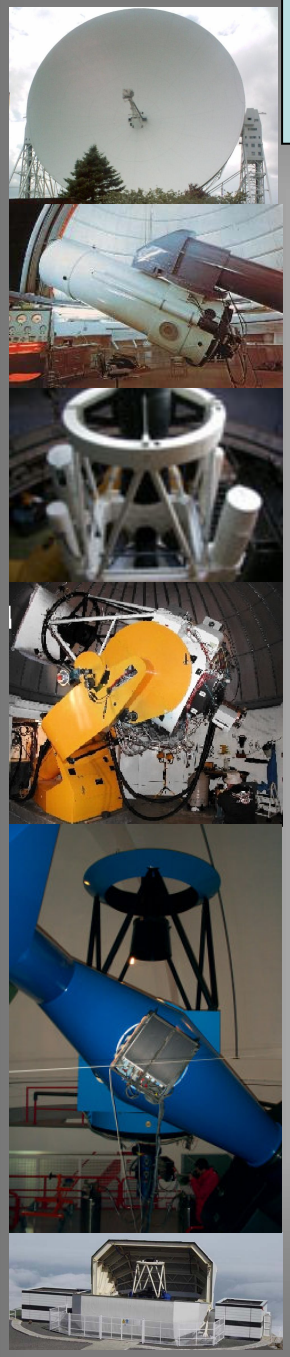

25 YEARS AFTER THE DISCOVERY: SOME CURRENT TOPICS ON LENSED QSOs

Santander (Spain), 15th-17th December 2004

FLUX RATIO ANOMALY

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with the help of ***Rodrigo Gil-Merino*** & ***Aurora Ullán*** (UC)

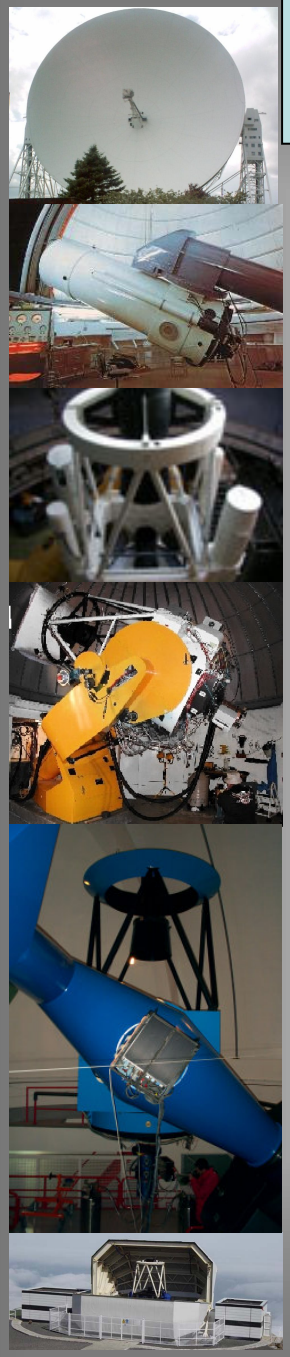
● While the macrolens scenarios predict the existence of achromatic and stationary flux ratios, the observations of GLQs often disagree with the macrolens predictions

●● The "anomaly" in a given GLQ may be related to three different kinds of "perturbation":

→ Dirty environment: **DUST** in an intervening object

→ Mass in granular form: **MICROLENSES** in the lens galaxy

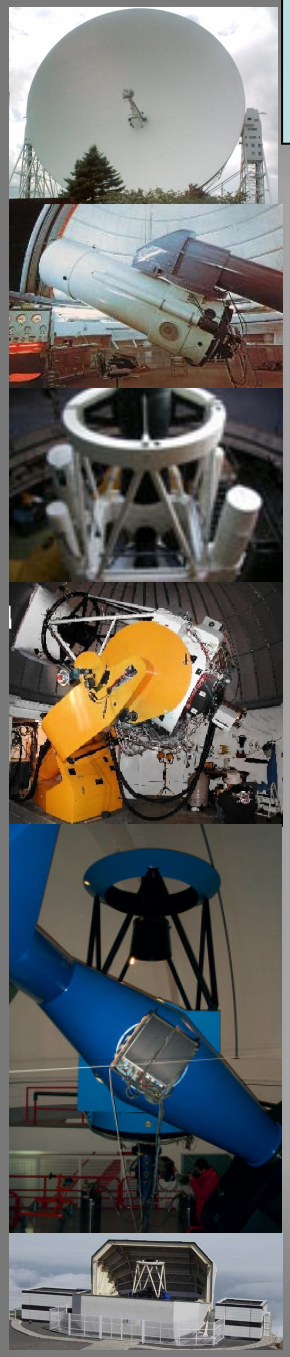
→ Clumpy mass: **SUBSTRUCTURE** in the lens galaxy

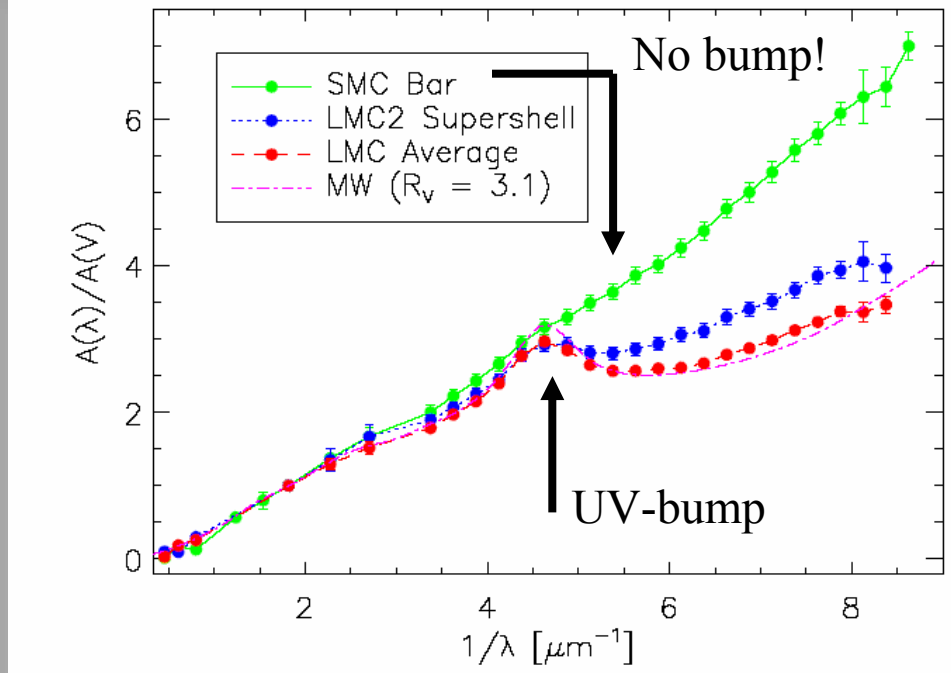


DUST

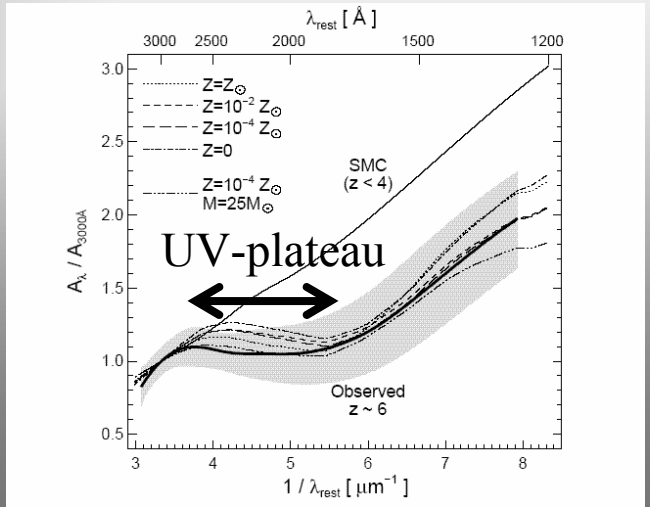
● Falco et al. (1999, ApJ 523, 617; see also Nadeau et al. 1991, ApJ 376, 430; Malhotra, Rhoads & Turner 1997, MNRAS 288, 138; Jean & Surdej 1998; A&A 339, 729) studied the possible MW (Milky Way)-like differential extinction in 23 GLQs. They did not use time delay corrected flux ratios (in magnitudes): $\Delta m_{ij}(\lambda,t) = m_i(\lambda,t) - m_j(\lambda,t + \Delta t_{ij})$, but flux ratios at the same observation time. *Most of the systems* seem to be *consistent with differential extinction*, and the extinction shows *no correlation with impact parameter*. They also obtain $\langle \Delta E(B-V) \rangle \approx 0.05$ *mag* and $R_V = A_V/E(B-V) \approx 1 - 7$.

●● Does the MW-like extinction law (Cardelli et al. 1989, ApJ 345, 245) describe the dust outside the Galaxy ($z \neq 0$)?. *The measured extinction curves in the LMC and SMC ($z << 1$) show trends similar to MW curves, as well as behaviours quite different*. For example, *sight lines in the star-forming bar of the SMC do not show MW-like behaviours*, especially in their 2175 Å bump and far-UV rise strengths.

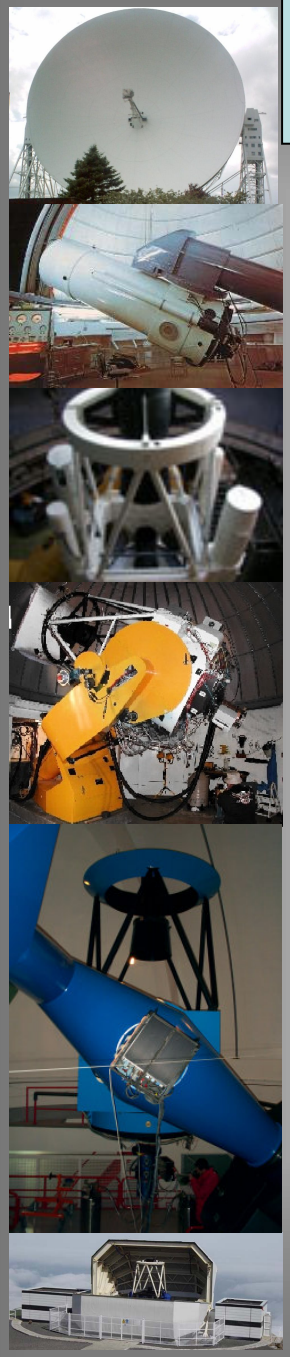




Gordon et al. (2003, ApJ 594, 279)

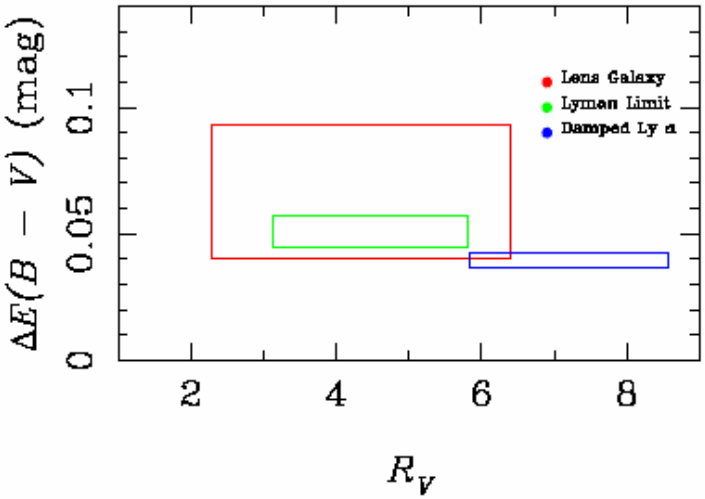


At the highest redshifts: *SDSS-QSO ($0 < z < 2.2$) colors seem to be consistent with SMC-like dust at the QSO redshifts* (Hopkins et al. 2004, AJ 128, 1112), and Maiolino et al. (2004, Nature 431, 533) reported a *supernova origin for dust in a $z = 6.193$ QSO*.

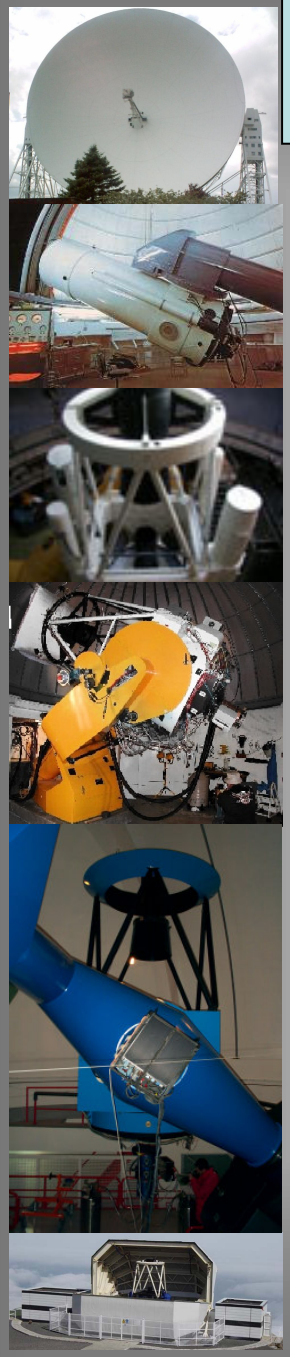


● Very recently, Motta et al. (2002, ApJ 574, 719) and Muñoz et al. (2004, ApJ 605, 614) analyzed the dust extinction in SBS 0909+532 (*z = 0.83 lens, MW-like extinction*), LBQS 1009-0252 (*z = 0.88 lens, SMC-like extinction*) and B0218+357 (*z = 0.68 lens, MW-like extinction:* $R_V = A_V/E(B-V) = 12 \pm 2 \rightarrow$ molecular cloud?).

●● Ullán et al. (2004, in Impact of Gravitational Lensing in Cosmology, Proc. IAU Symposium 225, eds. Y. Mellier & G. Meylan, Cambridge Univ. Press, in press) also presented *evidences in favour of MW-like extinction in the first multiple system* (Q0957+561). Although they only used *two wavelengths*, the analysis included *time delay corrected flux ratios* for the first time.



The differential extinction could be originated in the *z = 0.36 lens* or the *two Ly absorption-line systems* at *z = 1.125* and *z = 1.39*



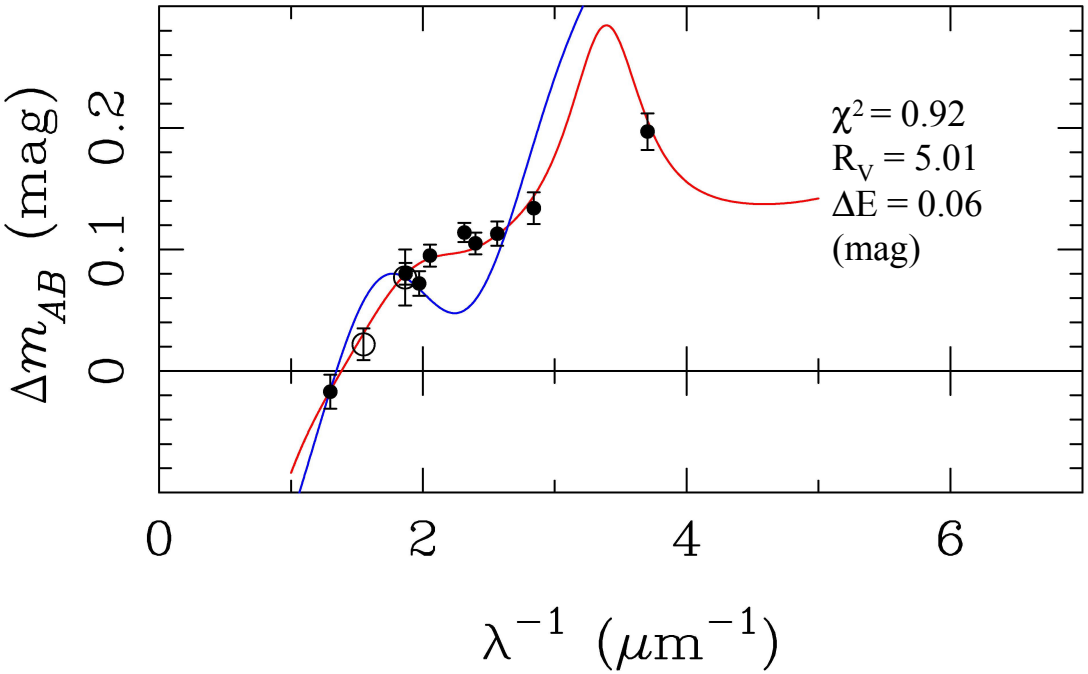
HST-STIS spectra obtained in April 15, 1999 (Q0957+561A) and June 2-3, 2000 (Q0957+561B) *lead to new evidences in favour of MW-like extinction (at z = 0.36) of the optical continuum (compact) source* (Goicoechea, Gil-Merino & Ullán 2005, in preparation)

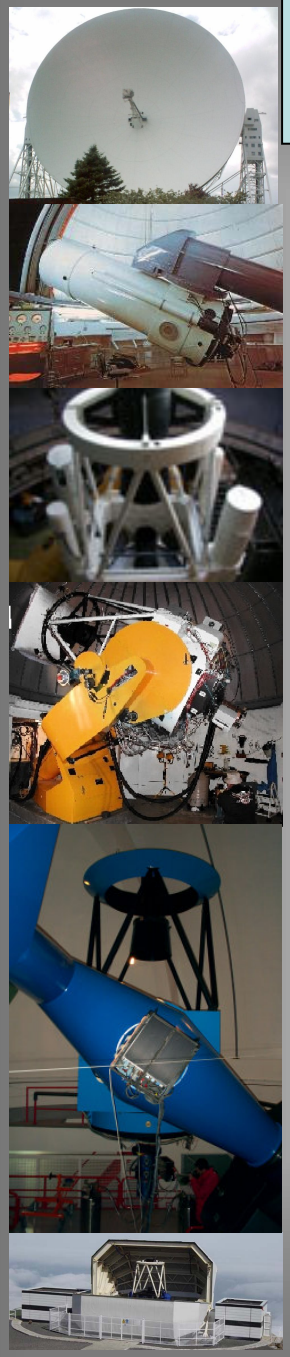
RED → MW-like at z = 0.36

BLUE → SN dust at z = 1.4

● HST-STIS

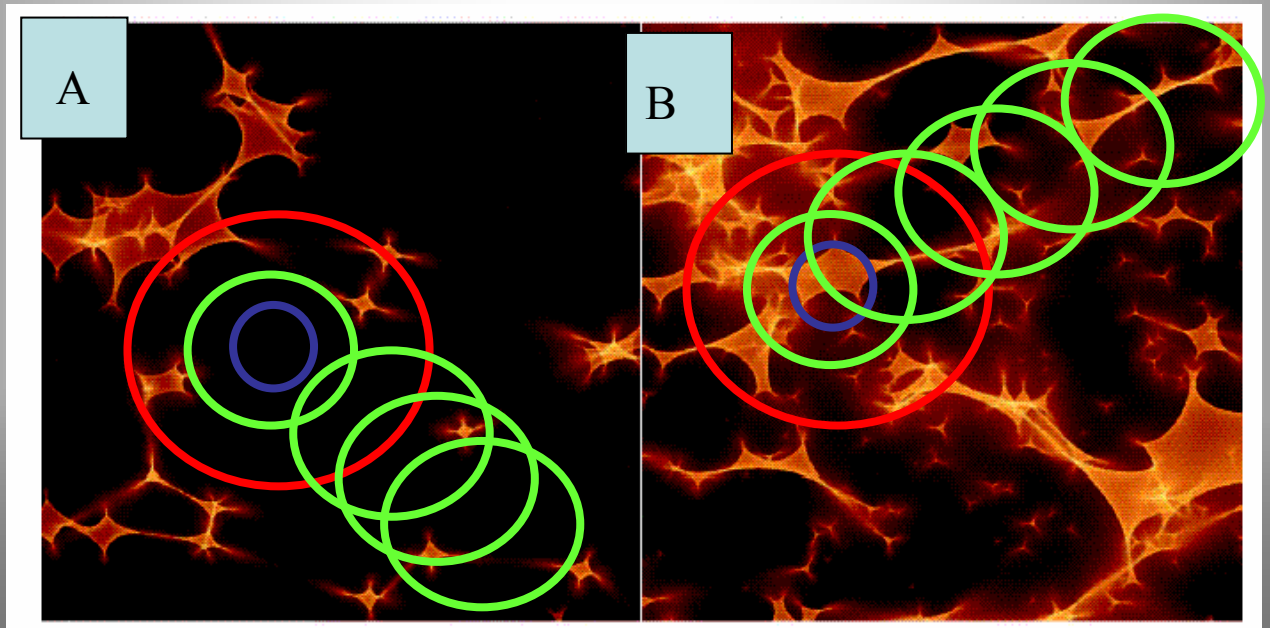
○ NOT

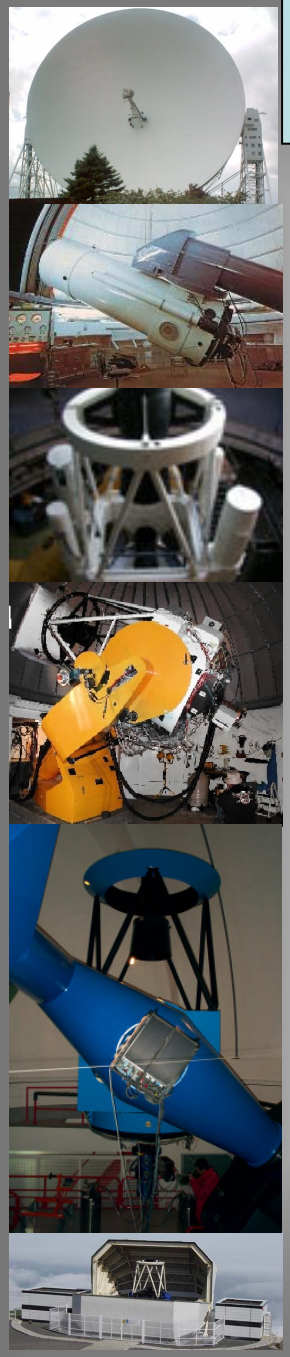




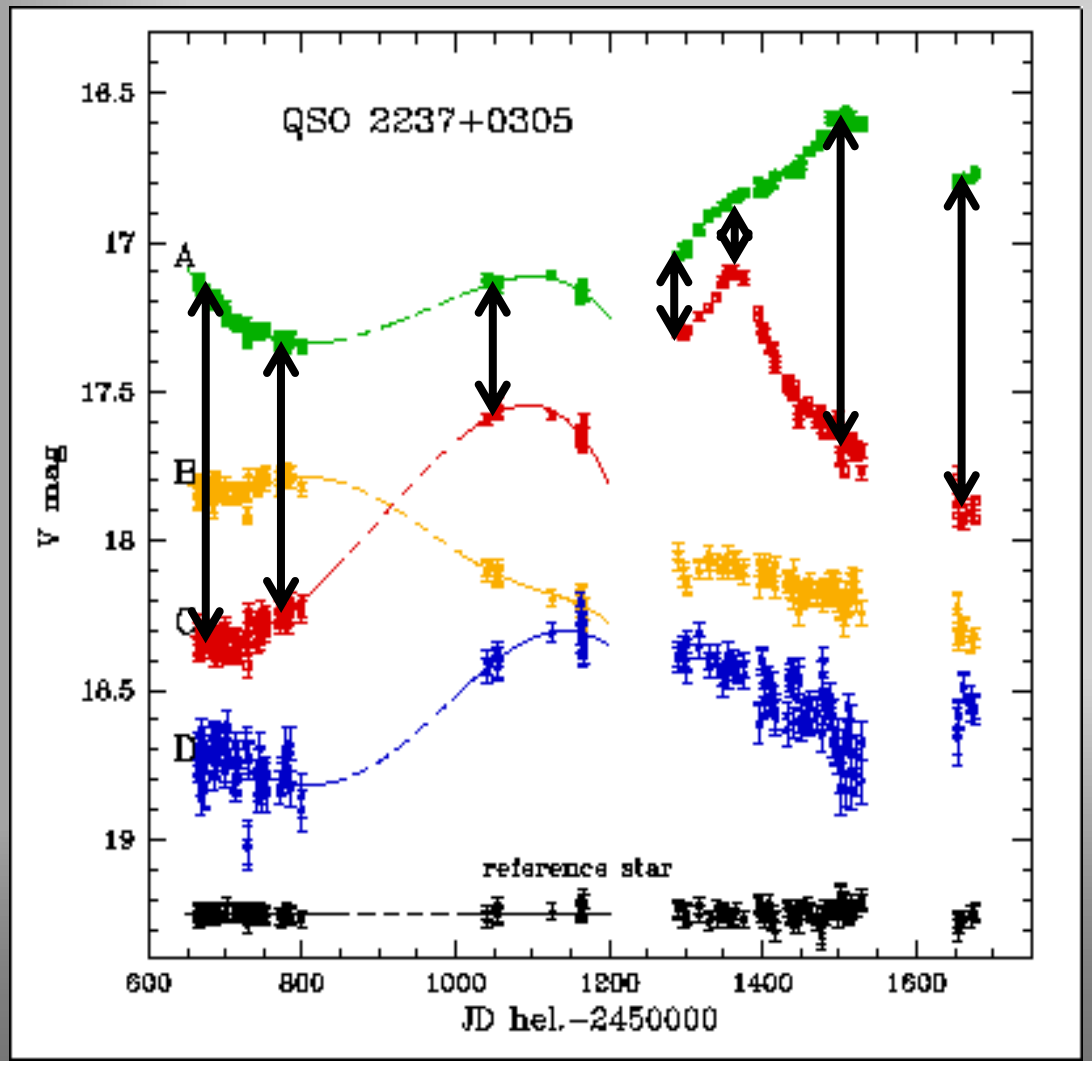
MICROLENSING (& DUST)

- Microlenses in a lens galaxy (stars or dark objects) may produce anomalies in the optical continuum flux ratios of the corresponding system, since the compact emission regions move along the magnification maps and have different sizes in different wavelengths (e.g., Chang & Refsdal 1979, Nature 282, 561; Wambsganss & Paczynski 1991, AJ 102, 864). Therefore, as due to microlensing phenomena, observed time delay corrected flux ratios could depend on both time and wavelength.

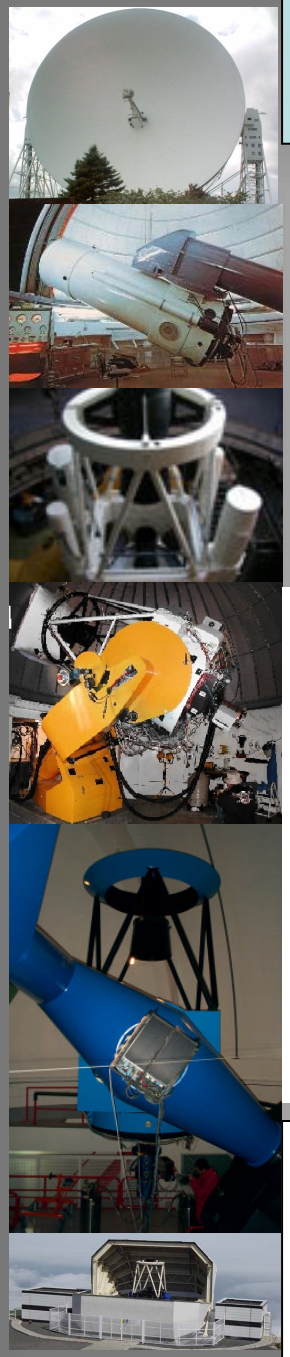




- *For Q2237+0305*, the OGLE collaboration have reported V-band trends (Wozniak et al. 2000, ApJ 540, L65):

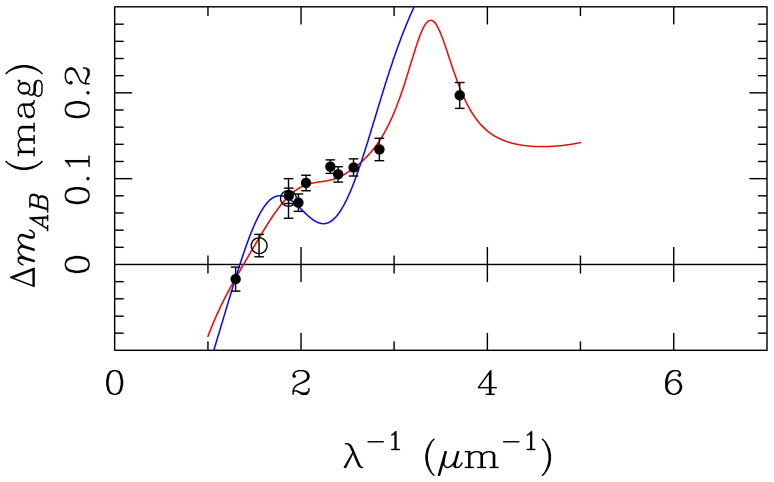


Evidences in favour of both MICROLENSING & DUST



●● Very recently, *to explain spectrophotometric observations of the lens system HE 0512-3329, Wucknitz et al. (2003, A&A 405, 445) also proposed a mixed scenario: extinction + microlensing. This mixed picture is consistent with other GLQs*, e.g., B1600+434 (Jaunsen & Hjorth 1997, A&A 317, L39; Burud et al. 2000, ApJ 544, 117; Koopmans et al. 2000, A&A 356, 391)

●●● *For Q0957+561, …*

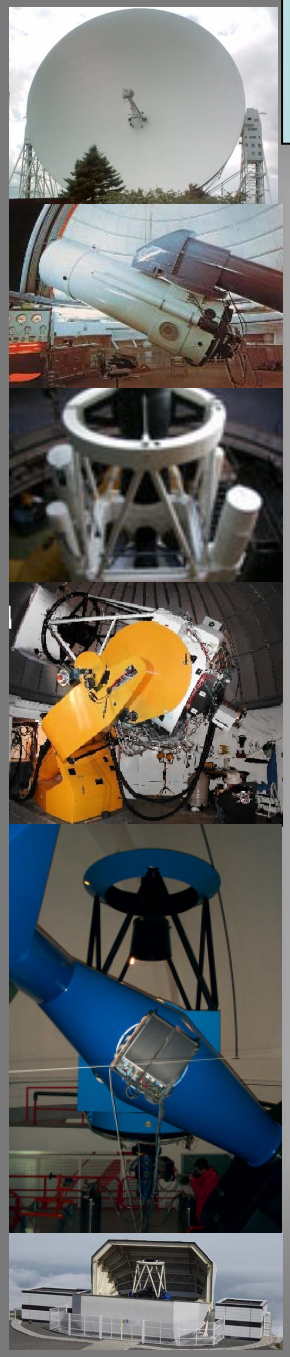


→ Δm_{AB} (radio) ≈ Δm_{AB} (emission lines) ≈ - 0.31 mag = Δm_{AB} (macrolens) [e.g., Garrett et al. 1994, MNRAS 270, 457; Schild & Smith 1991, AJ 101, 813]

→ Compact dust cloud crossing the A component

→ This picture agrees with a R-band ratio that has been basically constant for about 15 years (Pelt et al. 1998, A&A 336, 829; Oscoz et al. 2002, ApJ 573, L1; Ovaldsen et al. 2003, A&A 402, 891)

Multiwavelength observations of the optical continuum flux ratio suggest the existence of dust and differential extinction in the lens galaxy



SUBSTRUCTURE

In a recent review, Paul Schechter discussed on microlensing and millilensing (substructure) in GLQs (Schechter 2003, in Gravitational Lensing: a Unique Tool for Cosmology, eds. D. Valls-Gabaud & J.-P. Kneib, ASP Conference Series, in press). *N-body simulations of CDM produce large numbers of "mini-halos" within the halos of typical galaxies. These mini-halos may cause deflections of order a milliarcsecond, and therefore, millilensing of multiple QSOs*.

● *The timescale for millilensing variations would be thousands of years*, so the millilensing (substructure) signature in the time domain is quite different to the microlensing one.

●● *All the flux ratios* (optical continuum, emission lines and radio) *would be affected by the phenomenon* (millilensing)