



Telescope Bernard Lyot/Narval In 2012

Rémi CABANAC

TBL Director
Observatoire Midi Pyrénées

COST WORKSHOP
Warsaw
7-9 may 2012

The COST logo consists of a stylized 'C' made of three segments, followed by the word 'cost' in a bold, lowercase sans-serif font. Below it, the text 'EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY' is written in a smaller, all-caps font.

cost
EUROPEAN COOPERATION
IN SCIENCE AND TECHNOLOGY

A graphic showing a series of colorful, semi-transparent circles and lines in various colors (red, orange, yellow, green, blue, purple) arranged in a curved path, representing the study of polarization in the solar system.

Polarisation as a tool to study the
Solar System and beyond

Action MP1104



Telescope Bernard Lyot (TBL)

2-m Telescope at Pic du Midi

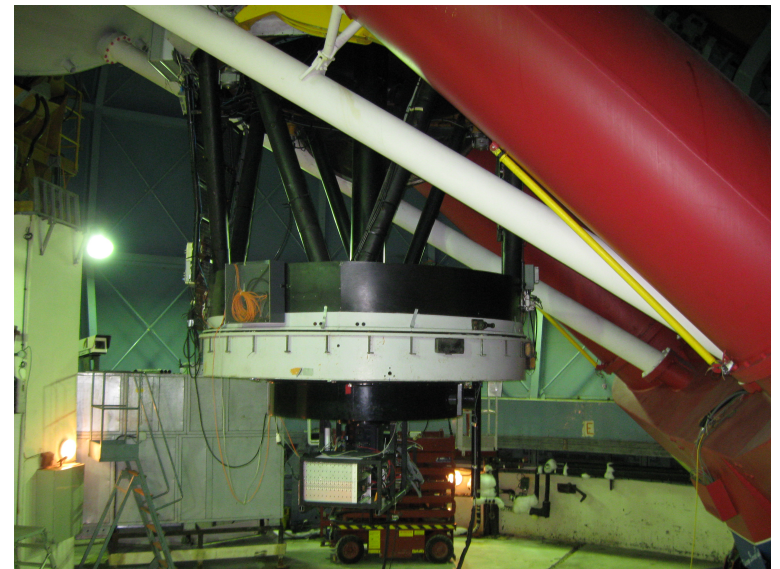
www.tbl.bagn.obs-mip.fr

- TBL is dedicated to spectro-polarimetry with Narval since 2007
- TBL completely refurbished with digital control.
- TBL operated in full service mode since 2009
- TBL part of OPTICON transnational access prog.

OPTICON Transnational Access (->2015)

www.astro-opticon.org

- Thinking of the future : 2 options
 - improving Narval
 - Narval → near IR (SPIP = SPIROU @ Pic)



A few stats since 2007

10 semesters with pressure 2-3

Nights offered : 1315

Programmes : 134

Publications : 89 (5 cit>50, 30 cit>10)

Since 2010B :

60% large programmes (2 years)

Next call 2013A (~20 oct 2012)



TBL OPERATION

Operations with TBL/Narval

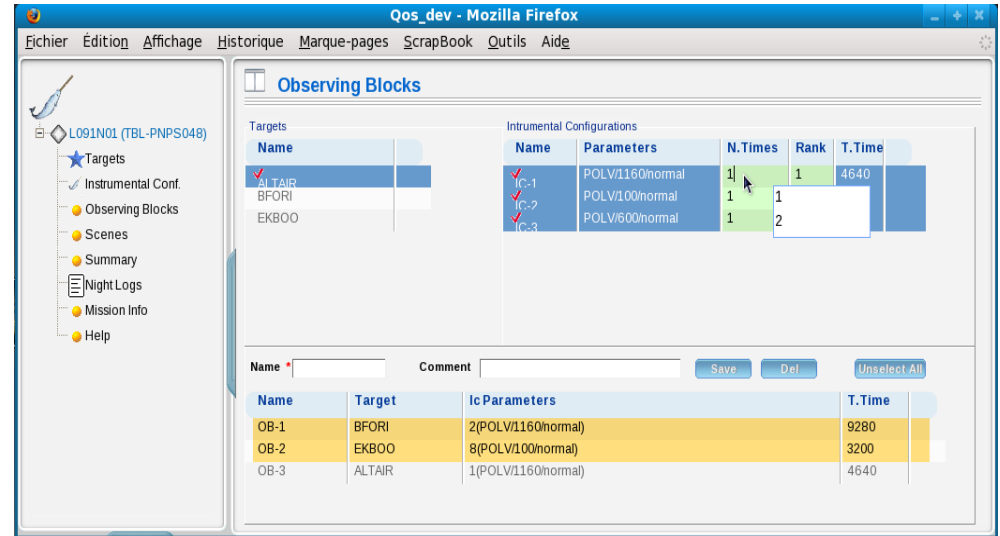
TBL/Narval is operated in queue service observing.

End-to-end data processing:

- call for proposals (next deadline 2013A → 20 oct 12)
<http://northstar.bagn.obs-mip.fr:8080/>
- Service Observers (training of young astronomers)
- Complete quality control and data processing: delivers reduced normalized/unnormalized 1D spectra + error
- Higher level tools (Least-Square Deconvolution)
- TBL/Narval reduced data are released 1yr after PI release (for Intensity spectra, 2 yr for polar data), fully compliant with VO spec tblegacy.bagn.obs-mip.fr

www.sciops.esa.int/index.php?project=ESAVO&page=vospec

Operations with TBL/Narval



Ph3

Night Rise Nautical 20:06:00.884 (UT) << 07h36 >> Night Set Nautical 03:42:59.904 (UT) Nuit en Préparation 2012-05-08

Og	Nummiss	Objet	Rank	Mode Obs	Alpha	Delta	Magb	Exec Time
tast	L121N99	RIGEL	A	POL3 Fast	05 14 32.27210	-08 12 05.8981	0.12	03h55m00s
SUNbyMOON	L121N98	MOON	C	POL3 Fast	09 00 00.00	+11 00 00.00	2.00	00h47m20s
GJ410	L121N07	GJ410	A	POL3 Normal	11 02 38.34171	+21 58 01.7008	9.57	00h33m40s
R_VIR	L121N05	RVIR	B	POL3 Normal	12 38 29.93417	+06 59 19.0306	7.77	02h31m00s
DelOph	L121N08	DELOPH	B	POL3 Fast	16 14 20.73853	-03 41 39.5612	2.74	00h52m00s
AlpLyn	L121N08	ALPLYN	B	POL3 Fast	09 21 03.30074	+34 23 33.2245	3.16	01h13m20s
DelVir	L121N08	DELVIR	B	POL3 Fast	12 55 36.20861	+03 23 50.8932	3.38	01h13m20s
GamSge	L121N08	GAMSGE	B	POL3 Fast	19 58 45.42863	+19 29 31.7281	3.53	01h13m20s
EK BOO	L121N08	EKBOO	C	POL3 Normal	14 46 05.94566	+15 07 54.4332	5.88	01h21m20s
HIP088533	L121N03	HIP088533	A	SPEC6 Normal	18 04 43.19833	+40 05 03.0574	6.53	00h12m40s
HIP088799	L121N03	HIP088799	A	SPEC6 Normal	18 07 36.64343	+58 58 32.4757	8.43	00h12m40s
HIP090179	L121N03	HIP090179	A	SPEC6 Normal	18 24 08.50378	+79 13 21.7113	6.53	00h12m40s
HIP090275	L121N03	HIP090275	A	SPEC6 Normal	18 25 11.84366	+49 51 52.3266	7.17	00h12m40s
HIP090902	L121N03	HIP090902	A	SPEC6 Normal	18 32 30.21169	+68 36 51.1092	7.59	00h12m40s
HIP091606	L121N03	HIP091606	A	SPEC6 Normal	18 40 56.40853	+62 44 58.0690	6.10	00h12m40s
HIP093746	L121N03	HIP093746	A	SPEC6 Normal	19 05 20.77341	+25 55 14.3797	7.18	00h12m40s
NEP54	L121N03	T4209-00146-1	A	SPEC6 Normal	18 10 31.80	+65 22 50.26501	7.84	00h09m40s
NEP55	L121N03	T4213-00521-1	A	SPEC6 Normal	18 07 47.78	+67 24 58.43300	7.85	00h09m40s
NEP56	L121N03	T4213-01098-1	A	SPEC6 Normal	18 07 00.84	+65 53 16.62000	7.98	00h09m40s
NEP57	L121N03	T4213-01344-1	A	SPEC6 Normal	18 01 23.27	+65 56 55.06800	8.01	00h09m40s
NEP58	L121N03	T4429-01467-1	A	SPEC6 Normal	18 08 55.67	+67 59 17.59898	8.04	00h09m40s
NEP59	L121N03	T4213-01438-1	A	SPEC6 Normal	18 13 48.64	+66 28 20.74900	8.09	00h09m40s

Night Logs

Mission L121N03 Night 02may12 Object * Status *

OG Name	Nummiss	Night	Object	Data	Results	ModTime	Status	Comment
RV_REF_HIP077346	L121N03	02may12	HIP077348	1 (1 1 300)	121768o {128 8.79 -0.075}	20:53:40	AGAIN	-
NEP11	L121N03	02may12	T4212-0045-1	1 (1 1 900)	121774o {74 11.42 -0.205}	19:54:29	VALID	-
NEP15	L121N03	02may12	T4212-01100	1 (1 1 900)	121769o {56 11.83 -0.169}	19:54:28	VALID	-
NEP41	L121N03	02may12	T4213-00622	1 (1 1 900)	121770o {50 11.77 -0.151}	19:54:26	VALID	-
NEP09	L121N03	02may12	T4212-00116	1 (1 1 600)	121773o {74 10.98 -0.211}	19:54:10	VALID	-
NEP04	L121N03	02may12	T4212-00380	1 (1 1 600)	121772o {96 10.61 -0.125}	19:54:08	VALID	-
NEP01	L121N03	02may12	T4212-00891	1 (1 1 600)	121771o {103 10.26 -0.163}	19:54:06	VALID	-
006_Hebe_Ref	L121N03	02may12	006_HEBE	1 (1 1 600)	121731o {53 11.54 -0.103}	16:34:13	AGAIN	-

Operations with TBL/Narval

**Télescope Bernard Lyot
Narval archive**

Query | Query results | Plotting | Quicklook | Statistics | VO Tools | User's guide

Show in results	Criteria	Condition
<input checked="" type="checkbox"/>	RA	
<input checked="" type="checkbox"/>	DEC	
<input type="checkbox"/>	V Magnitude	
<input type="checkbox"/>	Spectral type	
<input type="checkbox"/>	Obs. date (UT)	
<input type="checkbox"/>	Obs. time (UT)	
<input type="checkbox"/>	HJD (UTC)	
<input type="checkbox"/>	SNR (Max)	
<input type="checkbox"/>	Airmass	
<input checked="" type="checkbox"/>	Obs. mode	
<input checked="" type="checkbox"/>	Stokes params	
<input type="checkbox"/>	GJD (UTC)	
<input type="checkbox"/>	Hel. vel.	
<input type="checkbox"/>	Hour angle	
<input type="checkbox"/>	SNR (550nm)	

Show all columns in query results **SEND REQUEST**

Query on objects by name
Please enter the names of objects in the field below. For multiple names of objects to query on, names must be COMMA-SEPARATED.

VOSpec

File | Edit | View | Operations | Plastic | SAMP | Help

Wave Unit: micr... | Log:

Flux Unit: Jy |

RedShift: 0.00 |

De-reddening:

$\lambda-V$: 0.00 |

Y-axis error:

X-axis error:

Graphic Mode

Target: | Ra: | Dec: | Size: 1 | **Query**

Spectra List

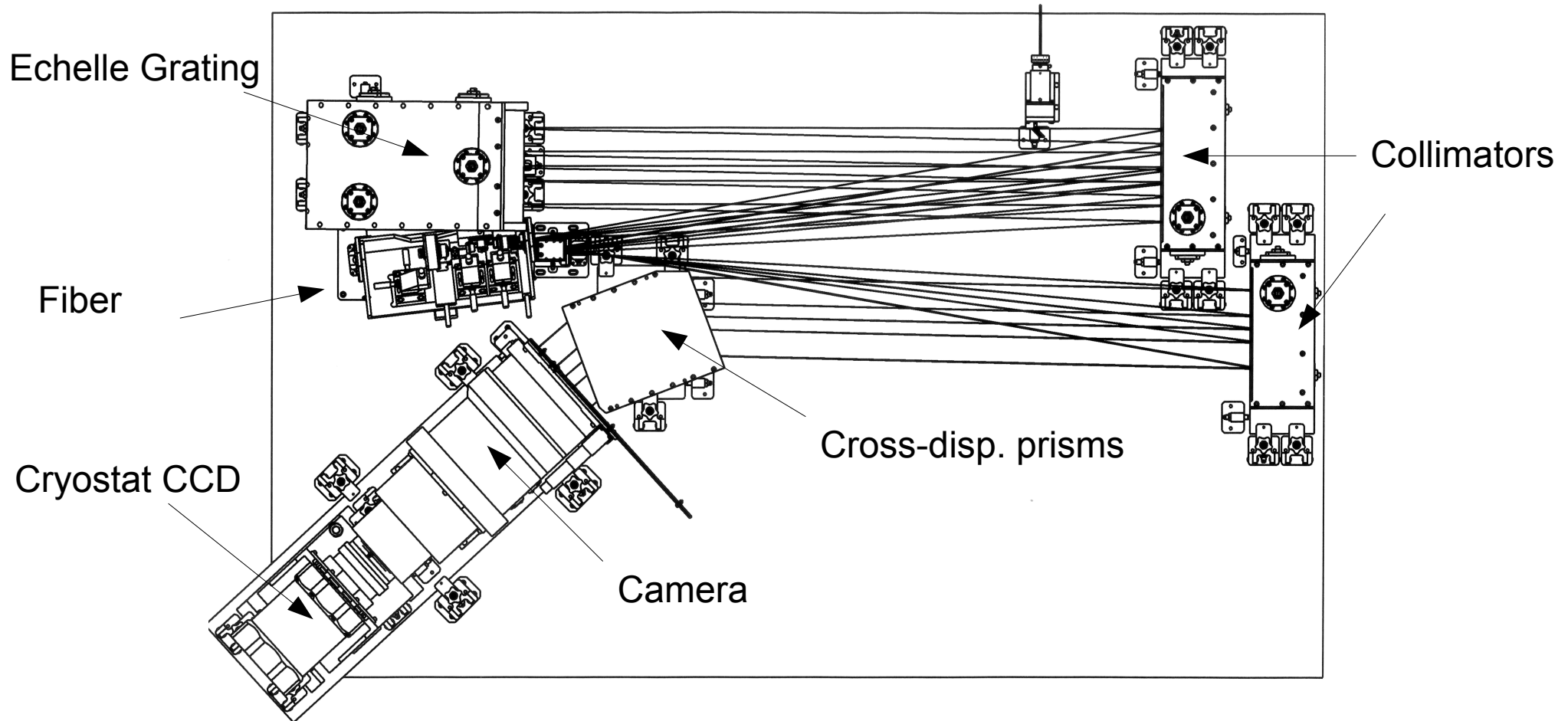
RETRIEVE **Unmark All** **Reset**

Copyright ESAC - Villanueva de la Cañada - Madrid, Spain

NARVAL

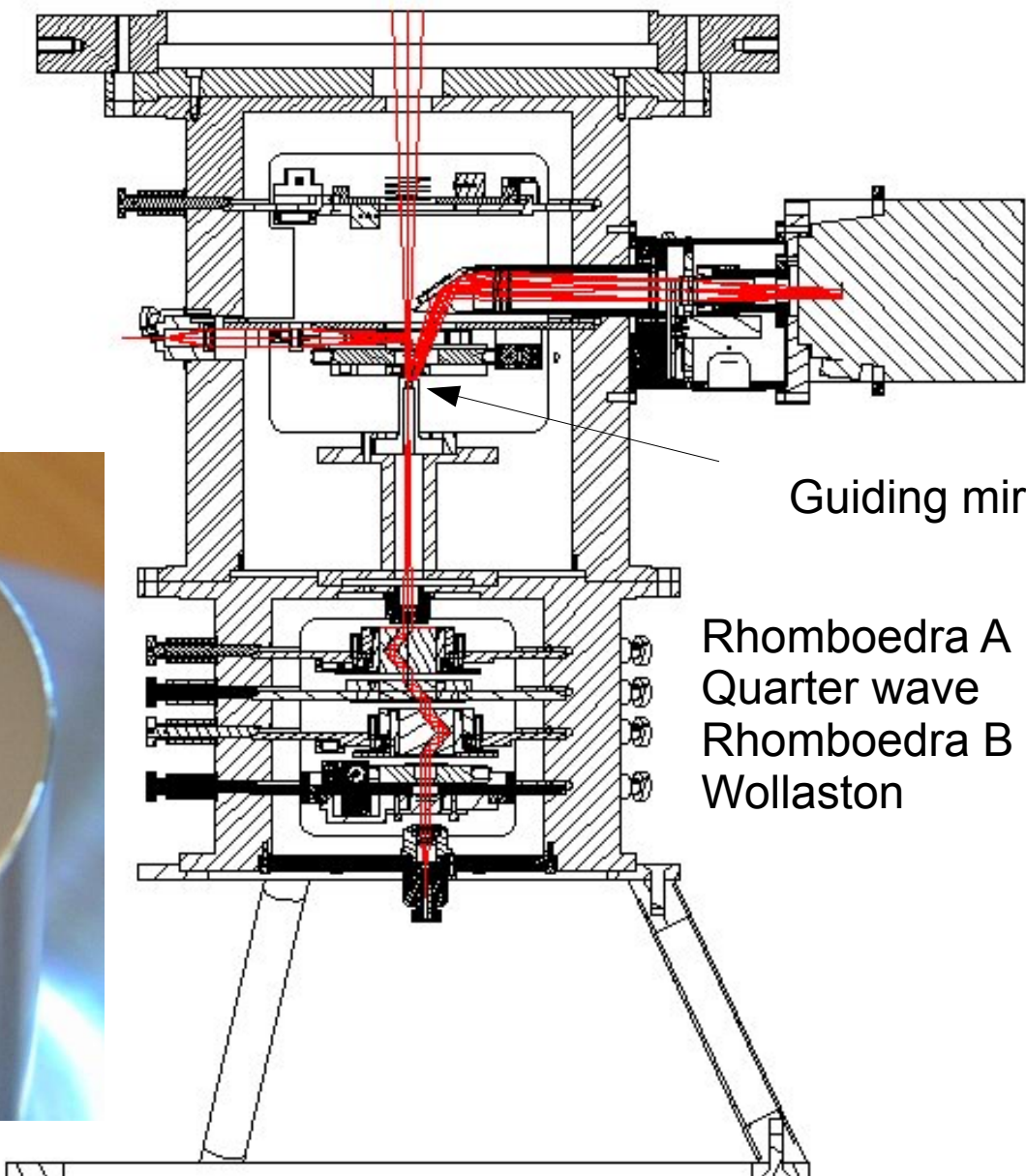
Narval is a spectrograph...

Temperature controlled enclosure, optical bench, stable (~ 10 m/s in a night), range 370-1000nm



... and a Polarimeter

Cassegrain focus sky



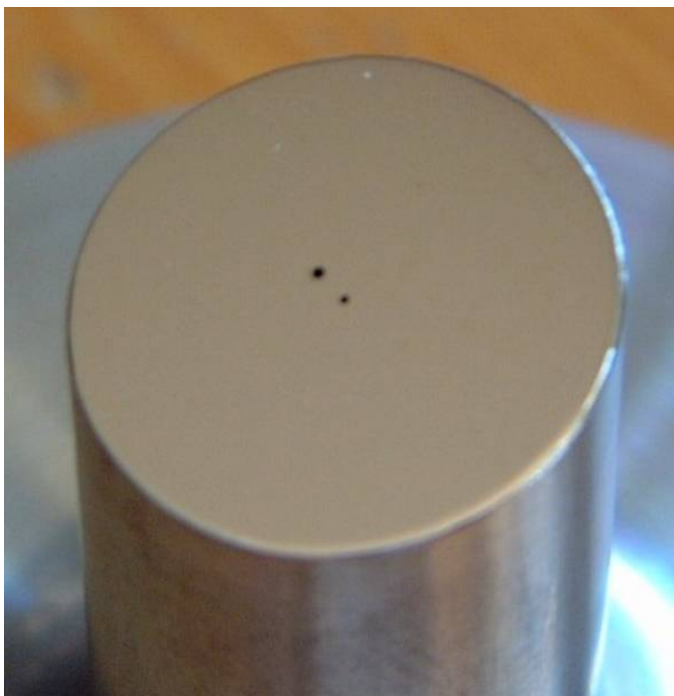
ADC

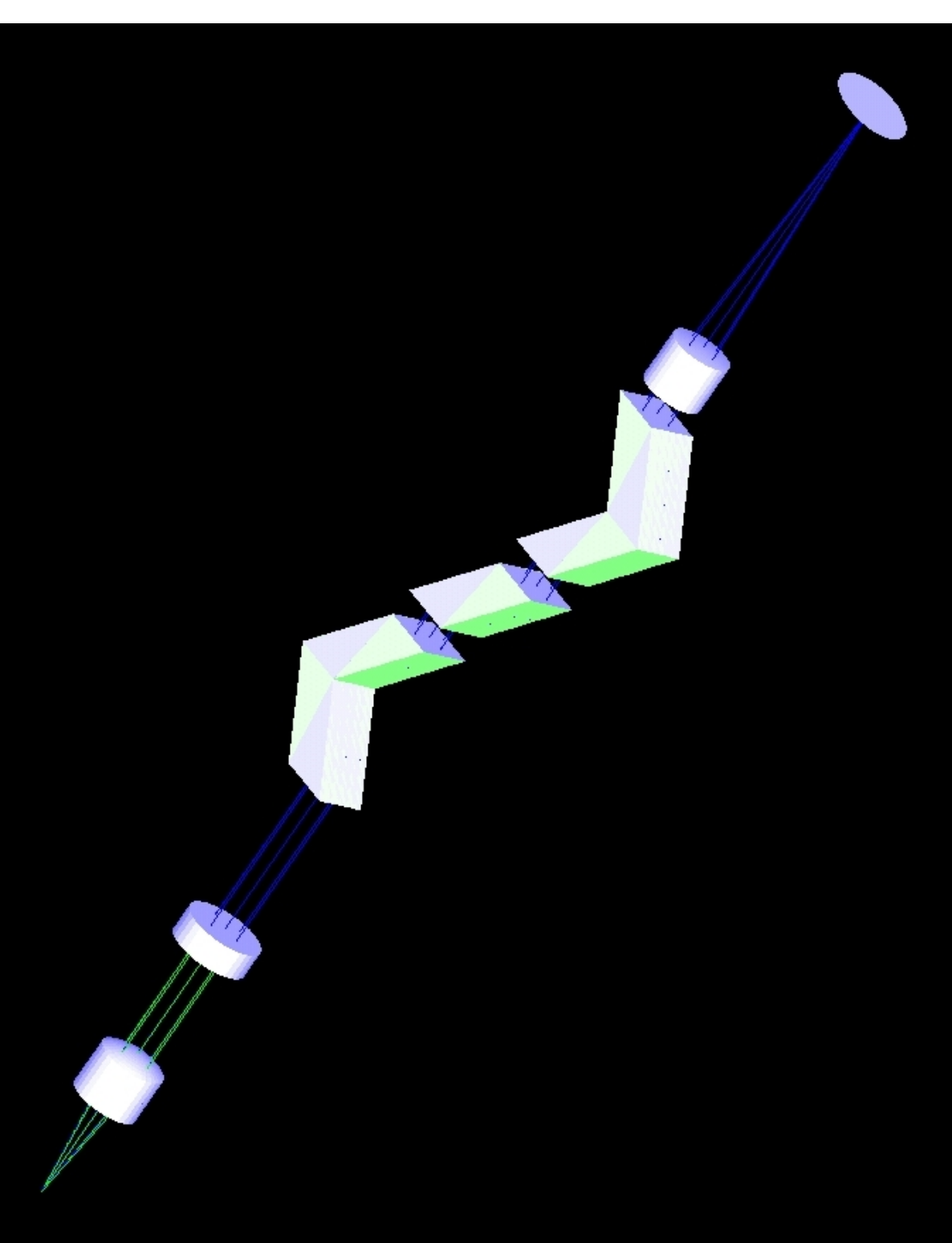
Calibration unit

Guiding

Guiding mirror, star/sky holes

Rhomboedra A
Quarter wave
Rhomboedra B
Wollaston





Polarisation parametrized through the Stokes parameters (E Field pola.):

100% Q	100% U	100% V
<p>+Q</p> <p>$Q > 0; U = 0; V = 0$ (a)</p>	<p>+U</p> <p>$Q = 0; U > 0; V = 0$ (c)</p>	<p>+V</p> <p>$Q = 0; U = 0; V > 0$ (e)</p>
<p>-Q</p> <p>$Q < 0; U = 0; V = 0$ (b)</p>	<p>-U</p> <p>$Q = 0; U < 0; V = 0$ (d)</p>	<p>-V</p> <p>$Q = 0; U = 0; V < 0$ (f)</p>

4 rel. pos. of Rhomb A, B and $\lambda/4$ plate leads to 4 pairs of orthogonally polarized spectra

$$\frac{P}{I} = \frac{R - 1}{R + 1},$$

where

$$R^4 = \frac{i_{1,\perp}/i_{1,\parallel} i_{4,\perp}/i_{4,\parallel}}{i_{2,\perp}/i_{2,\parallel} i_{3,\perp}/i_{3,\parallel}}, \quad R^4 = \frac{i_{1,\perp}/i_{1,\parallel} i_{2,\perp}/i_{2,\parallel}}{i_{4,\perp}/i_{4,\parallel} i_{3,\perp}/i_{3,\parallel}}.$$

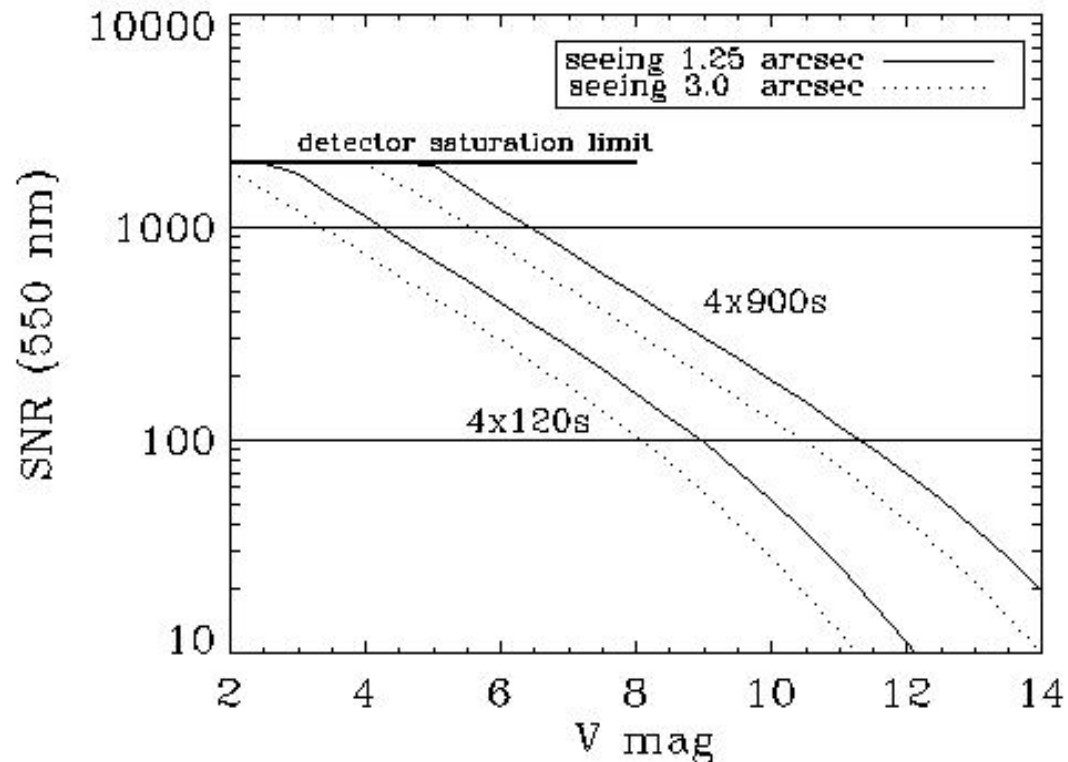
Operations with TBL/Narval

Offers 3 modes of operations:

- Spectroscopic mode star only, resolution ~ 77000
- Spectroscopic mode star+sky, resolution ~ 65000
- Polarimetric mode: Q U or V, resolution ~ 65000

Sensitivity of TBL/Narval:

S/N = 100 in 1h V=12



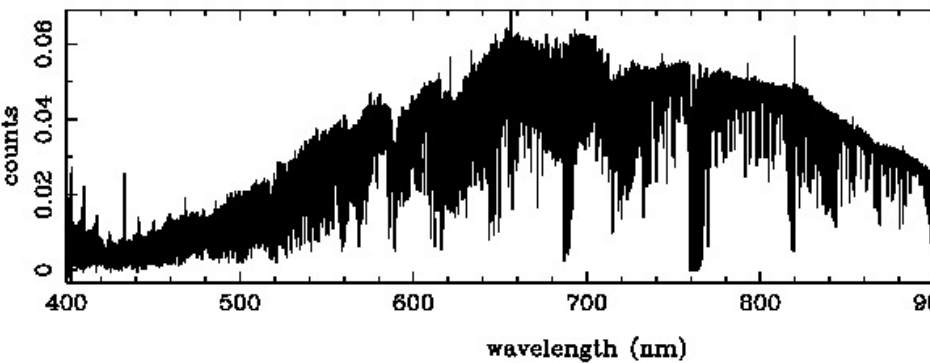
Operations with TBL/Narval

Example **V* DS Leo** -- Variable of BY Dra type Vmag = 9.5

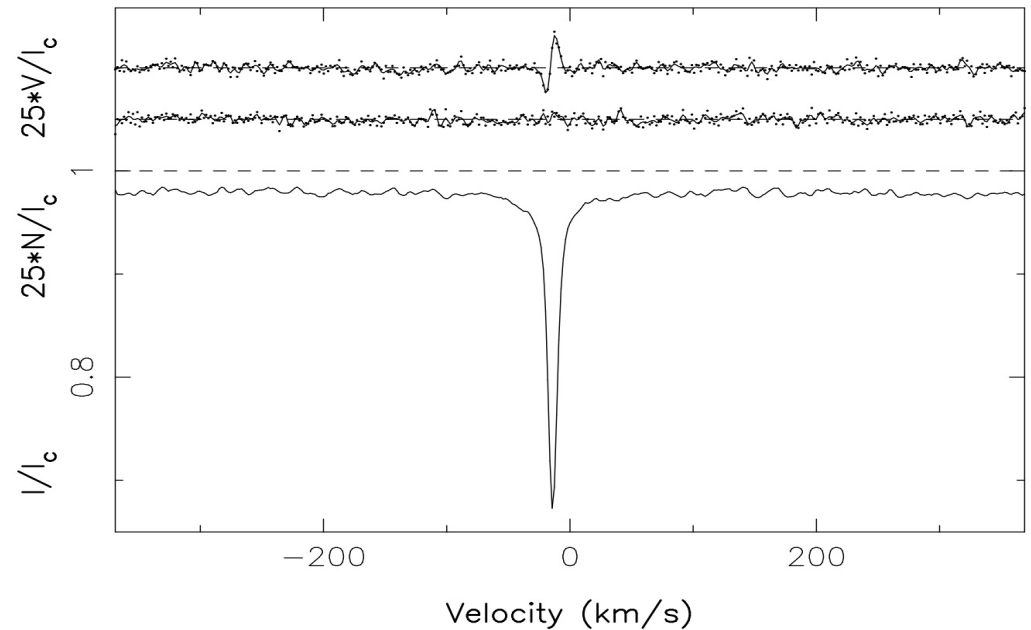
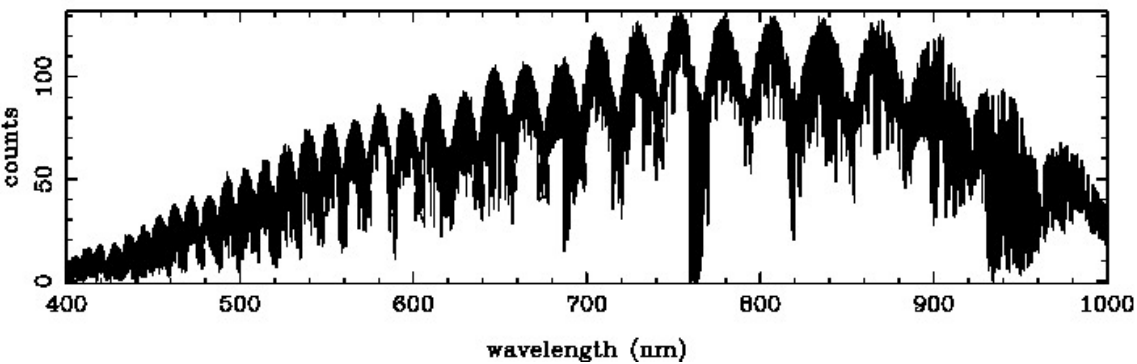
Exp. Time 4 x 400 sec

LS deconvolved Zeeman signature (4951 lines used)

Intensity spectrum of gj410_001.s



S/N spectrum of gj410_001.s



SCIENCE EXAMPLES

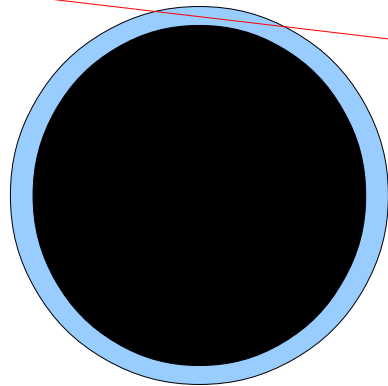
Science with TBL/Narval

In Spectroscopy:

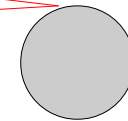
- Planet studies: Moon eclipses (Ferlet et al.)
- Spectro follow-up exoplanet transits (Miller et al.)

Each Moon eclipse: test of observability exoplanet atmospheres thru transit,
Next visible eclipse from Pic du Midi 2015 !

Sunlight



Earth



Moon

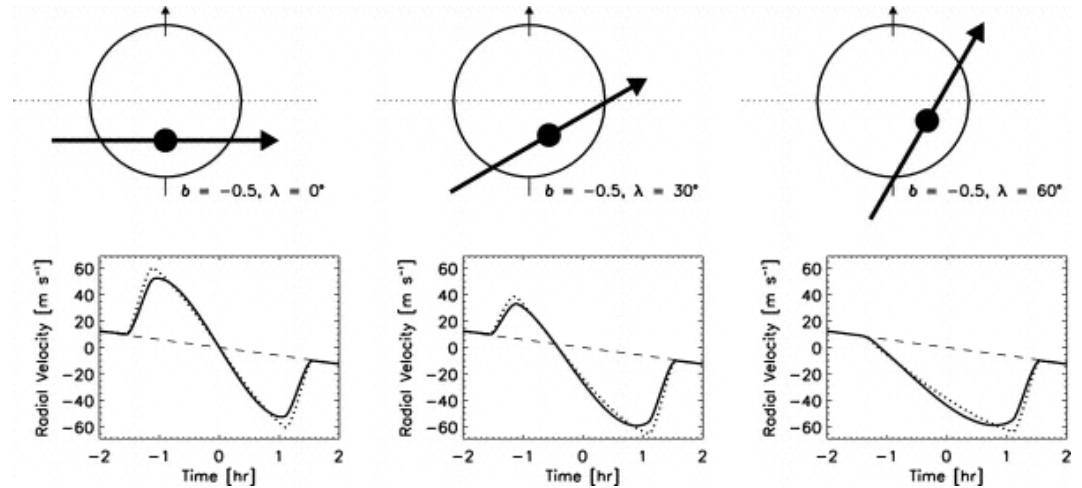
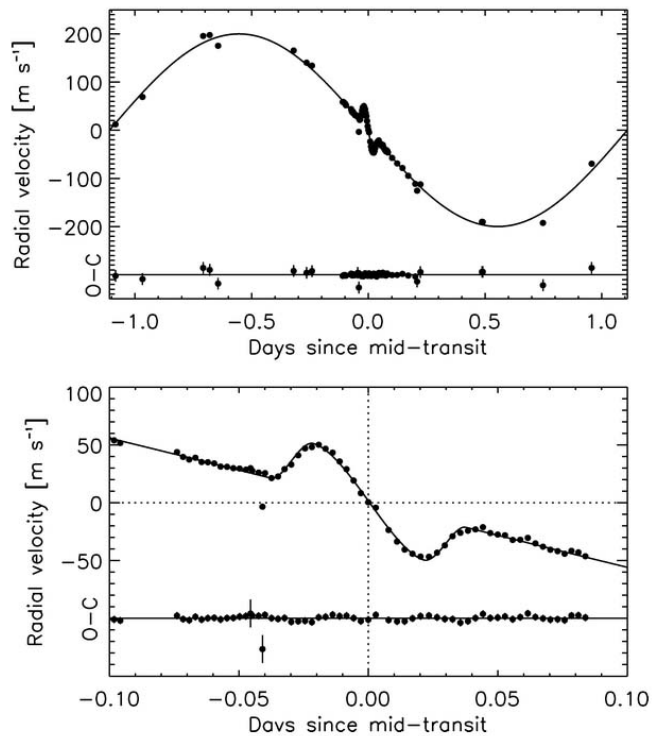
Detect water, methane, carbon dioxide, etc...

Science with TBL/Narval

In Spectroscopy:

- Planet studies: Moon eclipses (Ferlet et al.)
- Spectro follow-up exoplanet transits (Miller et al.)

The Rossiter-McLaughlin Effect



Science with TBL/Narval

In Polarimetry: Stellar Magnetism

Method: observing Zeeman splitting in absorption lines

HR + Least-Square Deconvolution → multiplexing effect , combination of many lines

Hot stars/fast rotators → more difficult to measure

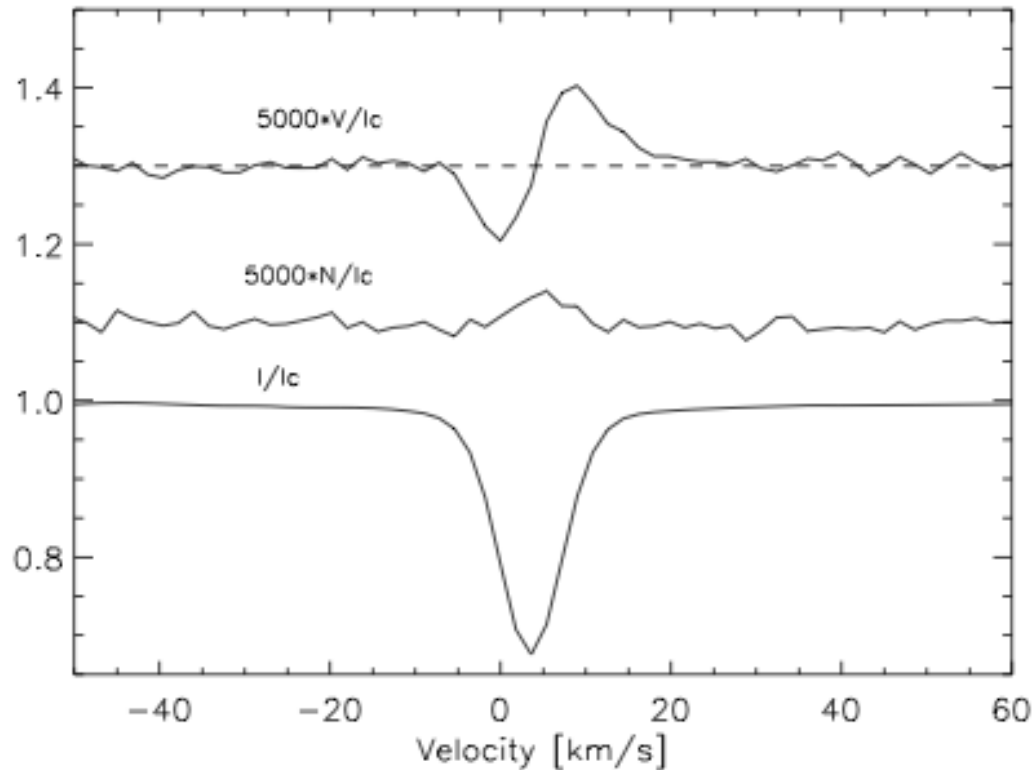
Cool giant/MS → extreme sensitivities ± 0.2 Gauss (Stokes V)

POLLUX K0III (34 ly) $\sim 0.7 \pm 0.2$ G

VEGA A0V (25 ly) $\sim 0.6 \pm 0.3$ G

Science with TBL/Narval

Pollux, averaged LSD profile



Vega, averaged LSD profile

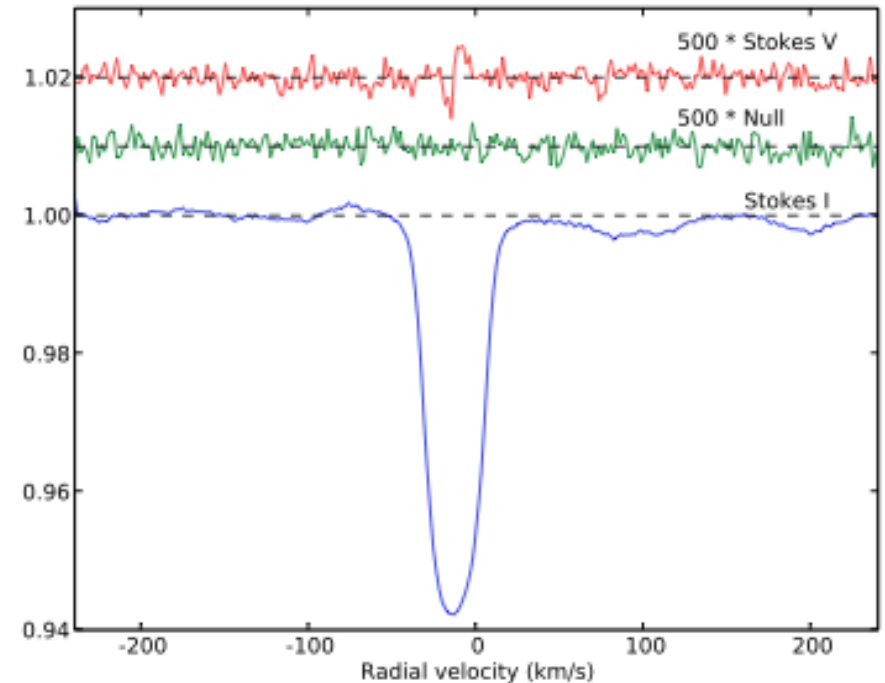


Fig. 1. Mean LSD profiles of Pollux from all 91 spectra acquired with ESPaDOnS and NARVAL in the September 2007–March 2009 period. From top to bottom are Stokes V , null polarisation N , and Stokes I profiles. For display purposes, the profiles are shifted vertically, and the Stokes V and diagnostic N profiles are expanded by a factor of 5000. The dashed line illustrates the zero level for the Stokes V profile.

Fig. 1. Average of the 257 normalized Stokes I (blue/bottom) and Stokes V (red/upper) LSD profiles of Vega, as a function of the radial velocity. The green/middle curve is the “null” profile. The Stokes V and null curves are shifted vertically and expanded by a factor of 500. Dashed lines indicate the continuum level for Stokes I , and the zero level for the circular and null polarization.

Science with TBL/Narval

A short summary on theory:

2 contenders for the origin of stellar magnetic fields

Star rotation + convection
(Dynamo)

Low mass stars (mostly)

Complex toroidal structure

Variable

Fossil remnants (Ap-Bp, few %)

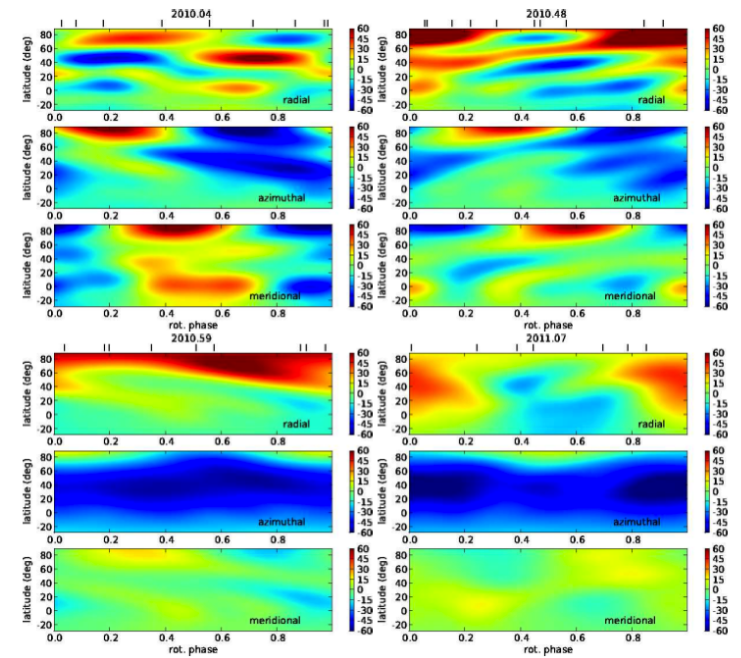
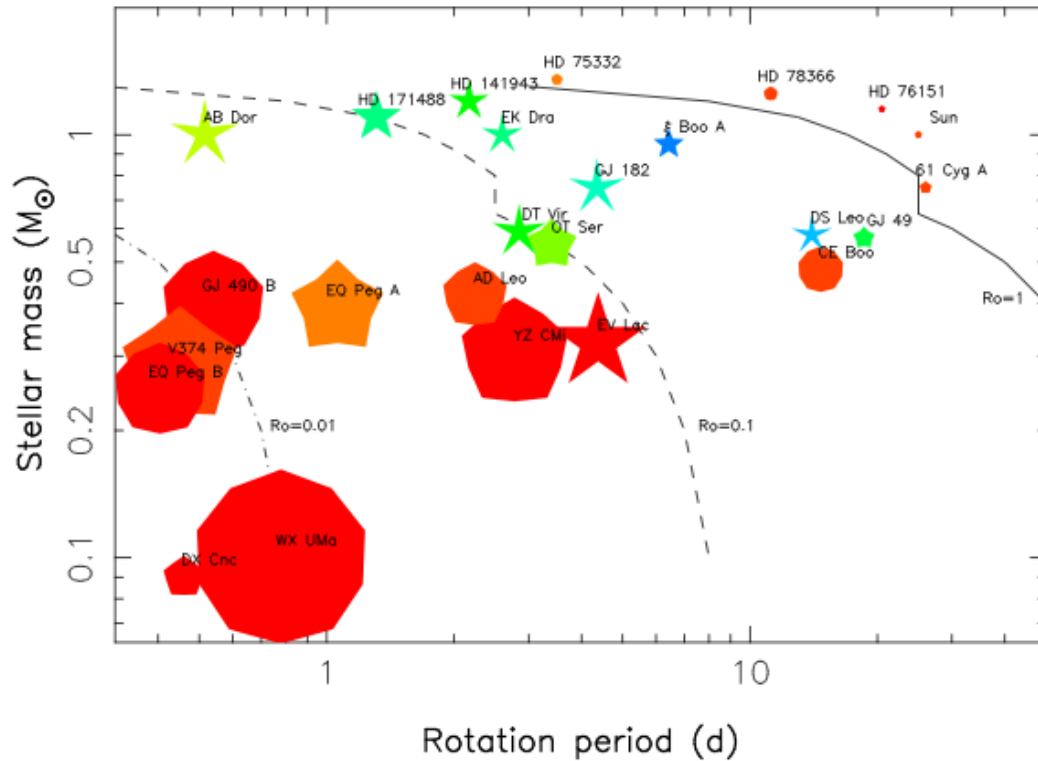
Large scale

Simple poloidal structure

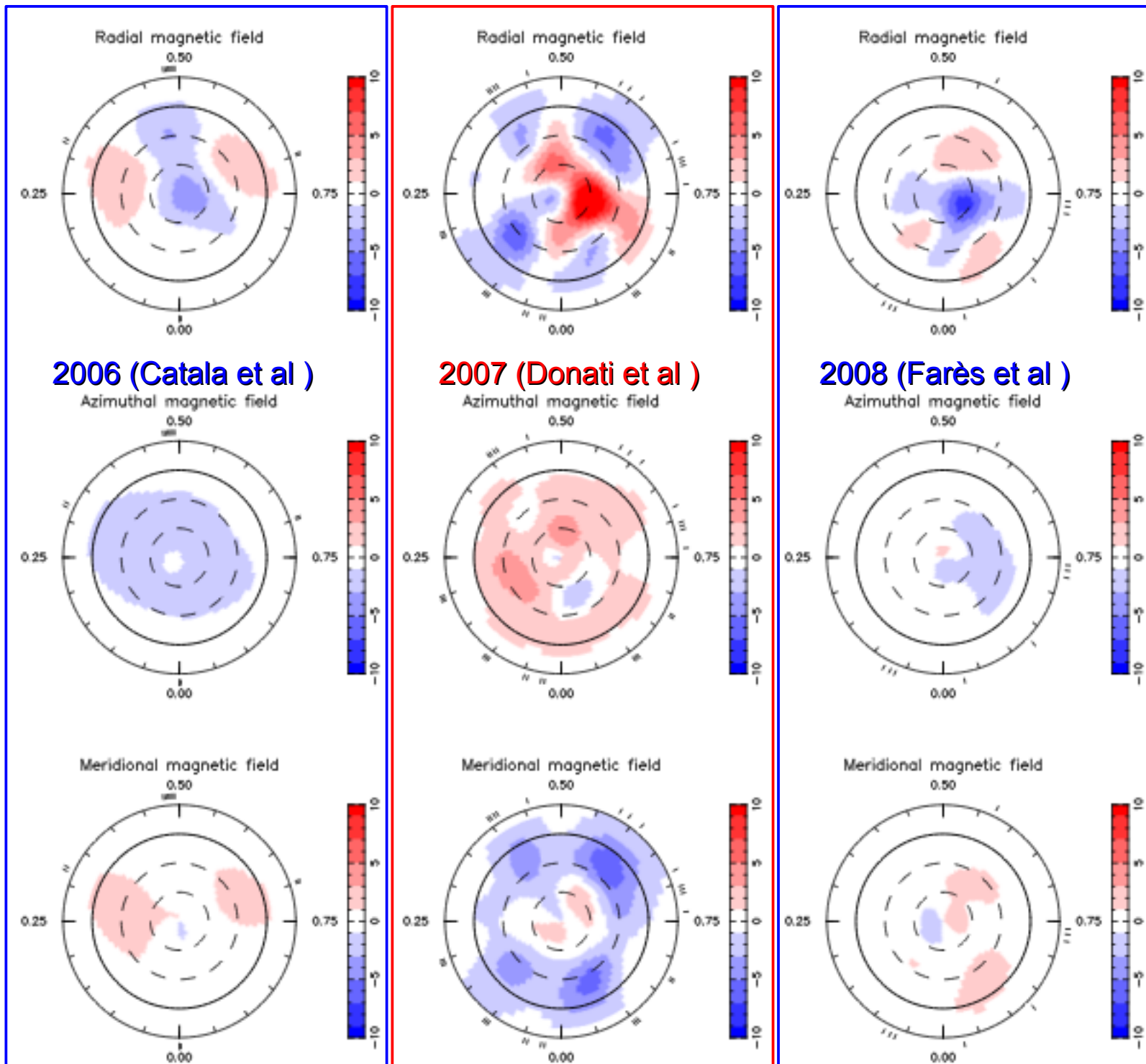
No variability

Science with TBL/Narval

bootis A Zeeman Doppler Imaging
(76 spectra 2007-2011, Morgenthaler et al.)



Donati & Landstreet (ARAA 47, 2009), Morin et al., Petit et al.



b)

Planet hosting τ Boo magnetic polarity flip

Science with TBL/Narval

Giant stars. (Auriere, Konstantinova, Charbonnel et al. in prep)
Mira (cf N. Fabas talk)

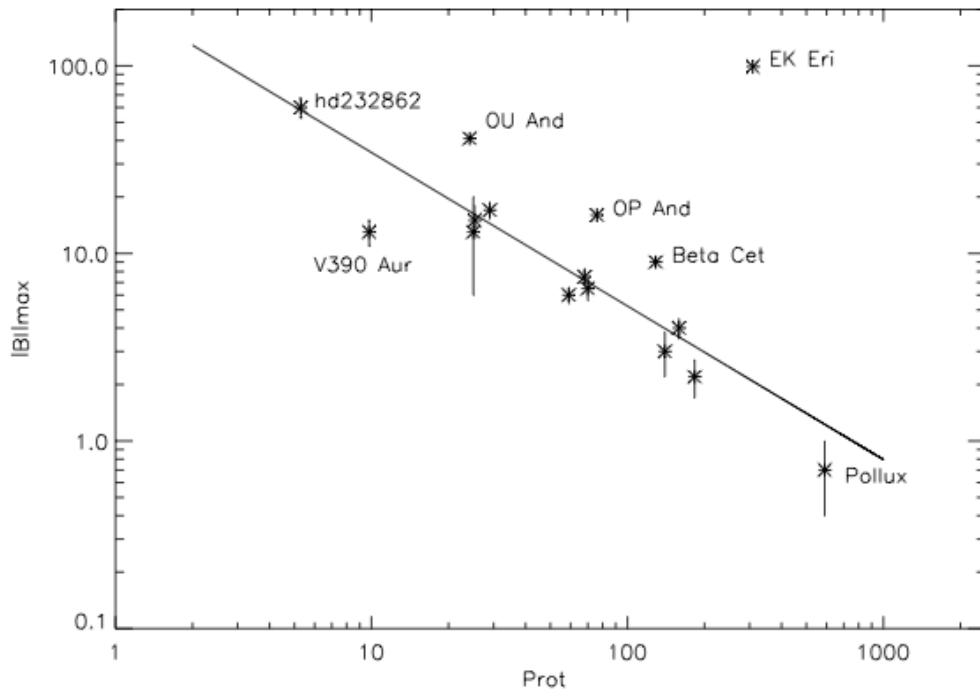


Fig. 8. Variations of the strength of the magnetic field ($|B_l|_{max}$) with the rotational period.

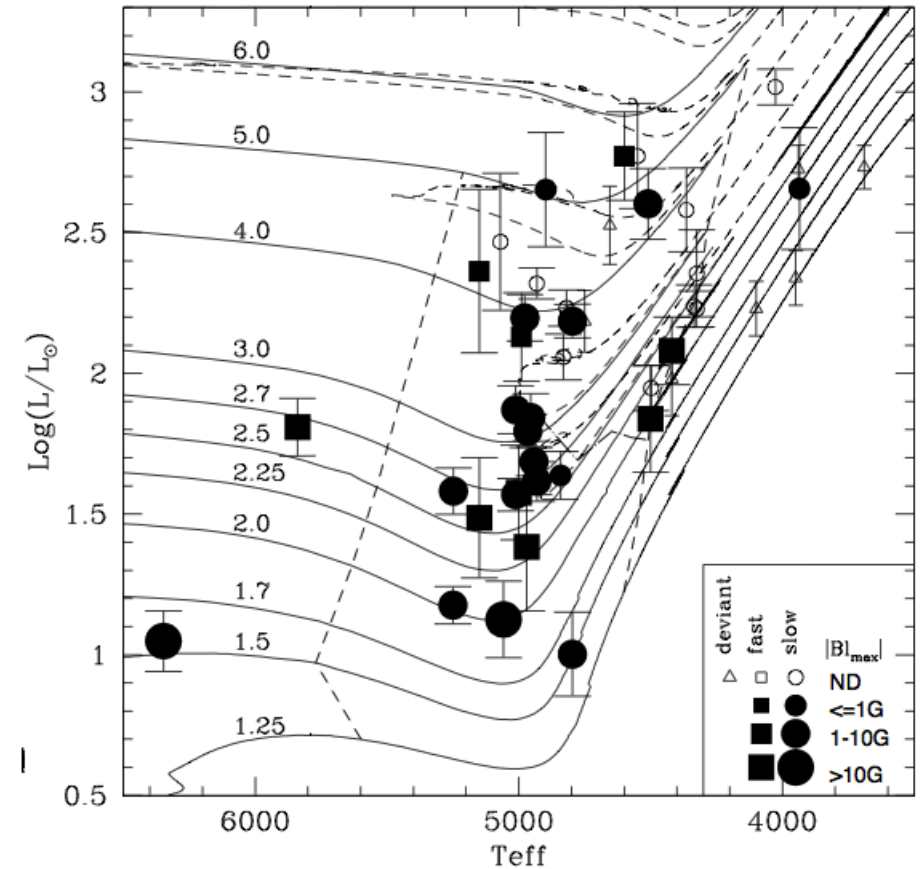


Fig. 3. Position of the Red Giants of our sample in the Hertzsprung-Russel Diagram. Tracks of the standard evolutionary models of Charbonnel and Lagarde (2010) are shown.

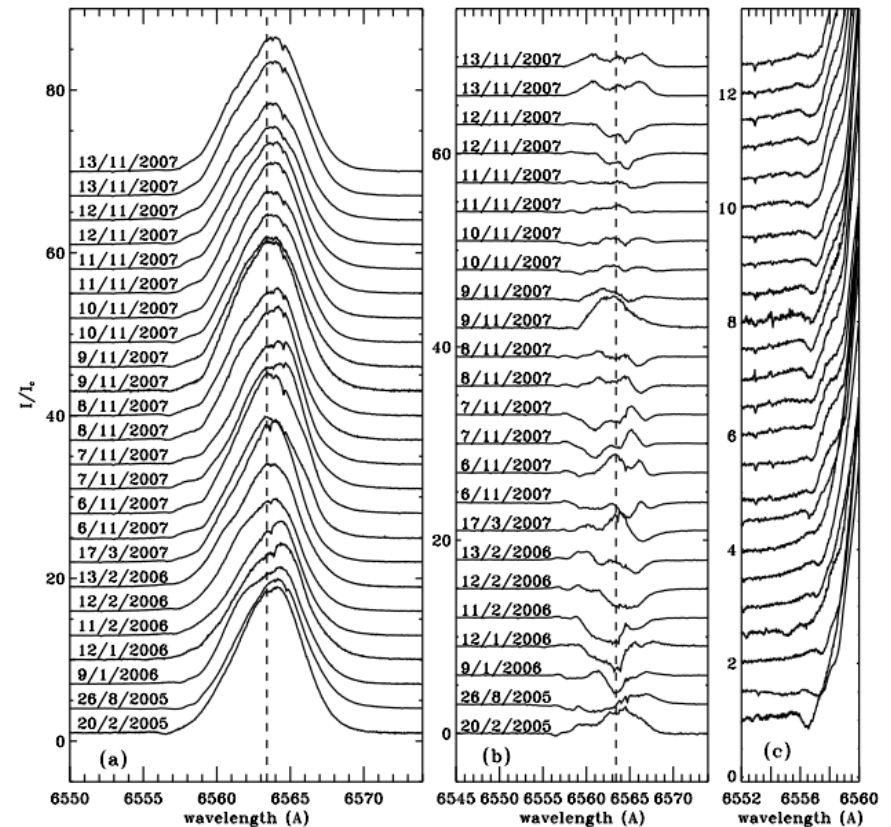
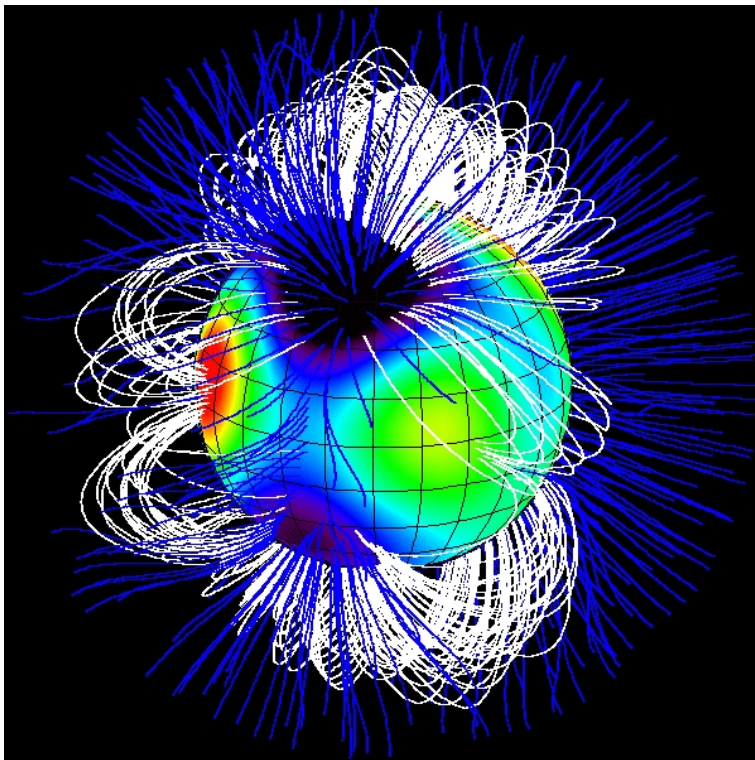
Science with TBL/Narval

The case of OB stars (Bouret, Neiner, Alecian, Wade et al.)

Program Magnetism in Massive Stars (MiMeS): origins and evolution of magnetic fields in hot stars, Herbig, OB

Complex field on Tau Sco (Jardine et al.)

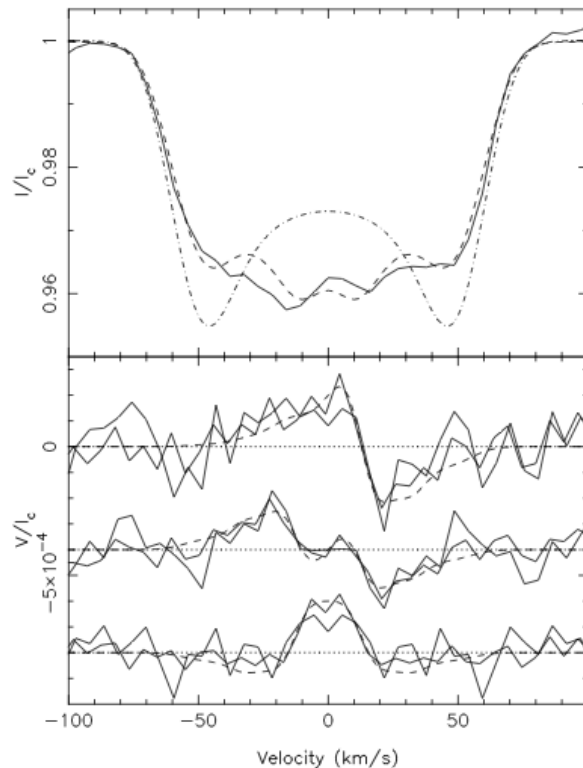
Herbig V380 Ori (Alecian et al)



Also work on ζ Ori O9 (Bouret et al., 2009)

Science with TBL/Narval

Proto-stars and accretion disks: FU Ori & TTauri stars
(large program MAPP; Bouvier & Donati)



- SPIROU precursors
- GAIA preparation
- Corot follow-ups

Fig. 6. Unpolarised and circularly polarised profiles of the protostellar accretion disc FU Ori. **Top panel:** observed Stokes I profile (solid line) and model profiles assuming either a Keplerian disc (dash-dot line) or a non-Keplerian disc (with 20% of the plasma rotating at strongly sub-Keplerian velocities, dashed line). **Bottom panel:** observed Zeeman signature (top curve) split into its anti-symmetric and symmetric components (middle and bottom curves, shifted by -4 and -8×10^{-4}) respectively characterising the vertical and azimuthal axisymmetric magnetic fields. The model (dashed line) requires the slowly rotating disc plasma to host a 1 kG vertical field plus a 0.5 kG azimuthal field (from [Donati et al. 2005](#)).

FUTURE

Future

TBL/Narval, (CFHT/ESPADONS) are still very unique instruments for the study of polarisation in high-res spectra.

A lot of interesting science besides stellar magnetism

Up to 20% of TBL can be used by European astronomers (OPTICON Access program FP7)

Narval is on TBL until 2015+

TBL Science council has started the process of new instrumentation

Call for proposal spring 2012. Two possibilities are explored.

Option 1 : improve Narval

Option 2 : SPIP → SPIrou @ Pic du midi : Narval in range 1-2.4 μ m

Future

Option 1 : continue the studies on stellar magnetism -> improve Narval

- better stability RV (10m/s long range)
- improve dome seeing (bad)
- guiding tip/tilt (gain 1-2 mag depth)
- decrease cross-talk (now ~1-3% ADC/Triplet)
- add continuum polar module

Option 2 : study young stellar system and planet formation

SPIP → SPIrou @ Pic du midi : Narval in range 1-2.4 μ m

lamwws.oamp.fr/magics/spirou

Specifications from main science drivers

- spectral domain: 0.98-2.4 μ m (w/ full coverage up to at least 2.3 μ m)
- spectral resolution >70,000 (goal 75,000) w/ 2 km/s sampling
- radial velocity precision < 1m/s
- S/N=110 per 2 km/s pixel in 1hr @ J=12 & K=11
- thermal background from instrument smaller than telescope emission @ 2.4 μ m
- all polarisation states accessible with <1% crosstalk over full spectral domain

Future

All that will be discussed at

TBL Users Meeting, June 4, 2012 Nice (France)

Thank you !