

Mini-Workshop on VLT/Calibrators  
Garching, 30-31 January 2003

*The use of M. Cohen's  
spectrophotometric reference stars as  
calibrators for optical interferometry*

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# *Interferometry & calibration*

- Interferometers measure fringe contrasts ( $\mu$ )
- Calibration is achieved thanks to the observation of reference sources interleaved with the scientific targets
- Visibilities ( $V$ ) can then be derived from:

$$V_* = \frac{\mu_*}{\mu_{\text{ref}}} V_{\text{ref}}$$

- A source can be used as a reference provided  $V_{\text{ref}}$  can be accurately predicted
- A non/barely resolved star can be described as a uniform disk (UD) = the angular diameter  $\theta_{\text{UD}}$  is the unique parameter:

$$V_{\text{ref}}(\theta_{\text{UD}}) = \frac{2J_1(x)}{x} \quad \text{with} \quad x = \frac{\pi B \theta_{\text{UD}}}{\lambda}$$

# *A spectro-photometric catalog*

*Cohen et al. 1999, AJ, 117, 1864-1889*

- 1) **1 primary IR reference spectrum** = Sirius
- 2) **~12 secondary IR reference spectra** = composite spectra made of observed fragments + absolute calibration in flux with respect to Sirius
- 3) A best-fit **Kurucz's model atmosphere** leads to a limb-darkened angular diameter  $\theta_{LD} \pm \Delta\theta_{LD}$
- 4) Fundamental hypothesis = the dereddened spectrum of a K0-M0 (II-IV) star can serve as a template for any other star of the same type
- 5) **Database of 422 stellar spectra** absolutely calibrated in flux by photometric measurements **with associated angular diameters and formal errors**  $\theta_{LD} \pm \Delta\theta_{LD}$

# *Selection criteria #1*

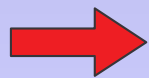
## *original spectro-photometric criteria*

- 1)  $>1 \star / 50 \text{ deg}^2$  in the IRAS database
- 2) Flux  $> 1 \text{ Jy @ } 25 \mu\text{m}$
- 3) “Normal ” position in the IR color-color diagram
- 4) Non-variable (proba  $> 90\%$ ), no emission line, no carbon star
- 5) Isolated  $\star$  (flux from objects within  $6'$  contribute to less than 5% to the total flux @ 12 and  $25 \mu\text{m}$ )
- 6) Not in a field of bright extended IR emission
- 7) Spectral type K0–M0 and luminosity class II–IV only

## *Selection criteria #2*

*additional criteria specific to interferometry*

- 1) No double or multiple star in the interferometric FOV  $\Rightarrow$  removal of all known spectroscopic binaries (Batten catalog)
- 2) Avoid confusion  $\Rightarrow$  removal of all double star with  $\rho_{AB} < 4''$  and/or  $V_B - V_A < 5$  in  $\emptyset < 30''$
- 3) Removal of eclipsing, pulsating and RS CVn-type stars

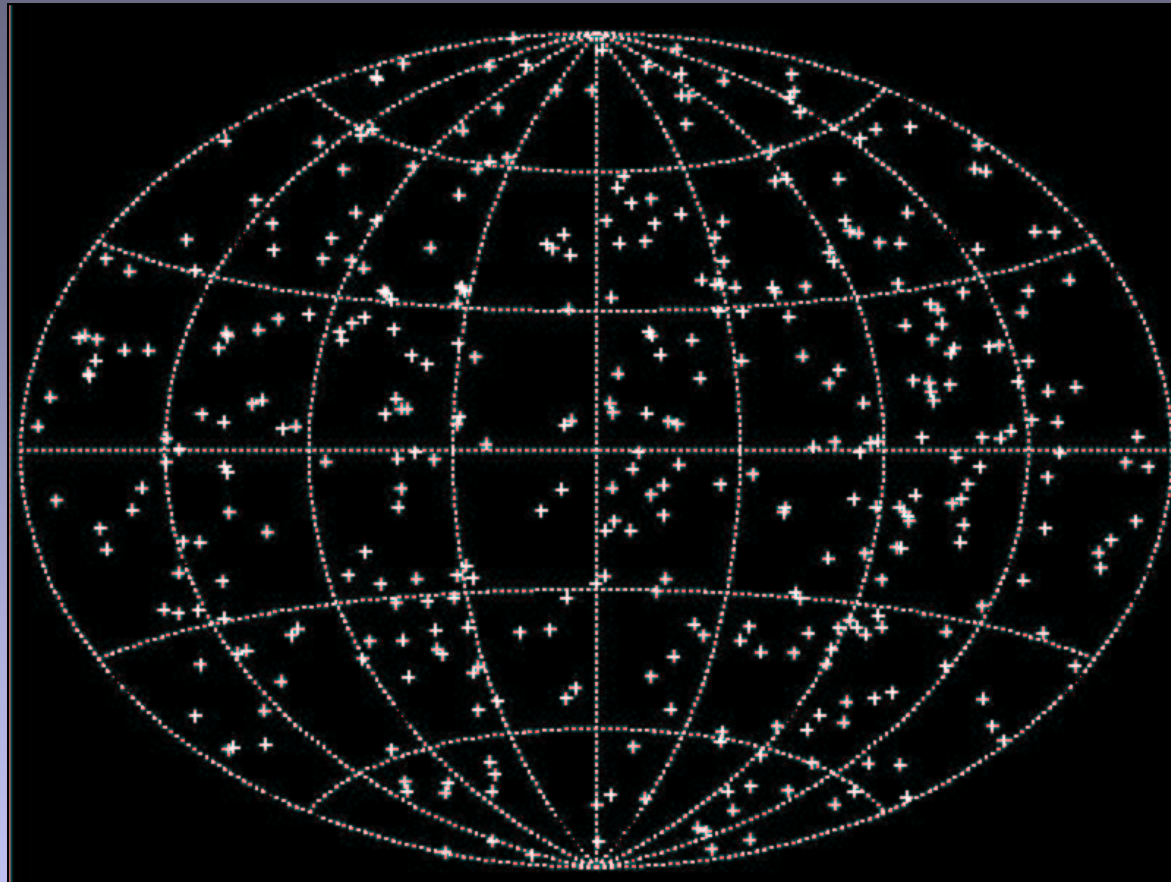


**Catalog of 374 reference stars**

# *Added content to the catalog*

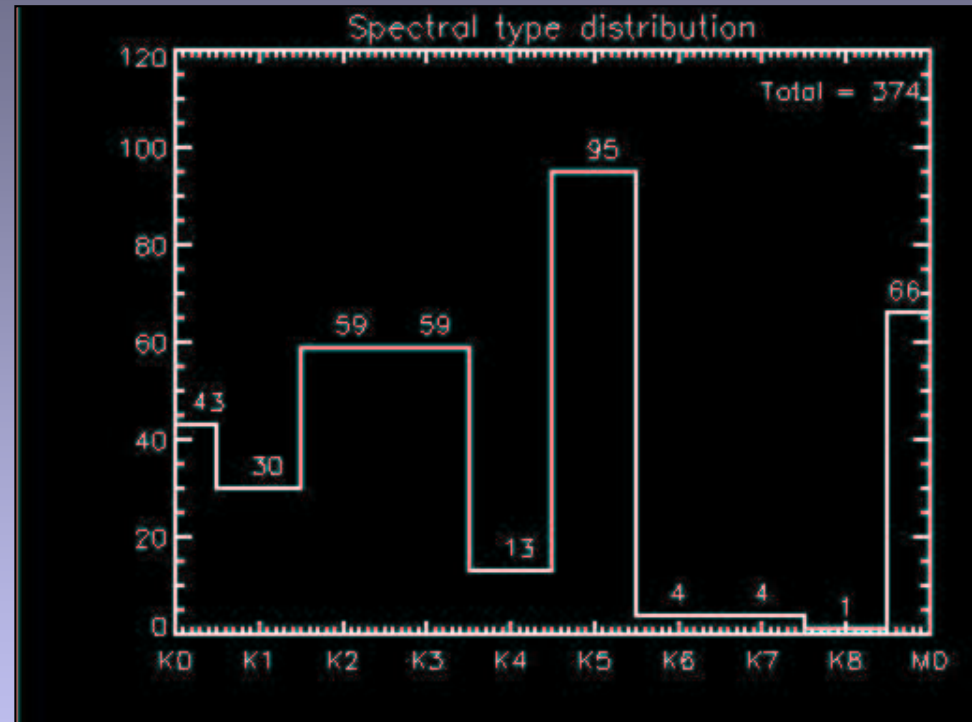
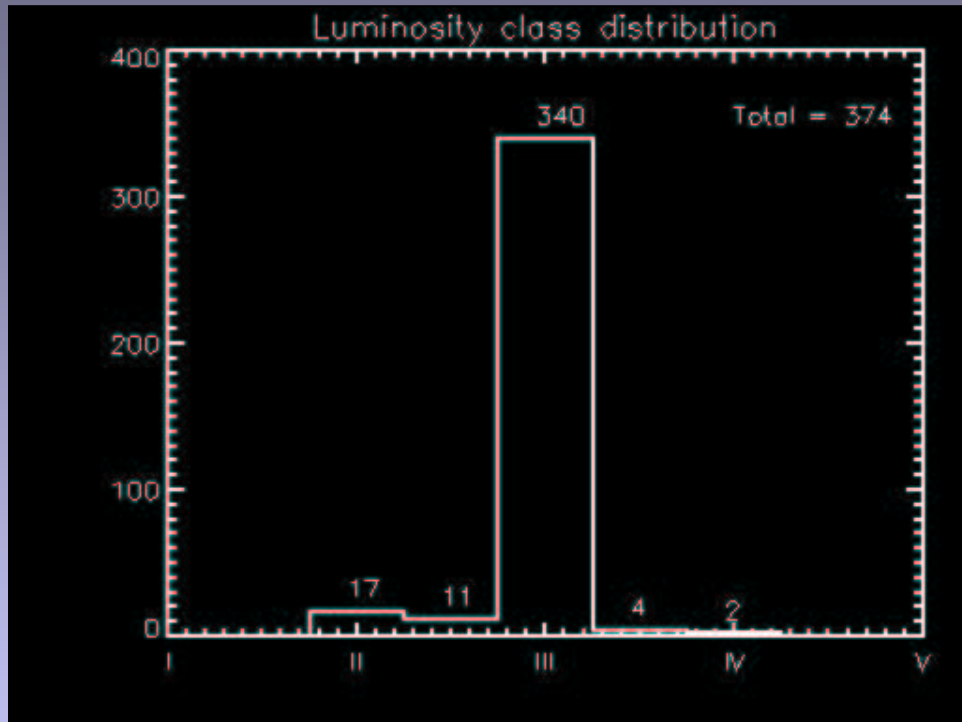
- 1) HD, HR, Bayer/Flamsteed
- 2) Coordinates ( $\alpha$ ,  $\delta$ ), prop. motion ( $\mu_\alpha$ ,  $\mu_\delta$ ), parallax  $\pi$
- 3) Spectral type,  $T_{\text{eff}}$ ,  $\log(g)$
- 4) **LD angular diameters *with formal errors***
- 5) Linear limb-dark. coef. in J, H, K
- 6) **UD angular diameters *with formal errors* in J, H, K**
- 7) Effective wavenumber and shape factor ( $K'$ )
- 8) **Photometry : B, V, J, H, K, L, M, N**
- 9) Simbad classification, sep. and mag. of companions

# *Sky coverage*



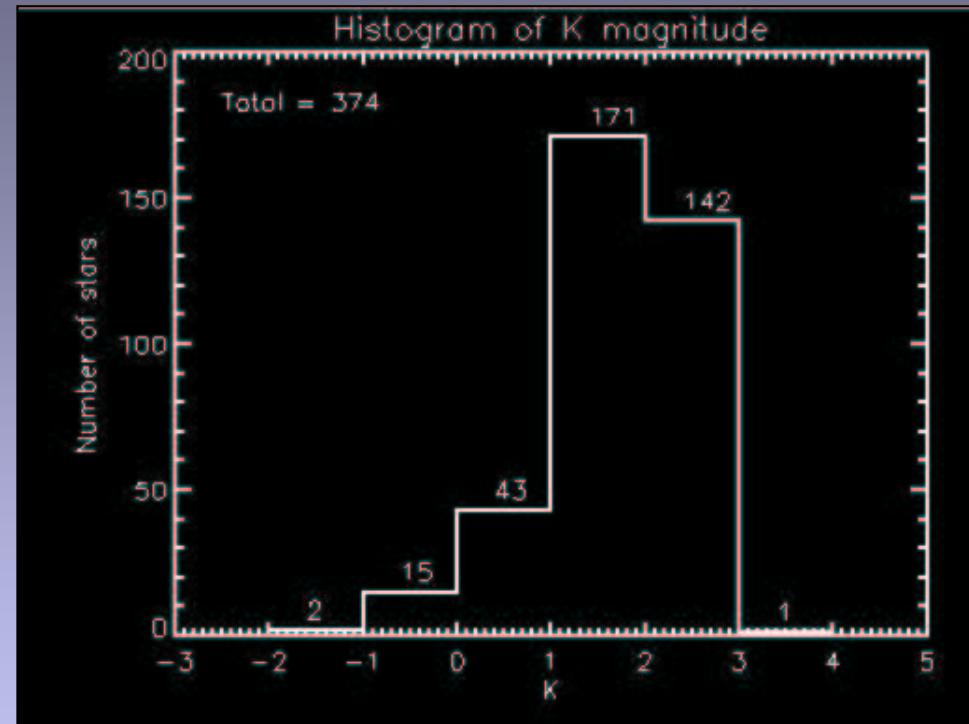
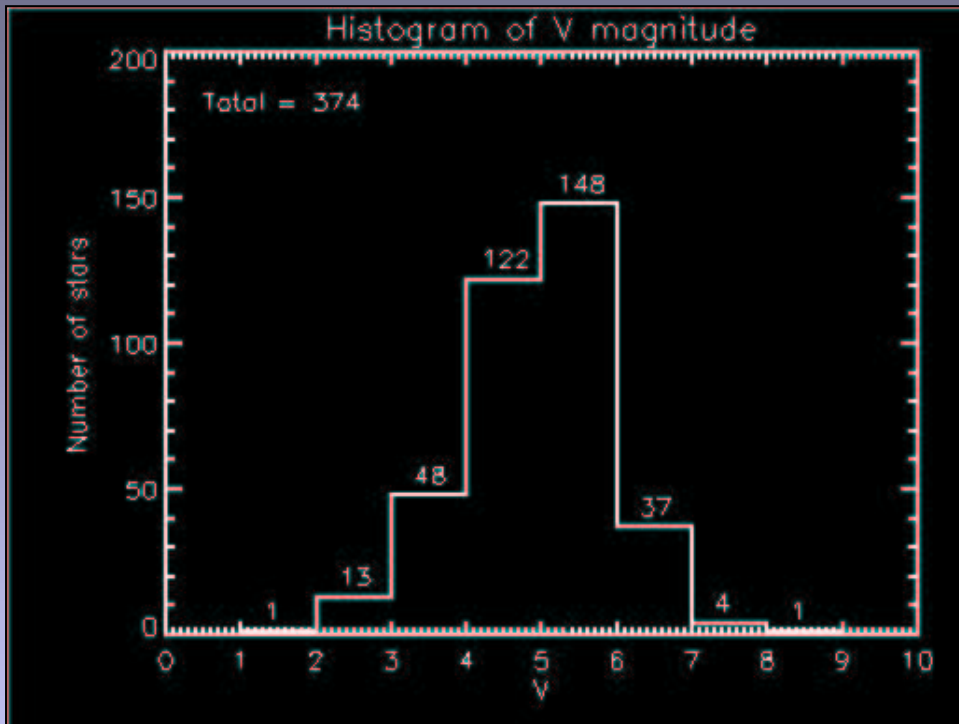
- Greatest distance to the closest reference =  $16.4^\circ$
- Median distance to the closest reference =  $5.2^\circ$

# *Luminosity class and spectral type*



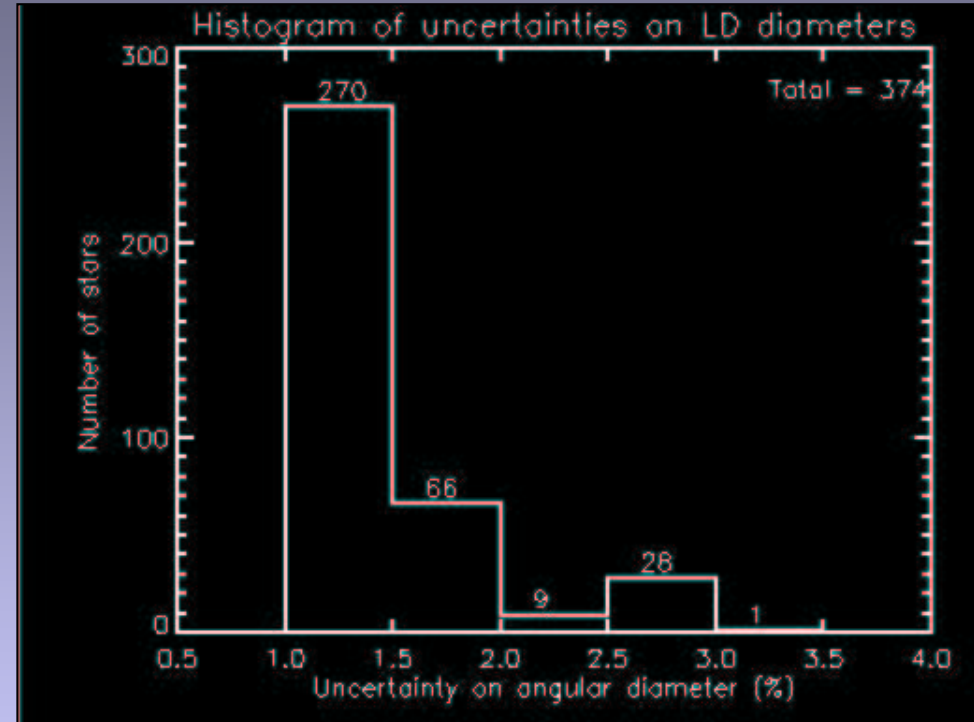
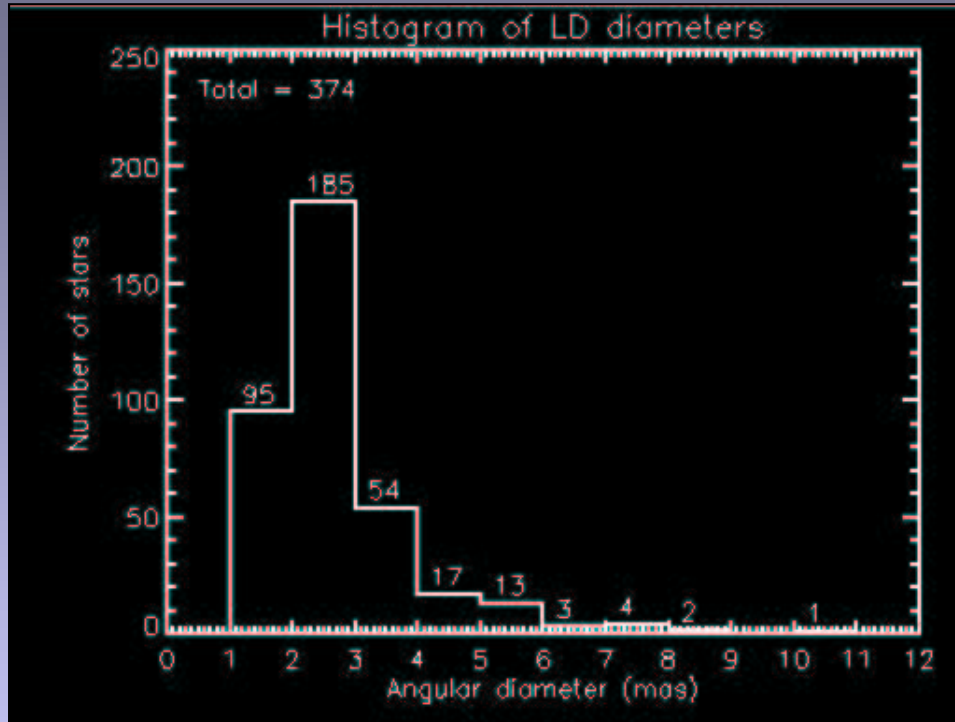
- Luminosity class: **III = 91%**
- Spectral type: **K = 82%** and **M0 = 18%**

# *V and K magnitudes*



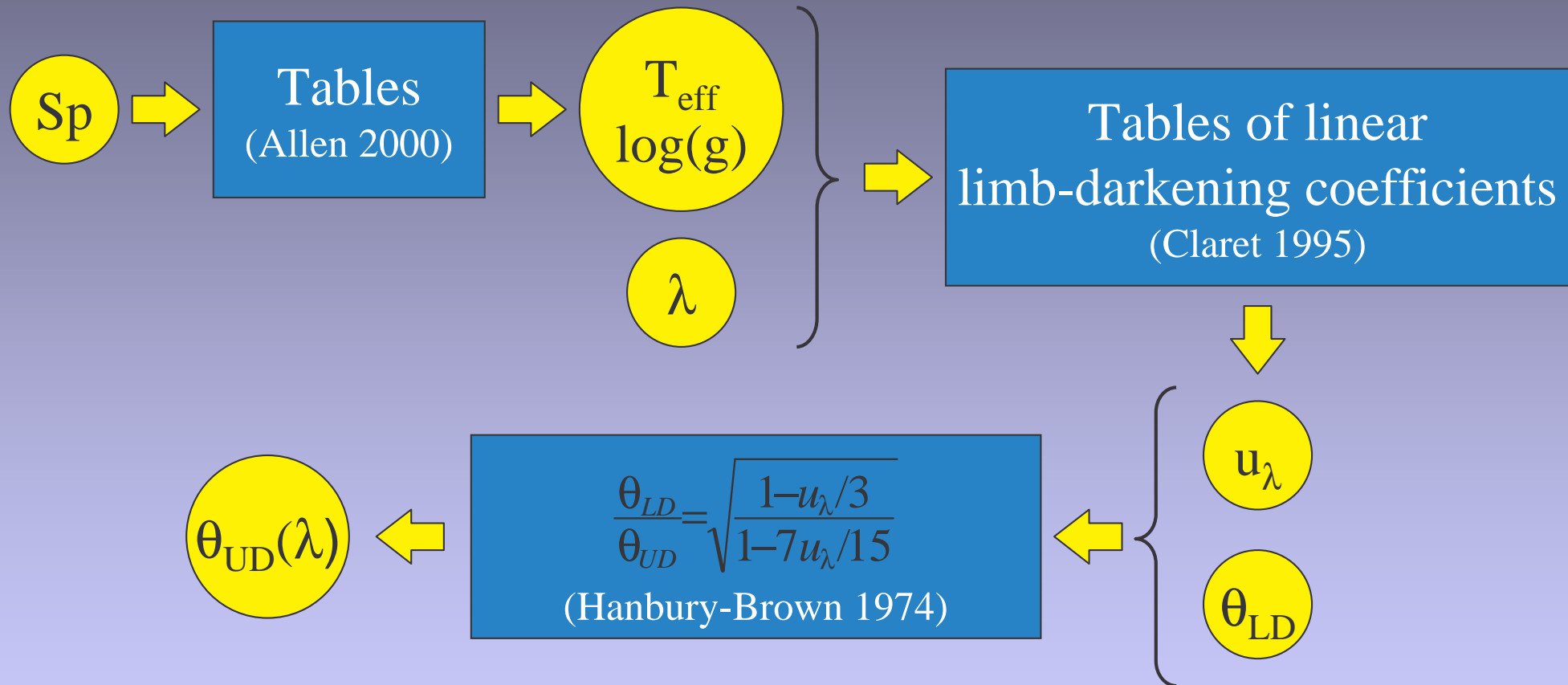
- $V_{\text{median}} = 5.0$  and  $3 \leq V \leq 7$  for 95% of the stars
- $K_{\text{median}} = 1.8$  and  $0 \leq K \leq 3$  for 95% of the stars

# *LD angular diameters*



- $(\theta_{LD})_{\text{median}} = 2.3 \text{ mas}$
- $(\Delta\theta_{LD}/\theta_{LD})_{\text{median}} = 1.2\%$

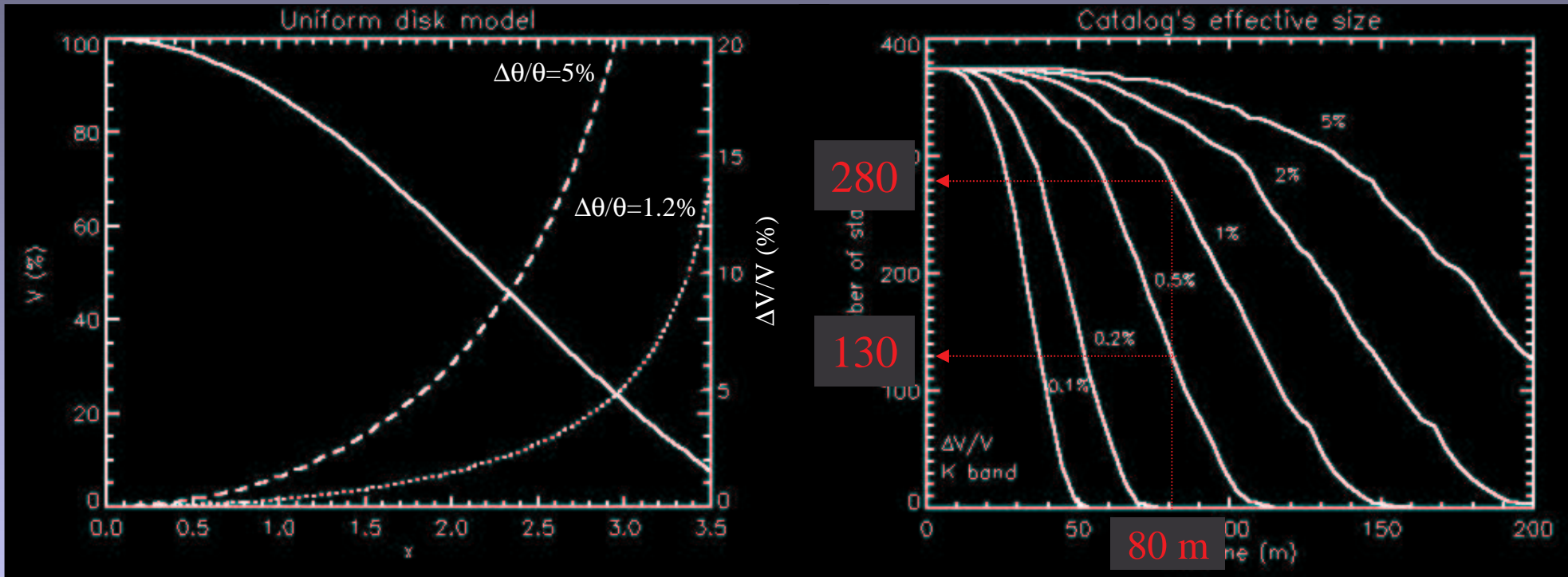
# *UD diameter computation*



- Application to J, H, and K bands
- Diameter errors only slightly increased

# Catalog's effective size

for the UD model in the K band



- 280 ★ for  $B = 80$  m and  $\Delta V/V \leq 1\%$
- 130 ★ for  $B = 80$  m and  $\Delta V/V \leq 0.5\%$

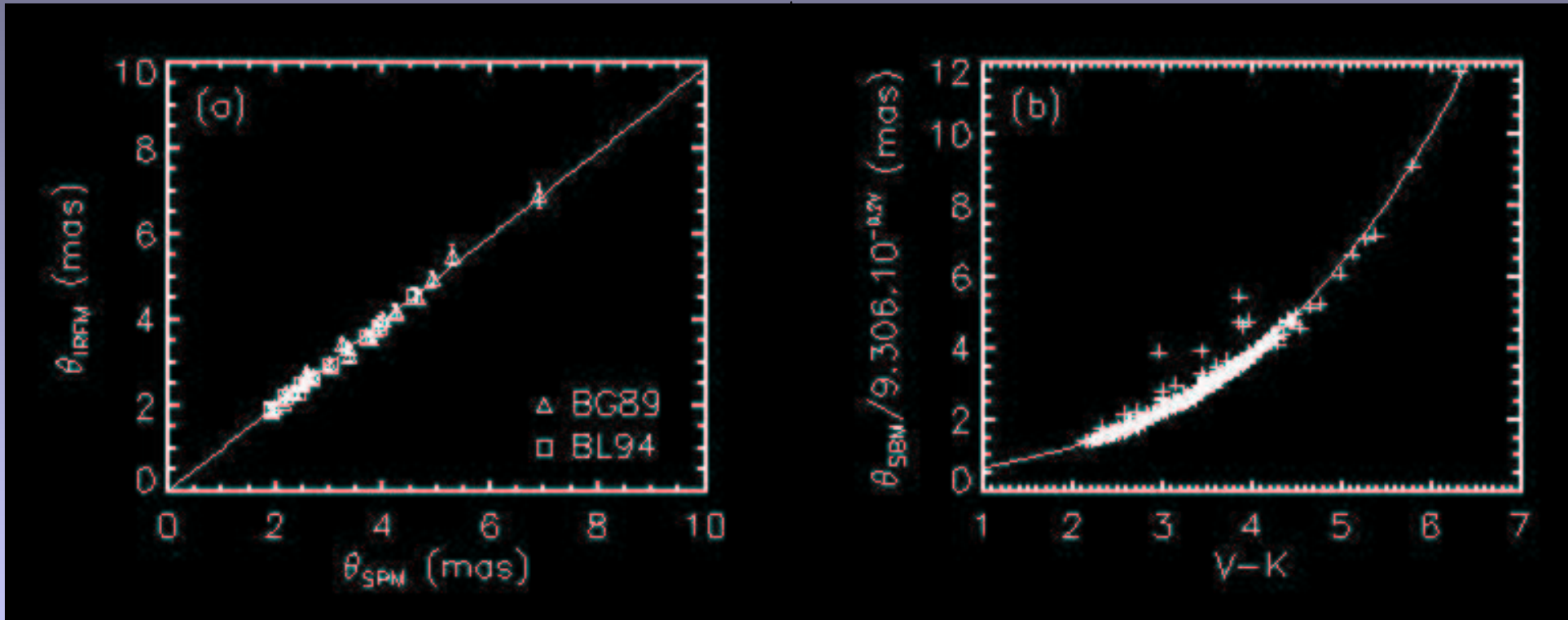
# *Catalog's effective size*

*for the UD model in the K band*

Baseline	$\Delta V/V \leq 0.5\%$	$\Delta V/V \leq 1\%$	$\Delta V/V \leq 2\%$	$\Delta V/V \leq 5\%$
50 m	316	354	366	372
100 m	24	186	305	341
150 m	0	4	126	266
200 m	0	0	4	127

# Other angular diameter determinations #1

*photometric estimates*

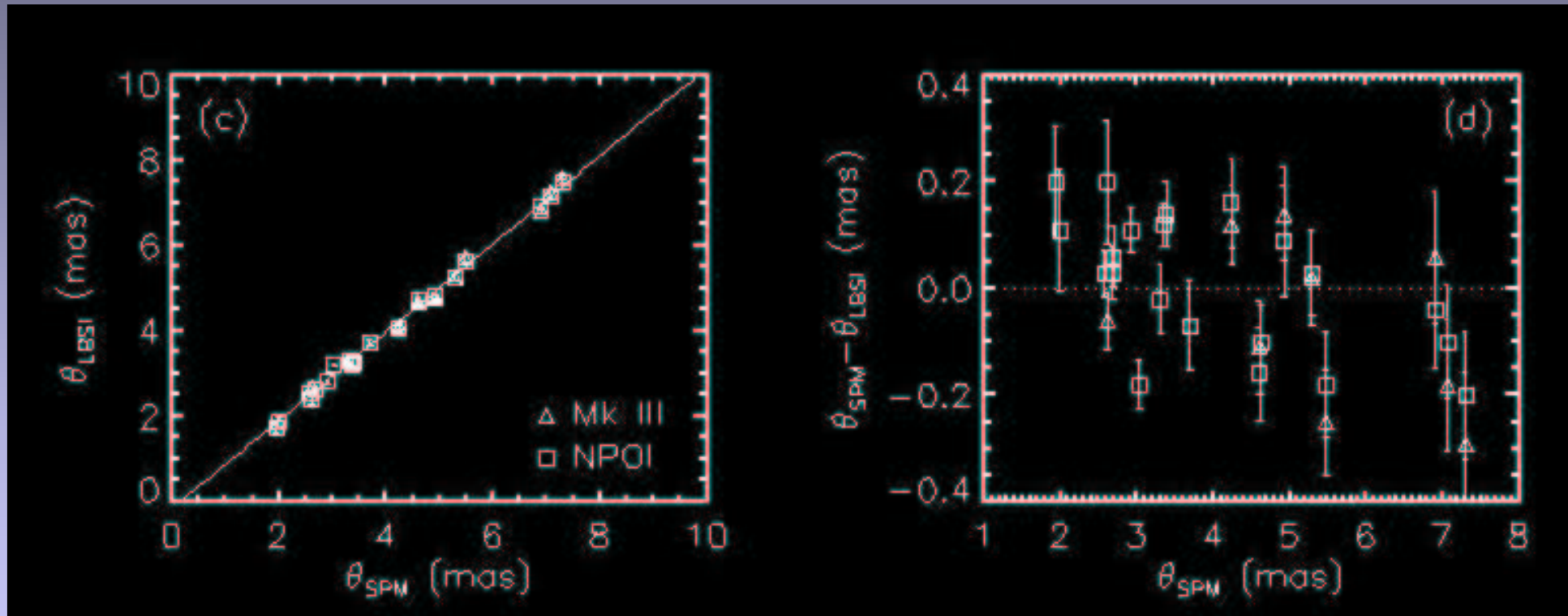


Infrared Flux Method (IRFM)  
*(Blackwell et al. 1994)*

Surface Brightness Method  
*(Di Benedetto et al. 1998)*

# Other angular diameter determinations #2

*interferometric measurements*



$\theta_{\text{LD}}$  derived from  $\theta_{\text{UD}}$  measured by the Mark III and the NPOI  
(Nordgren et al. 2001)

# *Other angular diameter determinations #2*

*Uniform disk diameter of  $\theta$  Cen (K band)*

$5.32 \pm 0.058$ mas	Computed from Cohen et al. 1999
$5.31 \pm 0.037$ mas	Measured by VINCI (Kervella et al. 2003)

# *Conclusion*

- Catalog highly homogeneous with a very good sky coverage
- Well adapted for baselines from 50 to 200 m depending on the required precision
- Very good agreement with other angular diameter determinations
- Routinely used with FLUOR since oct. 2000, with VINCI since first fringes in 2001
- Selected as the core list of primary calibrators for the software ASPRO (developped by the JMMC)