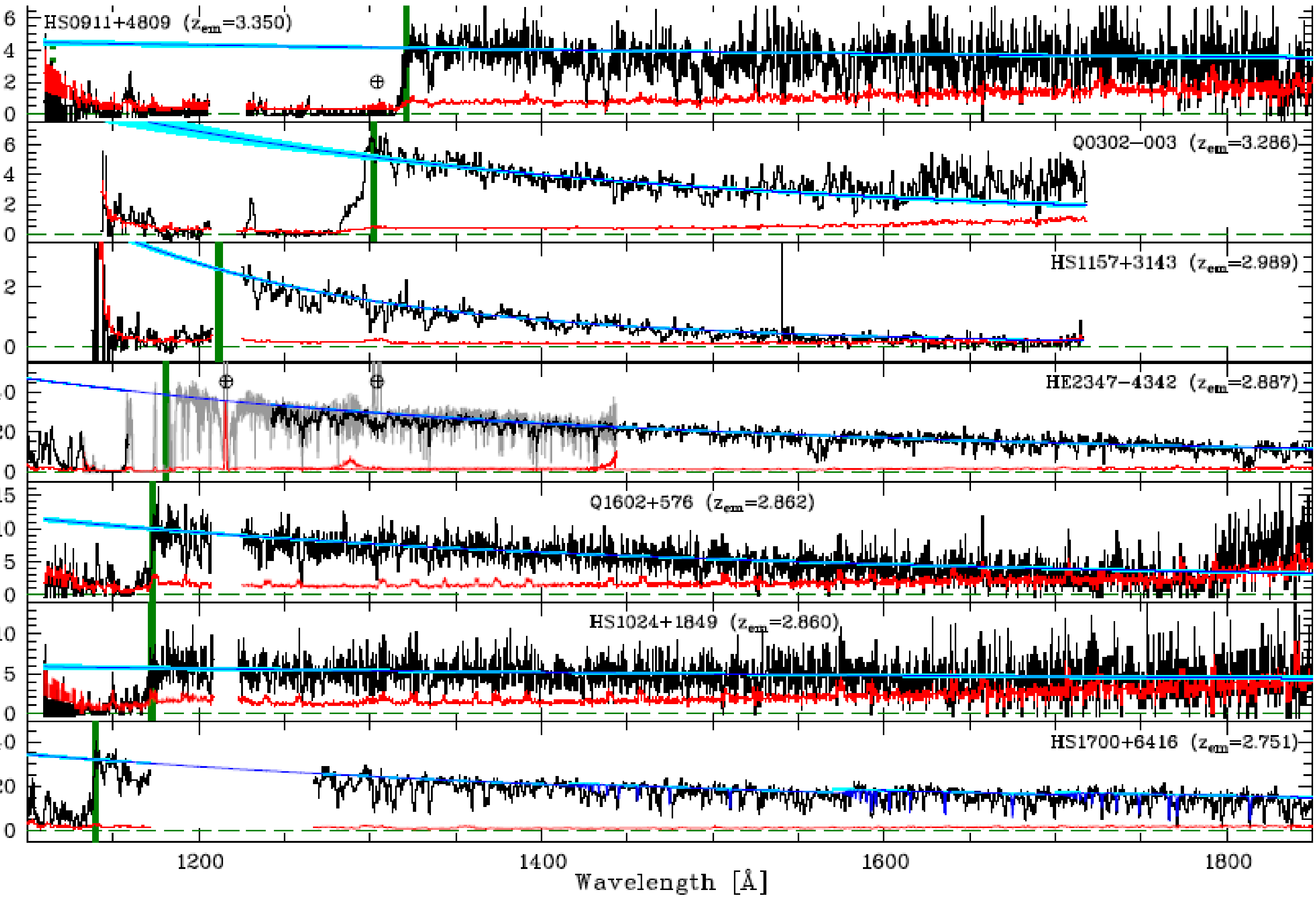
Å
Ly δ 1.1572
O V 629 2.308
O IV 608 2.315 + O IV
Ly γ 2.440
1.1572 + ?
C III 977 1.1572
N II 644 2.308
2.315
O V 629 2.433
N III 685 2.440
N IV 765 2.1678
O IV 608 1.8465 + ?
S III 1012 2.581
1.1572
Ly β 1.1572
O VI 1.1572
O IV 787 1.8465
Si III 1206 0.8642
O V 629 2.581
Ly α 0.8642
C II 687 2.315
α

HS 1700+6416



HE 2347-4342 z=2.885
optical / HST spectrum
flux f_λ [10^{-15} erg s^{-1} cm^{-2} Å^{-1}]
wavelength [Å]
HST data: the He II Lyman forest
normalized flux
wavelength [Å]



HS0911+4809 (z_{em}=3.350)
Q0302−003 (z_{em}=3.286)
HS1157+3143 (z_{em}=2.989)
HE2347−4342 (z_{em}=2.887)
Q1602+576 (z_{em}=2.862)
HS1024+1849 (z_{em}=2.860)
HS1700+6416 (z_{em}=2.751)
1200
1400
1600
1800
Wavelength [Å]

HeII reionization

- Transition between optically thick HeII 3038 Å absorption for $z \geq 3$ to a HeII Ly α forest for $z < 2.8$
  Patchiness in between
  The delayed HeII reionization phase of the Universe compared to hydrogen ($z > 6$) is due to the delayed occurrence of QSOs (stars cannot reionize HeII)

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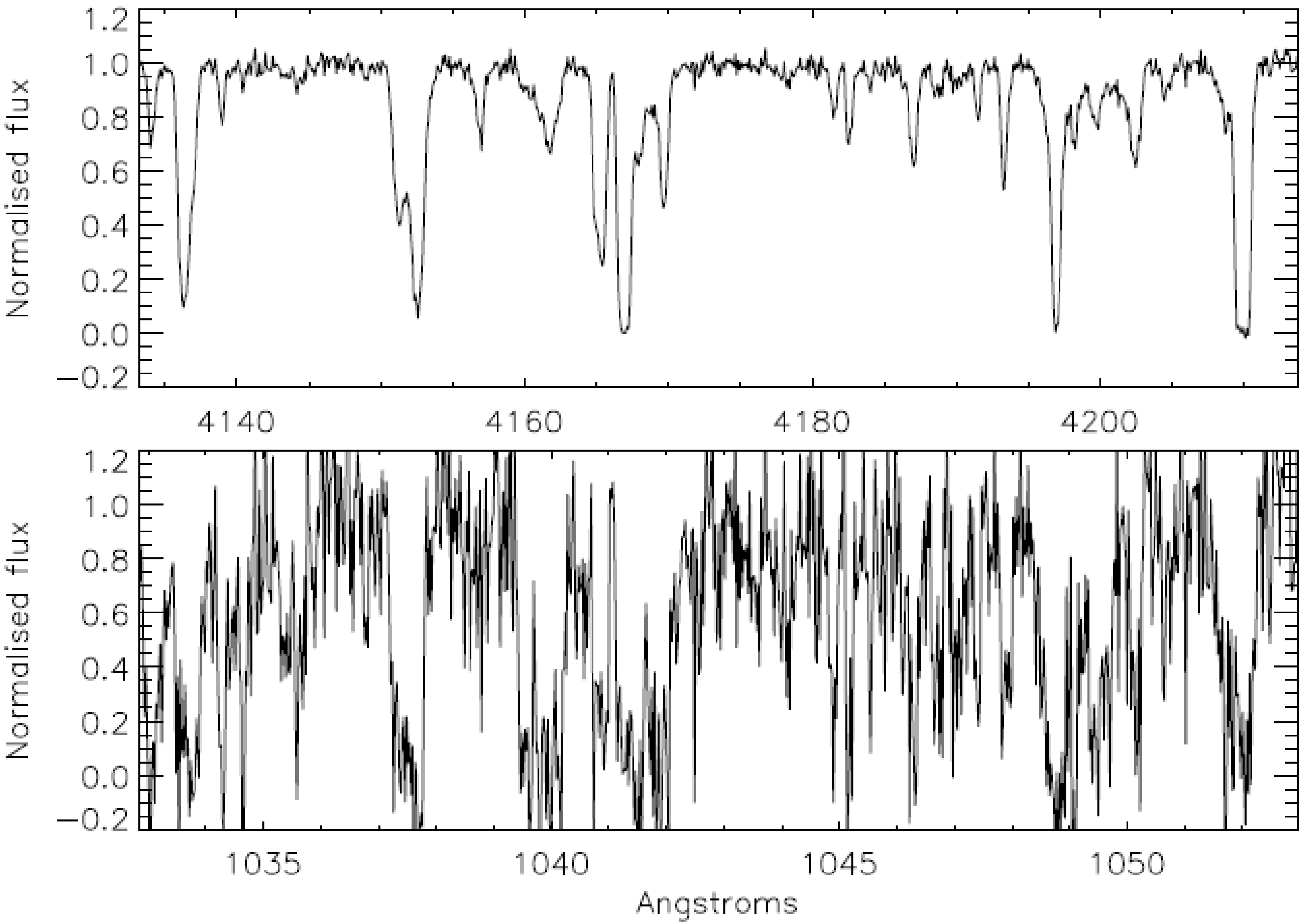
- HeII Ly α forest could be observed by FUSE in only HE 2347-4342 and HS 1700+6416 with high resolution

$$\eta = \frac{N(HeII)}{N(HI)} = 80$$

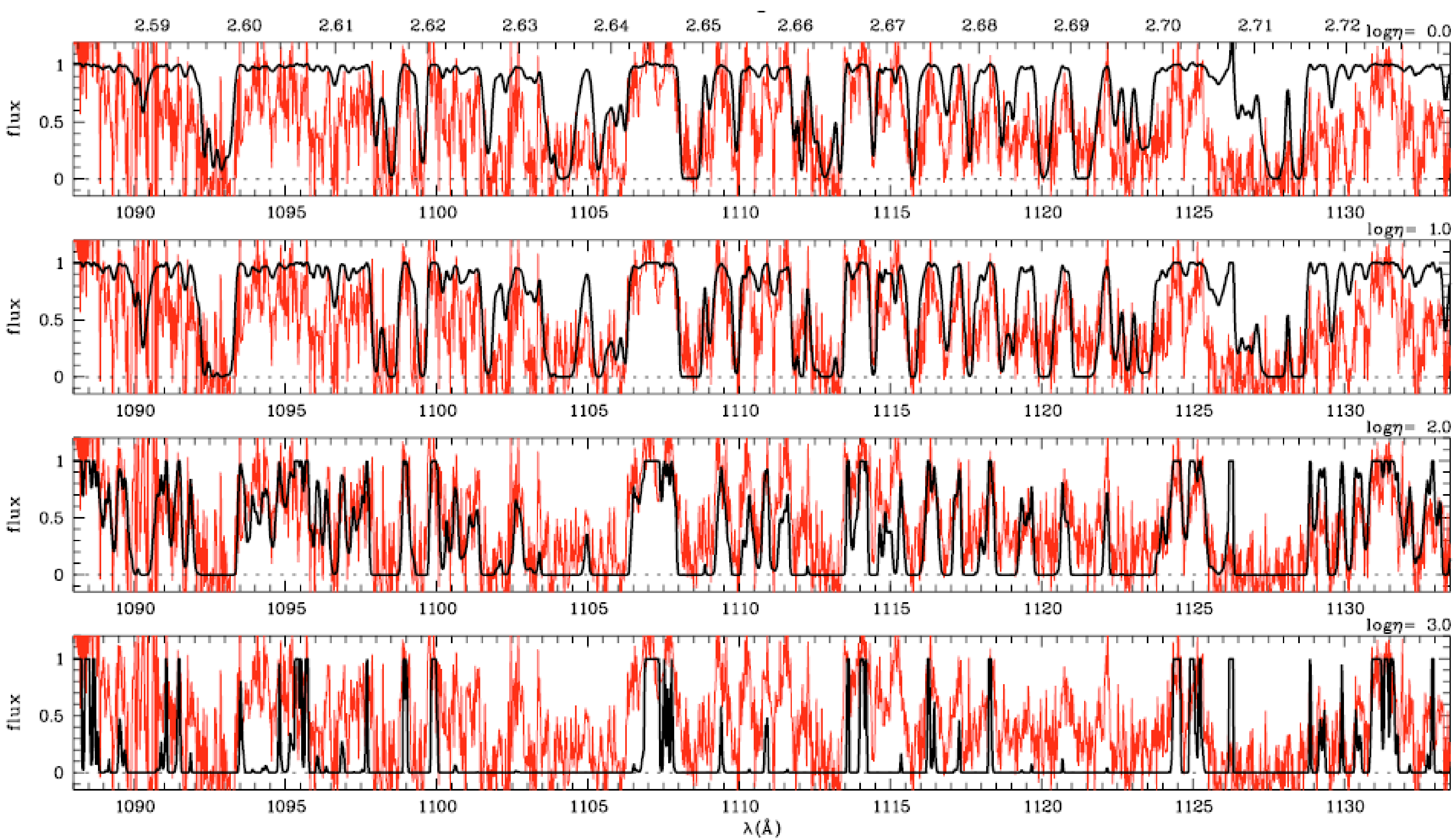
η, a measure of the spectral shape of the ionizing UV background, fluctuates on length scales of ~ 10 Mpc (comoving)
(Fechner et al. 2007)

$$\eta = \frac{n_{\rm He\,III}}{n_{\rm H\,II}} \frac{\alpha^{(A)}_{\rm He\,II}}{\alpha^{(A)}_{\rm H\,I}} \frac{\Gamma_{\rm H\,I}}{\Gamma_{\rm He\,II}} \approx (1.70)\, \frac{J_{\rm H\,I}}{J_{\rm He\,II}} \frac{(3+\alpha_4)}{(3+\alpha_1)}\, T_{4.3}^{0.055}. \quad (1)$$

Here $\alpha^{(A)}_{\rm H\,I}$, $\alpha^{(A)}_{\rm He\,II}$, $\Gamma_{\rm H\,I}$, and $\Gamma_{\rm He\,II}$ are the case-A recombination rate coefficients and photoionization rates for H I and He II, and $J_{\rm H\,I}$ and $J_{\rm He\,II}$ are the specific intensities of the radiation field at the H I (912 Å) and He II (228 Å) edges. The parameters α_1 and α_4 are the local spectral indices of the ionizing background at 1 and 4 ryd, respectively, which provide minor corrections to the photoionization rates. We adopt case-A



UVES spectrum (top) compared with FUSE HeII spectrum



FUSE spectrum of HE2347-4342(red) compared with simulatd HeII spectrum on basis of HI forest in UVES spectrum for different HeII/HI

Multiple QSOs (gravitationally lensed)

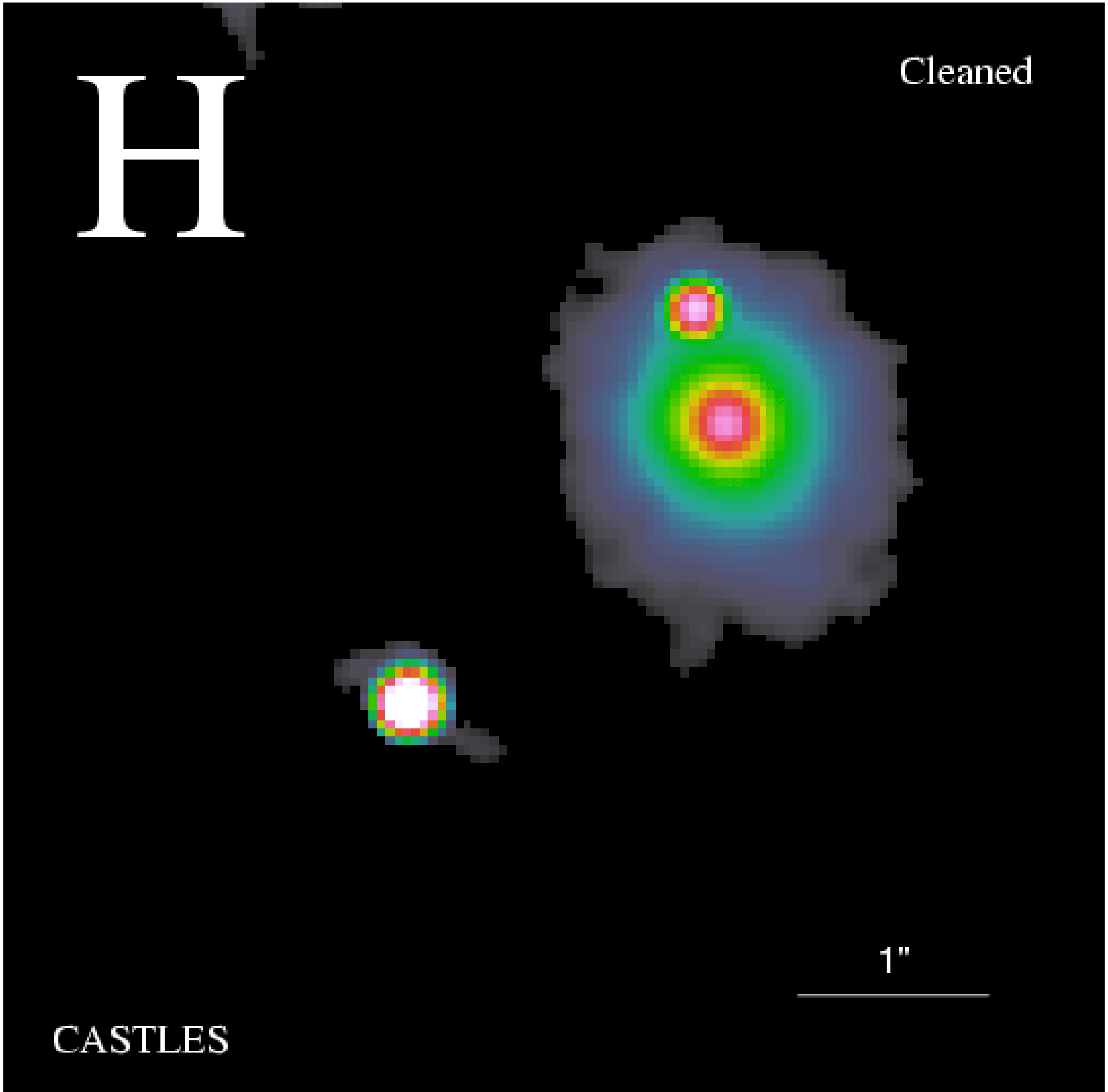
The HE and HS Surveys yielded 10 new lensed QSOs
(5 double, 5 quadruples)

- Time delay measured for 6 objects

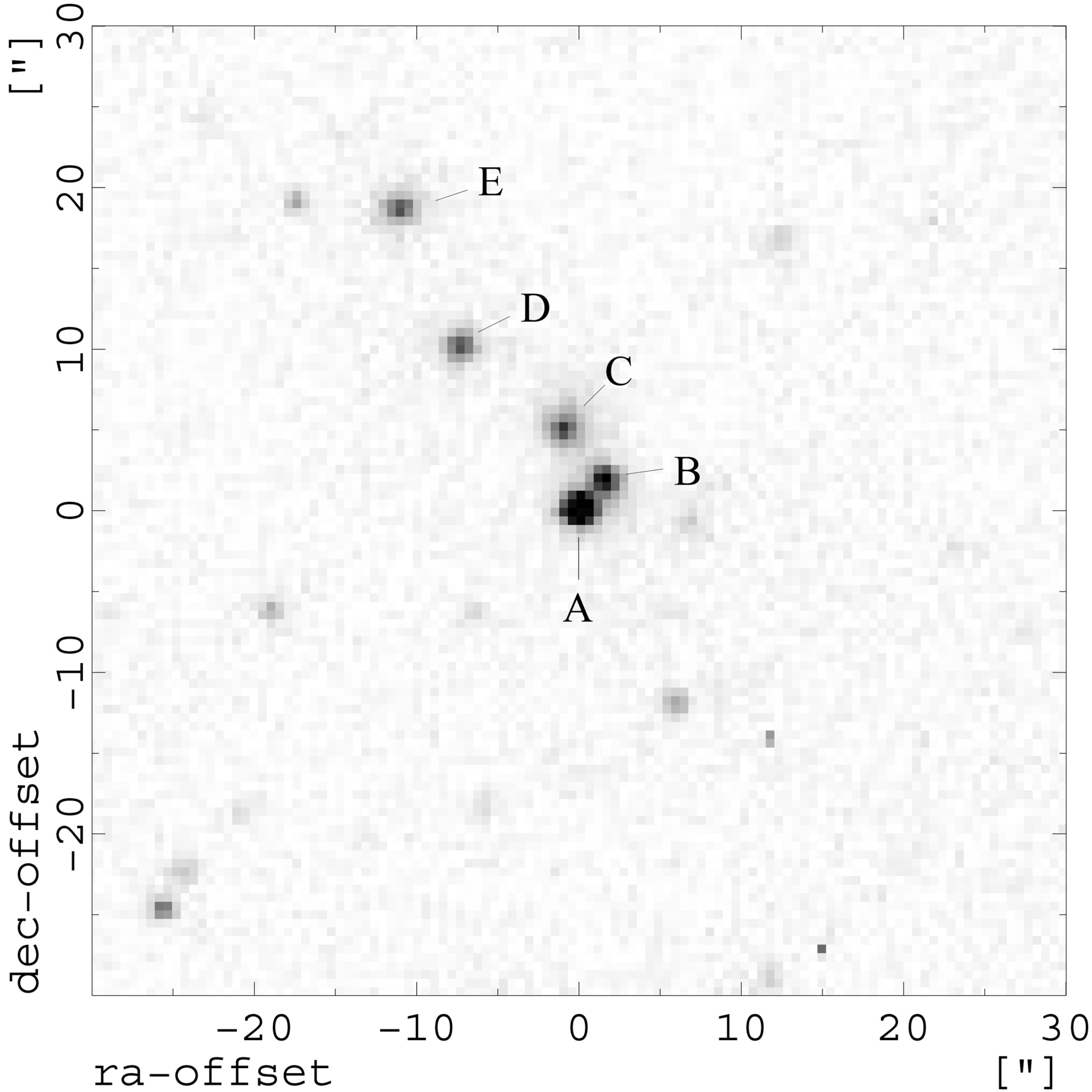
- Strong microlensing observed in HE 1104-1805:
  Small continuum source affected, while the Broad
  Line Region is not (Wisotzki et al. 1993)
  Accretion disk size estimated as $5 \cdot 10^{15}$ cm
  (Morgan et al. 2007)

- HE 0512-3329
  DLA at z = 0.93
  At a transverse separation of 5 kpc, one component is
  strongly absorbed (reddened) by dust, the other not

- HE 0818+1227
  Shear effect due to the fact that the lensing galaxy is
  the end of a chain of galaxies



HS 0818+1227



E
D
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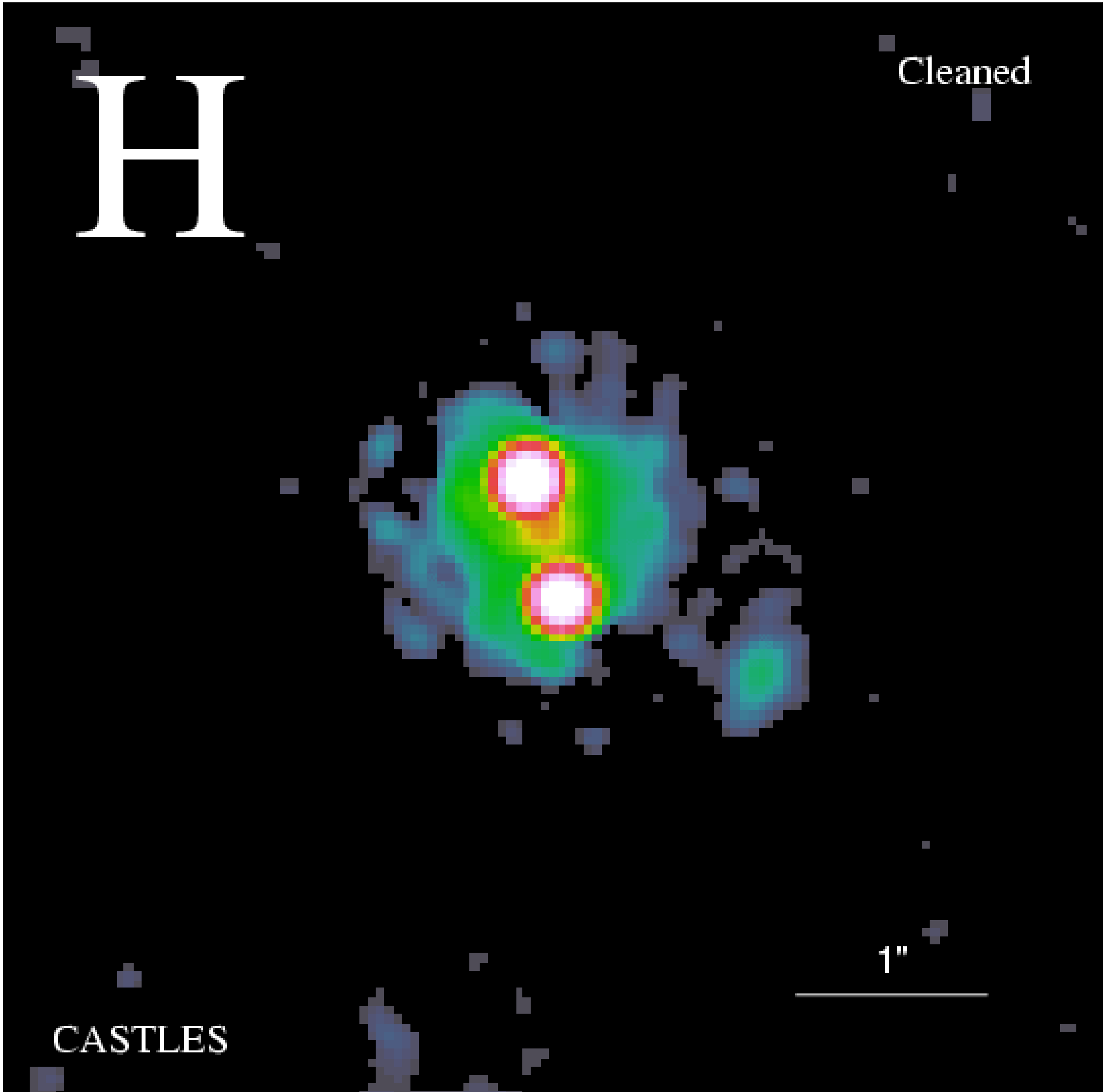
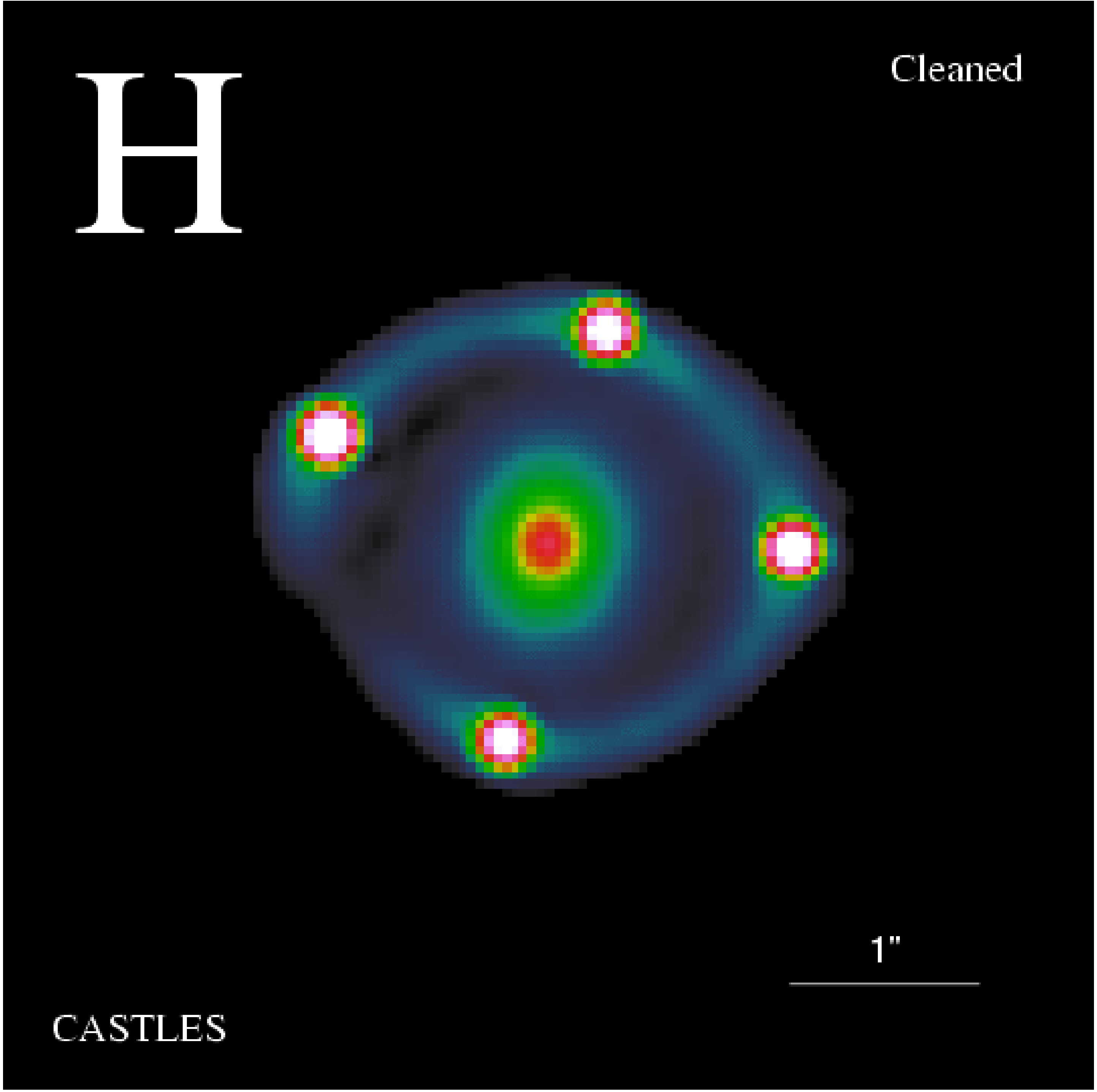
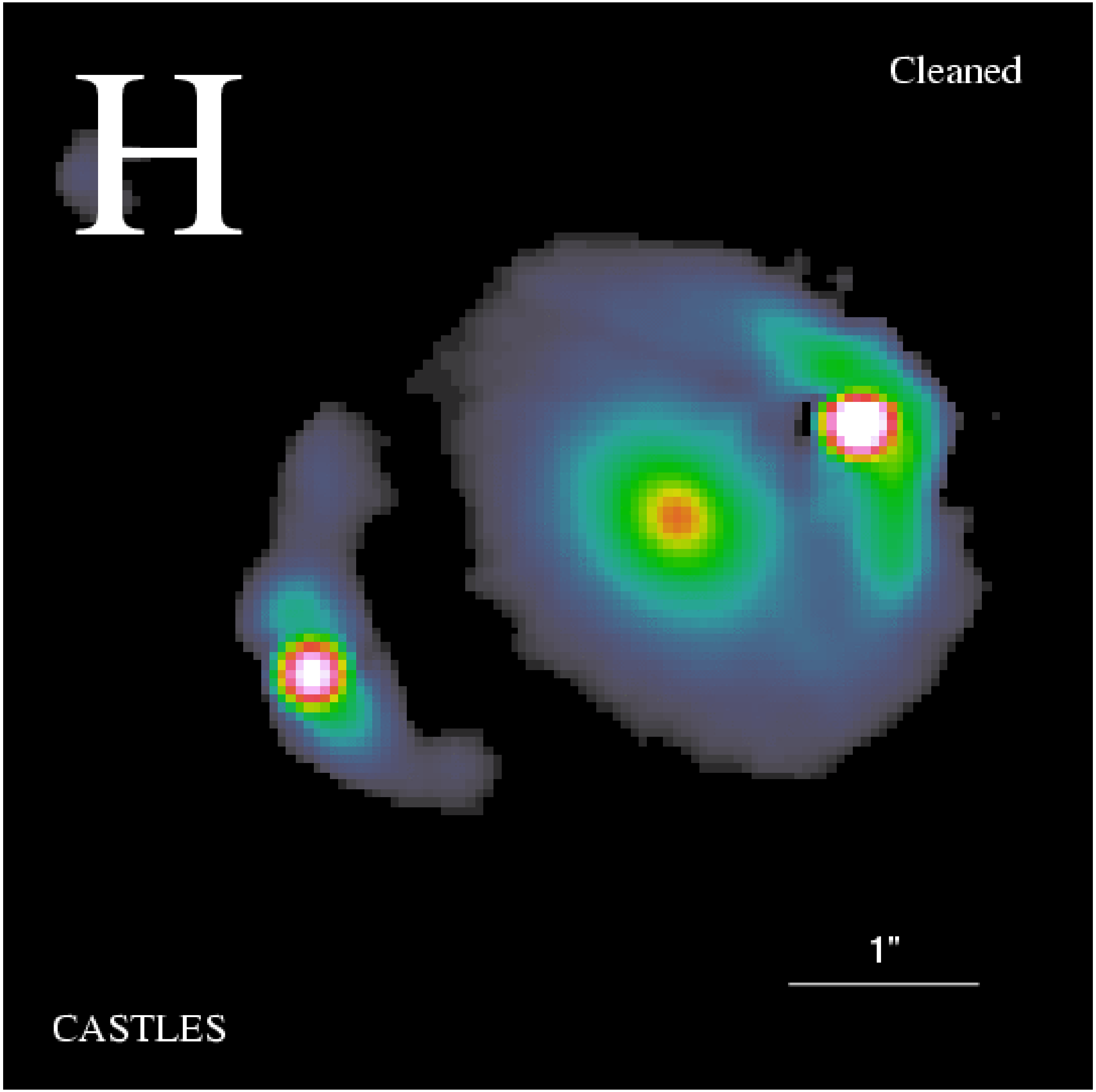
HE0512-3329



HE0435-1233



HE1104-1805



Time delays for multiple QSOs discovered by the HE and HS surveys

HE 1104-1805	**152d**
HE 0435-1223	**2,1d, 6d, 8,4d**
HE 0047-1756	**2,6d**
HE 2149-275	**103d**
HE 0911+055	**146d**
HS 2209+1914	**20d**

Best number for Hubble constant H fro time delays

H = 66 (+6 -4) km/s/Mpc

consistent (within error bars) with other methods

Stellar archaeology

The Objective Prism Schmidt plates of the ESO Schmidt with a resolution of 15 Å at Hγ allow an efficient search for extremely metal deficient stars.
Norbert Christlieb searched on 8853 deg^2 for stars with [Fe/H] < -2 by automated classification techniques

1. **20 270 candidates**

2. **Spectroscopic follow-up with 1 – 6.5m telescope in Australia, Chile and USA**
   March 2008: 6 840 stars observed

3. **Among them: 528 stars with metal abundance less than 1/1000 solar ([Fe/H] < -3)**

4. **Most interesting stars observed at high resolution with 10m class telescopes (206 high quality, 369 'snapshot')**

Highlights

1. The three most metal deficient stars known

HE 0107-5240	[Fe/H] = -5.2
HE 1327-2326	[Fe/H] = -5.4
HE 0557-4840	[Fe/H] = -4.75

All three have extreme overabundances of CNO elements

[C/Fe] ~ 4, [N/Fe] = 2 – 4, [O/Fe] = 2 – 3

Probable explanation: various scenarios

Later 2 extremely metal deficient stars
with [Fe/H] less than -4.5 have been
discovered with no CNO enhancement

2. The Uranium star HE 1523-0901 and the age of the Universe

This bright giant (V = 11.1) at [Fe/H] = -2.95 shows 16 different neutron-capture elements:

Besides U and Th also Os, Ir, ...

Several "chronometers" available:
U/Th, Th/Eur, U/Ir, Th/Os ratios
Resulting age: 13.2 Gyr