European Organisation for Astronomical Research in the Southern Hemisphere

OBSERVING PROGRAMMES OFFICE • Karl-Schwarzschild-Straße 2 • D-85748 Garching bei München • e-mail: opo@eso.org • Tel.: +49 89 320 06473

APPLICATION FOR OBSERVING TIME LARGE PROGRAMME PERIOD: **94A**

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

Category: **C–1**

ESO Diffuse Interstellar Bands Large Exploration Survey (EDIBLES)

2. Abstract / Total Time Requested

Total Amount of Time: 0 nights VM, 286.4 hours SM Total Number of Semesters: 4

The carriers of >400 broad interstellar absorption features, imprinted on stellar spectra, pose the oldest mystery in astronomical spectroscopy. Any identification of an individual or set of carriers of these diffuse interstellar bands (DIBs) will provide a unique tool to probe the organic content and physical conditions of the ISM in galaxies. We propose to undertake a large and systematic study of the physical and chemical parameters that influence the DIBs, allowing us to “reverse engineer” key molecular carrier properties. With EDIBLES we will determine (1) the chemical composition of DIB carriers by studying their relation to interstellar elemental abundances (depletion), (2) the relation between weak and strong diffuse bands through identifying DIB sequences, and (3) the physical-chemical parameters that influence the DIB properties from observed molecular transitions linked with PDR models. This requires a high-precision (S/N∼1000, R∼100 000) UV/VIS survey of 159 interstellar sightlines with well determined interstellar dust properties. This is achieved most efficiently with UVES-VLT in service/filler mode. EDIBLES will provide the input for comparison with dedicated laboratory programs, and has significant legacy value in terms of complementary stellar astrophysics studies. EDIBLES was ranked favourably in period 93, but was not scheduled due to technical reasons that are now resolved.

3.

Run	Period	Instrument	Time	Month	Moon	Seeing	Sky	Mode	Type
A	94	UVES	23.3h	any	n	n	THN	s	
B	94	UVES	48.3h	any	n	1.0	THN	s	
C	95	UVES	23.3h	any	n	n	THN	s	
D	95	UVES	48.3h	any	n	1.0	THN	s	
E	96	UVES	23.3h	any	n	n	THN	s	
F	96	UVES	48.3h	any	n	1.0	THN	s	
G	97	UVES	23.3h	any	n	n	THN	s	
H	97	UVES	48.3h	any	n	1.0	THN	s	

4. Principal Investigator:

Nick Cox, nick@ster.kuleuven.be, B, Instituut voor Sterrenkunde,Katholieke Universiteit Leuven

4a. Co-investigators:

J.	Cami	The University of Western Ontario,Department of Physics and Astronomy,CA
P.	Sarre	School of Physics and Astronomy,University of Nottingham,UK
M.	Spaans	Kapteyn Institute,University of Groningen,NL
R.	Lallement	Galaxies Etoiles Physique et Instrumentation,F
L.	Kaper	Pannekoek Institute,University of Amsterdam,NL
C.	Joblin	IRAP (Institut de Recherche en Astrophysique et Planetologie), UMR 5277,F

Following CoIs moved to the end of the document ...

5. Description of the proposed programme

A – Scientific Rationale:

The diffuse interstellar bands

The unknown identity of the carriers of the diffuse interstellar bands (DIBs) constitutes the longest standing spectroscopic mystery of modern astronomy. At present, >400 of these interstellar absorption features are recognized, superimposed on an otherwise nearly smooth interstellar extinction curve (Herbig 1995; Hobbs et al. 2008). Several examples are shown in Fig. 1. From observational work it is clear that for all Galactic and extra-galactic sightlines the strength of the strongest ∼20 of these features relates roughly linearly with the amount of gas and dust. It is striking that this relation has not been established for the remaining >380 bands, hence indicating a good mixing of the carrier with interstellar matter (Cox 2011). It is striking that this relation has not been established for the remaining >380 bands. A large scatter is observed in these relations and the relative strengths of several bands are known to vary as a function of radiation strength between different lines-of-sight (Vos et al. 2011). Whether or not there is a connection of DIB carriers and dust grains in terms of depletion onto grains or as carrier formation sites has not been determined yet. Studies of selected bands in a dozen sightlines reveal a complex substructure in the narrowest bands (Sarre et al. 1995, Ehrenfreund & Foing 1996) which show small variations with local temperature (Cami et al. 2004, Kazmierczak et al. 2010). In the last decade we have also firmly established that diffuse band carriers are universal; DIBs have been detected and mapped in the Magellanic Clouds (Cox et al. 2006, van Loon et al. 2013), in M31 and M33 (Cordiner et al. 2008, 2011) and beyond (Cox & Patat 2008, 2014). DIB carriers therefore constitute an important reservoir of organic material throughout the Universe. Identifying these carriers and understanding their properties must come from high-quality data in the nearby Galactic ISM. Undoubtedly, identification of a single species or set of DIB carriers will have far-reaching impact on our understanding of astrochemistry and heating/cooling of the ISM by large molecules. These topics are of major importance to star- and planet-formation in molecular clouds. Recent years have already seen increasing popularity in using DIBs – though often still naively – as probes of e.g. dust extinction and radiation field strength. However, without a properly calibrated (Galactic) reference sample and full assignments of DIBs to specific carriers, inaccuracies in interpretation will prevail. Recent progress, as demonstrated at the IAU Symposium 297 (Cami & Cox, 2014), in observational work, theoretical calculations, and laboratory astrophysics indicates that candidate carriers should primarily be sought among a large number of possible carbon-based "organic" molecules (Sarre 2006). It is clear that the ultimate confirmation must come from a direct comparison between astronomical and laboratory spectra over a broad wavelength range. The most straightforward approach is simply to acquire laboratory spectra - taken under astrophysically relevant conditions - of possible candidate carriers until an unambiguous match with the astronomical data, including verification at other (e.g. millimeter) wavelengths is found. This is a viable option only if most likely candidates can somehow be pre-selected out of the vast (billions!) collection of possible species. Hence it is necessary to systematically unravel the physical molecular and chemical properties of DIB carriers through analysis and modeling of DIB observations in terms of environmental conditions affecting their strengths/profiles, and molecular physics of candidate carriers.

Identifying key physical and chemical parameters of DIB carriers

In order to "reverse engineer" the DIB carrier identities we need to set tight constraints on their chemical and physical molecular properties. One aspect of our new approach is to put strong emphasis on the global properties of the ensemble of both weak and strong DIBs and variations therein as a function of depletion (patterns) and local physical conditions (Fig. 3). The latter can only be derived from accurate measurements of known atomic and molecular species that can be used to constrain detailed astrochemical models. Further evidence on the internal molecular processes will be obtained from spectral shifts or changes in band profiles as a consequence of different temperatures conditions or exposure to different flux and hardness of the UV radiation field. If some DIB profiles are found to be invariant this may indicate that the band width is determined by internal molecular processes such as life-time broadening. Substructure and variations are elusive attributes for weak DIBs but are key tools to relate those weak DIBs to the stronger DIBs; some of which reveal substructure while others do not. We will perform "DIB-sequencing", i.e. identify new groups of DIBs that behave coherently. Such groups have been identified for a few selected sightlines, but the lack of sufficiently accurate observations has thus far prohibited a broad systematic study of these bands. At the same time, the existence of molecular vibronic sequence or satellite bands is predicted from theoretical considerations of proposed carrier molecules, which will be tested observationally as part of this study. For instance, the asymmetry of many DIBs implies a change of geometry between the electronic states involved, which in turn implies the necessity of relatively long vibronic sequences, with many bands of comparable intensities and with near constant ratio between sightlines.

A number of studies have attempted to link the physical and chemical conditions of the ISM to the properties of the DIBs. However, most studies focus on a few strong bands in a moderate number ($\leq$100) of sightlines (Friedman et al. 2011, Vos et al. 2011), or on many DIBs in one or two sightlines (Hobbs et al. 2009). Most studies include only a (few) dozen sightlines and only a dozen or so interstellar lines/bands. Hence, progress in the field has been limited to the study of only a handful of the strongest DIBs due to high demands on the S/N, spectral resolution and stellar and telluric atmosphere modeling and the lack of large, uniform data sets.

5. Description of the proposed programme (continued)

We bring together a large part of the (European) community, including laboratory astrophysicists and theoretical chemists, to generate a focused and concerted effort to understand the nature (intrinsic 'molecular' characteristics) and behaviour (state variations due to external factors) of the DIB carriers. **Here we propose to undertake a large and systematic study of those physical and chemical parameters that influence the DIBs, and that will allow us to "reverse engineer" key molecular properties of their carriers.** Rather than a blind fishing-expedition, we define a survey with which we can determine

- **(1)** the chemical make up of DIB carriers by studying their relation to interstellar elemental abundances (depletion levels),
- **(2)** the relation between weak and strong diffuse bands through DIB-sequencing, and
- **(3)** the most effective (sets of) DIBs to measure different physical parameters of (extra)-Galactic environments.
- **(4)** the physical-chemical parameters that influence the DIB properties, in conjunction with detailed PDR modelling including extensive auxiliary line-of-sight (dust) data.

To pin-point these DIB carrier characteristics we propose the ESO Diffuse Interstellar Bands Large Exploration Survey (EDIBLES). This is a large homogeneous survey of UV/visible spectroscopic tracers across a broad spectral range, seen toward a broad variety of interstellar environments towards 159 stellar targets, at unprecedented high-precision and high-accuracy (S/N $\sim$ 1000, R $\sim$ 100 000). This can be achieved very efficiently with UVES at the VLT in service mode. Many of our targets are bright and well suited to be part of a filler programme (see Box. 9; time justification).

EDIBLES will have a high legacy value (Box 5.B). The final data products and measurements will establish a truly unique benchmark for scrutinizing future claims of carrier identifications, as a reference sample for direct comparison with high-precision laboratory gas phase spectra to confirm/disprove them as carriers for a specific DIB, or at the very least, to set firm upper limits of these astrophysically relevant molecules.

B – Immediate Objective:

In light of the lack of a complete, uniform sample of very high S/N and high-resolution spectra the immediate objective of our survey is to acquire a self-consistent set of observations from which we can extract:

1. Accurate column density measurements of the most important atomic and molecular species, necessary to derive depletion levels of metals, and infer and compute physical conditions using diffuse cloud models (e.g. Meudon PDR), across a broad spectral range (key transitions occur in the blue and red spectrum (the most important ones are: NaI $\lambda\lambda$3303, 5889; TiII λ3384; FeI $\lambda\lambda$3720, 3860; CN $\lambda\lambda$3874, 7906; CaII λ3933; CaI λ4226; CH$^+$ $\lambda\lambda$3958, 4232; CH $\lambda\lambda$3879, 4300; KI $\lambda\lambda$4044, 7698; C$_3$ λ4053; LiI λ6708, C$_2$ $\lambda\lambda$8753-8780). Complete spectral coverage and high-S/N are also important to place strong detection limits (i.e., abundance constraints) on specific molecular carriers for which laboratory spectra will become available in future. This requires two dichroic settings (Dic#1-346+564 and Dic#2-437+860; Fig. 2).
2. Accurate measurements of line profiles (asymmetries, wings, substructure) and variations thereof for the narrowest DIBs which requires a resolving power of $\geq$100 000, and hence narrow slit of $0.3''$.
3. Accurate measurements of inherently weak diffuse bands in single cloud sightlines. Typical values for E(B-V) range from 0.1–0.4 mag, which requires S/N$\sim$1000 to detect a significant fraction of weak DIBs. To detect $\sim$50 out of $\sim$400 DIBs with EW/E(B-V) $\geq$ 50 mÅ down to E(B-V) = 0.1 mag, the 3σ detection of features with FWHM $\sim$0.5 $-$ 1.0 requires a S/N of 1000 (Fig. 2).
4. Detection, measurement and cross-correlation of over 120 weak bands which requires a) broad spectral coverage from the near-UV/blue to the red and b) high S/N observations of 50-100 reddened (E(B-V)>0.4 mag) sightlines. For this part the sensitivity limit is 10 mÅ (i.e. 20 mÅ/E(B-V)). E.g. Fig. 4.

All the above measurements need to be attained for a statistically relevant, uniform survey sample that probes a wide range of interstellar environment parameters including visual extinction (A$_V$), total-to-selective extinction ratio (R$_V$), molecular hydrogen fraction f(H$_2$), dust continuum polarisation, and UV radiation field (Vos et al. 2011). This is essential to (a) trace depletion patterns from diffuse → translucent → dense clouds, (b) study the effect of shock processing, (c) probe the behaviour of DIBs with respect to grain properties, and (d) identify unusual DIB environments. For example, sightlines with extreme DIB ratios or very weak DIBs (Smith et al. 2013) or extreme deviations of DIB profiles (Dahlstrom et al. 2013) were previously missed due to insufficient S/N. To achieve these ambitious goals requires a long-term coherent observing strategy with a highly efficient well-characterized high-resolution spectrograph. These requirements are most easily met with an ESO Large Program on UVES at the VLT (we refer to Box 5.C for why we select UVES instead of HARPS).

Reported DIB data such as equivalent width, central depth, profile and substructure cannot be easily compared between surveys conducted so far due to differences in the procedures to normalize continua and measure the spectroscopic lines. Archival material comprises a heterogeneous mishmash of spectra with varying S/N, resolving power, and spectral coverage. EDIBLES will provide the most complete uniform - single instrument - spectroscopy of early-type (OBA) stars. The combination of very high S/N and high resolution spectra processed and analysed in a self-consistent uniform way, will provide a major leap forward in our understanding of the diffuse/translucent ISM.

5. Description of the proposed programme (continued)

Target selection: As explained above for the sample selection we require: (1) declination $< +30^o$; (2) visual magnitude < 8 mag; (3) O, B, or A spectral type; (4) the shape of extinction curve is known (either via R_V or λ_{max} polarisation); (5) visual extinction, A_V is known; After cross-matching, checking and pruning extinction / polarisation curve catalogues (Fitzpatrick 2007, Valencic et al. 2004, Whittet et al. 1992, Weitenbeck 2008) we have a preliminary sample of 457 potential targets. Given that f(H_2) (the H-H_2 self-shielding transition) depends non-linearly on A_V, we need many sightlines probing $A_V \sim 1 - 3$ mag and less, in small increments ΔA_V. The dust grain properties and attenuation of UV photons (important to photo-chemistry) are constrained with R_V. The final selection is motivated by the requirement to evenly sample different environments based on A_V (0 to 6 mag) and R_V (2.0 to 6.0) and include special environments (based on R_V). The R_V distribution is strongly peaked at 3.3±0.6 (84%). The bins at more than 1 standard deviation of the mean are poorly populated. Only 27 sightlines have $1.7 < R_V < 2.7$ and 26 have $4.5 < R_V < 7$. Out of 394 targets with median R_V, preference is given to the 42 targets for which measurements of the molecular hydrogen fraction (f_{H_2}) are available. This is very useful to constrain the PDR models. However, these 42 sightlines sample primarily A_V = 0.5-1.5 mag. We add the brightest 45 targets (out of 394) with nominal R_V and A_V = 1.5 - 5.0 to ensure a sufficient sampling of at least 1 targets per A_V bin of 0.1 mag. We noted this sample is primarily lacking sightlines with $f(H_2) < 0.2$ and > 0.5, hence we add 19 targets to properly sample this important parameter. With 159 targets we can sample A_V and R_V evenly over a large range - including a good sampling of f(H_2); For a general overview of the survey sample see Fig. 5. In addition the sample is optimized in terms of auxiliary data (Jenkins 2009). This sample corresponds to a total time request of 286.6 hours (see Box 9).

Processing and analysis strategy: Specific involvement in tasks of team members is given in Box 6. In addition to the standard UVES data processing steps we will apply additional processing steps including automated continuum normalisation (high-frequency filter, sigma-clipping, smoothing); barycentric velocity correction and rebinning to a common wavelength grid; least-squares fitting of atmospheric model transmission spectra (e.g. with TAPAS or MOLECFIT; Bertaux et al. 2012, Kaush et al. 2014) by experts on the EDIBLES team; weighted average spectra for each line-of-sight. Stellar parameters ($T_{\rm eff}$ and log(g); spectral type classification) will be derived from the average high-S/N telluric corrected spectra by stellar spectroscopy experts on the EDIBLES team . Subsequently, DIB features and their key properties (width, strength, position) will be extracted using appropriate atmospheric templates. Note that the majority of the stellar sample are fast rotators with weak metal lines making detection of interstellar features relatively easy. The last data analysis step is the retrieval of column density profiles and velocity component information for known interstellar species using VAPID/VPFIT software packages. At this point we will have the necessary input for the "forward" modelling (reverse engineering) method, as well as for the exhaustive statistical analysis tools, such as principal component analysis. Many steps in the process are inter-related and several iterative steps may be necessary.

Legacy value: EDIBLES will provide a significant legacy value to the ESO science archive. It will be an important reference database for direct comparisons of laboratory gas-phase spectra of DIB carrier candidates or other molecules that will be obtained by laboratory astrophysicists in our team (Linnartz at Leiden University, Salama at NASA Ames, and Joblin at IRAP/CNRS). We foresee additional science exploitation, especially in view of the updated distances becoming available from Gaia, in topics of 3D-ISM maps (co-I Lallement), small-scale structure of the ISM using close binaries, interstellar isotopic ratios from ^{12}CH/^{13}CH, stellar evolution and mass-loss studies. The wider community concerned with e.g. modelling of diffuse cloud gas-phase and dust chemistry will also benefit from measured atomic and molecular column densities and abundances.

EDIBLES will also be essential to interpret results that come from larger generic surveys (such as RAVE, Gaia-ESO, SDSS-III (APOGEE), Gaia spectroscopic survey) that are ongoing, but operate at either inferior resolution, lower signal-to-noise and/or restricted spectral coverage. These surveys focus primarily on stellar astrophysics and kinematics, but it has been realized that it is also possible to extract diffuse band measurements from these huge datasets, and construct 2D/3D ISM maps on scales of several degrees (e.g. Chen et al. 2013).

C – Telescope Justification: UVES at the VLT is the ideal European facility to execute in a very efficient way EDIBLES, the ESO diffuse interstellar bands large exploration survey. Although for the brightest 29 targets ($V \leq 4$ mag - perfect for a filler status) it is feasible to attain sufficiently high-S/N observations with smaller facilities, we note that even the most promising alternative, HARPS at the ESO-3.6m telescope, has several major disadvantages: (a) factor ∼4 loss in efficiency and a practical limitation to $V \leq 6$ mag (3600s exposure HARPS versus 900s UVES) an efficiency reduction which is even worse when using the UVES image slicer); (b) less efficient scheduling due to restriction to visitor mode; (c) inaccessibility of important wavelength ranges covering diagnostic species in the near-UV from 3000–3900 Å (e.g. Na I, Ti II, Fe I, CN) and near-infrared from 7000-10500 Å (e.g. K I, C_2).

D – Observing Mode Justification (visitor or service): We have chosen a observing strategy using standard dichroic settings which will allow for the most efficient scheduling of the programme in either service and/or visitor mode. Note that separate runs (A, C, E, G) are created for the "filler" targets that are suitable to be observed under poor(er) weather conditions and during twilight.

5. Attachments (Figures)

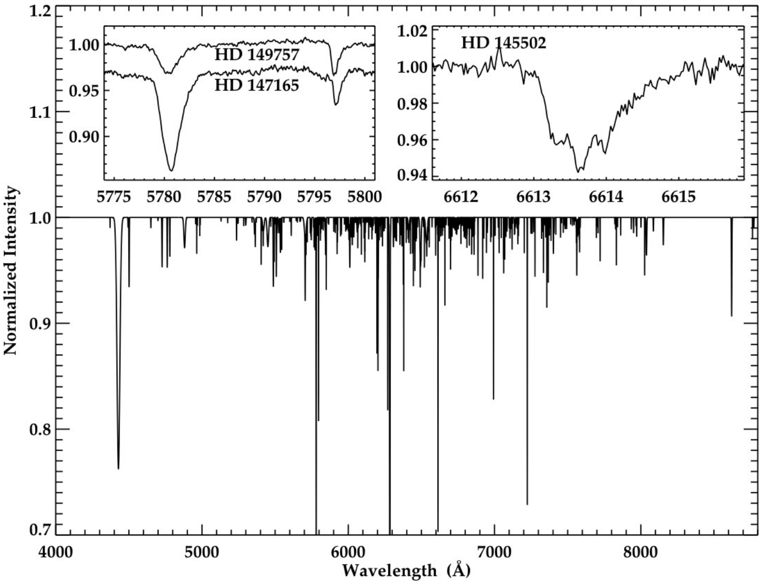

Fig. 1: Synthesized spectrum of DIBs observed towards BD+63 1964 (bottom panel). Top right panel: Detailed profile of 6614 Å DIB. Top left panel: Large variations in DIB strengths relative to each other.

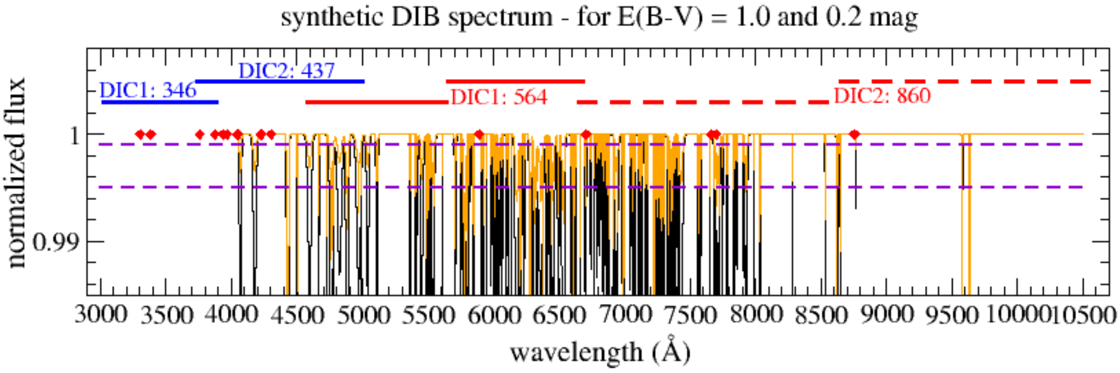

Fig. 2: Synthetic average DIB spectrum scaled to E(B-V) of 1.0 mag (black) and 0.2 mag (orange). Red diamonds indicate locations of atomic and diatomic interstellar species. The dashed horizontal lines indicate the cut-off levels at 0.5 and 0.1% of the continuum. S/N ∼ 1000 is required for accurate measurements for low reddening sightlines (orange). Higher reddening sightlines provides access to weaker bands (black). The bars above the spectrum show the spectral coverage for the indicated dichroic settings. Note that there are a few unavoidable gaps with this setup. We miss two very weak DIBs in the red detector gap for Dic#1-564 (5620-5640 Å) and the 8621 Å DIB in the red detector gap for Dic#2-860 (8543-8646 Å).

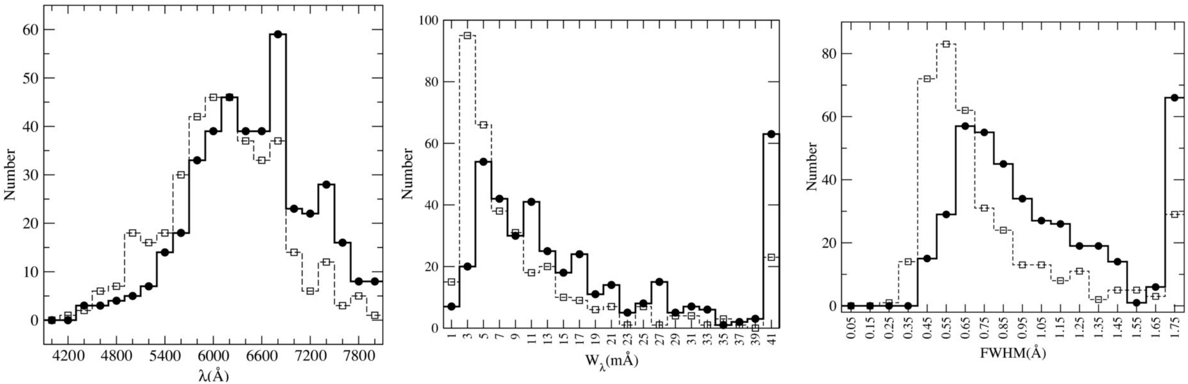

Fig. 3: Histograms of the number of DIBs versus wavelength (left), equivalent width (middle) and FWHM (right) for two canonical DIB sightlines, HD183143 and HD204827 (Hobbs et al. 2008).

5. Attachments (Figures)

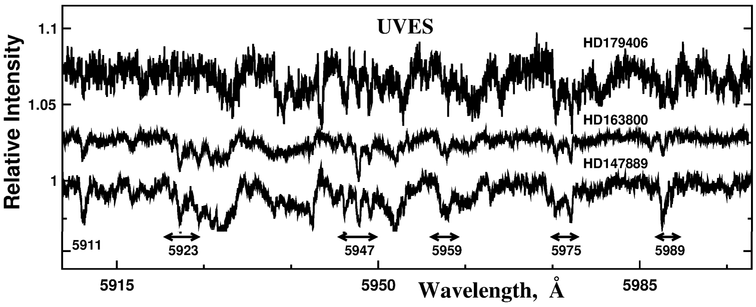

Fig. 4: Sequence of weak DIBs in range 5910 – 6020 Å (Bondar & Krelowski 2014).

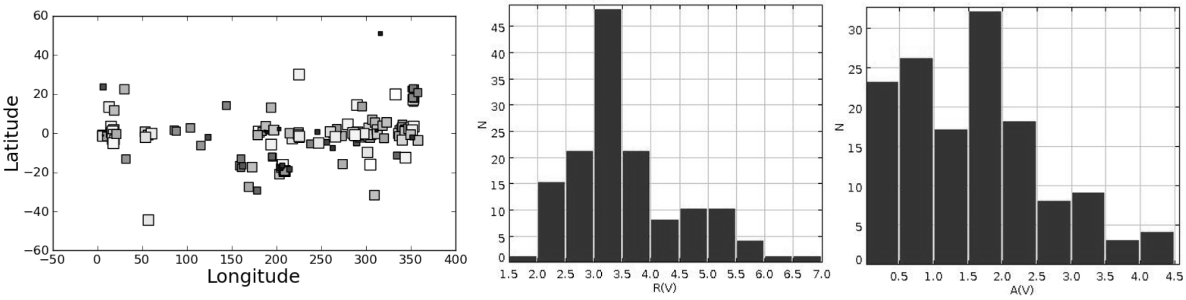

Fig. 5: EDIBLES overview. Left: Sky distribution. Shade/size indicate relative brightness. Middle and right panels: Histogram distribution of R_V and A_V.

Table 1: Results from the UVES Exposure Time Calculator. Top rows: Filler. Bottom rows: Regular. Exposure times are listed for B since these set primarily the S/N requirements (due to reddening the targets are up to several magnitudes brighter in V). S/N (blue) for quoted B, and S/N (red) for V=B-1 mag. The last two columns indicate the number of targets and the required observing time (including overheads). See Box 9 for details. Note that for the bright targets the exposure time is split in 3 to 4 short OBs, and hence have large overhead. Total time is per dichroic setting.

B / V	exposure time (sec)	S/N (blue)	S/N (red)	Nr. of Targets	Time Requested (h)
≤5 / ≤4	600 (4x150)	100-600	1200-1400	29	18.3
6 / 5	900 (3x300)	100-500	1000-1200	16	8.8
7 / 6	1800 (6x300)	200-800	1300-1500	23	19.6
8 / 7	2400 (6x400)	150-550	1000-1100	42	37.8
9 / 8	3600 (4x900)	100-450	800-900	33	39.6
10 / 9	3600 (2x1800)	50-300	500-550	16	19.2
				159	143.3

References: Bertaux et al. 2012, presented at ATA workshop; Bondar & Krelowski 2014, Proceedings IAU 297; Cami et al. 2004, ApJ, 611, 113; Cami & Cox, (eds.), 2013, IAU 297 Proceedings; Chen et al. 2013, A&A, 550, A62; Cordiner et al. 2008, A&A Letters, 492, 5; Cordiner et al. 2011, ApJ, 726, 39; Cox 2011, EAS Publications Series, Volume 46, 349; Cox 2011, Proceedings IAU 280; Cox & Patat 2008, A&A Letters, 485, 9; Cox & Patat 2014, A&A, in press; Cox et al. 2006, A&A, 447, 991; Dahlstrom et al. 2013, ApJ, 773, 41; Ehrenfreund & Foing 1996, A&A Letters, 307, 25; FitzPatrick et al. 2007, ApJ, 663, 320; Hobbs et al. 2008, ApJ, 680, 1256; Jenkins 2009, ApJ, 700, 1299; Kaush, Noll, Jones, et al. 2014, ADASS XXIII, ASP Conf. Series; Kazmierczak et al. 2010, MNRAS, 408, 1590; Roueff, et al. 2014, IAU Symposium 297 Sarre et al. 1995, MNRAS Letters, 277, 41; Sarre 2006, Journal of molecular spectroscopy, 238, 1; Smith et al. 2013, MNRAS 429, 939; Valencic et al. 2004, ApJ, 616, 912; van Loon et al. 2013, A&A, 550, A108; Vos et al. 2011, A&A, 533, A129; Weitenbeck 2008, ACTA Astronomica, 58, 433; Whittet et al. 1992, ApJ, 386, 562.

6. Experience of the applicants with telescopes, instruments and data reduction

The EDIBLES team has extensive experience with observing at large facilities such as the VLT, Keck, CFHT, AAT, Gemini, and SALT as well as numerous smaller facilities. If necessary, team members are available and committed to perform observing runs in this program, and where possible with research students under their supervision.

Team members have in-depth knowledge of the UVES instruments (e.g. former UVES instrument scientists Kaper and Smoker as well as the UVES/FLAMES pipeline developer Mulas) while others are experts in performing calibration and data processing (Cox, Bhatt, Cordiner, van Loon), including correction for telluric lines with TAPAS / MOLECFIT (Lallement, Smoker).

Advanced data analysis tools have been previously developed by the different team members. This includes, for example, synthetic stellar atmospheres of hot stars (Evans, De Koter, Monreal-Ibero) and cool stars (Lallement), but also spectroscopic signal-processing (Royer), interstellar line profile modelling (Cordiner, Smith), spatial mapping routines (van Loon), blind-signal decomposition techniques (Berné) and principal component analysis (Cami).

Furthermore, this observational and feature extraction expertise is supported by theoretical modelling of diffuse clouds (Spaans, Cox, Roueff, Bourlot) and rotational contours of electronic transitions (Sarre, Marshall, Mulas, Cami, Foing) as well as laboratory work providing astrophysical relevant reference samples (Linnartz, Salama, Joblin). Hence there is strong interest in further exploration and exploitation of the data-set beyond the primary goals of the EDIBLES Large Programme!

The team's expertise and experience with publishing in the field of the interstellar medium and the diffuse bands is also evident from the list of recent publications. We are well equipped to process and exploit this unique challenging data-set in a proper manner and in timely fashion.

7. Resources available to the team, such as: computing facilities, research assistants, etc.

EDIBLES goes beyond being an observational programme. We will implement - in part via coordinated European network activities - comprehensive physico-chemical modelling of the targeted interstellar clouds, as well as supported from laboratory experiments - driven partly by results provided by EDIBLES itself. Available resources in addition to the personal research time of the PI and co-Is:

Pending approval of this Large Programme dedicated PhD positions are expected to be financed, through national programs, at Keele University, UK (van Loon), University of Amsterdam, NL (Kaper), University of Groningen, NL (Spaans), as well as post-docs through EU Marie Curie actions and other personal fellowships (e.g. ESA/ESTEC (Foing), KU Leuven (Cox)). Several co-Is have close contact with students enrolled in MSc Astronomy & Astrophysics degrees who can take part in this study through master (thesis) research projects hence providing also training in areas of analysis of high-resolution echelle spectroscopy and stellar and interstellar medium research.

As indicated in the Box 6, developers of the Meudon PDR code are intimately involved with EDIBLES allowing for optimal code custimization as well as training for young researchers.

Extensive computational resources (32-cores 64bit cluster for parallel computing) are available at KU Leuven, the PI institute. Local resources (KU Leuven) are available to set up dedicated web-pages that will be used to present and promote EDIBLES, including social media (blogs), and which will contain necessary details on observing strategy, data processing, and data analysis as well as the final science products (reduced and normalized spectra, stellar spectral classification, primary and secondary derivatives of the data (e.g., line strengths and abundances, resp.). The final processed "science verified" co-added, concatenated, and normalised spectra will be deposited into the ESO science archive. Extracted quantities and measured stellar and interstellar parameters for all stars and sightlines will be made available to the community - in addition to our dedicated project web-page - via catalogue services including CDS/ViZier.

8. Special remarks:

This is a re-submission of 193.C-0883. EDIBLES has been improved following OPC comments. In particular, a new observing strategy has been devised that (1) relies on standard UVES settings suitable for execution in service mode, and (2) differentiates between bright "filler" (no constraints) targets and fainter "normal" service mode targets (moderate constraints). Observing blocks are kept relatively short (<30 min) and are duplicated simply to achieve the required S/N. In addition, we have addressed the concern for a "fishing" experiment and discuss in more detail the hypotheses that will be tested with EDIBLES. We also acknowledge the need for further UV and near-infrared observations of (extra) galactic interstellar environments. Coordinated efforts are ongoing to obtain UV spectra below 3000 Å. In addition, near-infrared DIB surveys of selected NIR DIBs are under way with VLT/CRIRES (PI: Smoker) and Gemini/GNIRS (PI: Cami).

9. Justification of requested observing time and observing conditions

Lunar Phase Justification: There are no lunar phase constraints.

Time Justification: (including seeing overhead)

Following OPC-P93 comments we have implemented a standard instrument setup to make the program more flexible and suitable for service mode / filler observations. As explained in Box 5 we require a S/N of 1000 for the low-reddened lines-of-sight, reducing to S/N of 500 for sightlines with E(B-V) $\geq$ 1 mag. Slit width is $0.3''$ (highest resolving power). The Table on page 6 (Box 5) lists the total exposure times, S/N (in B and V), number of targets and total observing time for different V-band magnitude bins. Note that for the bright "filler" targets we adopt a high airmass of 2.5, and poor seeing of $2''$. For the fainter, regular targets we adopt an airmass of 1.6 and seeing of $1.''$.

Per dichroic setting we require for the entire sample of 159 targets about 143.3 hours (including overhead). Hence, we request 286.6 hours ($\sim$32 nights) for EDIBLES. In our observing strategy we have divided both "filler" (93.4 hours; runs A,C,E,G) and "regular" (193.2 hours; runs B,D,F,H) service mode targets over the maximum number of allowed periods to limit demand to 71.65 hours (or $\sim$7-9 nights) of UVES time per period. We note that filler programs of 50 hours or more have previously been completed in only 1 or 2 periods. Hence even in the event of excellent weather conditions in the next four periods we understand it is not unlikely to complete the full survey. We remark that it is possible to include also fainter stars (up to V = 7 mag) in the filler runs, but this would incur additional cost in observing time (up to 40 hours or more) due to increased overhead (OB splitting) and longer exposure times (to account for lower efficiency in filler conditions). We kindly request extra (day-time) flat-fields are obtained on a best-effort basis (in addition to the night time flats included in with the science observing blocks).

9a. Calibration Request:

Standard Calibration

10. Report on the use of ESO facilities during the last 2 years

The analysis of NIR DIBs observed at high resolution with CRIRES (P91; PI: Cox) is ongoing.
Smoker et al; 091.C-0655(A), CRIRES NIRDIBS study (50h). The last data were taken in September 2013. Data have been reduced and DIBs detected in half the sightlines. Pending is the removal of the telluric lines and analysis. Smoker & de Witt.; 092.C-0218(A); UVES: "HyaSiNth - a high resolution, high signal to noise optical spectrum of the interstellar medium" (50h). Data obtained. Smoker et al.; 093.C-0480(A); CRIRES: "TIRDIB explodes - small scale structure", Data not yet taken.

11. Applicant's publications related to the subject of this application during the last 2 years

Bertaux J.L., **Lallement R.**,et al. "TAPAS: atmospheric transmission computation for astronomy", Atmospheric Spectroscopy Application workshop, France (2012)
Cami, J. & Cox, N. (Eds.), Proceedings IAU Symposium 297, "The Diffuse Interstellar Bands" (2014)
Chen, H.-C., **Lallement, R.**, Babusiaux, C., "Extracting interstellar diffuse absorption bands from cool star spectra.", A&A, 550, A62 (2013)
Cordiner, M. et al. "Small-scale Structure of the Interstellar Medium toward ρ Oph Stars: Diffuse Band Observations", ApJ Lett., 764, L10 (2013)
Cox, N., & Patat, F., "Dense molecular clouds in the SN 2008fp host galaxy", A&A, in press (2014)
Cox, N., Cami, J., Ehrenfreund, E., Foing, B., Kaper, L., Ochsendorf, B., Van Hooff, S., Salama, F., "VLT/X-shooter survey of near-infrared diffuse interstellar bands" A&A, in press (2014)
Lallement, R. et al. "3D maps of the local ISM from inversion of individual color excess measurements", A&A, arXiv:1309.6100 (2013)
Montillaud, J., **Joblin, C.**, Toublanc, D., "Evolution of PAHs in photodissociation regions. Hydrogenation and charge states", A&A, 552, A15 (2013)
Puspitarini, L.; Lallement, R.; Chen, H.-C. "Automated measurements of diffuse interstellar bands in early-type star spectra", A&A, 555, A25 (2013)
Roueff, E. et al. "Diffuse Cloud Models : Successes and Challenges", IAU Symposium 297 (2014) **Smith K. T., et al.** "Small-scale structure in the ISM: time-varying IS absorption towards κ Vel", MNRAS 429, 939 (2013)
Smoker J., et al., "Early-type stars observed in the ESO UVES Paranal Observatory Project - IV. Studies of CN, CH$^+$, and CN in the ISM", **Van Loon, J.**, et al. 2013: "The VLT-FLAMES Tarantula Survey. IX. The interstellar medium seen through diffuse interstellar bands and neutral sodium", A&A, 550, A108 (2013)
Vos, D., **Cox, N., Kaper, L., Spaans, M., Ehrenfreund, P.**, "Diffuse interstellar bands in Upper Scorpius: probing variations in the DIB spectrum due to changing environmental conditions", A&A, 533, A129 (2011)
Walsh, A.J., Zhao, D., Ubachs, W., **Linnartz, H.**, "Optomechanical shutter modulated broad-band cavity-enhanced absorption spectroscopy of molecular transients of astrophysical interest", J. Phys. Chem. A, in press (2013)

12. List of targets proposed in this programme

Run	Target/Field	α(J2000)	δ(J2000)	ToT	Mag.	Diam.	Additional info	Reference star
A	gamma Cas	00:56:42.53	+60:43:00.3	0.6	2.39			
A	HD 23016	03:42:18.95	+19:42:00.9	0.9	5.67			
A	40 Per	03:42:22.65	+33:57:54.1	0.6	4.98			
A	omicron Per	03:44:19.13	+32:17:17.7	0.6	3.86			
A	zeta Per	03:54:07.92	+31:53:01.1	0.6	2.88			
A	xi Per	03:58:57.90	+35:47:27.7	0.6	4.04			
A	HD 25204	04:00:40.82	+12:29:25.3	0.6	3.47			
A	alpha Cam	04:54:03.01	+66:20:33.6	0.6	4.3			
A	delta Ori A	05:32:00.40	-00:17:56.7	0.6	2.23			
A	HD 36695	05:33:31.45	-01:09:21.9	0.9	5.34			
A	HD 36822	05:34:49.24	+09:29:22.5	0.6	4.42			
A	HD 36861	05:35:08.28	+09:56:03.0	0.6	3.39			
A	HD 37022	05:35:16.46	-05:23:23.2	0.9	5.13			
A	P 1993	05:35:22.90	-05:24:57.8	0.9	5.07			
A	epsilon Ori	05:36:12.81	-01:12:06.9	0.6	1.7			
A	HD 37367	05:39:18.31	+29:12:54.8	0.9	5.95			
A	zeta Ori A	05:40:45.53	-01:56:33.5	0.6	1.7			
A	kappa Ori	05:47:45.39	-09:40:10.6	0.6	2.05			
A	HD 40111	05:57:59.66	+25:57:14.1	0.6	4.83			
A	HD 251204	06:05:05.67	+23:23:38.5	0.6	0.28			
A	HD 252325	06:09:00.31	+20:38:25.9	0.6	0.79			
A	Walker 67	06:40:37.25	+09:47:29.7	0.6	0.8			
A	HD 57061	07:18:42.49	-24:57:15.8	0.6	4.39			
A	CD-28 5205	07:58:42.94	-28:26:19.8	0.6	1.16			
A	HD 66194	07:58:50.55	-60:49:28.1	0.9	5.82			
A	LS 908	07:59:12.05	-28:34:04.3	0.6	1.59			
A	HD 66811	08:03:35.05	-40:00:11.3	0.6	2.24			
A	gamma2 Vel	08:09:31.95	-47:20:11.7	0.6	1.81			
A	HD 79186	09:11:04.40	-44:52:04.4	0.9	5.04			
A	HD 80558	09:18:42.36	-51:33:38.3	0.9	5.88			
A	HD 93030	10:42:57.40	-64:23:40.0	0.6	2.76			
A	HD 105416	12:08:14.71	-48:41:33.0	0.9	5.34			
B	HD 27778	04:23:59.76	+24:18:03.6	0.9	6.36			
B	HD 34748	05:19:35.28	-01:24:42.8	0.9	6.31			
B	HD 36982	05:35:09.84	-05:27:53.3	1.2	8.47			

Following targets moved to the end of the document ...

Target Notes: Targets are split (at RA = 12:30h) initially over Period 94 (A,B) and 95 (C,D). Placeholders are given at the end of the target list for runs in periods 96 (E,F) and 97 (G, H).

12a. ESO Archive - Are the data requested by this proposal in the ESO Archive (http://archive.eso.org)? If so, explain the need for new data.

A cross-match with the ESO Archive gives 32 targets in common with UVES. According to our analysis, based on V-band magnitude and exposure time, only a handful have sufficient S/N for our purposes, while there instrument set up in terms of spectral coverage (dichroic settings) and resolution (slit width) are not consistent with our survey. The survey sample is complementary to other Large Programmes such as the ESO-Gaia survey. In addition CRIRES observations of selected NIR DIBs are available for 44 targets (Program: 091.C-0655(A); Smoker (PI).

12b. GTO/Public Survey Duplications:

We have cross-checked our target list with the ESO archive observation log of the ESO-Gaia spectroscopic public survey. We found no duplicates. In any case the spectral coverage, spectral resolution and continuum sensitivity of the ESO-Gaia survey are not adequate for the science goals we address with this Large Programme.

13. Scheduling requirements

14. Instrument configuration

Period	Instrument	Run ID	Parameter	Value or list
94	UVES	A	DIC-1	Standard setting: 346+564
94	UVES	B	DIC-1	Standard setting: 346+564
95	UVES	C	DIC-1	Standard setting: 346+564
95	UVES	D	DIC-1	Standard setting: 346+564
96	UVES	E	DIC-1	Standard setting: 346+564
96	UVES	F	DIC-1	Standard setting: 346+564
97	UVES	G	DIC-1	Standard setting: 346+564
97	UVES	H	DIC-1	Standard setting: 346+564
94	UVES	A	DIC-2	Standard setting: 437+860
94	UVES	B	DIC-2	Standard setting: 437+860
95	UVES	C	DIC-2	Standard setting: 437+860
95	UVES	D	DIC-2	Standard setting: 437+860
96	UVES	E	DIC-2	Standard setting: 437+860
96	UVES	F	DIC-2	Standard setting: 437+860
97	UVES	G	DIC-2	Standard setting: 437+860
97	UVES	H	DIC-2	Standard setting: 437+860

4b. Co-investigators:

…continued from Box 4a.

H.	Linnartz	Sterrewacht,University of Leiden,NL
P.	Royer	Instituut voor Sterrenkunde,Katholieke Universiteit Leuven,B
K.	Smith	Other,UK
G.	Mulas	INAF - Osservatorio Astronomico di Cagliari,I
O.	Berne	IRAP (Institut de Recherche en Astrophysique et Planetologie), UMR 5277,F
J.	Smoker	ESO Office Santiago,ESO
A.	de Koter	Pannekoek Institute,University of Amsterdam,NL
B.	Foing	Vrije Universiteit Amsterdam,Faculty of Sciences,Division of Physics & Astronomy,NL
P.	Ehrenfreund	Other,NL
C.	Evans	UK Astronomy Technology Centre, Royal Observatory, Edinburgh,UK
C.	Marshall	School of Physics and Astronomy,University of Nottingham,UK
A.	Monreal-Ibero	Galaxies Etoiles Physique et Instrumentation,F
L.	Puspitarini	Galaxies Etoiles Physique et Instrumentation,F
F.	Lepetit	Laboratoire d'Etude du Rayonnement et de la Matiere en Astrophysique,F
E.	Roueff	Laboratoire d'Etude du Rayonnement et de la Matiere en Astrophysique,F
E.	Bron	Laboratoire d'Etude du Rayonnement et de la Matiere en Astrophysique,F
F.	Salama	NASA/Ames Research Center,US
J.	van Loon	Astrophysics Group,School of Physics and Geographical Sciences,Lennard-Jones Laboratories,Keele University,UK
M.	Cordiner	NASA/GSFC,US
N.	Bhatt	The University of Western Ontario,Department of Physics and Astronomy,CA

12c. List of targets proposed in this programme

…continued from box 12.

Run	Target/Field	α(J2000)	δ(J2000)	ToT	Mag.	Diam.	Additional info	Reference star
B	HD 37020	05:35:15.82	-05:23:14.3	0.9	6.73			
B	P 1863	05:35:16.07	-05:23:07.3	1.2	7.96			
B	P 1889	05:35:17.20	-05:23:15.6	0.9	6.7			
B	HD 37040	05:35:31.08	-04:21:50.6	0.9	6.31			
B	HD 37061	05:35:31.37	-05:16:02.6	0.9	6.83			
B	HD 37776	05:40:56.37	-01:30:25.8	0.9	6.98			
B	HD 37903	05:41:38.39	-02:15:32.5	1.2	7.83			
B	HD 38087	05:43:00.57	-02:18:45.4	1.2	8.3			
B	HD 38708	05:48:53.65	+29:08:10.0	1.2	8.22			
B	HD 39680	05:54:44.74	+13:51:16.9	1.2	7.99			
B	HD 43384	06:16:58.71	+23:44:27.3	0.9	6.26			
B	HD 45314	06:27:15.77	+14:53:21.1	0.9	6.64			
B	HD 49787	06:49:55.52	-05:30:47.5	1.2	7.48			
B	HD 50820	06:54:42.04	-01:45:23.4	0.9	6.21			
B	HD 53257	07:05:18.37	+22:38:14.9	0.9	6.02			
B	HD 53975	07:06:35.98	-12:23:38.0	0.9	6.47			
B	HD 54439	07:08:23.20	-11:51:08.6	1.2	7.69			
B	HD 54662	07:09:20.26	-10:20:47.8	0.9	6.21			
B	HD 55879	07:14:28.25	-10:18:58.5	0.9	6.02			
B	HD 61827	07:39:49.34	-32:34:42.2	1.2	7.65			
B	HD 73882	08:39:09.54	-40:25:09.3	1.2	7.22			
B	HD 75309	08:47:27.96	-46:27:04.0	1.2	7.85			
B	HD 75860	08:50:53.24	-43:45:05.4	1.2	7.57			
B	HD 76868	08:58:59.33	+03:39:22.0	1.2	7.98			
B	HD 89137	10:15:40.08	-51:15:24.1	1.2	7.98			
B	HD 91824	10:34:46.63	-58:09:22.0	1.2	8.18			
B	HD 93160	10:44:07.27	-59:34:30.6	1.2	7.88			
B	HD 93205	10:44:33.74	-59:44:15.5	1.2	7.75			
B	HD 93222	10:44:36.24	-60:05:29.0	1.2	8.1			
B	HD 303308	10:45:05.85	-59:40:06.4	1.2	8.16			
B	HD 93632	10:47:12.48	-60:05:49.9	1.2	8.31			
B	HD 93843	10:48:37.78	-60:13:25.5	1.2	7.33			
B	HD 94493	10:53:15.10	-60:48:53.2	1.2	7.27			
B	HD 96715	11:07:32.81	-59:57:48.7	1.2	8.25			
B	HD 97484	11:12:04.51	-61:05:42.9	1.2	8.36			
B	HD 99953	11:29:15.14	-63:33:14.2	0.9	6.5			
B	HD 101065	11:37:37.04	-46:42:34.9	1.2	8.03			
B	HD 103779	11:56:57.55	-63:14:56.7	1.2	7.21			
B	HD 104705	12:03:23.91	-62:41:45.8	1.2	7.79			
C	CPD-63 2495	13:02:47.65	-63:50:08.7	0.6	0.05			
C	HD 113904	13:08:07.15	-65:18:21.7	0.9	5.5			
C	alpha Vir	13:25:11.58	-11:09:40.8	0.6	1.04			
C	beta Cen	14:03:49.41	-60:22:22.9	0.6	0.6			
C	HD 135591	15:18:49.14	-60:29:46.8	0.9	5.49			
C	HD 143275	16:00:20.01	-22:37:18.2	0.6	2.31			
C	HD144470	16:06:48.42	-20:40:09.1	0.6	3.95			
C	HD 145502	16:11:59.73	-19:27:38.6	0.6	4.0			
C	Omicron Sco	16:20:38.21	-24:10:09.8	0.6	4.55			
C	HD147165	16:21:11.32	-25:35:34.1	0.6	2.88			
C	HD147933	16:25:35.10	-23:26:48.7	0.6	4.59			

Following targets moved to the next page...

12c. List of targets proposed in this programme

…continued from previous page.

Run	Target/Field	α(J2000)	δ(J2000)	ToT	Mag.	Diam.	Additional info	Reference star
C	chi Oph	16:27:01.44	-18:27:22.5	0.6	4.42			
C	HD 148379	16:29:42.33	-46:14:35.6	0.9	5.27			
C	HD 148605	16:30:12.48	-25:06:54.8	0.6	4.78			
C	HD 148688	16:31:41.77	-41:49:01.7	0.9	5.35			
C	HD 149038	16:34:05.02	-44:02:43.1	0.6	4.89			
C	HD 149404	16:36:22.56	-42:51:31.9	0.9	5.48			
C	HD149757	16:37:09.54	-10:34:01.5	0.6	2.57			
C	HD 150136	16:41:20.41	-48:45:46.7	0.9	5.54			
C	HD 151804	16:51:33.72	-41:13:49.9	0.9	5.25			
C	HD 152236	16:53:59.73	-42:21:43.3	0.6	4.71			
C	HD 152408	16:54:58.50	-41:09:03.1	0.9	5.78			
C	HD 155806	17:15:19.25	-33:32:54.2	0.9	5.52			
C	HD 157246	17:25:23.66	-56:22:39.8	0.6	3.34			
C	lambda Sco	17:33:36.52	-37:06:13.8	0.6	1.62			
C	HD 164740	18:03:38.30	-24:22:35.0	0.6	0.3			
C	HD 315023	18:04:20.56	-24:13:54.9	0.6	0.1			
C	HD 167264	18:15:12.91	-20:43:41.8	0.9	5.33			
C	BD-13 4920	18:18:26.21	-13:50:05.2	0.6	0.02			
C	HD 170740	18:31:25.69	-10:47:45.0	0.9	5.72			
C	HD 184915	19:36:53.45	-07:01:38.9	0.6	4.96			
C	59 Cyg	20:59:49.56	+47:31:15.4	0.6	4.74			
C	55 Cyg	20:48:56.29	+46:06:50.9	0.6	4.86			
C	lambda Cep	22:11:30.58	+59:24:52.2	0.9	5.09			
C	sigma Cas	23:59:00.54	+55:45:17.7	0.9	5.0			
D	HD 109399	12:35:16.53	-72:43:00.8	1.2	7.61			
D	HD 111934	12:53:37.62	-60:21:25.4	0.9	6.86			
D	HD 112272	12:56:33.73	-64:21:39.2	1.2	7.36			
D	HD 114886	13:14:44.39	-63:34:51.8	0.9	6.82			
D	HD 115842	13:20:48.34	-55:48:02.5	0.9	6.0			
D	HD 116852	13:30:23.52	-78:51:20.5	1.2	8.47			
D	HD 119159	13:42:56.11	-56:46:04.7	0.9	6.0			
D	HD 122879	14:06:25.16	-59:42:57.3	0.9	6.43			
D	HD 124314	14:15:01.61	-61:42:24.4	0.9	6.64			
D	HD 129557	14:45:10.96	-55:36:05.9	0.9	6.03			
D	HD 133518	15:06:55.97	-52:01:47.2	0.9	6.3			
D	HD 134591	15:11:51.01	-34:45:47.4	1.2	8.37			
D	HD 147888	16:25:24.28	-23:27:36.8	0.9	6.74			
D	HD 147889	16:25:24.32	-24:27:56.6	1.2	7.9			
D	HD 148937	16:33:52.39	-48:06:40.5	0.9	6.73			
D	HD 152235	16:53:58.85	-41:59:39.6	0.9	6.34			
D	HD 152248	16:54:10.06	-41:49:30.1	0.9	6.1			
D	HD 152249	16:54:11.64	-41:50:57.2	0.9	6.47			
D	HD 152424	16:55:03.33	-42:05:27.0	0.9	6.32			
D	HD 153919	17:03:56.77	-37:50:38.9	0.9	6.53			
D	HD 154043	17:05:18.88	-47:04:08.5	1.2	7.06			
D	HD 154368	17:06:28.37	-35:27:03.8	0.9	6.13			
D	HD 155851	17:15:33.77	-32:41:23.1	1.2	8.15			
D	HD 156201	17:17:45.52	-35:13:27.0	1.2	7.89			
D	HD 157038	17:22:39.22	-37:48:16.7	0.9	6.41			
D	HD 157857	17:26:17.33	-10:59:34.8	1.2	7.78			

Following targets moved to the next page...

12c. List of targets proposed in this programme

…continued from previous page.

Run	Target/Field	α(J2000)	δ(J2000)	ToT	Mag.	Diam.	Additional info	Reference star
D	HD 157978	17:26:19.01	+07:35:44.3	0.9	6.04			
D	HD 161056	17:43:47.02	-07:04:46.6	0.9	6.32			
D	HD 163181	17:56:16.08	-32:28:30.0	0.9	6.49			
D	HD 164073	18:02:00.56	-48:48:37.7	1.2	8.03			
D	HD 164865	18:04:15.22	-24:11:00.1	1.2	7.64			
D	HD 164906	18:04:25.84	-24:23:08.3	1.2	7.48			
D	HD 165016	18:04:58.19	-24:40:50.9	1.2	7.32			
D	HD 165319	18:05:58.84	-14:11:53.0	1.2	7.92			
D	HD 167838	18:17:37.71	-15:25:50.6	0.9	6.73			
D	HD 167971	18:18:05.89	-12:14:33.3	1.2	7.46			
D	HD 168076	18:18:36.42	-13:48:02.0	1.2	8.17			
D	HD 169454	18:25:15.19	-13:58:42.3	0.9	6.61			
D	HD 170938	18:32:37.79	-15:42:05.9	1.2	7.87			
D	HD 171957	18:38:04.49	-14:00:16.9	0.9	6.47			
D	HD 172694	18:42:16.57	-15:51:20.8	1.2	8.2			
D	HD 183143	19:27:26.57	+18:17:45.2	0.9	6.8			
D	HD 185418	19:38:27.48	+17:15:26.1	1.2	7.45			
D	HD 185859	19:40:28.32	+20:28:37.5	0.9	6.48			
D	HD 186745	19:45:24.35	+23:56:34.4	1.2	7.02			
D	HD 186841	19:45:54.13	+24:05:47.0	1.2	7.89			
D	HD 203532	21:33:54.58	-82:40:59.1	0.9	6.37			
D	HD 210121	22:08:11.90	-03:31:52.8	1.2	7.67			
E	gamma Cas	00:56:42.53	+60:43:00.3	0.6	2.39			
F	HD 27778	04:23:59.76	+24:18:03.6	0.9	6.36			
G	CPD-63 2495	13:02:47.65	-63:50:08.7	0.6	0.05			
H	HD 109399	12:35:16.53	-72:43:00.8	1.2	7.61			