

A LONG-TERM SPACE ASTROPHYSICS RESEARCH PROGRAM

THE EVOLUTION OF THE QUASAR CONTINUUM

CONTINUATION OF NAGW-2201

NASA Grant NAG5-6078

Final Report

For the Period 1 October 1997 through 31 March 2002

Principal Investigator
Dr. M. Elvis

June 2002

Prepared for:

National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, MD 20771

Smithsonian Institution
Astrophysical Observatory
Cambridge, Massachusetts 02138

The Smithsonian Astrophysical Observatory
is a member of the
Harvard-Smithsonian Center for Astrophysics

The NASA Technical Officer for this grant is Ronald K. Oliverson, NASA/GSFC, Greenbelt,
MD 20771



This grant was given a 6-month no-cost extension in order to cover page charges on the main Astrophysical Journal papers resulting from this program. These papers have now been published and the grant can be closed out.

The previous report on the program includes the science results. We reproduce it here, with updated references for the papers.

"Four papers have been written. One reports on the major study funded by this grant: a pan-chromatic study of the quasar continuum at redshift 3. Two others make use of the quasar continuum shapes to find the minimum total accretion luminosity of the Universe, and hence the efficiency and spin of supermassive black holes; the second shows that the reemission of absorbed quasar radiation alleviates a major problem with galaxy formation and the FIR background. The last paper recognizes the role quasars may play in the initial formation of dust in the early Universe."

"The major study of a sample of $z=3$ and its comparison with a sample of $z=0.1$ quasars across the whole X-ray to radio spectrum was completed and accepted for publication in ApJ Supplements. This study comprises the thesis work of Olga Kuhn. The two samples are matched in evolved luminosity, and so should be sampling the same black hole population at different z , and in different accretion states. Despite this no strong differences were found between the samples, except in the 'small bump' region of the optical/UV. This region is dominated by FeII emission, and may indicate abundance evolution in quasars. The lack of overall spectral changes argues strongly against a single population of quasars fading over cosmic time, and for a multiple generation, or multiple outburst model for quasars."

"A study of the total luminosity absorbed from quasars and reemitted in the infrared produced two results (reported in two papers): The minimum intrinsic luminosity/Gpc(3) from AGN compared with the measured mass density in supermassive black holes [Gpc(-3)] requires a conversion efficiency of accreted mass into luminosity of $>15\%$. Non-rotating black holes cannot exceed 5% efficiency, while rapidly rotating black holes can reach 47%. Hence our result requires that most supermassive black holes must be rapidly rotating."

"The second result comes from considering the contribution that the reradiated quasar radiation makes to the far infrared background (FIRB). The effective temperature of the reradiation is tightly constrained, but the detailed shape (e.g. line emission, range of temperature) is only of second order importance. At least 15%, and perhaps 20-25% of the FIR background must come from AGN. This contribution significantly relieves problems in galaxy evolution that come from trying to use only starlight to make the FIRB."

"The third paper addresses the origin of the dust obscuration that is so widespread in AGN. The standard assumption is that the dust comes from the normal star-formation processes in galaxies and is drawn close to the nucleus along with the gas that powers the accretion. In complete contrast, using a wind outflow model for the broad emission line (BEL) region (Elvis 2000) as a basis, we show that BEL clouds will expand, cool and form dust as they flow outward, in strict analogy to the stellar winds of red supergiants."

Kuhn O., Elvis M., Bechtold J. & Elston R., 2001 ApJ Suppl, 136, 225 'A search for signatures of quasar evolution: Comparison of the shapes of the rest-frame optical/UV continua of quasars at $z > 3$ and $z < 0.1$.

Elvis M., Risaliti G. & Zamorani G., 2001, ApJ Letters, 565, L75 'Most Supermassive Black Holes must be Rapidly Rotating'.

Risaliti G., Elvis M. & Gilli R., 2001, ApJ Letters, 566, L67 'The Contribution of AGNs to the Far Infrared Background'.

Elvis M., Marengo M. & Karovska M., 2001, ApJ Letters, 576, L107 'Smoking Quasars: A New Source for Dust'.