
Senior People: Beverley J. Wills, D. Wills

Service:
D. Wills continues as technical editor for the popular science program “Earth and Sky”, on National Public Radio.

Science:

Introduction

All my current projects investigate aspects of radio-loud, radio-quiet, BAL QSOs, and buried (IRAS-selected) QSOs and the relationships among these different classes, with the aim of probing the nature of accretion onto the massive central black hole – via relativistic jets, X-ray and optical absorption outflows, and the kinematics of the surrounding gas whose emission lines are excited by the accretion continuum.

Emission Lines, Continua, and the Energy Source in Radio Quiet Quasars

In collaboration with A. Laor (Technion, Israel), B. J. Wilkes (Harvard-Smithsonian Center for Astrophysics), G. Ferland (Univ. Kentucky), D. Wills and M. Brotherton (LLNL), we continue to investigate relations of UV and optical broad emission lines, absorption lines, and continua, with the ROSAT X-ray spectra. This is for a complete subset of 23 of the Palomar-Green (B-V-selected) sample having redshift <0.4 and Galactic hydrogen columns <1.9 x 10^21 cm^-2 (Laor, Fiore, Elvis, Wilkes, & McDowell 1997, ApJ, 477, 93). Observations and all data reductions are complete, but some latest STScI re-calibration is being completed by grad student, Zhaohui Shang. This research has turned up more exciting new results, extending well-known Fe II, [O III], line-width, and X-ray relationships to ultraviolet emission lines. Correlations are among the strongest found in AGN spectroscopy and show great promise for understanding several ‘classic’ problems – the great strength of Fe II and other low-ionization broad emission lines (the energy budget problem), the ‘Baldwin effect’ and the meaning of ‘eigenvector 1’ relationships. Results have been presented at the QSO Broad-Line Region conference in Nebraska, 1998, and at the La Serena ‘QSOs as Standard Candles’ workshop in Chile (1997). In the two years, PhD student, Zhaohui Shang, has reduced and combined all optical and space-based data, and is preparing a paper on the spectral principal component analysis of this sample. The latter analysis reveals 3 orthogonal relationships among emission line and continuum properties – one involves an anticorrelation between luminosity and the strength of low-velocity emission from the Broad Emission Line Region (BLR) that is related to the Baldwin Effect, another involves an anticorrelation between optical Fe II emission and [O III] strengths that is similar to Boroson and Green’s (1992) ‘eigenvector 1’, and the third involves the UV continuum slope and may simply represent the differences in spectral energy distributions among the sample QSOs, including the effects of (possible dust) reddening. We have interpreted these relationships as driven by accretion rate, Eddington accretion ratio, and dust reddening. We have shown how it may be possible to extend these analyses to larger samples, and higher redshift to investigate QSO evolution.

D. Grupe (now at MPE, Garching) obtained and reduced complete spectrophotometry for a revised version of his soft-X-ray-selected AGN sample. The data paper will be submitted this week. B. Wills, D. Grupe, K. Leighly (Columbia Univ.) are investigating the emission-line properties of the sample, with ASCA and Chandra follow-up. In addition, we (with Hans-Christoph Thomas of MPE-Garching) have obtained NIR spectroscopy at McDonald Observatory, to investigate the strengths of hydrogen Paschen emission lines (published).

Intrinsic Absorption in QSOs vs. Luminosity

In collaboration with A. Laor and W.N. Brandt, B. Wills has completed an investigation of the relation between UV and X-ray absorbing material in AGNs, and we have also investigated absorption-luminosity relationships. Three papers are published. This research is not completely distinct from the above study of emission lines and continua.
The Synchrotron Continuum in Radio-Loud Quasars

Feng Ma and B.J. Wills investigated the characteristic signature of CIV λ emission line variability, predicted by the expected collisional excitation excited by the beamed, infrared, jet emission in radio-loud quasars (cf Ma and Wills 2001). Ma has received his PhD degree (December 2000).

Three investigations of broad-band polarization in radio-loud quasars are in preparation: (i) A paper by Wills, Tran, Wills and Yuan concerns variability of blazar polarization over a 20–30-year timescale, (ii) Wills and Cross describe day timescale UBVRJHKL' variability of synchrotron polarization in the bright quasar 3C 273, and (iii) B. J. Wills has investigated the synchrotron polarization of a sample of radio core-dominated quasars, including model-fitting of accretion disk and synchrotron continua. Undergraduate, Marty Bitner, and graduate student Michael Yuan, are helping with this.

Buried AGN: A Complete Sample of Warm IRAS-selected QSOs

In collaboration with D.C. Hines, K. Gordon, M. L. Sitko, and G. Schmidt, B. J. Wills is investigating HST polarization and imaging, of the dusty, IRAS AGN in our complete sample of luminous IRAS-detected AGN (continuing project).

Some Other Projects

Other projects are coordinated STIS/Chandra spectroscopy of UV/X-ray Absorption in the Seyfert Galaxy NGC 4051 (completed, with Collinge et al. 2001), and a major FUSE project, 'The Far-UV Spectral Energy Distributions of Quasars' – to observe our previously and presently-investigated PG sample).

We have investigated HST imaging of the narrow line region (NLR) in a complete sample of low-redshift radio quiet quasars (collaborators are Andrew Wilson and Heino Falcke).

We have obtained quasi-simultaneous Chandra–HST spectroscopy of the brightest BAL QSO, PG 2112+059, and investigated dramatic X-ray spectral variability, as well as analyzing the line locking exhibited in new and archival HST (STIS and FOS) spectral data.

We have investigated the use of widths of [OIII]λ5007 lines as a surrogate for bulge velocity dispersion of QSOs' host galaxies, and compared the resulting stellar velocity dispersions with estimates of blackhole mass obtained from the width of Hβ and continuum luminosity. QSOs at moderately high redshift extend the relationship found by Nelson (2000).

Other projects and results are also included in the Publication list.


Black Hole Accretion and the X-ray Spectra of QSOs, Yuan, J. M., Wills, B. J. 2002 Space Science Reviews, 000, 000.
Indicators of Black Hole Mass and Eddington Accretion Ratio from QSO X-ray and UV Spectra, Wills, B. J., & Shang, Zhaohui 2002 Space Science Reviews, 000, 000.


Conference Papers


Absorption and scattering properties in polarized bright soft X-ray selected ROSAT AGN, Grupe, D., Wills,


A Principal Component Analysis of a Complete QSO Sample, Shang, Zhaohui, Wills, B. J., Robinson, E. L., & Yuan, M. J. 2001 January AAS Meeting No. 197, paper no. 000.

The Physics of Jets in 3C 273 and other Blazars: Clues from Optical-IR Polarization, Wills, B. J. presented at the annual Stromlo Agn meeting, in honor of Charlene Heisler, 2000 December, Mt. Stromlo Observatory, ACT, Australia.


Invited talks

"Are Most QSOs Buried? – A Polarization Survey of IRAS-selected AGN", IGPP, LLNL, April, 1998

"Are Most QSOs Buried?", 2000 April, Columbia University.


"Quasars' Supermassive Black Holes", Department of Physics, Sam Houston State University (Huntsville), 2002 Nov. 21.

Thesis Supervision/Advising

Feng Ma, Discovery of Hidden Blazars inside Quasars, PhD degree awarded December, 2000.


Juntao (Michael) Yuan – thesis in progress.