Why Do Compact Active Galactic Nuclei at High Redshift Twinkle Less?

J. Y. Koay[1]*, J.-P. Macquart[1], B. J. Rickett[2], H. E. Bignall[1], D. L. Jauncey[3,4], T. Pursimo[5], C. Reynolds[1], J. E. J. Lovell[6], L. Kedziora-Chudczer[7], and R. Ojha[8,9]

ABSTRACT

The fraction of compact active galactic nuclei (AGNs) that exhibit interstellar scintillation (ISS) at radio wavelengths, as well as their scintillation amplitudes, have been found to decrease significantly for sources at redshifts $z \gtrsim 2$. This can be attributed to an increase in the angular sizes of the μas-scale cores or a decrease in the flux densities of the compact μas cores relative to that of the mas-scale components with increasing redshift, possibly arising from (1) the space-time curvature of an expanding Universe, (2) AGN evolution, (3) source selection biases, (4) scatter broadening in the ionized intergalactic medium (IGM), or (5) gravitational lensing. We examine the frequency scaling of this redshift dependence of ISS to determine its origin, using data from a dual-frequency survey of ISS of 128 sources at $0 \lesssim z \lesssim 4$. We present a novel method of analysis which accounts for selection effects in the source sample. We determine that the redshift dependence of ISS is partially linked to the steepening of source spectral indices ($\alpha_{4.9}^{8.4}$) with redshift, caused either by selection biases or AGN evolution, coupled with weaker ISS in the $\alpha_{4.9}^{8.4} < -0.4$ sources. Selecting only the $-0.4 < \alpha_{4.9}^{8.4} < 0.4$ sources, we find that the redshift dependence of ISS is still significant, but is not significantly steeper than the expected $(1 + z)^{0.5}$ scaling of source angular sizes due to cosmological expansion for a brightness temperature and flux-limited sample of sources. We find no significant evidence for scatter broadening in the IGM, ruling it out as the main cause of the redshift dependence of ISS. We obtain an upper limit to IGM scatter broadening of $\lesssim 110\mu$as at 4.9 GHz with 99% confidence for all lines of sight, and as low as $\lesssim 8\mu$as for sight-lines to the most compact, $\sim 10\mu$as sources.

*e-mail: kevin.koay@icrar.org

[1] International Centre for Radio Astronomy Research, Curtin University, Bentley, WA 6102, Australia

[2] Department of Electrical and Computer Engineering, University of California, San Diego, La Jolla, CA 92093, USA

[3] CSIRO Astronomy and Space Science, Australia Telescope National Facility, Epping, NSW 1710, Australia

[4] Mount Stromlo Observatory, Weston, ACT 2611, Australia

[5] Nordic Optical Telescope, Apartado 474, 38700 Santa Cruz de La Palma, Spain

[6] School of Mathematics and Physics, University of Tasmania, TAS 7001, Australia

[7] School of Physics and Astrophysics, University of New South Wales, Sydney, NSW 2052, Australia

[8] NASA, Goddard Space Flight Center, Greenbelt, MD 20771, USA

[9] Institute for Astrophysics & Computational Sciences, The Catholic University of America, 620 Michigan Ave., N.E., Washington, DC 20064, USA