The Visible light Road-Map

N. Nardetto, P. Stee, D. Mourard et al.

Preliminary scientific requirements from the White Book of P. Stee et al.
Cf. message on OLBIN the 11th Sept 2015
50 co-authors, 134 pages.

https://www.dropbox.com/s/7nb4lfmmn5x4qra/Science_cases_visible.pdf?dl=0

Summary of science cases: as derived from the white book (part 1/3)

1 - Fundamental parameters (of main sequence stars)

O. Creevey, L. Bigot, A. Chiavassa, P. Petit, F. Allard, R. Ligi, N . Nardetto, D. Shulyak, M. Wittkowski

1a – Diameter of stars

i - Toward planet radii **(1)**
ii - Toward radii and effective temperature **(2)**
iii - Toward stellar mass and age (asteroseismology) **(3)**
iv - IRSB, binary masses... **(4)**

1b – Stellar activity

i - Planet detection and convection **(5)**
ii – Spots **(6)**

2 - Pre-Main Sequence stars

K. Perraut, M. Benisty, S. Kraus, G. Schaefer, Simon

i - Fundamental parameters (binaries) **(7)**
ii - Environment (disk) **(8)**

Summary of science cases: as derived from the white book (part 2/3)

3 – Distances

N. Nardetto, P. Kervella, A. Chiavassa, A. Gallenne, A. Merand, D. Mourard, J. Breitfelder + Araucaria Project collaborations

3a – Cepheids

i - the projection factor derived from Cepheids in binaries **(9)**
ii - the LD of Cepheids as a constrain on the projection factor **(10)**
iii - the CSE of Cepheids in the visible **(11)**
iv - Applying the inverse BW method with Gaia parallaxes to get the projection factor **(12)**
v - A new method to derive the distance using spectro-interferometry **(13)**

3b – Eclipsing binaries

i - the SBCR of early and late-type stars: distance in the local group **(14)**
ii - the distance to Galactic eclipsing binaries:
a cross-check for the method **(15)**

4 - Massive stars (mostly early-type stars)

P. Stee, A. Meilland, F. Millour, Borges Fernandes, Carciofi, Wit, A. Domiciano, Faes, Kostogryz, N. Nardetto, Zorec

i - Massive multiple stars **(16)**
ii - Stellar rotation among Be stars (study of their CE) **(17)**
iii - Measuring differential rotation on the surface of Bn stars (no CE) **(18)**
iv - Physics of B[e] stars **(19)**
v - Direct detection of Non-Radial pulsation of massive stars **(20)**

Summary of science cases: as derived from the white book (part 3/3)

5 - Evolved stars, Planetary Nebulae

C. Paladini, A. Chiavassa, K. Ohnaka, N. Fabas, Hillen, N. Nardetto, van Winskel, M. Wittkowski, M. Ireland, J. Monnier

i - The AGB stars: dust distribution, magnetic and velocity fields **(21)**
ii - the Red Supergiant Stars **(22)**
iii - the post-AGB stars **(23)**
iv - The projection factor of delta Scuti and RR Lyrae + pulsating stars in Binaries **(24)**

6 - Interacting binaries

N. Blind, H. Boffin, Borges Fernenades, A. Gallenne, Guerrero Pena, Hillen , A. Labeyrie, Marsch, Simon, F. Millour, Steeghs, T. ten Brummelaar

i - Finding a companion **(25)**
ii - Determining accurate masses **(26)**
iii - Probing the mass transfer mechanisms (case of SS Lep) **(27)**

7 – AGNs

Petrov, Rakshit, Martin, Kishimoto, Marconi, Meilland, Millour, Weigelt

i - Accretion disks (<1mas - unrealistic 50km baseline)
ii - Broad Line Region (BLR) **(28)**
iii - Narrow Line Region (NLR) **(29)**
iv - Dust Torus (limited impact in visible but should be studied)

8 - Imaging, technics and the FRIEND prototype (not presented in this talk)

SCIENCE CASES REQUIREMENTS SYNTHESIS (29 PROGRAMS)

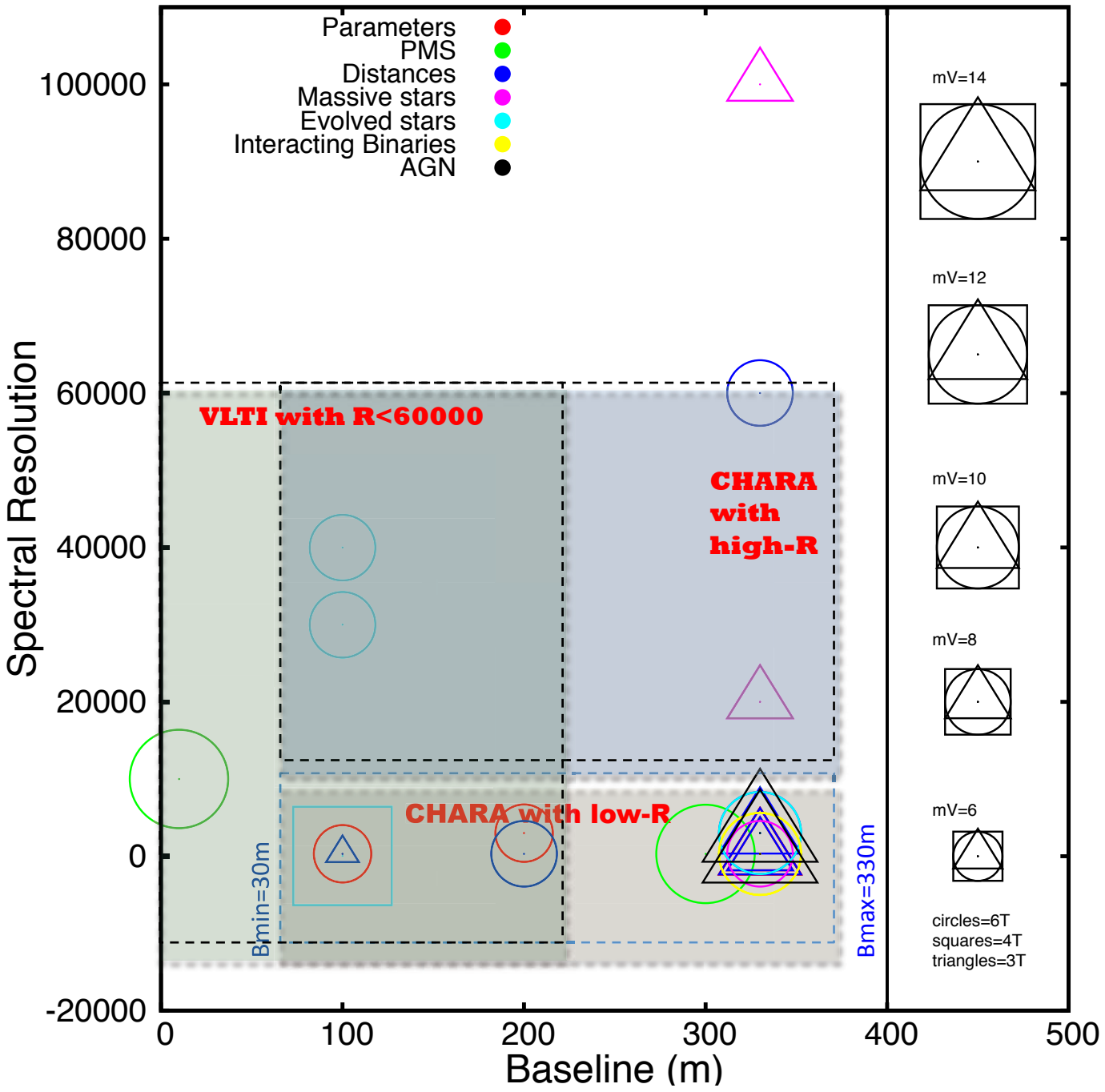
	Minimum	Maximum	Driver
baseline (m)	10	330	array geometry
# Telescopes	3	6	array geometry
limiting magnitude	4	14	telescopes/AO + instrument itself
lambda (nm)	500	800	seems not critical
Spectral Resolution (R)	30	100000	instrument
# objects	2	10000	instrument/drs
time resolution (days)	0.5	365	array (winter closure of chara ?)
$\sigma V^2/V^2$ (%)	1	2	mostly 1%
$\sigma\theta/\theta$ (%)	1	2	mostly 1%
image ot not			6T but otherwise not critical

Details for each program

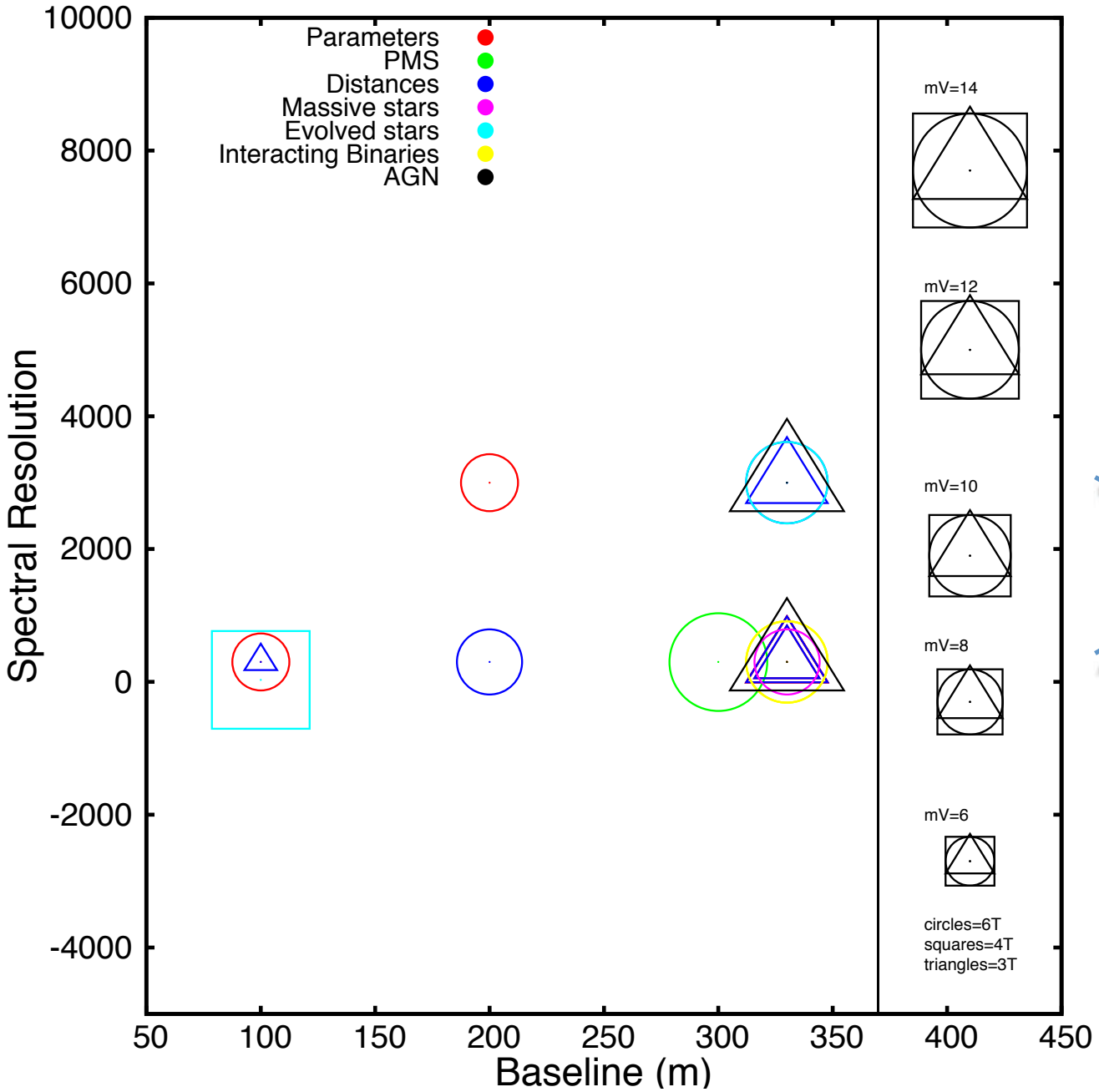
		Bp (m)	#T	mV	lambda (nm)	R	# objects	Dt	eV2/V2(%)	noImage=0	eDiam/diam(%)
1ai	**1**	330	3	10	700	300	15	365	1	0	2
1aii	**2**	330	3	10	700	300	27	365	1	0	2
1aiii	**3**	330	3	8	700	300	1000	365	1	0	2
1aiv	**4**	330	3	10	700	300	10000	365	1	0	2
1bi	**5**	100	6	7	700	300	10	1	1	1	
1bii	**6**	200	6	7	700	3000	10	365	1	1	
2i	**7**	300	6	12	700	300	15	7	2	0	
2ii	**8**	10	6	12	700	10000	15	7	2	0	
3ai	**9**	330	3	8	700	300	15	30	2	0	
3aii	**10**	100	3	4	700	300	2	1	1	0	1
3aiii	**11**	200	6	8	700	300	20	1	1	1	1
3aiv	**12**	330	3	10	700	300	100	1	1	0	1
3av	**13**	330	6	8	700	60000	50	1	1	0	1
3bi	**14**	330	3	10	700	3000	200	1	1	0	1
3bii	**15**	330	6	10	700	3000	50	1	1	0	1
4i	**16**	330	6	8	700	300	100	1	1	0	1
4ii	**17**	330	3	8	700	20000	100	365	1	1	1
4iii	**18**	330	3	8	700	100000	100	365	1	0	1
4iv	**19**	330	3	8	700	20000	100	365	1	0	1
4v	**20**	330	3	8	700	20000	100	365	1	0	1
5i	**21**	100	3	8	700	40000	10	1	1	1	1
5ii	**22**	100	3	8	700	30000	10	1	1	1	1
5iii	**23**	100	4	12	700	30	60	1	1	1	1
5iv	**24**	330	3	10	700	3000	10	0,5	1	0	1
6i	**25**	330	6	10	700	300	250	30	1	1	1
6ii	**26**	330	6	10	700	300	250	30	1	1	1
6iii	**27**	330	6	10	700	300	250	30	1	1	1
7ii	**28**	330	3	14	700	300	10	1	1	0	1
7iii	**29**	330	3	14	700	3000	10	1	1	0	1

In red, inputs not clearly indicated in the white book.

Please send me your specifications if wrong !


Parameters
PMS
Distances
Massive stars
Evolved stars
Interacting Binaries
AGN
VLTI with R<60000
CHARA with high-R
CHARA with low-R
Bmin=30m
Bmax=330m
mV=14
mV=12
mV=10
mV=8
mV=6
circles=6T
squares=4T
triangles=3T
Spectral Resolution
Baseline (m)
100000
80000
60000
40000
20000
0
-20000
0
100
200
300
400
500

ZOOM on the CHARA with low-R Area



2 groups actually

Summary of science requirements:

1 - CHARA with low-R, i.e. R < 4000: fundamental parameters, distances, interacting binaries (21 programs)

NB: two groups actually:

. R<2000

. 2000<R<4000

2 - CHARA with high-R, i.e. R from 20000 to 60000: rotation of massive stars, velocity fields of evolved stars, dynamical structure of Cepheids (6 programs)

3 - VLTI with R<60000, i.e. R < 60000: stellar activity, PMS stars, part of Cepheids, massive and evolved stars programs (8 programs + 4 potential).

NB:

- with concepts 1 and 2 we cover all the programs except number 8 (disk environment of PMS stars which requires short baseline) and number 18 (differential rotation of Be stars which requires R=100000).
- concept 3 is overlapping with 1 and 2.

CHARA with low-R: *R<2000 (1-5+7+9-12+16+23+26-29)*

1 - Fundamental parameters (of main sequence stars)

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ii - Broad Line Region (BLR) **(28)**

2 - Pre-Main Sequence stars

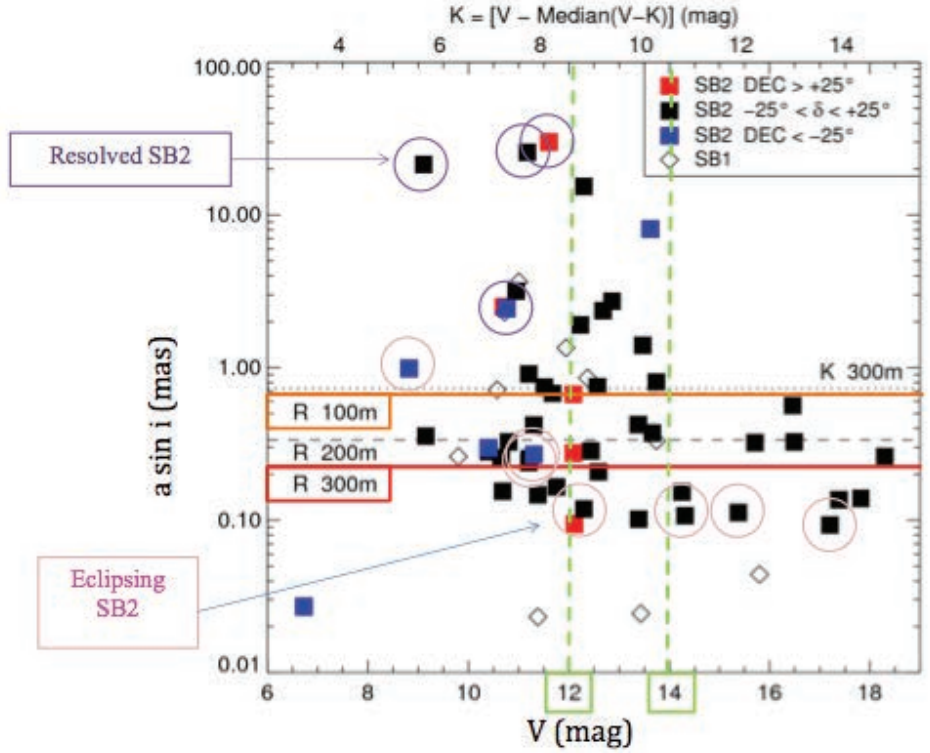
K. Perraut, M. Benisty, S. Kraus, G. Schaefer, Simon

i - Fundamental parameters (binaries) **(7)**
ii - Environment (disk) **(8)**

Bp=300
6T
mV=12
R=300
#Obj = 15

i – fundamental parameters (binaries) (7)

Interferometric orbits of Pre-main sequence binary stars => individual orbital masses (constrain on star formation models).



The best is 300 meters of baseline with limiting magnitude of 14. NB: interesting synergy between CHARA and VLTI

Fig. 3.2 Separations vs. limiting magnitudes for spectroscopic binaries of star-forming regions (Taurus-Auriga, Ophiuchus, Sco-Cen, Chamaeleon, Orion, NGC 2264). Spectral types range from F to M.

NB: the angular diameter of stars

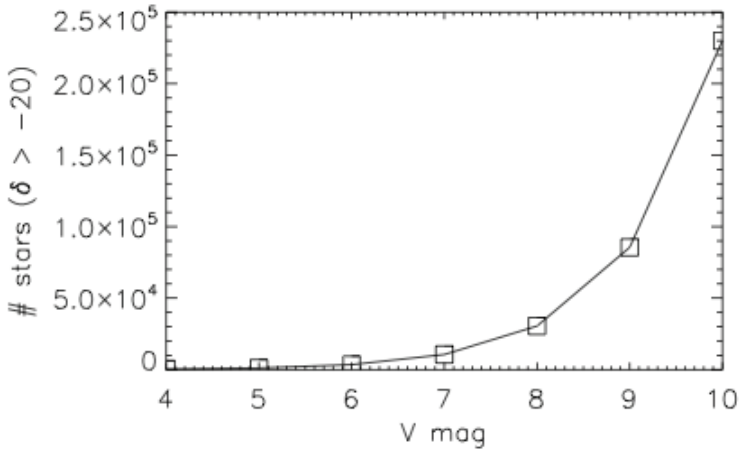


Fig. 2.1 The number of stars with declinations above –20° (observable from CHARA) as a function of magnitude

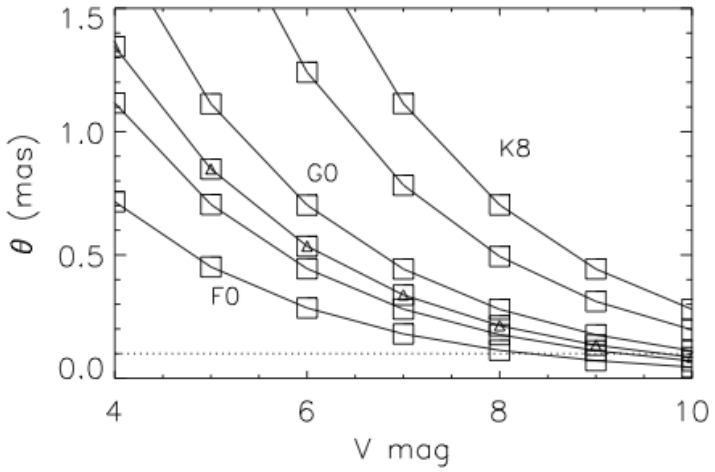


Fig. 2.2 The predicted angular diameters of stars of different spectral types as a function of magnitude number of stars grows exponentially as the magnitude limit is extended. The dotted line is the hard lower limit in angular diameter.

mV=10 means 250000 objects with angular diameter mostly between 0.1 and 0.5 mas !

CHARA with low-R: *2000<R<4000 (6, 14, 15, 24, 29)*

1 - Fundamental parameters (of main sequence stars)

ii – Spots **(6)**

3b – Eclipsing binaries

i - the SBCR of early and late-type stars: distance in the local group **(14)**

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5 - Evolved stars, Planetary Nebulae

iv - The projection factor of delta Scuti and RR Lyrae + pulsating stars in Binaries **(24)**

7 – AGNs

iii - Narrow Line Region (NLR) **(29)**

- R<2000 is fine for 14, 15, 24
- What about R<2000 for 6 and 29 ?
- 29: additionnal problem of limiting mag (see slide 25).

Conclusion: only one sub-group in Concept 1

CHARA with high-R, i.e. R from 20000 to 60000: 13, 17, 19, 20, 21, 22 (6 programs)

3 – Distances

3a – Cepheids

v - A new method to derive the distance using spectro-interferometry **(13)**

4 - Massive stars (mostly early-type stars)

ii - Stellar rotation among Be stars (study of their CE) **(17)**

iii - Measuring differential rotation on the surface of Bn stars (no CE) **(18)**

=> R = 100000

iv - Physics of B[e] stars **(19)**

v - Direct detection of Non-Radial pulsation of massive stars **(20)**

5 - Evolved stars, Planetary Nebulae

i - The AGB stars: dust distribution, magnetic and velocity fields **(21)**

ii - the Red Supergiant Stars **(22)**

3av – A new method to derive the distance using spectro-interferometry (13)

The visibility signal within the metallic lines is linked to the stellar rotation, the angular diameter, the spectral line characteristics (width, detph, pulsation and dynamical structure of the atmosphere).

Bp=330
6T
mV=8
R=60000
#Obj = 50

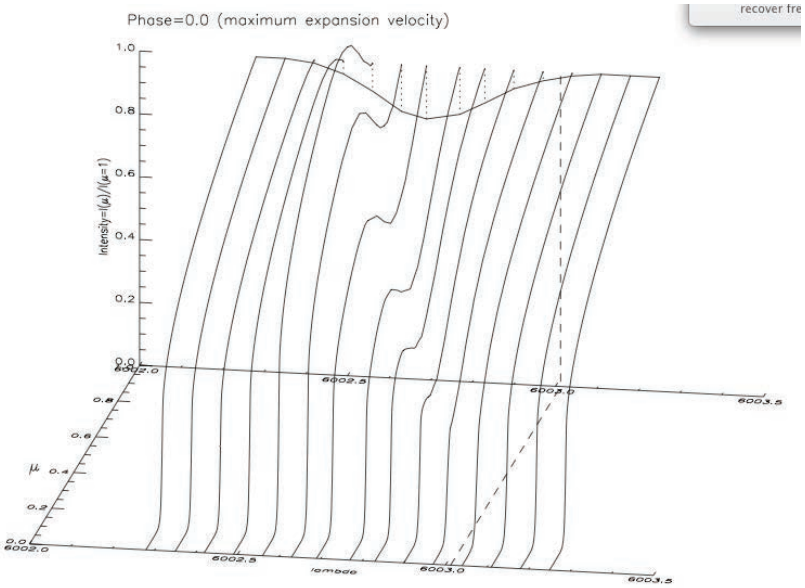
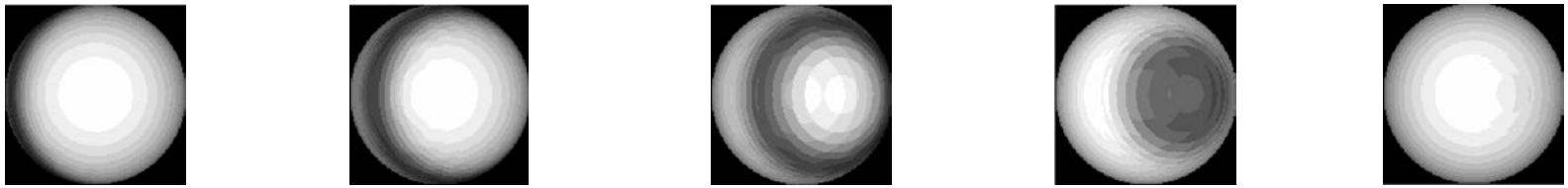


Fig. 4.3 A 3D diagram that represents the spectral line profile (FeI 6003.012 Å) for the maximum expansion velocity ($\phi = 0.00$) with the corresponding intensity distributions. The dashed line represents the reference wavelength in the stellar rest frame.

Nardetto+ 2006



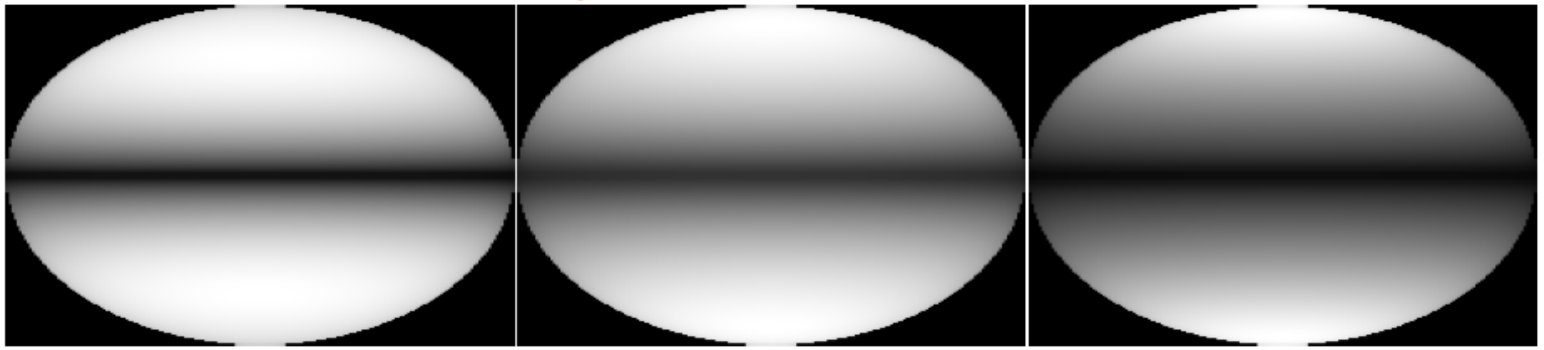
3iii - Measuring differential rotation on the surface of Bn stars (no CE) (18)

Gravitational darkening in the visible !

=> The only program with R=100000. Is R=60000 enough ?

Bp=330
3T
mV=8
R=100000
#Obj = 100

The pole turn faster the equator (α > 0) | **Rigid rotation (α = 0)** | **The Equator turn faster the pole (α < 0)**



Theoretical result : stellar brightness distribution (β) modified by the differential rotation (α)...

Delaa et al. (2013)

See Talk of Michel Rieutord yesterday

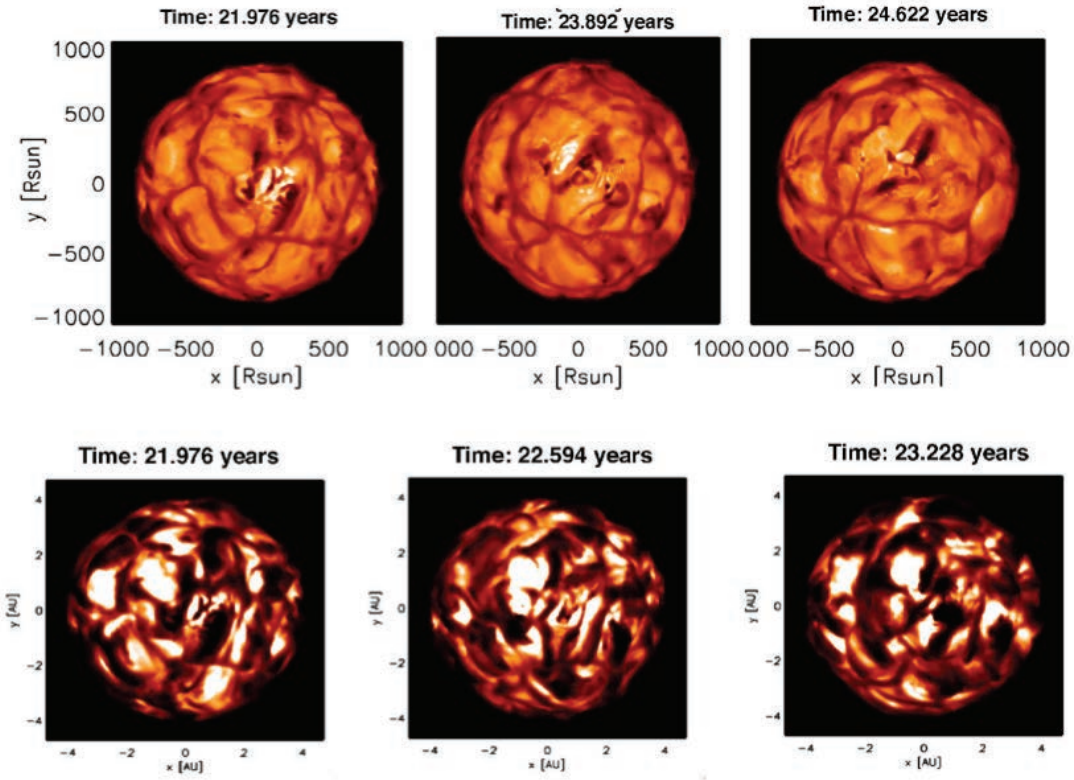
5ii - the Red Supergiant Stars (>10Ms) **(22)**

Observables: size of granulation, surface intensity contrast, velocity field and convection motions.

⇒ photosphere dynamics, mass loss process, accurate abondances

=> all spectral resolution are useful: R=30, 3000 and 30000

Bp=100
3T
mV=8
R=30000
#Obj = 10



IR (contrast 3%)

Optical
(constrast ~10%)

Fig. 6.1 Synthetic maps (linear intensity) of a RSG simulations at different stellar time in the H band (top row, Chiavassa *et al.*, 2009) and in the optical region (bottom row, Chiavassa *et al.*, 2011).

VLTI with R<60000

In green, potentially for VLTI if a 200m baseline enough...

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1b – Stellar activity

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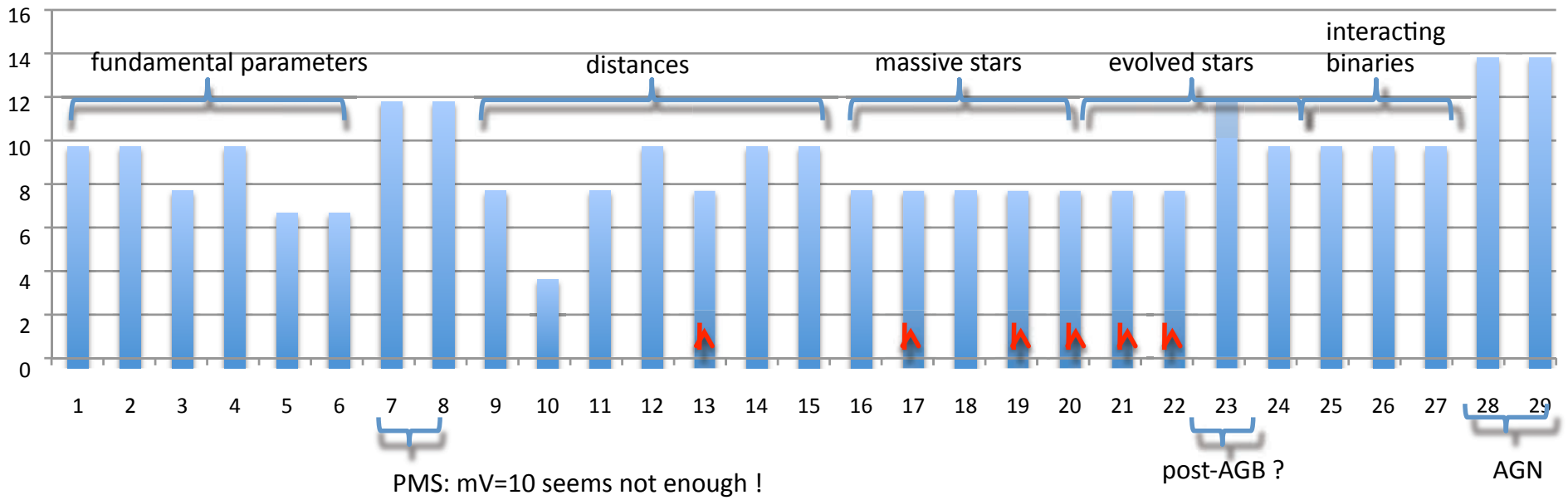
Problem of the limiting magnitude



- mv=8 seems enough for most of programs with high-R (13, 17, 19, 20, 21, 22)
- A magnitude limit of 10 is enough for 78% of low resolution programs.
- A magnitude limit of 8 is enough for 40% of the low resolution programs
- NB : 50000 stars reachable with mv=8, but 250000 with mv=10. mv=10 is critical for fundamental parameters and important for distances.

If reachable, mv=10 seems the best compromise for low-R programs (**except PMS and AGN**)
mv=8 is the best for high-R programs

Conclusions :

Three concepts:

1. CHARA with low-R [R<2000 and mv=10]. R<2000 seems to be actually enough (except 6 and 29) => Fundamental parameters, distances.
2. CHARA with high-R [20000<R<40000 with mv=8] => rotation of massive stars, velocity fields of evolved stars, dynamical structure of Cepheids.
3. VLTI with R<60000 with two or three modes (part of 1 + most of 2).
   NB: if R=low OR R=high, very few programs at the end.

Additionnal requirements:

- For all concepts, we need at least 1% of precision on $\sigma V^2/V^2$
- For all concepts we need at least 1% of precision on the derived diameters
- The wavelengths domain is not so critical: some lines are important Hα, Hβ, CaII lines.
- We are talking of a lot of diameters in concept 1 ! The instrument should be very efficient (20 diameters per good night, easy DRS also).