Are There Distant Quasars Observable Along Antipodal Directions?

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Abstract

This paper puts forth the idea that distant quasars may be observable along two antipodal sightlines as seen from Earth; that is, along two extremal paths: the shortest and the longest.

The analogy is often made of the universe to the surface of an (expanding) balloon. An observer also on the surface would see sufficiently energetic, sufficiently distant sources from two directions (nearby sources would only be seen from one direction, as the other path would be too long). If the analogy holds for our universe, we should expect to find very distant, energetic sources observable simultaneously along two directions in the sky. A natural set of directions to investigate are the antipodal directions; that is, those with sign-inverted declinations, and right ascensions differing by twelve hours (i.e., 180 degrees).

We searched a recent electronic catalog of 11,358 quasars for antipodal object pairs. Of sixty-four distant ($z > 4$) candidate sources, we found eight nearly antipodal pairs involving fourteen catalogued sources. We compared the reported characteristics of the objects comprising each pair. The objects of one pair, quasars 0046-293 and 1247+3406, exhibit strikingly similar spectra. The directions in which these objects lie are nearly six degrees apart.

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1 Introduction

The analogy is often made of the universe to the surface of an (expanding) balloon. An observer also on the surface would see sufficiently distant, sufficiently energetic sources from two directions at once (Figure 1-a). (Less distant sources would be observed only in one direction, as the alternate path would be too long.) If the analogy holds for our universe, we should expect to find very distant, energetic sources observable simultaneously along two directions in the sky. A natural set of directions to investigate are the antipodal directions on the celestial sphere (Figure 1-b); that is, those with sign-inverted declinations, and right ascensions differing by twelve hours (i.e., 180 degrees).

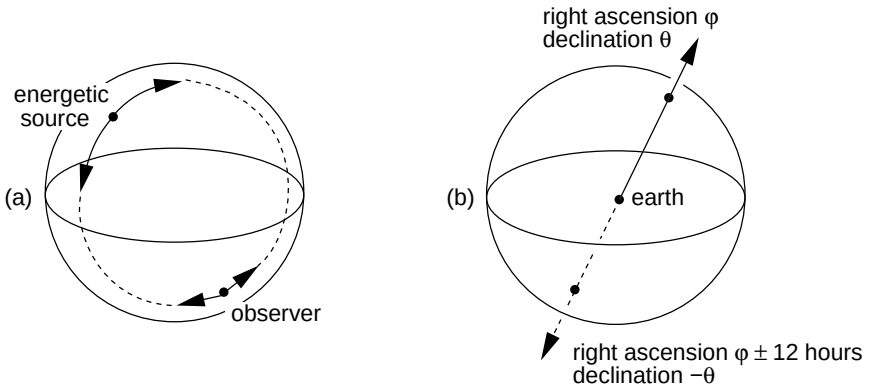

Figure 1: An observer in a curved, two-dimensional universe could see a sufficiently distant source along two directions (a). A direction, and its antipode, shown on the three-dimensional celestial sphere (b).

2 Observations

All distant quasars ($z > 4$) were selected from Veron's 1998 catalog of 11,358 quasars [Veron98]. Of these, sixty-four quasars had $z > 4$. For each, the right ascension, declination, red shift, and absolute magnitude were read by a computer program (see Appendix). For each object, the program searched for the distinct object in the most nearly antipodal direction. Eight pairs of nearly antipodal observations (within six degrees) were selected for further inspection. These eight pairs involved fourteen distinct catalog entries. The elements comprising each object pair were then compared by red shift, absolute magnitude, and spectral characteristics, using observations reported in the literature.

3 Discussion

The eight object pairs identified by the program are listed below (all quantities and reference numbers follow Veron+ 1998).

Name	R. Ascension H M S	Declination D M S	z	abs. mag.	ref.
Pair 1, deviation from antipodal 4.86 degrees:					
*Q 0046-293	0 48 29.5	-29 3 21	4.008	-28.5	1386
*PC 1247+3406	12 49 42.1	33 49 53	4.897	-27.7	1389
Pair 2, deviation from antipodal 4.93 degrees:					
*Q 0101-304	1 3 37.4	-30 9 1	4.073	-27.5	1386
*PC 1247+3406	12 49 42.1	33 49 53	4.897	-27.7	1389
Pair 3, deviation from antipodal 5.06 degrees:					
*BRI 0151-0025	1 53 39.5	0 11 0	4.194	-29.0	1531
*BRI 1335-0417	13 38 3.4	4 32 35	4.396	-28.4	1531
Pair 4, deviation from antipodal 3.80 degrees:					
*PC 0953+4749	9 56 25.2	47 34 42	4.457	-28.4	1388
*Q 2133-4625	21 36 31.4	-46 11 41	4.18	-26.7	630
Pair 5, deviation from antipodal 5.73 degrees:					
*BRI 1013+0035	10 15 49.0	0 20 19	4.405	-29.0	1531
*BRI 2235-0301	22 38 22.5	-2 45 53	4.249	-29.5	1531
Pair 6, deviation from antipodal 3.53 degrees:					
*BR 1033-0327	10 36 23.7	-3 43 20	4.509	-29.4	1531
*BRI 2235-0301	22 38 22.5	-2 45 53	4.249	-29.5	1531
Pair 7, deviation from antipodal 0.81 degrees:					
BRI 1050-0000	10 53 20.4	0 16 50	4.286	-29.1	1531
*DMS 2247-0209	22 49 52.1	-1 53 32	4.3	-26.2	605
Pair 8, deviation from antipodal 4.80 degrees:					
*BR 1144-0723	11 46 35.6	-7 40 5	4.147	-29.0	1531
PC 2331+0216	23 34 32.0	2 33 21	4.093	-27.6	1386

3.1 Apparently Coincidental Pairings

Six of the pairs (numbers 2, 3, 4, 6, 7, and 8) appear to have arisen coincidentally. Each appears to involve distinct objects which happen to lie in nearly antipodal directions. However, two of the pairs (numbers 1 and 5) exhibited sufficient similarity to merit closer inspection.

3.2 Antipodal Pair 0046-293 and 1247+3406

The objects in one antipodal pair: 0046-293 (z = 4.008, absolute magnitude -28.5) and 1247+3406 (z = 4.897, absolute magnitude -27.7), exhibited some notable similarities. The objects' absolute magnitudes differ by only 0.8 (about a factor of two in energy). Spectra from both observations are reproduced in Figures 2 and 3.

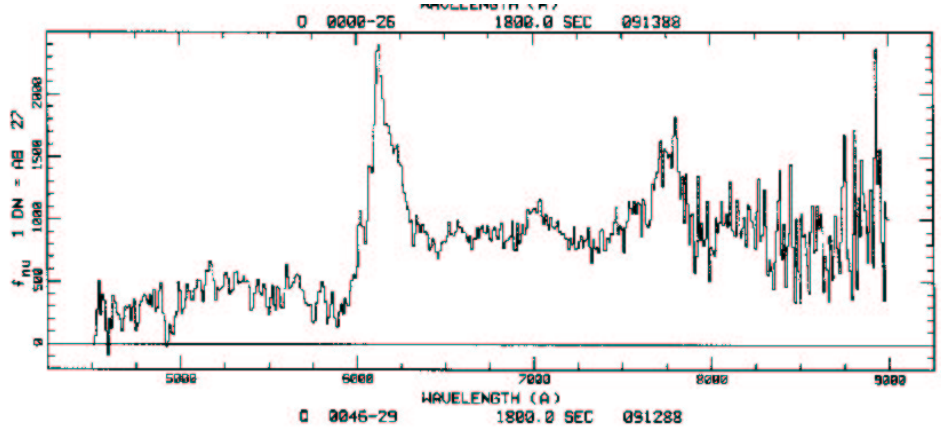

Figure 2: Spectrum of 0046-293, reproduced from reference 1386.

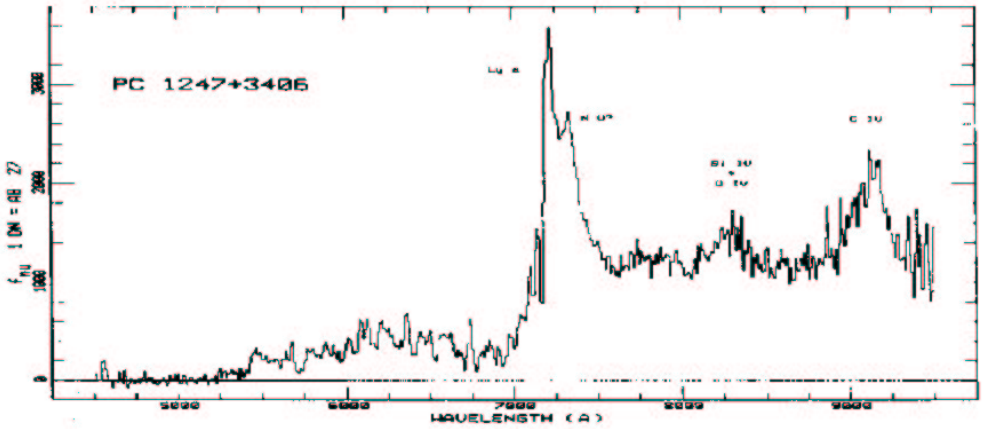

Figure 3: Spectrum of 1247+3406, reproduced from reference 1389.

We overlaid the two spectra, shifting them to align principal peaks (Figure 4). Even without rescaling to correct for the z difference, the agreement between the two spectra is striking. Schneider et al. (in ref. 1389) hold out the possibility that "the direction of PC 1247+3406 is a relatively clean line of sight (there is,

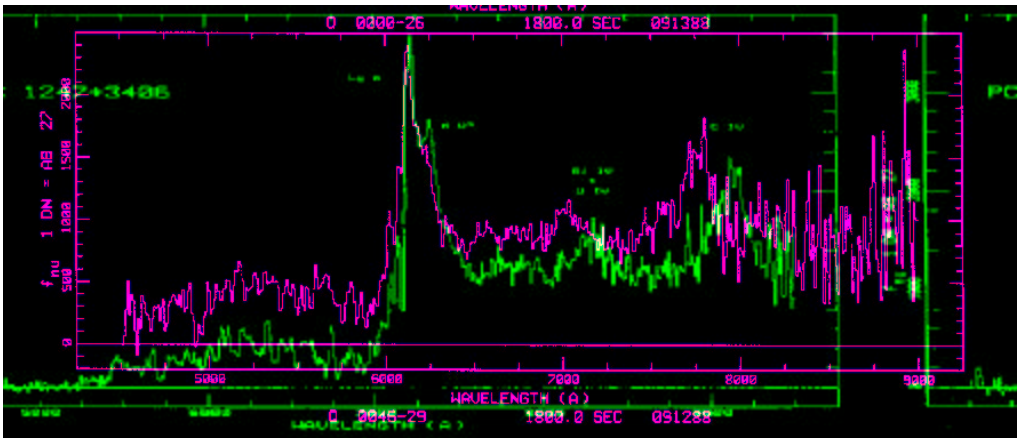

Figure 4: A shifted overlay of the spectra of 0046-293 and 1247+3406.

for example, no evidence of any damped Lyman α absorption systems)." If the same holds for the line of sight to 0046-293, and it is indeed the same object as 1247+3406, very similar spectra would be observed.

We believe that 0046-293 and 1247+3406 may be the same object. At the least, the appearance of objects with such similar spectra and absolute magnitudes along nearly antipodal directions warrants further investigation.

3.3 Antipodal Pair 1013+0035 and 2235-0301

The second pair, involving 1013+0035 ($z = 4.405$, absolute magnitude -29.0) and 2235-0301 ($z = 4.249$, absolute magnitude -29.5), also exhibited similarities. The objects' absolute magnitudes differ by only 0.5. Spectra from both observations are reproduced in Figures 5 and 6.

As before, we shifted and overlaid the two spectra (Figure 7). These spectra appear similar to a lesser degree than that of the first pair, perhaps due to differing absorption artifacts arising from the distinct observation paths (or, of course, because they arise in fact from distinct objects).

There is, however, a notable similarity between the two objects: both may contain an MgII doublet. Storrie-Lombardi et al. (Ref. 1531) describe 1013+0035 ($z = 4.405$) as

> The Lyα+NV, IO, CII, SiIV+OIV], and CVI emission lines are weak. There is a damped Lyα candiate at $z = 3.10$ with corresponding FeII detected. There is an MgII doublet at $z = 2.054$ with 6 corresponding FeII lines at $z = 2.058$. There is a Lyman-limit system at $z = 3.78$.

The authors go on to describe the object 2235-0301 ($z = 4.249$):

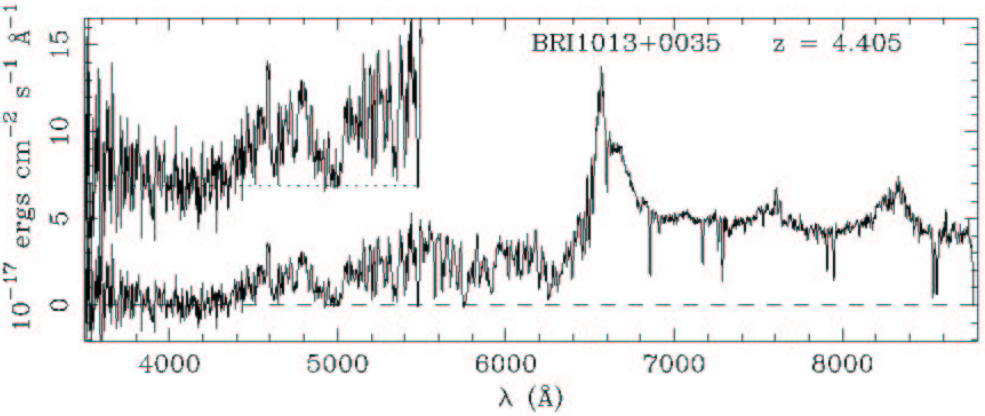

Figure 5: Spectrum of 1013+0035, reproduced from reference 1531.

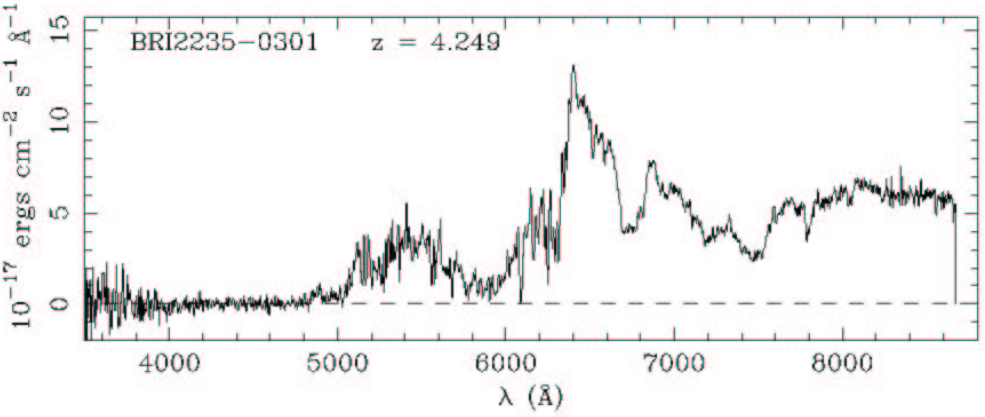

Figure 6: Spectrum of 2235-0301, reproduced from reference 1531.

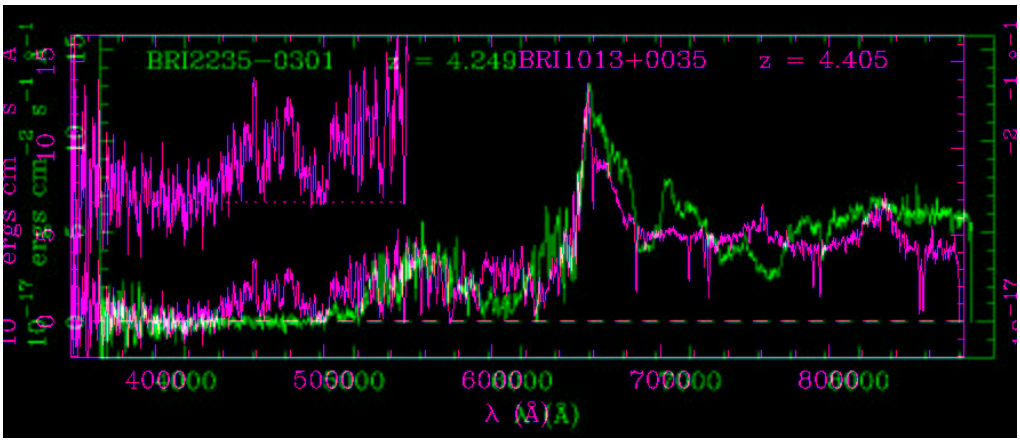

Figure 7: An overlay of the spectra of 1013+0035 and 2235-0301.

> This QSO is the highest redshift BAL in the sample and has very broad absorption troughs. The emission lines are almost completely absorbed, making it difficult to determine an accurate redshift. It exhibits broad absorption lines of OVI ($z = 4.08$), NV ($z = 3.74$), SiIV ($z = 3.83$), and CIV ($z = 3.65, 3.82, 4.03$). There is a possible MgII doublet at $z = 1.873$.

If these are the same object, but have been observed across distinct regions of space, different absorption effects could account for the differences in their spectra. If 2235-0301 does indeed exhibit an MgII doublet, it matches that of 1013+0035 well. If a jet is causing the doublet to arise, we can compute its velocity in each object's rest frame using the rule for relativistic addition of velocities. For 1013+0035, the velocity is $0.993c$. For 2235-0301, the velocity is $0.991c$. The computed velocities agree to a fraction of a percent. Although the evidence in this case is less compelling, it seems possible 1013+0035 and 2235-0301 are the same object.

4 Conclusion

We examined a recent catalog of distant quasars to find antipodal pairs of observations. Of eight antipodal pairs, six appear to have arisen coincidentally, one appears to involve strikingly similar objects, and one involves somewhat similar objects. If any of these pairs really do arise from single quasars observed along antipodal lines of sight, that would be really cool.

5 Acknowledgments

We gratefully acknowledge Gerry Sussman for his encouragement, and the creators and maintainers of the NASA Astrophysics Data System Abstract Service for their incredibly useful archives.

6 REFERENCES

Citation numbers follow those of Veron+ 1998 (cited below).

```
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```

7 Appendix

Source code for the `nawk` and `C` programs used to parse the Veron+ catalog can be found at the URL `http://graphics.lcs.mit.edu/~seth/antipodes` .