A unique UV flare in the optical lightcurve of the z~2 quasar J004457.9+412344

H. Meusinger[1], M. Henze[1,2], K. Birkle[3], W. Pietsch[2], B. Williams[4], D. Hatzidimitriou[5], R. Nesci[6], H. Mandel[3], S. Ertel[1,7], A. Hinze[1,8], T. Berthold[9], B. Kaminsky[1,10]

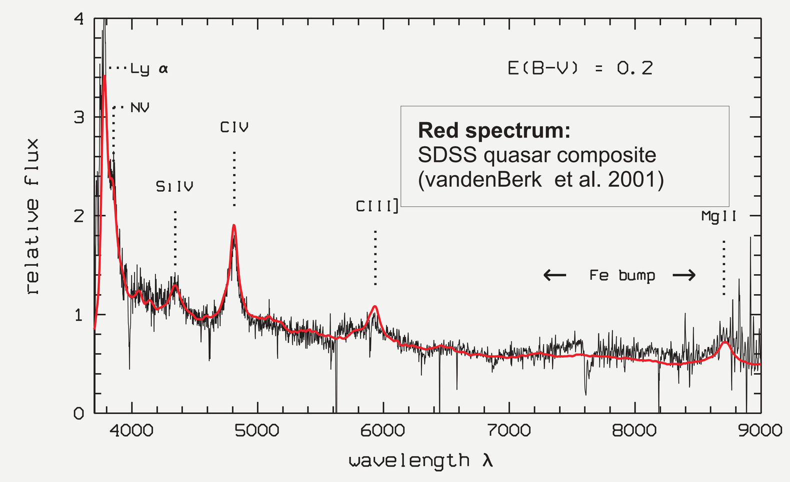
[1] Thüringer Landessternwarte (TLS) Tautenburg, Germany
[2] Max-Planck-Institut für extraterrestrische Physik, Garching, Germany
[3] Max-Planck-Institut für Astronomie, Heidelberg, Germany
[4] University of Washington, Seattle, USA
[5] University of Athens, Athens, Greece
[6] University of Roma La Sapienza, Roma, Italy
[7] Christian-Albrechts-Universität, Kiel, Germany
[8] Universität Bern, Bern, Switzerland
[9] Sternwarte Sonneberg, Sonneberg, Germany
[10] University Leipzig, Leipzig, Germany

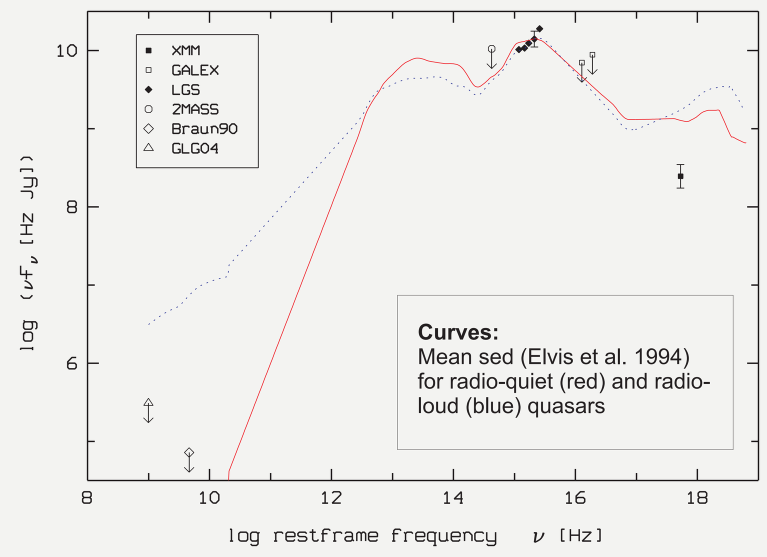
The history of the discovery

J004457.9+412344 was originally discovered as a variable star-like source in the Andromeda galaxy M31 (Nedialkov et al. 1996) and was classified as a nova showing both an unusual lightcurve (Sharov et al. 1998) and a possible X-ray counterpart (Nedialkov et al. 2002; Pietsch et al. 2005).

We found that J004457.9+412344 is a typical radio-quiet type 1 quasar at z = 2.109 seen through the outer parts of the disk of M31 (Meusinger et al. 2010). Using the mass scaling relation for the CIV line (Vestergaard & Peterson 2006) we derive a black hole mass of $M_{\rm bh} \sim 5 \cdot 10^8\, M_\odot$.

An AGN misclassified as a variable star is neither unexpected nor unprecedented. However, the confusion of a luminous radio-quiet high-z quasar with a nova indicates a remarkably strong outburst in the far UV that points towards a very rare event.



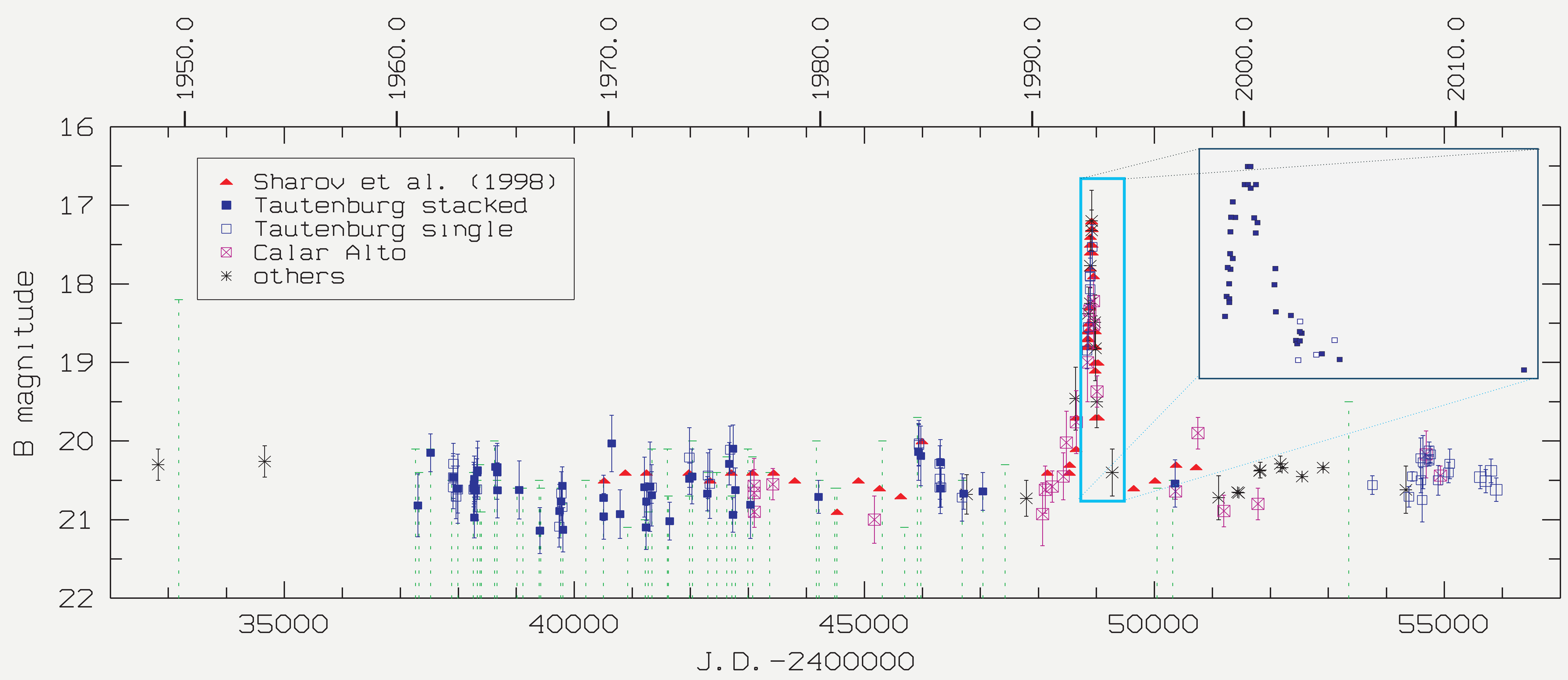


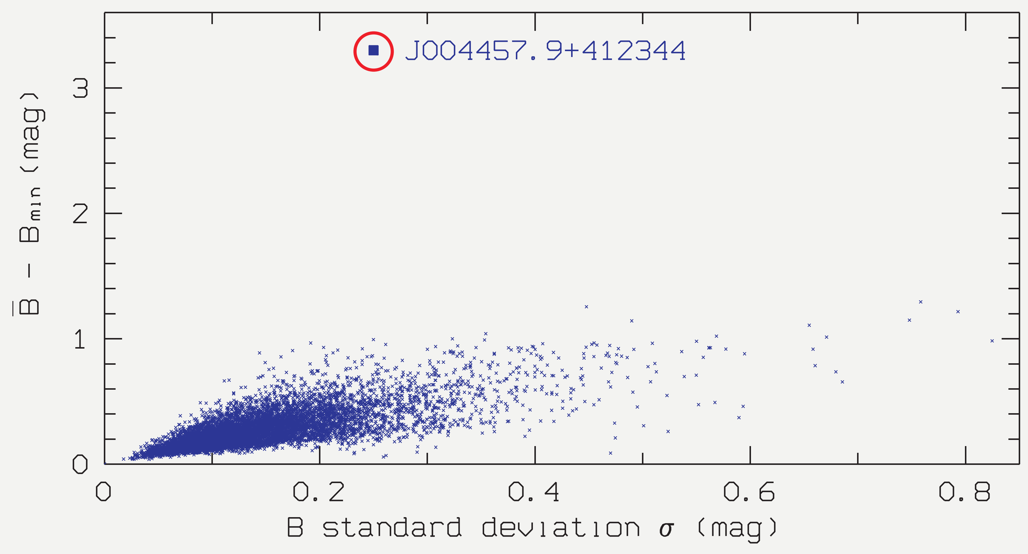
Top left and left: Optical spectrum (reddening corrected) and wide band sed, respectively. Top: optical image around J004457.9+412344.

The optical long-term lightcurve

We constructed a long-term lightcurve based on ~400 observations taken with the Tautenburg Schmidt telescope between 1961 and 2012 in combination with archival observations, published data, and targetted new observations from another 14 wide-field telescopes. J004457.9+412344 was detected at 225 epochs between 1948 to 2012. In addition, we derived useful upper limits for 12 epochs from 1900 to 1949.

The long-term lightcurve clearly displays two phases: (*a*) A rather quiet "ground state" at B~20.5 with quasar-typical fluctuations of ~0.2 mag and (*b*) one single strong bump ("flare") in 1992 corresponding to an increase of the far UV flux by a factor ~20. The comparison with the lightcurves of 8744 quasars from the stripe S82 (Bramich et al. 2008; Meusinger et al. 2011) of the Sloan Digital Sky Survey clearly indicates that such strong+single events are extremely rare.





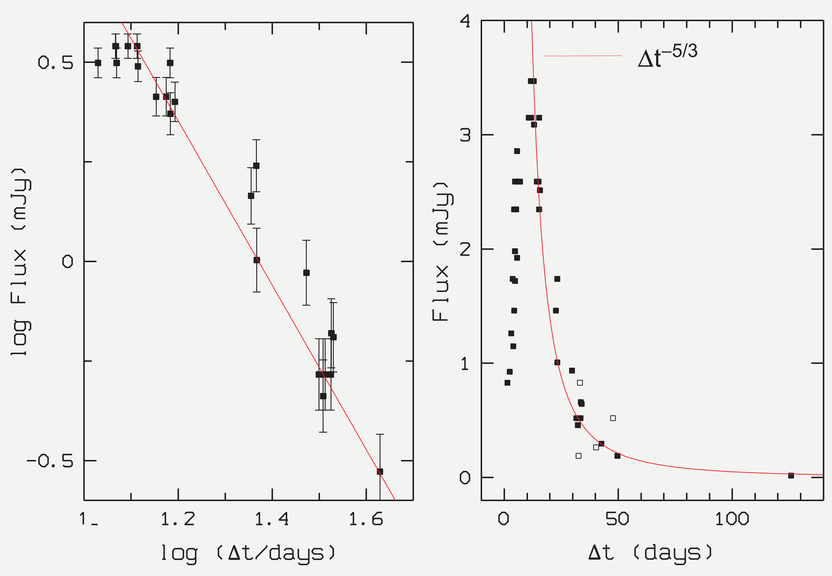
**Top:
Long-term optical lightcurve of J004457.9 +412344 over more than half a century. Insert: blow-up of the flare.**

**Left:
Maximum amplitude versus standard deviation from the lightcurves of 8744 SDSS quasars (x) and of J004457.9 +412344 (■).**

Microlensing or stellar tidal disruption?

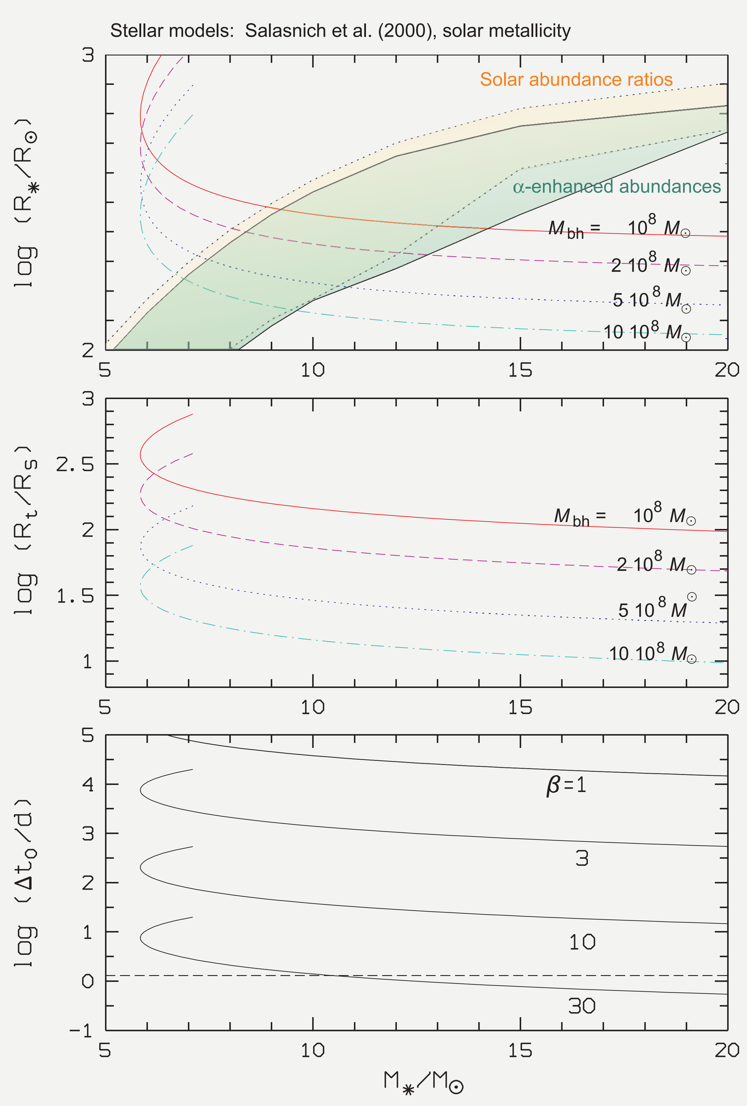
Even though the quasar is seen through M31, the microlensing probability is very low (optical depth ~ $2 \cdot 10^{-4}$). The best fit is achieved for a low-mass binary star with 0.3 and 0.1 $M_\odot$ crossing the sightline at $u_{\rm min}$ = 0.05 and 0.8 (in units of the Einstein angle), respectively. However, the source appears to be redder in the flare. Chromatic amplification is expected only if the angular size α_S of the source is comparable to $u_{\rm min}$. However, a standard accretion disk (AD) yields $u_{\rm min} \geq 30\, \alpha_S$. Hence, the size of the source is negligible, even if ADs are a factor of ~3 larger than expected (e.g. Morgan et al. 2010). Microlensing is thus considered rather unlikely to explain the flare.

With the exception of the onset of the flare, the shape of the lightcurve supports the interpretation as a stellar tidal disruption event (Meusinger et al. 2010): The profile is asymmetric with a sudden increase towards the peak followed by a power-law decline with an exponent of about -5/3.



The radiated flare energy of E ~ $2 \cdot 10^{54}$ erg (if intrinsic and isotropic) corresponds to a stellar mass $M_* = E \eta^{-1} f_{\rm acc}^{-1} c^{-2} \sim 10\, M_\odot$ (assuming an efficiency η = 0.1... 0.4 of the mass-radiation convertion and a fraction of accreted mass $f_{\rm acc}$= 0.5). The peak monochromatic UV continuum luminosity of the flare at 1350 Å amounts to $\lambda L_{\lambda,\rm peak} \sim 2 \cdot 10^{47}$ erg s^{-1}.

The properties of the flare of J004457.9+412344 are broadly consistent with the tidal disruption of a ~ 10 $M_\odot$ giant star by a ~ 2 ... $5 \cdot 10^8\, M_\odot$ black hole (see Fig.s at the right hand side).



Left: Parameters of the star in the TDE model.

The black-body temperature $T_{\rm eff} = \left(\frac{L}{4\pi\sigma R_*^2}\right)^{1/4} \left(\frac{M_{\rm bh}}{M_*}\right)^{-1/6}$ of the tidal debris is used as a free parameter to compute the R_* - M_* relation for different black hole masses $M_{\rm bh}$. The comparison with stellar models (Salasnich et al. 2000) yields a consistent solution for giant stars of ~10 $M_\odot$.

For such stars, the tidal radius $R_t = R_*(M_{\rm bh}/M_*)^{1/3}$ is clearly out of the Schwarzschild radius of the black hole.

The short return time Δt ~1 day derived from the decline of the lightcurve corresponds to a high penetration factor β~30.

$$\frac{\Delta t_0}{10^{-4}\,\rm yr} \sim \beta^{-3} \left(\frac{M_{\rm bh}\, R_*^3}{M_*^2\, k^3}\right)^{1/2}, \quad \beta \equiv \frac{R_t}{R_p}$$

k ~1 : black hole spin parameter
R_p : pericentric distance

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