arXiv:1909:13512

TRUTH OR DELUSION? A POSSIBLE GRAVITATIONAL LENSING INTERPRETATION OF THE ULTRA-LUMINOUS QUASAR SDSS J010013.02+280225.8 AT $z = 6.30$

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ApJ in press

1. SDDSJ0100+2802
   - z=6.30
   - Lbol=4e14Lsun
   - M_BH=1.2e10Msun (MgII輝線幅)
   - z=40で1e3MsunのBHにsuper-Eddingtonで降着してなんとか作れるレベル
2. ALMA 観測
   - Band6 0.15” resolution
   - 4つの像に分裂
3. Foreground absorber = lens galaxy?
   - VLT/X-shooter観測
   - z=2.33にMgII吸収 + LyA輝線
   - SFR=1Msun/yr => Mstar=1e10-11Msun (assuming SFMS)
4. 重力レンズモデル
   - HST F850天体 がSub-mm天体と~50pc offsetしていると説明可能
   - 増幅率はALMA像が60倍、HST像で最大450倍 (数倍の不定性あり)
   - その場合 M_BH=1e9Msun以下まで減少

$$M_{\rm BH} = 10^{6.86}\left(\frac{\lambda L_{\lambda,3000}}{10^{44}{\rm erg\,s^{-1}}}\right)^{0.5}\left(\frac{\rm FWHM_{MgII}}{\rm km\,s^{-1}}\right)^{2}, \quad (2)$$

   - ただしレンズではなくて、実際に4つの天体があるという可能性も排除しきれない

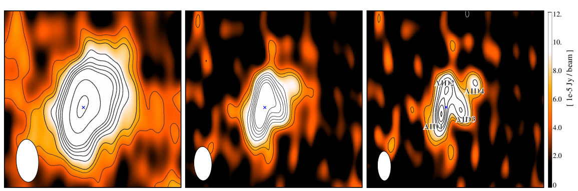

Figure 1. ALMA 1.″2 × 1.″2 images of J0100+2802. The LR (natural-weighted), MR (briggs-weighted, robust = 0.5), and HR (briggs-weighted, robust = 0.2) maps are presented from left to right. The white contour shows the -3σ level, and the black contour denotes the 3σ, 4σ, 5σ, 6σ, 7σ, 8σ, 9σ, 10σ, 15σ, and 20σ levels. The rms noise levels of the LR, MR, and HR maps are 16 μJy/beam, 17 μJy/beam, and 20 μJy/beam, respectively. The ALMA synthesized beam is presented at the bottom left. We confirm that the MR map shows the consistent morphology in the previous study (see Figure 1 in Wang et al. 2019). The blue cross represents the optical emission peak position in the GAIA DR2 catalog.

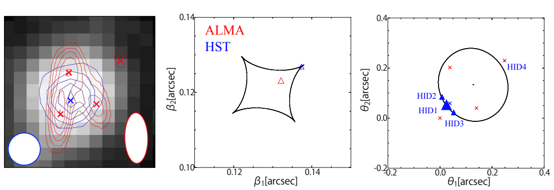

Figure 4. **Left:** The HST/F850LP 0.″6 × 0.″6 image for J0100+2802. The blue and red contours denote the continuum emission identified in the HST/F850LP and the ALMA HR maps, respectively. The crosses indicate the peak positions of these emission. The PSFs of the HST and ALMA maps are presented in the bottom left and right, respectively. **Middle:** The continuum peak positions in the source plane. The red open triangle indicates the best-fit position of the ALMA continuum emission in the simple mass model fitting (Section 3.1), and the blue open triangle shows a possible position of the HST continuum emission. The black line is the caustics. **Right:** The continuum peak positions in the image plane. The red and blue crosses are assigned in the same manner as the left panel. The blue triangles denote a possible peak positions of the HST emission in the resolution-free map predicted with our fiducial mass model, if the HST emission originates near from the cusp of the caustic in the source plane. The size difference among the triangles correspond to the ratio of the magnification factors of the four components in our fiducial mass model. The black line denotes the critical curve. In the middle and right panels, the same coordinate system is assigned as the left panel of Figure 3.

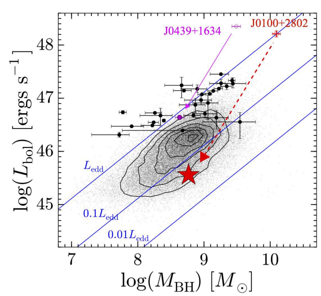

Figure 6. Distribution of bolometric luminosity $L_{\rm bol}$ and BH mass $M_{\rm BH}$ estimated from Mg II line among QSOs. The red open circle indicates the apparent property of J0100+2802 (Wu et al. 2015), while the red star denotes the potential intrinsic property after the gravitational lensing correct. For comparison, the magenta open and filled circles present the apparent and intrinsic properties of J0439+1634 that is identified as a gravitationally lensed QSO at $z = 6.42$ (Fan et al. 2019). The black circles are other QSOs at $z \gtrsim 6$ (Mortlock et al. 2011; Mazzucchelli et al. 2017; Bañados et al. 2018), and the grey dots and black contours are the distribution of the SDSS QSOs at $z = 0-2$ (Shen et al. 2011). The blue lines present fractions of the Eddington luminosity.

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REALITY OR MIRAGE? OBSERVATIONAL TEST AND IMPLICATIONS FOR THE CLAIMED EXTREMELY MAGNIFIED QUASAR AT $Z = 6.3$

Fabio Pacucci[1,2] and Abraham Loeb[1,2]

1. Lensed quasar at z>6
   - Fan+19 : z=6.51 with u~50
   - Paucci+19 : 標準的なLFを仮定すると、今のサーベイではz>6 quasarを半分くらい見落としている？
   - Fujimoto+19が正しいとして、quasar LFがどのようになるのかを考察 特にpower-law slope (beta)
2. Comparison of observation with lensed model
   - 観測 : Jiang+16 (z>5.7 52 quasars) / beta=2.8
   - モデル : u=450のquasarが一個入るようにパラメータ調整
   - beta>3.7でないとovershoot (Fig. 1)
3. Lens probability : Fig. 2
   - 51/52天体がu<10の可能性は1e-5
   - 少なくとももう一天体 u>100の天体がある可能性は60%
   - WFIRSTだとu>10が500天体、u>100が50天体見つかるはず
4. Intrinsic LF
   - 15天体程度がそれなりに増幅されていると観測されるLFは真のLFから有意にずれる。(Fig 3) => Fig. 4がその実例
5. SDDSJ0100+2802が増幅されていない可能性もありうる
   - 大きなproximity zone (7.9Mpc)
   - その場合、beta<3.7でもOKになる
   - deeper ALMA obsによるチェックが必要

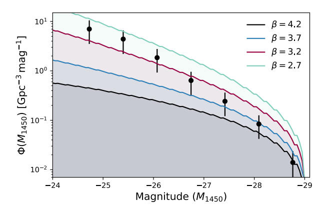

Figure 1. The $z \gtrsim 6$ SDSS quasar LF calculated from Jiang et al. (2016) is shown with black symbols and 1σ error bars. The lines show the expected number of lensed quasars assuming a bright-end slope of the intrinsic quasar LF of $\beta = 2.7, 3.2, 3.7, 4.2$ as indicated in the legend. The lensing probability model (Pacucci & Loeb 2019) assumes the detection of one quasar with $\mu = 450$ in the $M_{1450} \approx -29$ luminosity bin.

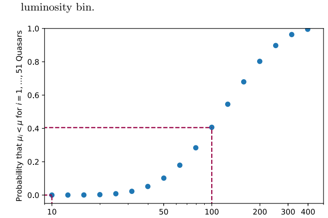

Figure 2. Probability $P_{\rm SDSS}$ that all the remaining 51 sources in the SDSS sample have magnifications $\mu_i < \mu$. Assuming the presence of one source with $\mu = 450$, it is nearly impossible, e.g. $P(\mu < 10) \sim 10^{-5}$, that all of the remaining sources are not magnified. The values discussed in the text are indicated with red dashed lines.

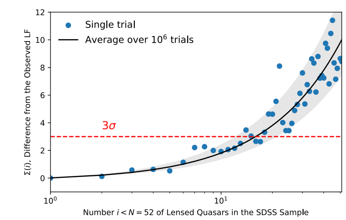

Figure 3. Plot showing how the intrinsic LF would differ (in terms of the standard deviation σ) from the SDSS one (Jiang et al. 2016) if an additional number $i < 52$ of quasars in the sample are lensed. Blue points are the results for a single trial, the black line is the average over 10^6 trials, the shaded region indicates the 1σ uncertainty.

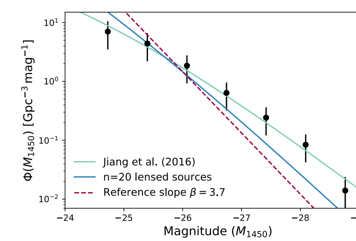

Figure 4. Example of the lensing effect on the quasar LF for a number $i = 20$ of lensed quasars in the SDSS sample. Black symbols are data from Jiang et al. (2016); the green line being their best fit, and the blue line being the quasar LF that we obtain assuming that additional 20 randomly chosen quasars in the sample are magnified. The red dashed line indicates a slope $\beta = 3.7$, for reference.