The highest redshift radio quasar as seen with

the

VLA

S. Frey (FÖMI SGO, H) Z. Paragi (JIVE, NL) L. Mosoni (Konkoly Obs., H) L.I. Gurvits (JIVE, NL)

7th EVN Symposium, 12-15 Oct 2004, Toledo

The outline of the talk

- SDSS J0836+0054: a radio quasar at $z \approx 5.8$
- What do we know about z~6 quasars in optical and X-rays?
- SDSS J0836+0054 with the EVN at 1.6 GHz
- 5-GHz EVN and VLA observations: a status report
- Surprise

Discovery





Sloan Digital Sky Survey (SDSS)

Fan et al. (2001) AJ 122, 2833

Spectrum

redshift: z=5.82



More recently from near-IR spectroscopy: z=5.774

Stern et al. (2003) ApJ 596, L39

The highest redshift quasars in OPTICAL

• 12 quasars at *z*>5.7 from SDSS to date

Fan et al. (2004) AJ 128, 515

- black hole masses are estimated ~10⁹ M_o
 (based on the Eddington luminosity, assuming no magnification)
- for SDSS J0836+0054: $M_{bh} \approx 4.8 \times 10^9 M_o$
- we are now close to place strong limits on structure formation models: the possible growth time is comparable to the age of the Universe at this redshift!

Haiman & Loeb (2001) ApJ 552, 459

- only one of them is radio-loud
- highest redshift: SDSS J1148+5251 (z=6.42)
- Gunn-Peterson effect is seen blueward of the Ly α line for all quasars at *z*>6.1: they are close to the reionization epoch
- metallicity ~ solar



CHANDRA

29 Jan 2002

Brandt et al. (2002) ApJ 569, L5 Mathur et al. (2002) ApJ 570, L5 Schwartz (2002) ApJ 571, L71 Bechtold et al. (2003) ApJ, 588, 119

The highest redshift quasars in X-rays

- the first four z>5.7 SDSS quasars are all detected in X-rays (Chandra & XMM-Newton)
- no clear sign of multiple images by gravitational lensing
- point sources



phase-referencing with 5-min cycles, calibrator 0.8° apart 256 Mbit/s (64 MHz)

Phase-reference calibrator: J0839+0104



As we see the phase-reference calibrator at 1.6 GHz...



natural weighting

uniform weighting



SDSS J0836+0054: the 1.6-GHz image



SDSS J0836+0054: gravitational lensing?

- the lensing probability depends on little-known parameters of the intrinsic luminosity function which is not directly observable
- one may assume a LF and calculate the probability of multiple imaging by gravitational lensing
- is it about 1/3 for z~6 quasars?

Wyithe & Loeb (2002) Nature 417, 923

- magnification is important if one puts luminosities in the structure formation models
- the lensing probability can be much lower ... or as high as ~100%

Comerford et al. (2002) ApJ 580, 63

- there is *not* a single case of multiply imaged $z\sim6$ quasar found to date
- this fact can actually be used to constrain the LF

SDSS J0836+0054: luminosity vs. black hole mass



example: Parkes Half-Jansky Flat-Spectrum Sample

Jarvis & McLure (2002) MNRAS 336, L38



Jarvis & McLure (2002) MNRAS 336, L38



phase-referencing to a "new" calibrator (J0836+0052), at only 5' separation data rate: 512 Mbit/s

Supporting short VLA experiment a day after (5 Nov 2003)

- to obtain radio spectrum
- to assess compactness by comparing 5-GHz VLA and EVN flux densities







The "companion"

- also seen by others before
- ~10" away to the SE, present at both 1.4 and 5 GHz
- S_{1.4}=0.8 mJy and S₅=0.2 mJy
- present also at 8.4 GHz (VLA archive, AR479, May 2002)
- It does not seem to be a lensed image...

10.0783"

D. Rusin, B. McLeod, priv. comm.

...but maybe nobody has done spectroscopy on the second source.

And the surprise I promised...

We spent a few scans at 5 GHz on our "old" reference source J0839+0104 – and found a hint on a two-sided mas-scale jet structure!



The same source with the VLA

J0839+0104 (alias PKS 0837+012) – a quasar at a redshift of z=1.123



from the VLA archive at 5 GHz, with short-baseline (<100 kλ) data only (AR493, 5 May 2002)

Near future

- we expect SDSS J0836+0052 to eventually detect at 5 GHz
- the total survey area of SDSS is 10 000 deg² → one z≈6.6 quasar is expected

Fan et al. (2001) AJ 122, 2833

- some of the newly found quasars in SDSS will be radio-emitting and thus potential EVN targets
- imaging of such sources could be further improved (1 Gbit/s data rate, in-beam phase-referencing?)

Thank you for watching me!