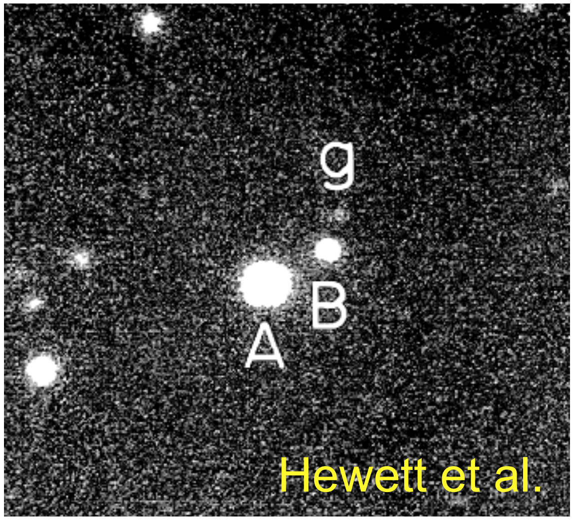
Discovery of a Probable Triple QSO

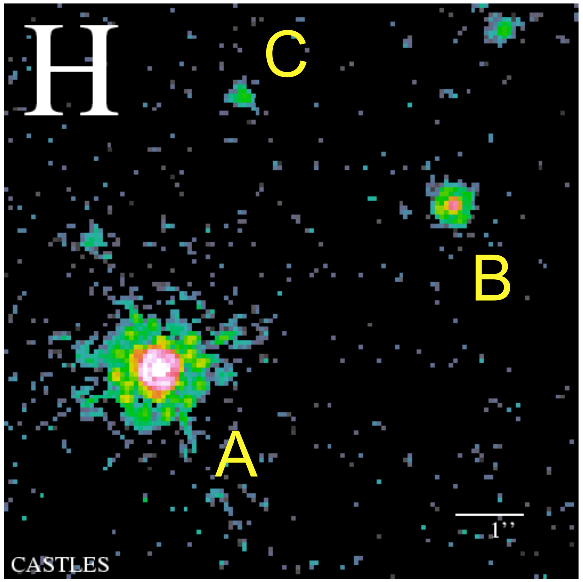
S. G. Djorgovski[1], F. Courbin[2], G. Meylan[2], D. Sluse[2], D. Thompson[3], A. Mahabal[1], E. Glikman[1]

[1]Caltech, [2]EPFL, [3]LBTO

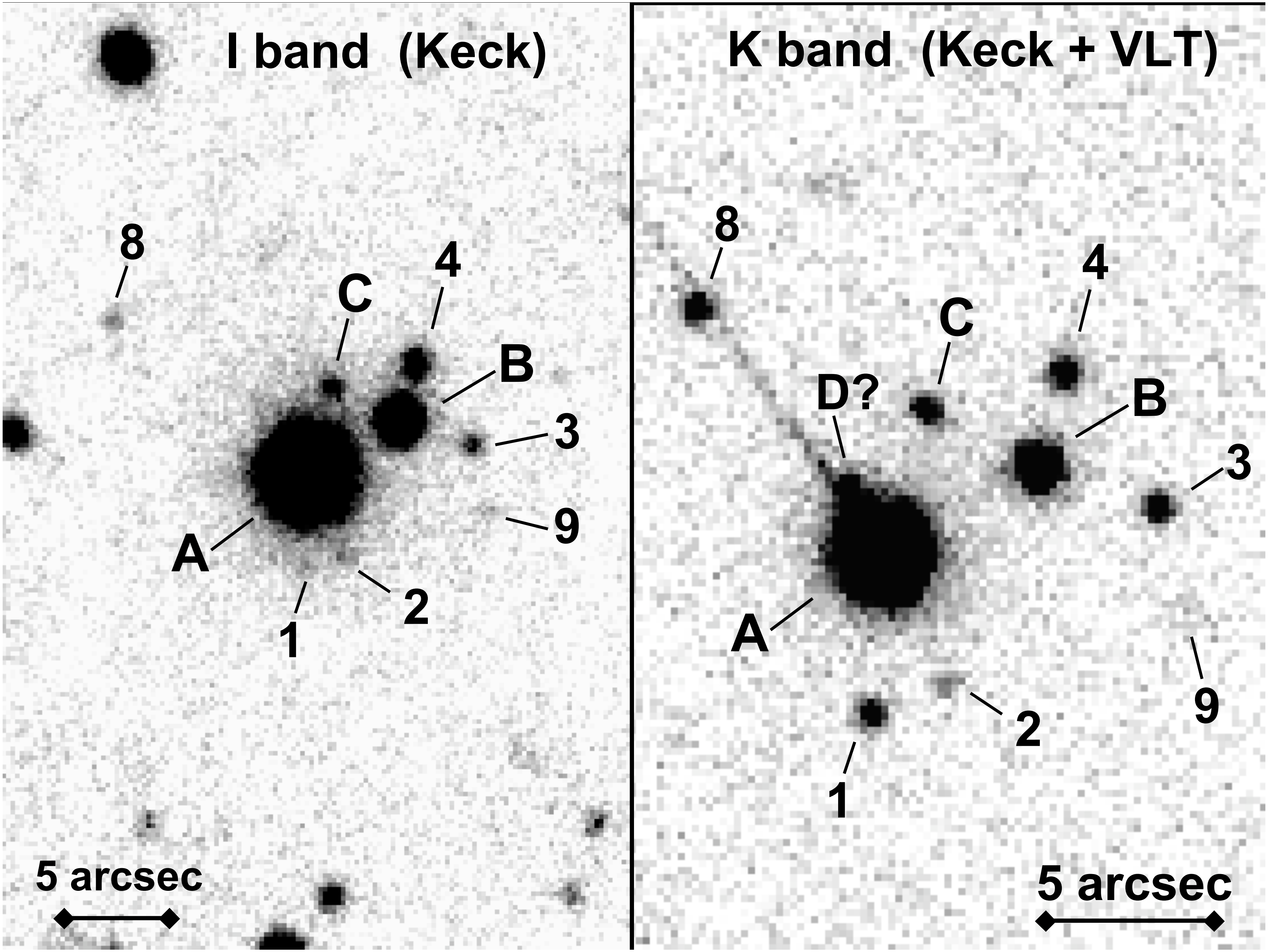
LBQS 1429-008

- Discovered by Hewett et al. (1989), two QSO components (A and B), proposed as a *gravitational lens*; $z = 2.076$
- Suggested as a *binary QSO* by Kochanek et al. (1999), Mortlock et al. (1999), and Faure et al. (2003)
  - No obvious lensing galaxy, or even overdensity of faint galaxies
  - Difficult to model as a lens
  - Faure et al. find no weak lensing distortion in the field
- Keck and VLT images reveal additional components, one of which *(C) is a QSO at the same redshift*

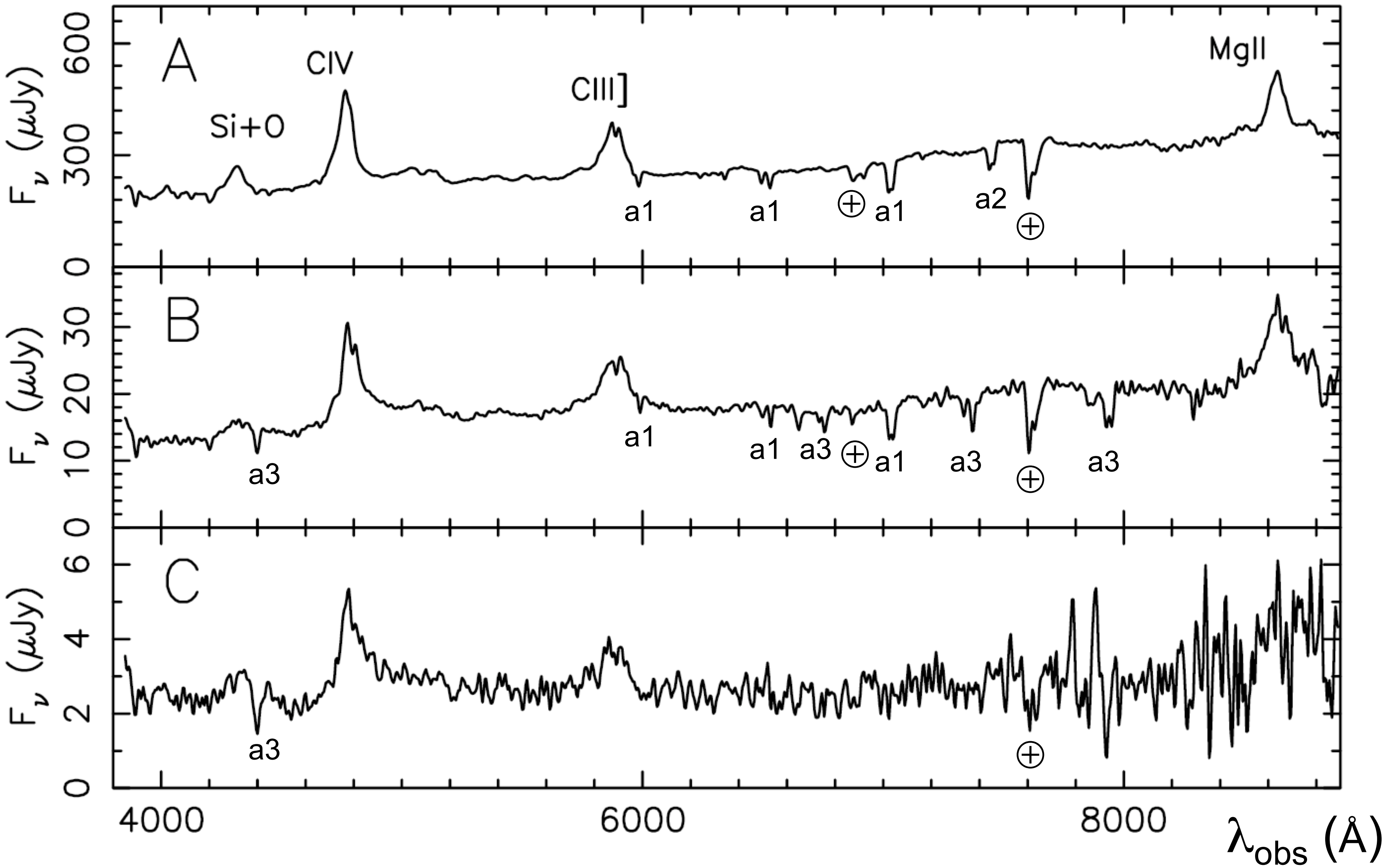




CASTLES HST image


I band (Keck)
K band (Keck + VLT)
A
B
C
D?
1
2
3
4
8
9
5 arcsec
5 arcsec

Keck Spectra of the QSO Components



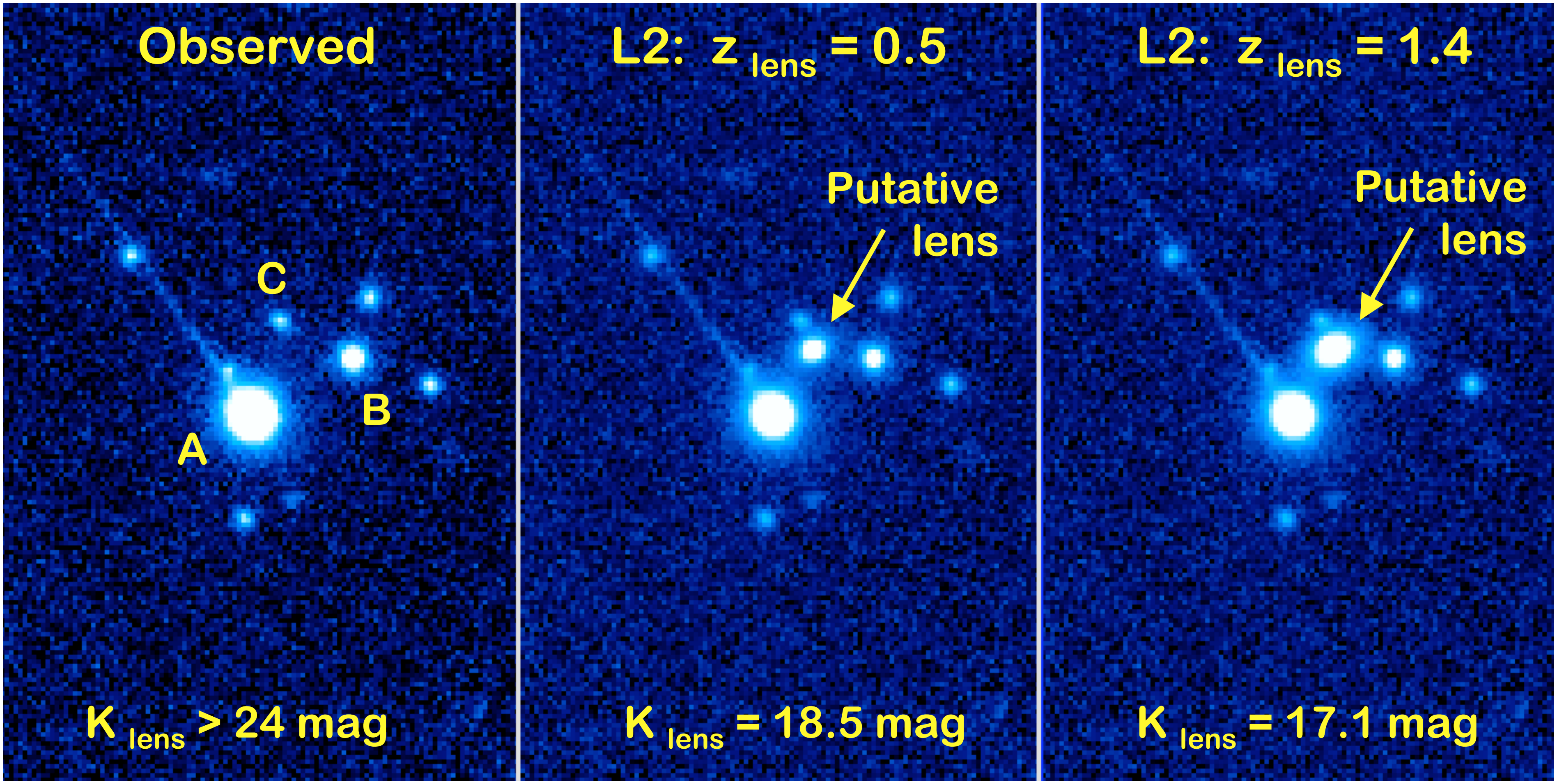
Absorbers: z_{a1} = 1.512 (A,B), z_{a2} = 1.662 (A), z_{a3} = 1.837 (B,C)

Gravitational Lens Models

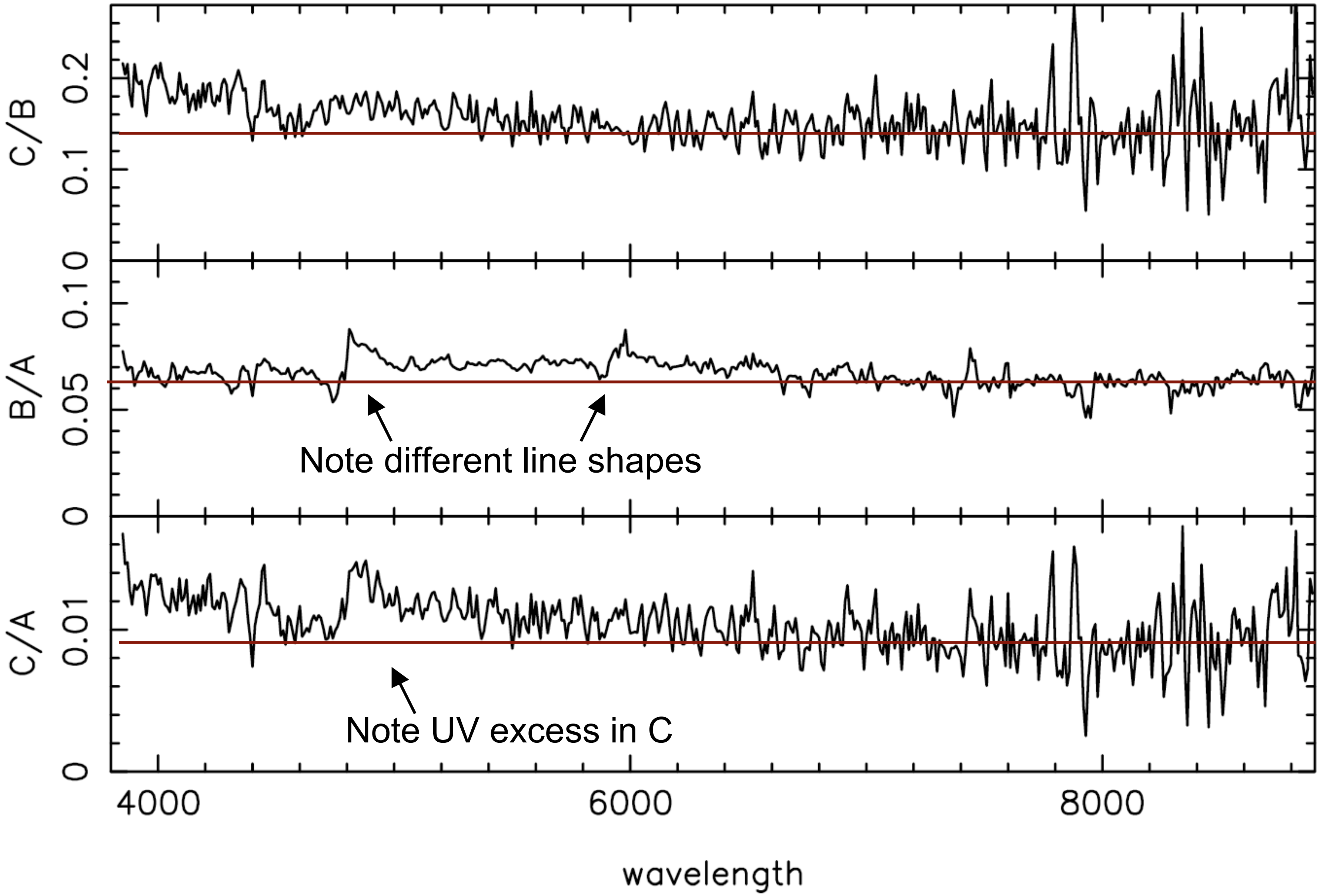
- Assume a singular isothermal sphere + external shear
  - A standard model which reproduces most known lenses
  - Use C. Keeton's *gravlens* software
  - Explore the parameter space, seek the best fit solutions
- Model always produces *four* QSO images; assume two viable scenarios:
  - Model L1: the faint image D is the 4th component
  - Model L2: image A is an unresolved blend, $\Delta\theta$ < 0.05"
- **Both scenarios fail:**
  - L1: best reduced χ^2 = 1941 (!), image D is the brightest, images B and C about equal, positions off by ~ 0.5"
  - L2: best reduced χ^2 = 74, image A is ~ 1.2" displaced
- *Conclude that the lensing hypothesis is unlikely*

What about the lensing galaxy?

Our "best" lensing model L2 predicts a massive and luminous lens galaxy, which is not seen, even if placed in an optimal position:



Flux Ratios of the QSO Spectra



Spectrum Differences

- Component C has a bluer UV continuum, but redder optical to IR colors:

(Due to a contamination by the host galaxy?)

	A	B	C
(R-K)	2.49 ± 0.03	2.27 ± 0.03	3.23 ± 0.21
(J-K)	1.13 ± 0.03	0.85 ± 0.03	1.87 ± 0.13

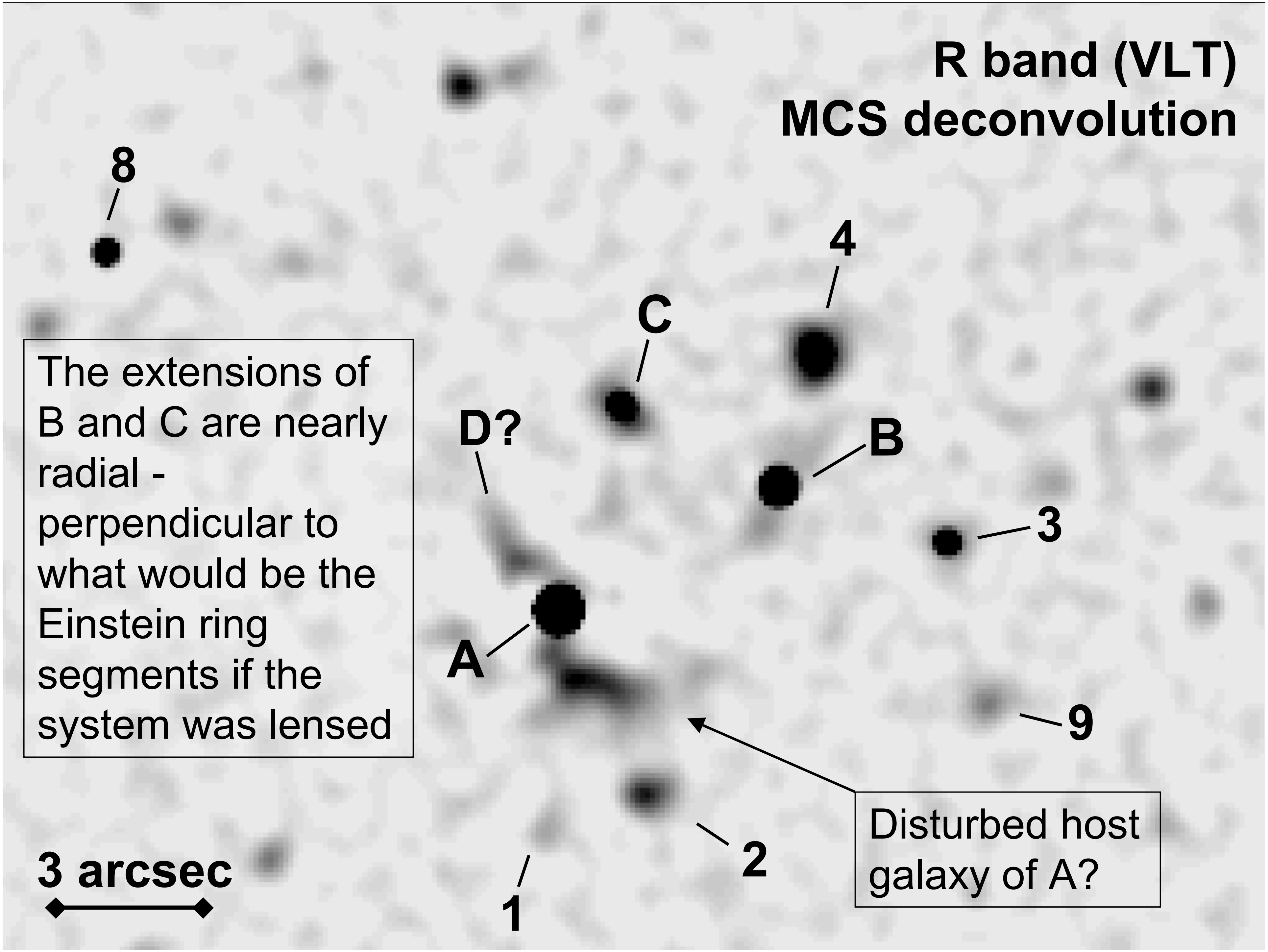
- Spectrum differences between components A and B are about as expected for a random pair of QSOs at this redshift (Mortlock et al. 1999)
- Different shape of the C IV line; possibly C III] as well
- Marginal redshift differences from cross-correlation:

$$\Delta V_{AB} = 280 \pm 160 \text{ km/s}, \; \Delta V_{BC} = 100 \pm 400 \text{ km/s}$$

- While the optical and IR flux ratio is A/B = 25 ± 3, but in X-rays it is A/B = 5.3 ± 1.8 (from ChaMP; Kim et al. 2006)

Triple QSO vs. Gravitational Lens

- **We are unable to reproduce the observed geometry and image intensities using a plausible range of models**
- **No evidence for a massive lensing galaxy, group, or a cluster in the images**
- **No weak lensing distortions in the field (Faure et al.), even if there was a dark, massive lens present**
- **Different absorbers in the spectra of ABC**
- **Observed spectroscopic and color differences are much easier to explain if these were physically distinct AGN**
- **Therefore, we conclude that this is most likely a case of a *physical close triple QSO***
  - **Projected separations are typical for interacting galaxy systems: $\Delta\theta_{AB}$ = 43 kpc, $\Delta\theta_{AC}$ = 36 kpc, $\Delta\theta_{BC}$ = 30 kpc**
    (proper units, for $h = 0.7$, $\Omega_m = 0.3$, $\Omega_\Lambda = 0.7$ cosmology)


R band (VLT)
MCS deconvolution
8
4
C
D?
B
3
A
9
2
1
3 arcsec
The extensions of B and C are nearly radial - perpendicular to what would be the Einstein ring segments if the system was lensed
Disturbed host galaxy of A?

Concluding Comments

- We see this system at a peak epoch of QSO activity and galaxy merging
  - Binary QSOs at comparable redshifts are known to occur with frequencies up to ~ 100 times higher than what may be expected from galaxy clustering alone
  - This can be understood if galaxy interactions enhance the probability of a QSO activity
  - In this case, we may be witnessing a 3-galaxy interaction, with AGN ignited in all of them
- Further studies of this system, and discoveries of more such QSO triples may provide useful new insights into a joint hierarchical formation of galaxies and SMBHs
- For more details, please see astro-ph/0701155