EUROPEAN SOUTHERN OBSERVATORY

Organisation Européenne pour des Recherches Astronomiques dans l'Hémisphère Austral
Europäische Organisation für astronomische Forschung in der südlichen Hemisphäre

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APPLICATION FOR OBSERVING TIME PERIOD: **71A**

To be submitted only to: proposal@eso.org
Important Notice:

By submitting this proposal, the PI takes full responsibility for the content of the proposal, in particular with regard to the names of COIs and the agreement to act according to the ESO policy and regulations, should observing time be granted

1. Title Panel: **B–6**
Polarization Properties of a Large, Uniformly Selected Sample of BAL and non-BAL Quasars

2. Abstract

The conventional wisdom about broad absorption line (BAL) quasars is that they are on average more polarized than non-BAL quasars, consistent with being seen through ∼1 mag of extinction along lines of sight which graze obscuring torii. However, this is based on polarization studies of non-BAL quasars from the PG survey, which is known to be incomplete even for the very blue objects it selected, and of BAL quasars from heterogeneous, mostly B-selected samples. Recent polarization studies of K-selected 2MASS quasars show that they are just as highly polarized as such BAL quasars, so the conventional wisdom may just be a selection effect. Thus we propose a survey of BAL and non-BAL quasars selected from the Sloan survey, which is sensitive to both types of quasars and to normal and reddened examples of each. Our large i-band selected sample, equal in size to the PG survey, will provide the first directly comparable polarization distributions for non-BAL and BAL quasars.

3.

Run	Telescope	Instrument	Time	Month	Moon	Seeing	Sky Trans.	Obs.Mode
A	3.6	EFOSC2	5n	apr	g	n	THN	v

4.

Number of nights/hours	Telescope(s)	Amount of time
a) already awarded to this project:		
b) still required to complete this project:	3.6/EFOSC2	5n nov P72

5. Special remarks

6. Principal Investigator: P. HALL (P. Universidad Catolica, RCH, phall@astro.puc.cl)
CoI(s): D. HUTSEMEKERS (Liege, B)

7. Is this proposal linked to the PhD thesis preparation of one of the applicants?

8. Description of the proposed programme

A) Scientific Rationale:

One in every ten quasars is a Broad Absorption Line (BAL) quasar, but how normal and BAL quasars are related is unclear. Most BAL quasars have outflowing absorption only in high ionization lines like C IV ('HiBALs'), but 1 in 7 BAL quasars also have outflows in low-ionization lines like Mg II as well ('LoBALs'), and 1 in 50 are 'FeLoBALs' with excited-state Fe II absorption. At one end of the range of BAL quasar models, these fractions represent the fraction of sky around every quasar covered by that type of BAL outflow; at the other, the fraction of all quasars completely surrounded by that type of outflow. Since BAL outflows have mass loss rates comparable to quasar accretion rates and may be present around every quasar for at least part of its lifetime, determining the correct model(s) for BAL quasars will improve our understanding of all quasars and of the influence of outflows on the IGM (Furlanetto & Loeb 2001) and on AGN hosts (Appleton et al. 2002).

Polarization offers one way to study the structure of the emitting and absorbing regions in normal and BAL quasars. It has long been known that individual BAL quasars can have high polarizations, and the surveys of Hutsemekers, Lamy & Remy (1998) and Schmidt & Hines (1999) confirmed that BAL quasars are on average more highly polarized than non-BAL quasars from the PG survey (Berriman et al. 1990). The different polarization distributions are consistent with BAL quasars being seen through $\sim$1 mag of extinction along a line of sight grazing an obscuring torus. Such a geometry will make any scattered, polarized light component present in all quasars a greater fraction of the observed light from BAL quasars, creating their higher polarizations.

However, recent polarization studies of K-selected 2MASS quasars (Smith et al. 2001, 2002) show that a substantial population of non-BAL quasars exists with polarizations — and thus extinctions — just as high as the BAL quasars in previous studies (Fig. 1). A handful of such objects had been seen with IRAS (Hines 1994), but only the 2MASS survey was able to show that their space densities are comparable to those of previously known UV-excess quasars of similar luminosity.

This discrepancy probably arises from the different selection criteria of the samples (Figs. 2-3). The PG survey (Schmidt & Green 1983) selected only very blue objects (U-B<-0.44) and is known to be incomplete even for those objects (Wisotzki et al. 2000), while the 2MASS AGN of Smith et al. were selected for their red colors (J-K>2), and the BAL quasars studied to date have been drawn from heterogeneous, mostly B-selected samples.

Given these varying selection criteria, it now seems impossible to be sure from current data what the polarization distribution of quasars really is, let alone whether or not BAL quasars truly are on average more polarized than non-BAL quasars. The conventional wisdom that BALs are on average more highly polarized than non-BAL quasars may just be a selection effect, and neither the PG nor the 2MASS samples are the right comparison samples for BAL quasar studies.

What is needed is a *uniformly selected* BAL and non-BAL quasar sample from a single survey sensitive to blue *and* red quasars: in other words, the Sloan Digital Sky Survey (SDSS). We therefore propose a polarization survey of BAL and non-BAL quasars selected from the SDSS Early Data Release (EDR; Schneider et al. 2002, Tolea et al. 2002, Reichard et al. 2002). The SDSS is sensitive to both BAL and non-BAL quasars, and to unreddened and reddened examples of each, due to its i-band selection and its very thorough quasar candidate selection algorithm (Richards et al. 2002a). The SDSS quasar selection algorithm does rely primarily on optical colors (radio sources are targeted regardless of color), but nonetheless it is sensitive to even extremely reddened quasars (Hall et al. 2002ab, Richards et al. 2003), unlike traditional B-band selected surveys which are more sensitive to the reddening effects of dust (Goodrich 1997).

Our sample will consist of 70 BAL quasars and an equal number of comparison non-BAL quasars. This large i-band selected sample will be equal in size to the 2MASS and PG surveys of non-BALs, and larger than any previous single polarization survey of BAL quasars (30-50 objects). It will provide the first directly comparable polarization distributions for non-BAL and BAL quasars. In particular, our sample will include sufficient numbers of red BAL and non-BAL quasars to see if the former are on average more polarized than the latter, a test which is impossible with the $z\lesssim0.6$ 2MASS sample. Existing high-quality $ugriz$ photometry and optical spectroscopy ($R\simeq1900$) will enable us to study correlations of polarization not just with color, but also with radio-loudness, BAL trough strength, and spectroscopic properties such as emission line strengths and emission line blueshifts (a possible orientation indicator for radio-quiet quasars; see Richards et al. 2002b).

We will pay careful attention to sample selection. We will restrict the redshift range to 1.7<z<4.2, where two semi-automated BAL trough measurement algorithms have been used to define the SDSS EDR BAL quasar sample (Tolea et al. 2002, Reichard et al. 2002). We will match the luminosity and redshift distributions of the BAL and non-BAL quasar samples, and measure polarimetry through filters approximating the same rest wavelength in all objects, to be sure that any differences in the samples' polarizations are due only to the presence or absence of BAL troughs. All our BAL quasars will be high ionization BAL quasars, since Smith et al. (personal communication) are obtaining polarimetry of a similarly sized sample of low ionization SDSS BAL quasars. Combining with that sample will be very interesting, but our survey will be more representative of the majority of BAL quasars (which are HiBALs).

This project will require 5 nights this period and 5 next period on the 3.6m.

8. Description of the proposed programme (continued)

B) Immediate Objective: To a uniform magnitude limit of $i = 19$, there are 139 BAL quasars in the areas of the SDSS EDR visible from La Silla (Reichard et al. 2002). Our sample will consist of 70 of those BAL quasars and an equal number of comparison non-BAL quasars. This period we will obtain polarization measurements with $\sigma_p \simeq 0.3\%$ or better for 35 BAL and 35 non-BAL quasars (an average of 28 minutes' exposure per object). Next period we will obtain an equal number of measurements to complete the survey. (The SDSS has equatorial regions at 10h<RA<15h and 23h<RA<4h.)

C) Telescope Justification: Our targets are faint enough to require a 4m-class telescope, but do not require VLT. EFOSC2 is the only polarization-capable instrument available on any southern hemisphere 4m-class telescope.

D) Observing Mode Justification (visitor or service): Only visitor mode is possible at the 3.6m.

E) Strategy for Data Reduction and Analysis: Both investigators have experience with the acquisition and reduction of polarimetric data, and Hutsemekers has extensive experience with polarization observations with EFOSC2.

REFERENCES

Appleton *et al.* 2002, ApJ, 566, 682
Berriman et al. 1990, ApJS, 74, 869
Furlanetto & Loeb 2001, ApJ, 556, 619
Goodrich 1997, ApJ, 474, 606
Hall *et al.* 2002a, ApJS, 141, 267
Hall *et al.* 2002b, ApJL, 575, L51
Hines 1994, Ph.D. Thesis, University of Texas
Hutsemekers, Lamy & Remy 1998, A&A, 340, 371
Hutsemekers & Lamy 2000, A&A, 358, 835
Reichard *et al.* 2002, submitted to AJ
Richards *et al.* 2002a, AJ, 123, 2945
Richards *et al.* 2002b, AJ, 124, 1
Richards *et al.* 2003, submitted to AJ
Schmidt & Green 1983, ApJ, 269, 352
Schmidt & Hines 1999, ApJ, 512, 125
Schneider *et al.* 2002, AJ, 123, 567
Smith *et al.* 2001, ApJL, 545, L19
Smith *et al.* 2002, ApJ, 569, 23
Tolea *et al.* 2002, ApJL, 578, L31
Wisotzki *et al.* 2000, A&A, 358, 77

8. Attachments (Figures)

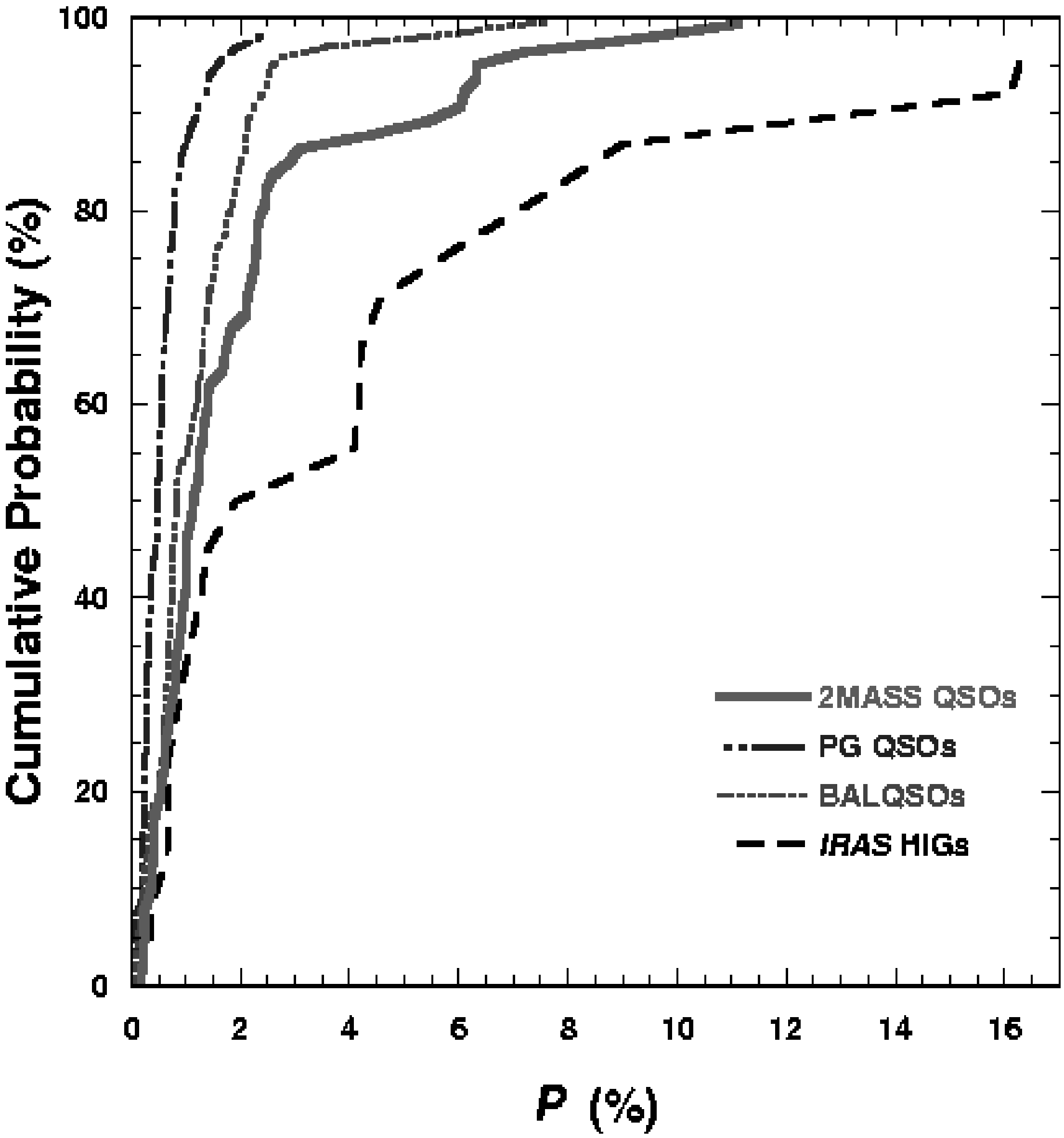
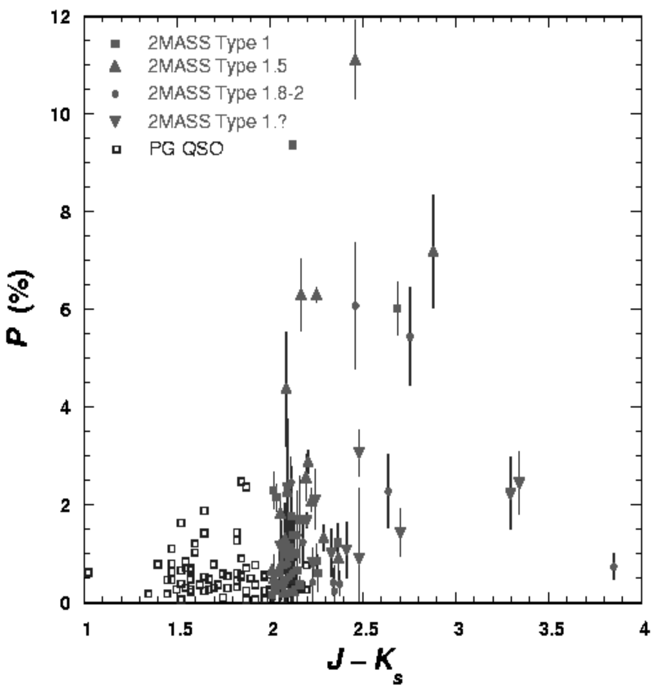
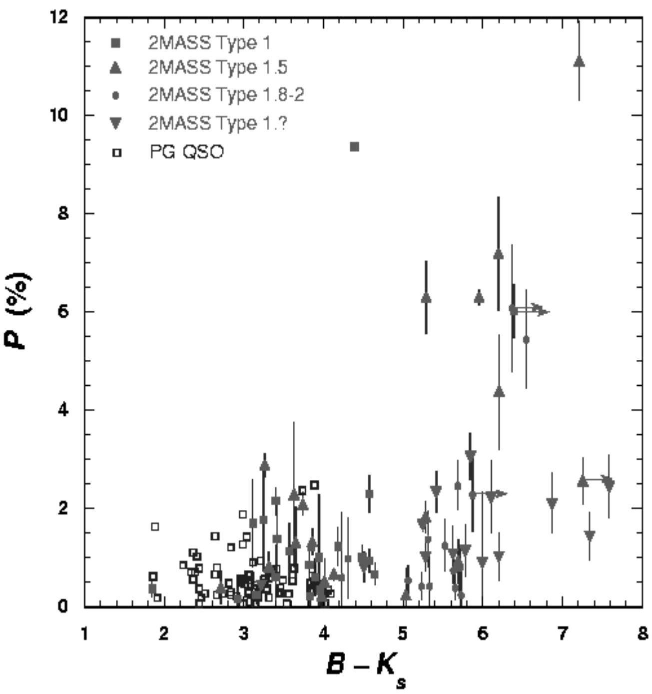


Fig. 1: The cumulative distributions of optical polarization [$P(\%)$] for the 2MASS, PG, BAL quasar, and *IRAS* quasar samples. The PG and BAL quasar histograms are indistinguishable if the BAL quasars are assumed to be reddened by 1 magnitude in the observed optical (Schmidt & Hines 1999). However, the existence of 2MASS and IRAS quasars with equally large polarizations suggests that this may be due to incompleteness in the PG sample rather than a true difference between the reddenings of BAL and non-BAL quasars. Data for the samples are from Smith et al. 2002 (2MASS, 70 objects); Berriman et al 1990 (PG; 75 objects); Hutsemekers, Lamy & Remy 1998, Schmidt & Hines 1999, and Hutsemekers & Lamy 2000 (BAL quasars; 85 objects); and Hines 1994 (*IRAS*; 19 objects).

8. Attachments (Figures)



Figs. 2-3 (Smith et al. 2002): polarization vs. J-K (top) and B-K (bottom) colors for 2MASS J-K>2 AGN compared to PG survey quasars; there is almost no color overlap. We propose a polarization study of a *uniformly selected* quasar sample (including BALs) from a *single* survey sensitive to blue *and* red quasars: the SDSS.



9. Justification of requested observing time and lunar phase

Lunar Phase Justification: Grey time up to 7 days from new moon is acceptable for these observations. Brighter objects can be done when the moon is up.

Time Justification: We have 70 targets at 23h<RA<4h and 70 targets at 10h<RA<15h. Since many quasars have polarizations of $\leq$1% (Fig. 1), our goal is polarization measurements with $\sigma_p \simeq 0.2\%$, sufficient to keep non-detections to a minimum. Hutsemeker has extensive polarimetric observing experience with EFOSC. Based on that experience, we calculate that with an average of 28 minutes' exposure per object we can obtain $\sigma_p \simeq 0.2\%$ for 50% of our $i < 19$ sample, with the remainder having $\sigma_p \leq 0.3\%$. Including 10 minutes' overhead per object, the full sample of 140 objects will require 10 nights. Thus we request five nights in April/May of this period, and will request five nights in November P72.

Calibration Request: Standard Calibration

10. Report on the last use of ESO facilities

69.A-0068 / P. Hall / The Reddening Effect of High Redshift Galaxies on Background QSOs

Telescope	Instrument	Obs. Dates	Completion (%)	Time lost (%)	Reason
1.5D	DFOSC	4 Sept 2002	0%	100%	weather
NTT	SUSI	8-9 Sept 2002	0%	100%	weather
NTT	SOFI	8-9 Sept 2002	0%	100%	weather

Current status of obtained data: paper-submitted

Remarks: The DFOSC time was completely clouded out, while the NTT time was competely nonphotometric and thus useless for the primary program. Nonetheless, backup spectroscopy obtained at the NTT has already resulted in the submission of a short ApJ Letter on the persistent Hα-emitting L dwarf 2MASS 1315-2649.

11. Applicant's publications related to the subject of this application during the past two years

- Duc & Hall *et al.* 2002, A&A, 389, L47: An Unusual Iron LoBAL Quasar Detected by ISOCAM
- Hall, P., *et al.* 2000, AJ, 120, 2220: Active Galactic Nuclei in the CNOC2 Field Galaxy Redshift Survey
- Hall, P., *et al.* 2001, in Mass Outflow from AGN: New Perspectives, eds. Crenshaw, Kraemer & George (astro-ph/0107182): Extreme Broad Absorption Line Quasars from the Sloan Digital Sky Survey
- Hall, P., *et al.* 2002, ApJS, 141, 267: Unusual Broad Absorption Line Quasars from the SDSS
- Hall & Hutsemekers *et al.* 2002, submitted: VLT+UVES Spectroscopy of Two Unusual BAL Quasars
- Hall *et al.* 2002, to be submitted: VLT Spectroscopy and Polarimetry of Three Unusual SDSS Quasars
- Hutsemekers & Lamy 2000, A&A, 358, 835: The optical polarization of radio-loud and radio-intermediate broad absorption line quasi-stellar objects
- Lamy & Hutsemekers 2000a, A&A, 356, L9: Spectropolarimetry of the iron low ionization broad absorption line quasar Q 0059-2735
- Lamy & Hutsemekers 2000b, A&AS, 142, 451: Optical polarization of 47 quasi-stellar objects: The data
- Menou, K., *et al.* [including Hall] 2001, ApJ, 561, 645: Broad Absorption Line Quasars in the Sloan Digital Sky Survey with VLA-FIRST Radio Detections
- Reichard, Richards, Schneider, Hall *et al.* 2002, AJ, submitted: A BAL Quasar Catalog in the SDSS EDR
- Richards, Hall *et al.* 2003, AJ, submitted: Red and Reddened Quasars in the SDSS
- Schneider, Richards, Fan, Hall, *et al.* 2002, AJ, 123, 567: The SDSS Quasar Catalog I. Early Data Release

12. List of targets proposed in this programme

Run	Target/Field	α	δ	Eq.	Mag.	Diam.	Additional info	Reference star
A	SDSS starting RA	08 00 00	+00 00 00	J2000			'Spring' strip	
A	SDSS ending RA	16 40 00	+00 00 00	J2000			'Spring' strip	

Target Notes: $\sim$70 BAL quasars are available in the 'Spring' SDSS EDR equatorial strip delimited above; we will choose 35 of them for our observations this period, along with 35 non-BAL comparison quasars, as discussed in the scientific justification.

13. Scheduling requirements

14. Instrument configuration

Telescope	Instrument	Run ID	Parameter	Value or list
3.6	EFOSC2	A	Polarimetry	$\lambda/2$ retarder plate