



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: **79A**

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

<p>1. Title</p> <p>Circumbinary dusty envelope of the ups Sgr hydrogen-deficient binary.</p>	<p>Category: D-8</p>																																																																								
<p>2. Abstract</p> <p><i>v</i> Sgr(HD 181615) is among the very rare binaries that can be caught in the rapid phase of large mass exchange. Recently, an extensive spectroscopic study of <i>v</i> Sgr from Koubsky, Harmanec et al. (2006) renewed the interest on this object: the main observational characteristics of this system seem dominated by the presence of a dense, optically thick disk, evidenced by a strong infrared excess and also by numerous emission lines in visible and near infrared. The objective of this proposal is to measure, for the first time, the size and geometry of the non-spherical dusty envelope of <i>v</i> Sgr by interferometric observations with the VLTI instruments MIDI and AMBER. AMBER observations performed with a medium spectral resolution are particularly well-suited to evidence putative bipolar jets that are strongly suspected, as seen in the famous system β Lyr.</p>																																																																									
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<p>5. Special remarks:</p> <p>2h MIDI observation time awarded in P76 but never achieved.</p>																																																																									
<p>6. Principal Investigator: D. Bonneau (Côte d'Azur Observatory, F, daniel.bonneau@obs-azur.fr) Col(s): P. Koubsky (Ondrejov Observatory, RCH), O. Chesneau (OCA, F), P. Harmanec (Ondrejov Observatory, RCH), D. Mourard (OCA, F), Ph. Stee (OCA, F)</p>																																																																									
<p>7. Is this proposal linked to a PhD thesis preparation? State role of PhD student in this project</p>																																																																									

8. Description of the proposed programme

A) **Scientific Rationale:** Close binaries are complex objects from both the observational and modelling point of view. Due to the interaction between the components, physical processes like apsidal motion, mutual reflection, tidal interaction, mass loss and mass transfer have to be taken into account to investigate structure, physical conditions and evolution of these objects.

Both spectroscopic and photometric observations of interacting binaries show that in some cases the structure of circumstellar environment is very complicated. Accretion discs, gaseous streams, jets, and scattering envelopes were found and studied in particular objects by the proposers. With the exception of eclipsing binaries, presence of the circumstellar structures is mainly deduced from the often ambiguous transformation from the velocity into Cartesian space. From this point of view, interferometry or even more spectro-interferometry, can bring a new insight into these complicated systems, permitting at least a partial direct imaging of circumstellar structures. In the literature, one can already find examples of successful application of interferometric observations, supplementing either "classical" studies of interacting binaries or studies of envelopes around single stars. Here we mention a few cases only. One of the best results of the interferometer GI2T is the study of the well-known interacting binary β Lyrae and a discovery of bipolar jets in this system (Harmanec et al. 1996 A&A 312, 879; for a detailed review on β Lyr see Harmanec 2002 AN 323, 87). Chesneau et al. 2005 A&A 435, 275 observed the Be star α Ara with VLTI/MIDI. Though there is clear evidence from Balmer emission lines that a circumstellar disk must be present around the star, the data from VLTI/MIDI show a nearly unresolved disk in N band. The recent observations obtained with VLTI/AMBER show that the disk around α Ara is a Keplerian disk and that the mass loss from the star through the stellar wind is emerging from the polar regions (ESO PR 35/06). Combination of spectroscopic and interferometric observations lead to a conclusion that disk may be truncated by an invisible companion in the system. Peculiar envelope around HD 62623 was studied by Stee et al. (2004 ApJ 602, 978) and Bittar et al. (2001 A&A 368, 197). The combination of interferometric and photometric observations allowed to derive an improved model of the envelope around HD 62623 containing gas and dust. Spiral structure of the dust envelope around Wolf-Rayet star WR 104 revealed by aperture-masking interferometry on the Keck telescope was described by Tuthill et al. (1999 Nature 398, 487).

The target selected for our proposal - system of v Sgr - has long been known as a single-lined spectroscopic binary ($P = 137.9$ d). The secondary orbit was determined by the cross-correlation technique applied to the IUE spectra (Dudley and Jeffery 1990 MNRAS 247, 400). The secondary ('invisible') component seems to be more massive ($q = 1.59$), while the luminosity ratio of visible to 'invisible' seems to be about 100. However, the detection of the secondary lines is uncertain and deserves an independent verification. Numerous photometric observations by several authors do not provide any evidence of binary eclipses but are indicative of variations on a time scale of about 20 (or 40) days (Frame et al., 1995 MNRAS 276, 383, Koubsky et al., 2006 A&A in press DOI:10.1051/0004-6361:20065274 and references therein). Majority of the spectroscopic studies of v Sgr was devoted to the primary spectrum which combines the absorption lines of low and high degree of ionization, and the $H\alpha$ emission. Already Hack and Passinetti (1963, Contr. Oss. Astr. Milano-Merate, No 215, 1) demonstrated that the chemical composition of the primary star is a peculiar one - strong hydrogen deficiency and overabundance of C and N. v Sgr was interpreted as a bright member of the class of extremely hydrogen-deficient binary stars (HdB) and the evolutionary scenarios for v Sgr were presented by Schoenberner and Drilling (1983 ApJ 268, 225) and by Eggleton (2002 ApJ 575, 1037). The most compelling evidence of circumstellar matter in v Sgr comes from the complex $H\alpha$ absorption/emission profile. It is now well documented that the overall shape of the $H\alpha$ profile alternates between two distinct appearances, on a time scale which is not quite clear, but which is definitely at least several times longer than the binary orbital period:

1. *Stage A: a quiet phase* It is characterized by an almost stationary emission peak ($\sim +10$ km/s) with a redward extended emission wing ($\sim +10$ to $+500$ km/s) and *no blue-shifted absorption*. The variations observed in this phase do not seem to follow the orbital motion of the system. A possible explanation was suggested that this stage is associated with a non-uniform shell surrounding the system (Frame et al. 1995, MNRAS 276, 383).

2. *Stage B: an active phase* It is characterized by the $H\alpha$ profile composed from an almost stationary peak without a redward extended wing and a blue-shifted absorption component (~ -300 km/s). The active phase has been recorded by various observers several times since 1949.

Nariai (1967, PASJ 19, 564) proposed that the displaced $H\alpha$ absorption is formed in a supersonic flow generated as the gas is transferred from the primary via the L1 point and adopts a form of a cone directed towards the secondary and partly escapes from the system in the form of an outflowing spiral arm encircling the whole binary (Figure 1). Such a scenario had already been suggested by Kuiper 1941 ApJ 93, 133 for β Lyr. The proposed geometry is reminiscent of the pinwheel nebula discovered, much later, by Tuthill et al. (1999), but within a different physical context of mass-exchange i.e. the dusty nebulae produced by the wind-wind collision in a Wolf-Rayet/OB binary. Koubský et al. (2006) have shown that the blue-shifted absorption in the $H\alpha$ is visible throughout the whole orbital cycle (Figure 2)(though with strongly varying strength) and derived the radial-velocity curve which seems to challenge the Nariai's model. Koubský et al. (2006) therefore tentatively suggested an alternative model: v Sgr might be a non-eclipsing analog of the β Lyr system (peculiar spectrum of the primary would come from a rim and face of a disk, while the blue-shifted absorption would originate from the slowly precessing bipolar jets)(Figure 3). Radial-velocity curve of the blue-shifted absorption in $H\alpha$, based

8. Description of the proposed programme (continued)

on the observations presented in Koubský et al. (2006) and on more recent observations (covering almost three consecutive orbital cycles), is shown in Fig. 4.

The circumbinary material is also evidenced by the strong infrared excess of ν Sgr, and in particular by the prominent silicate dust signature at $9.7\mu\text{m}$ and also by numerous emission lines. The large infrared excess causes an apparent increase of the angular diameter with the wavelength if computed via the infrared-flux method of Blackwell and Shallis. This estimated angular diameter ranges from ~ 1 mas at $\lambda 2.3\mu\text{m}$ to ~ 5 mas at $\lambda 10\mu\text{m}$ (Shallis and Blackwell, A&A 79, 48, 1979).

B) Immediate Objective: The main objective of this proposal is to measure, for the first time, the size and geometry of the non-spherical circumbinary envelope of ν Sgr as a function of wavelength, in the effort to decide between two alternative models described above (Nariai's spiralling circumbinary model - NSCM hereafter - vs. Koubský et al. jet and optically thick disk model, similar to the current model of β Lyr- KJDM hereafter). Note that KJDM and NSCM differ in geometry which can be detected by an interferometer. The first one implies strongly asymmetric structures, extended along one dominant direction and centred on the primary, while the second one predicts a much larger but essentially symmetric structure around the whole system.

In the K band, the radiation coming from dusty envelope contribute strongly to the SED of ν Sgr, since the maximum energy distribution peaks in this range of wavelengths. The emission line $\text{Br}\gamma$ can be used as a tracer of the gas stream ejected by the primary through the Lagrangian point L1 towards the secondary and expending around the binary at a scale of about 1 to 10 AU (Nariai, 1967), and can also probe a putative jet-like emission. It must be stressed that ν Sgr has been chosen for its strong scientific interest but also because its brightness perfectly suits the VLTI capabilities: K and N band magnitudes of 2.6 and -1.5 respectively.

On the basis of the works of Nariai (1967), Shallis and Blackwell (1979), and Walker (1985) we have adopted about 2-5 mas at $2.1\mu\text{m}$ and about 5-10 mas at $10.2\mu\text{m}$ for the angular diameter of the circumstellar envelope around ν Sgr. However it should be noticed that these calculations are made on the assumption of the uniform disc brightness and the computed values could thus be lower limits of the true angular size of the object. With MIDI instrument, for the baseline UT1-UT4 - 130m, we expect a visibility between about 0.4-0.8 (at $8\mu\text{m}$) and 0.7-0.9 (at $13\mu\text{m}$). With AMBER instrument, at $2.1\mu\text{m}$, we expect a visibility between about 0.2-0.8 (baseline UT2-UT4 - 89m) and 0.7-0.9 (baseline UT2-UT3 - 47m).

The observed values of the visibility will depend on the exact envelope geometry. Also, due to the asymmetry of the envelope, the fringe visibility will vary as a function of the baseline position angle for each wavelength channel.

The longest baseline (UT1-UT4) is essential for MIDI to resolve the envelope close to the binary, i.e., in the continuum outside the silicate features in the N band and the combination of spatial and spectral resolution is mandatory to understand such a complex object. The estimates above show that MIDI and AMBER can resolve the circumbinary envelope of ν Sgr and can provide key input pieces of information that will allow us to highly constrain the physical structure of this system.

This proposal is of single-shot type since it can be completed in a few hours of observations and is focused on one scientific target.

C) Telescope Justification: The VLTI is the only instrument able to spatially and spectrally resolve objects at the scale of 20 - 50 mas in the N band with MIDI or at 2 - 10 mas in the K band with AMBER. With MIDI, the PRISM mode ($R = 30$) allows enough spectral resolution to study separately the angular size of the envelope inside and outside the observed silicate feature through the N band. 2h of MIDI observations were requested for the two following reasons: first with the longest baseline the correlated flux will probably be too low for satisfactory observations with ATs; second, it is of great importance for the interpretation to check the amount of N band emission that originates outside the 300mas beam of a 8m telescope.

With AMBER, the medium spectral resolution mode ($R = 1500$) is mandatory to deduce the angular size of the $\text{Br}\gamma$ emission line region compared to the continuum extension, and implies observations with UTs.

A bidimensional coverage of the uv-plane is mandatory to allow a direct measurement of the envelope asymmetry: this task is mainly devoted to the ATs with MIDI and AMBER.

D) Observing Mode Justification (visitor or service): This program can be done in service mode.

E) Strategy for Data Reduction and Analysis: As members of the consortia, we are familiar with the MIDI and AMBER data reduction software package. The data analysis and interpretation should be performed at several steps with increasing complexity:

- interpretation with simple zero-order analytical models (e.g. elliptical Gaussian disk in N band, plus point source in K band).

- comparison with more detailed models (such as Basikaló et al., A&A 353, 1009, 2000 or Malbet et al., A&A, in press arXiv:astro-ph/0510350, 2006)

8. Attachments (Figures)

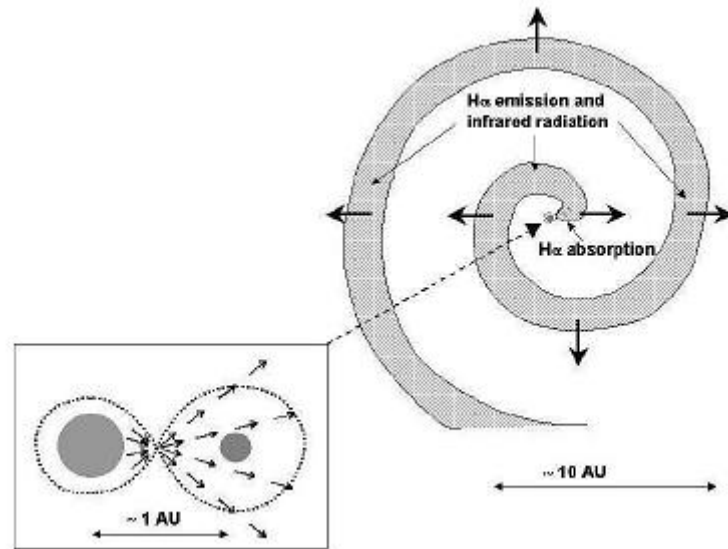


Fig.1 - Large scale structure of the circumbinary envelope of ν Sgr as proposed by Nariai (1967)

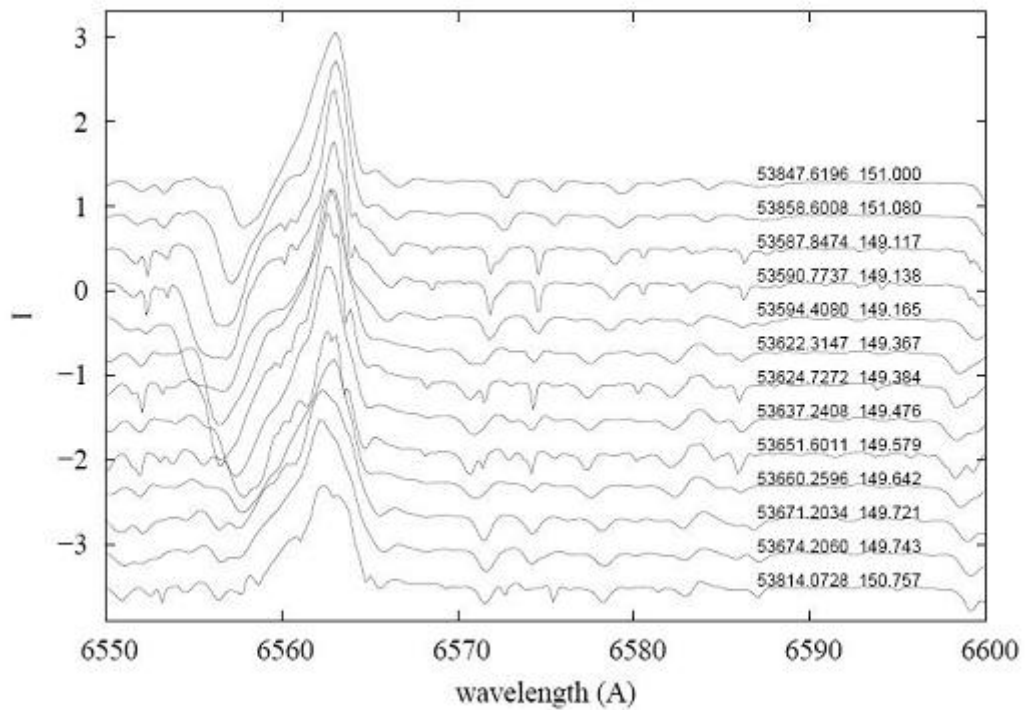


Fig 2 - Selected H α line profiles from DAO and Ondrejov spectrograms showing permanent presence of blue-shifted absorption of variable strength. Data cover period autumn 2005 and spring 2006. HJD-2400000 and cycle phase are shown in the right part of the particular spectrum.

8. Attachments (Figures)

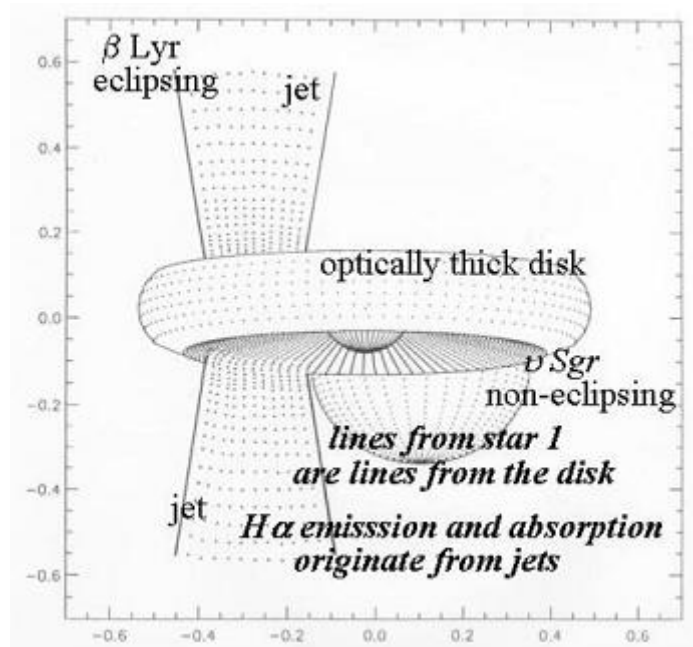


Fig 3 - An alternative model for v Sagittarii: a non eclipsing analog to β Lyrae?

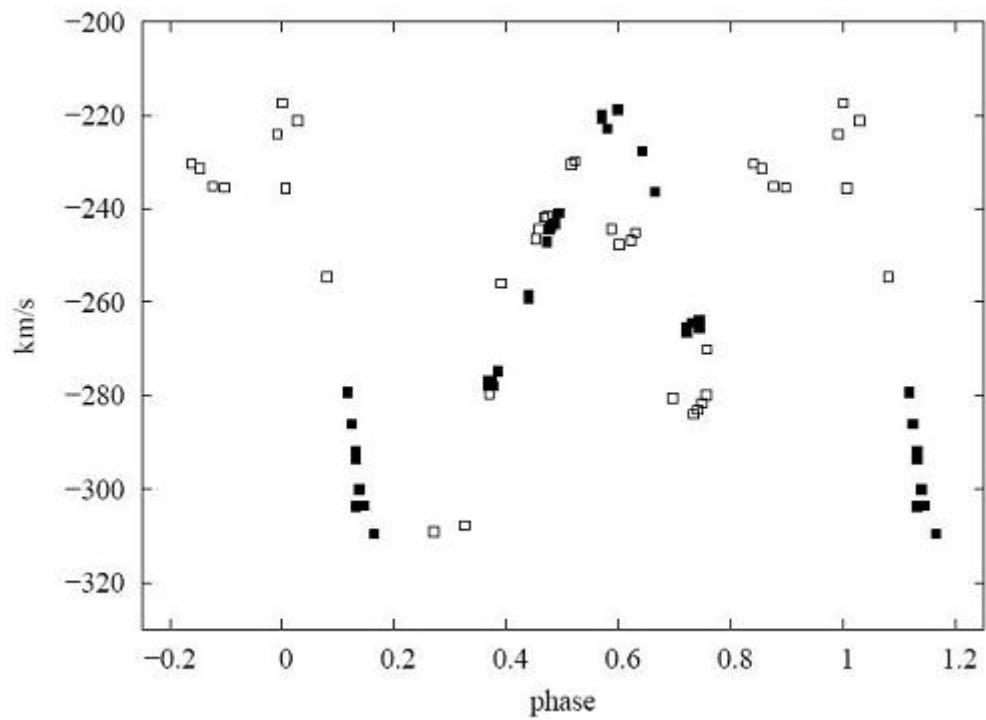


Fig 4- RV curve of the blue-shifted absorption in the $H\alpha$ profile of v Sgr. Observations collected at Ondřejov and Dominion Astrophysical Observatory during 2005 (filled symbols) and 2006 (open symbols) are shown.

9. Justification of requested observing time and lunar phase

Lunar Phase Justification: No constraint

Time Justification: (including seeing overhead) Following the discussion in part 6.11 (MIDI) and 6.12 (AMBER of the ESO Call for Proposals):

- for observations with MIDI (1 single UTs baseline), considering 60mn for one calibrated Visibility, at least 2 slots are mandatory to get an estimate of the dust envelope extension, so we require 2h of observation for ν Sgr.

- for observations with MIDI (4 single ATs baseline), considering 60 mn for one calibrated Visibility, at least 3 slots are mandatory to get an estimate of the dust envelope extension, so we require $3h \times 4 = 12h$ of observation for ν Sgr.

- for observations with AMBER (3 UTs baselines), considering 2h for one calibrated visibility, one single shot observation is needed to get a minimal 2D information on the source geometry. To get more precise information, we require $2 \times 90mn = 3h$ observations on ν Sgr.

- for observations with AMBER (3 ATs baselines), considering 90mn for one calibrated visibility, one single shot observation is needed to get a minimal 2D information on the source geometry. To get more precise information, we require $3 \times 90mn = 4,5h$ observations on ν Sgr.

Calibration Request: Special Calibration - standard calibration

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

- 1) NACO observations on Eta Car (Open time 074.D-0140(A), 076.D-0586, data in reducing process)
- 2) NACO and MIDI Open Time observations of pre-planetary nebulae (P73; PI: O. Chesneau; 073.D.-0130 (A and B); one paper accepted (Lagadec et al. 2005), one in preparation (Chesneau et al.)
- 3) Open Time MIDI and GTO Time AMBER Observations of a B[e] star, CPD-572874, one paper accepted (Domiciano et al. 2006)

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

Koubsky, P. Harmanec, P., Yang, S. et al., 2006, A&A, accepted: 'Properties and nature of Be stars: 25. A new orbital solution and the nature of a peculiar emission-line binary ν Sgr'

Domiciano de Souza, A., Driebe, T., Chesneau, O. et al., 2006, A&A, accepted: 'VLTI/AMBER and VLTI/MIDI spectro-interferometric observations of the B[e] supergiant CPD-572874'

Lagadec, E., Chesneau, O., Matsuura et al., 2005, A&A, accepted (2005astro.ph 9014): 'New insights on the complex Planetary Nebulae Hen2-113'

Chesneau, O., Min, M., Herbst, T., et al., 2005, A&A, 435, 1043: 'The sub-arcsec dusty environment of Eta Car'

Chesneau, O., Verheolst, T., Lopez, B., et al., 2005, A&A, 435, 563: 'The mid-IR spatially resolved environment of OH 26.5+0.6 at maximum luminosity'

Stee, Ph., Bittar, J. and Lopez, B., 2004 ApJ, 602, 978S: A Gas+Dust Model of the Peculiar Envelope of HD 62623 Based on Interferometric Observations

12. List of targets proposed in this programme

Run	Target/Field	α (J2000)	δ (J2000)	ToT	Mag.	Diam.	Additional info	Reference star
A	<i>v</i> SGR	19 21 43.6	-15 57 18.1	2	4.60		target	
B	<i>v</i> SGR	19 21 43.6	-15 57 18.1	3	4.60		target	
C	<i>v</i> SGR	19 21 43.6	-15 57 18.1	3	4.60		target	
D	<i>v</i> SGR	19 21 43.6	-15 57 18.1	3	4.60		target	
E	<i>v</i> SGR	19 21 43.6	-15 57 18.1	3	4.60		target	
F	<i>v</i> SGR	19 21 43.6	-15 57 18.1	3	4.60		target	
G	<i>v</i> SGR	19 21 43.6	-15 57 18.1	4.5	4.60		target	

Target Notes: V magnitude.

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

None

13. Scheduling requirements

14. Instrument configuration

Period	Instrument	Run ID	Parameter	Value or list
79	MIDI	A	PRISM	SCI-PHOT
79	MIDI	B	PRISM	HIGH-SENS
79	MIDI	C	PRISM	HIGH-SENS
79	MIDI	D	PRISM	HIGH-SENS
79	MIDI	E	PRISM	HIGH-SENS
79	AMBER	F	MR-K	2.1
79	AMBER	G	LR-HK	2.1

15. List of interferometry targets proposed in this programme

Run	Name	Vmag	mag(λ)	λ_{obs}	size(λ)	Baseline	Vis.	mag_c	Tot
A	<i>v</i> SGR	4.60	-1.0	10.6	10	UT1-UT4-130m	0.6	-0.45	2
B	<i>v</i> SGR	4.60	-1.0	10.6	10	D0-H0-64m	0.9	-0.9	3
C	<i>v</i> SGR	4.60	-1.0	10.6	10	G0-H0-32m	0.95	-0.95	3
D	<i>v</i> SGR	4.60	-1.0	10.6	10	D0-G1-72m	0.85	-0.8	3
E	<i>v</i> SGR	4.60	-1.0	10.6	10	H0-G1-72m	0.8	-0.75	3
F	<i>v</i> SGR	4.60	2.6	2.1	5	UT2-UT3-UT4	0.7/0.2/0.45	3.0/4.3/3.4	3
G	<i>v</i> SGR	4.60	2.6	2.1	5	D0-H0-G1	0.75/0.65/0.65	2.9/3.1/3.1	4.5