On Route to accurate NIR Photometry from AO systems

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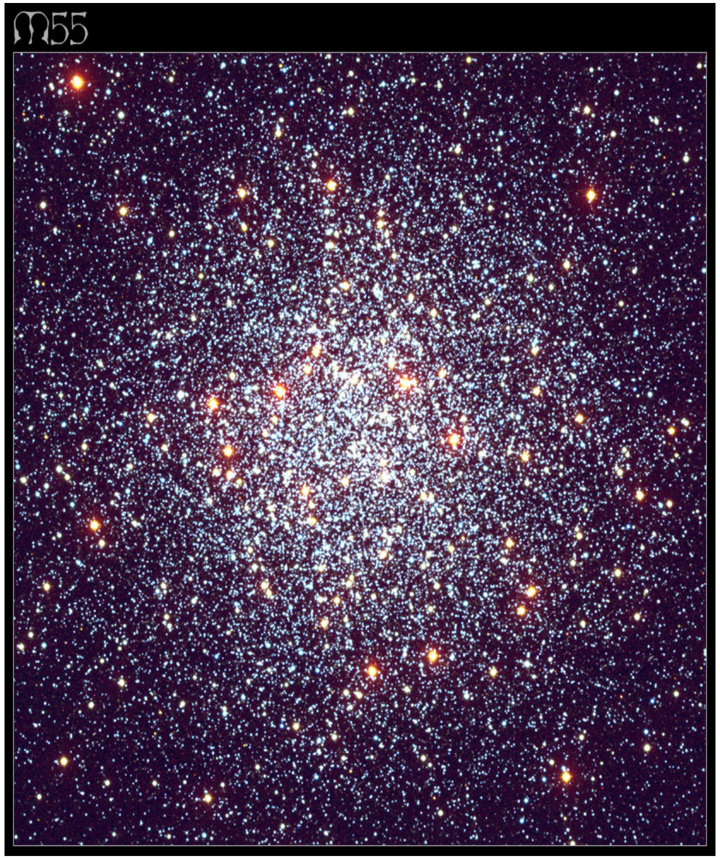
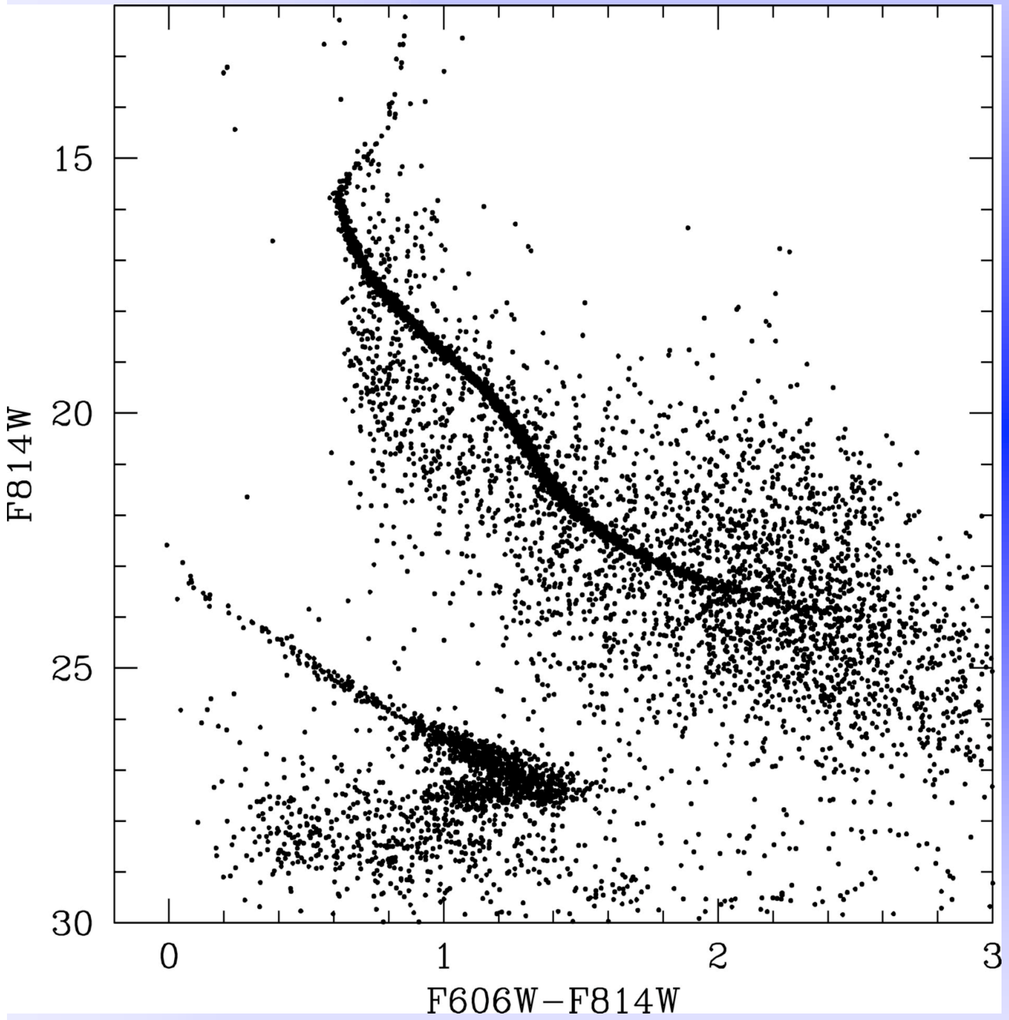


OUTLINE OF THE TALK

→ Introduction
→ Symmetric vs Asymmetric PSF
→ Preliminary results
→ Conclusions

Stellar Astrophysics

[i.e. the pleasure of meaningful error bars]



Absolute ages of stellar systems (GC, Old/Interm. OCs)
MS Turn-Off – MS Knee (NIR bands) – WD Turn-off

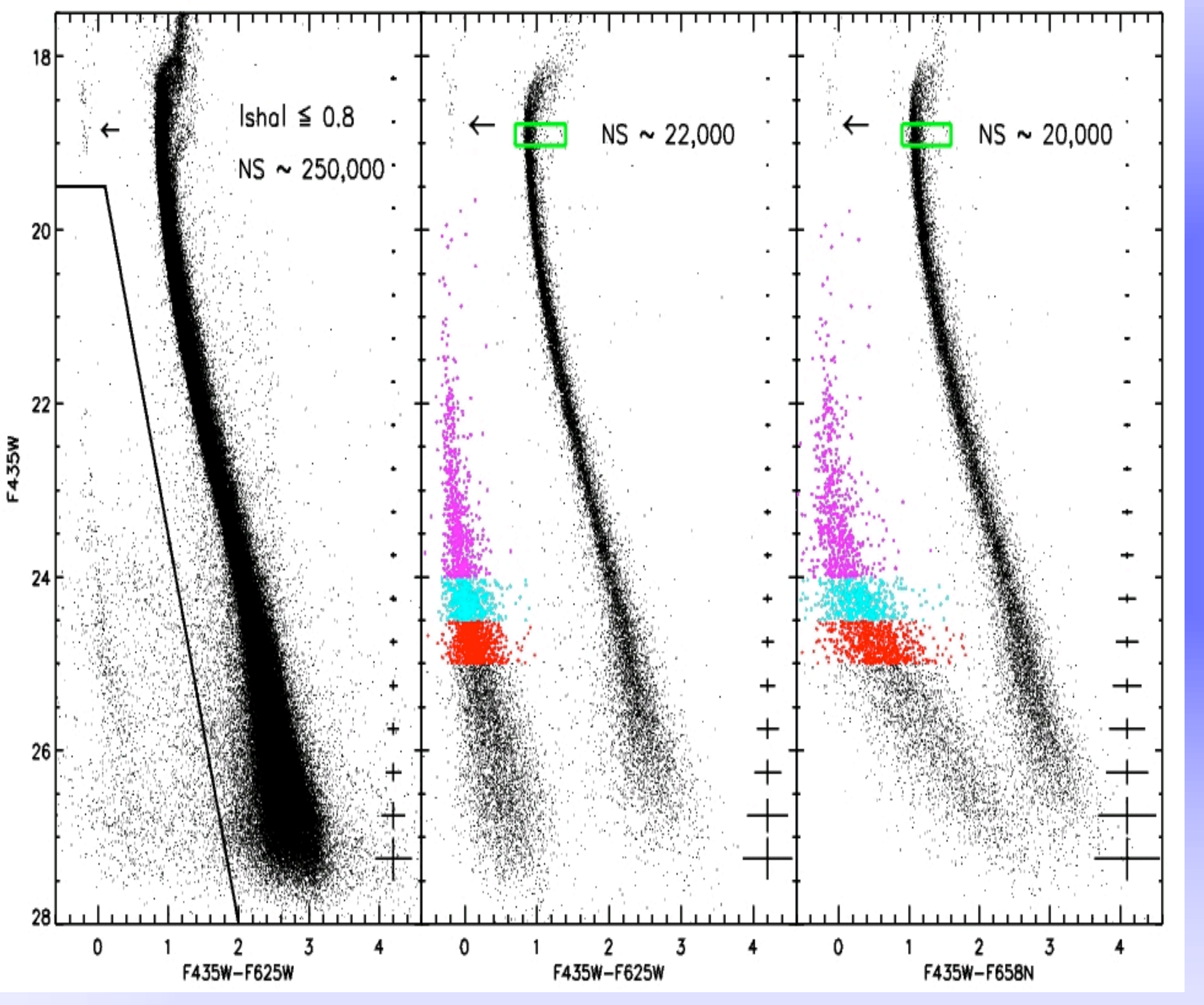
Isochrones AND Luminosity functions (different systematic)

Different evolutionary diagnostic

GCs (M31): MSTO & MSknee

Hansen **et al. 2008, HST@ACS, NGC6397**

Stellar Astrophysics
[i.e. the pleasure of meaningful error bars]



Calamida et al. 2008, ACS@HST, Omega Cen

Medium resolution spectroscopy in crowded fields.

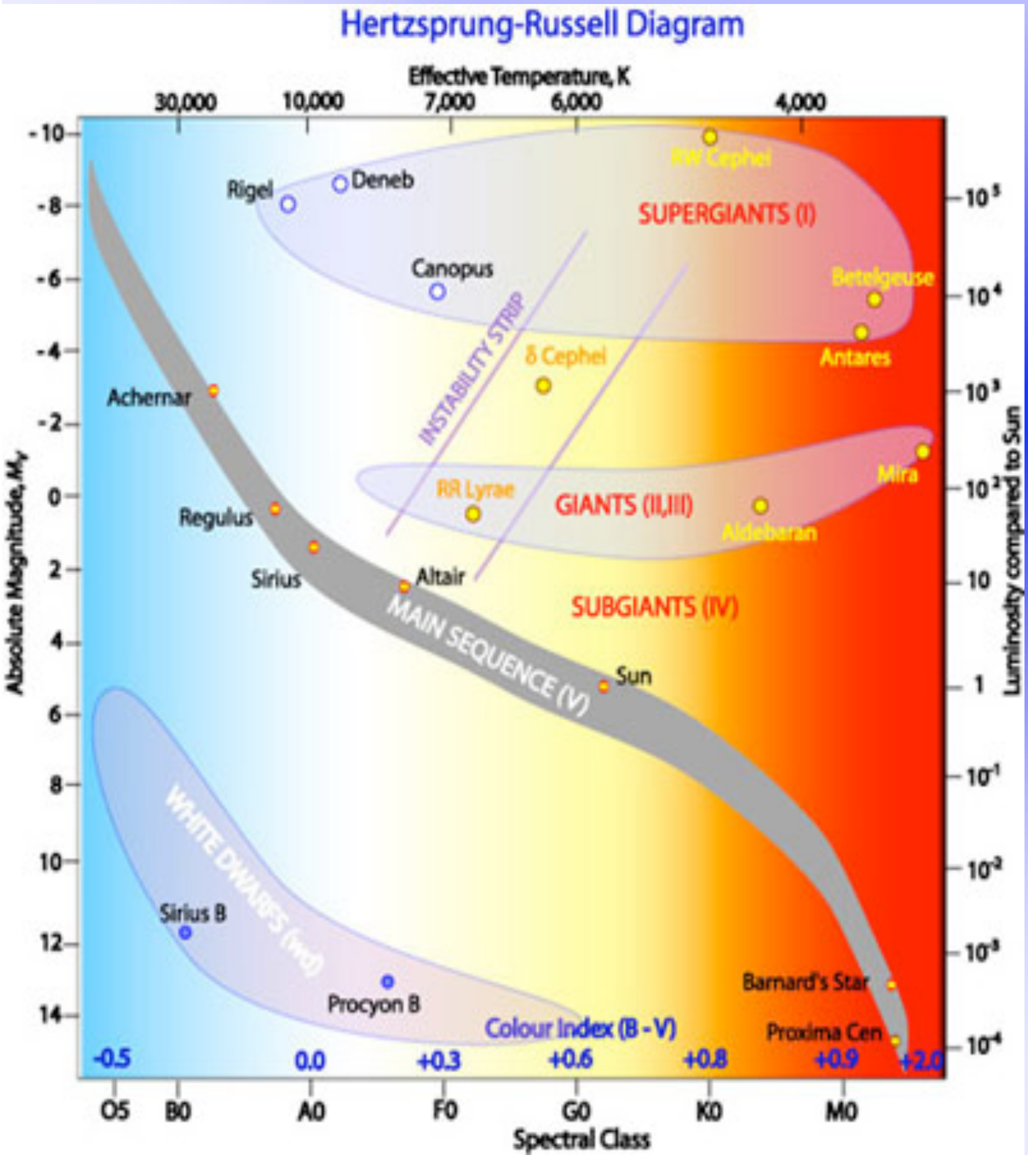
He, CNO &α-elements in evolved faint stars:

WDs:
He-core vs CO-core
DA vs non-DA

Extreme HB:
hot He-flasher vs He-enhanced

Stellar Astrophysics

[i.e. the pleasure of meaningful error bars]



Estimate of the Hubble constant only using primary indicators.

Cepheids in the Coma Cluster (NIR PL relation)

First homogeneous calibration of SNIa (spirals & ellipticals) using RR Lyrae stars in the Virgo cluster

WHY NGC3201?

• Distance & reddening:

RR Lyrae → Piersimoni et al. (2002)
SX Phoenicis → Leiden et al. (2003), Mazur et al. (2003)
W UMA Blue Straggler → von Braun & Mateo (2002)

• Chemical composition:

[Fe/H] +[α/Fe]→ Kraft & Ivans (2003), Covey et al. (2003), Pritzl et al. (2005)

• Kinematics:

retrograde orbit → Gonzalez & Wallerstein (1998), Casetti-Dinescu et al. (2007)

probably connected either with “orphan stream” (Belokurov et al. 2007) or by Grillmair (2006) [Bell’s talk]

•Absolute age: quite poor → differential reddening

MAD J,K Images of NGC3201 [SD2]

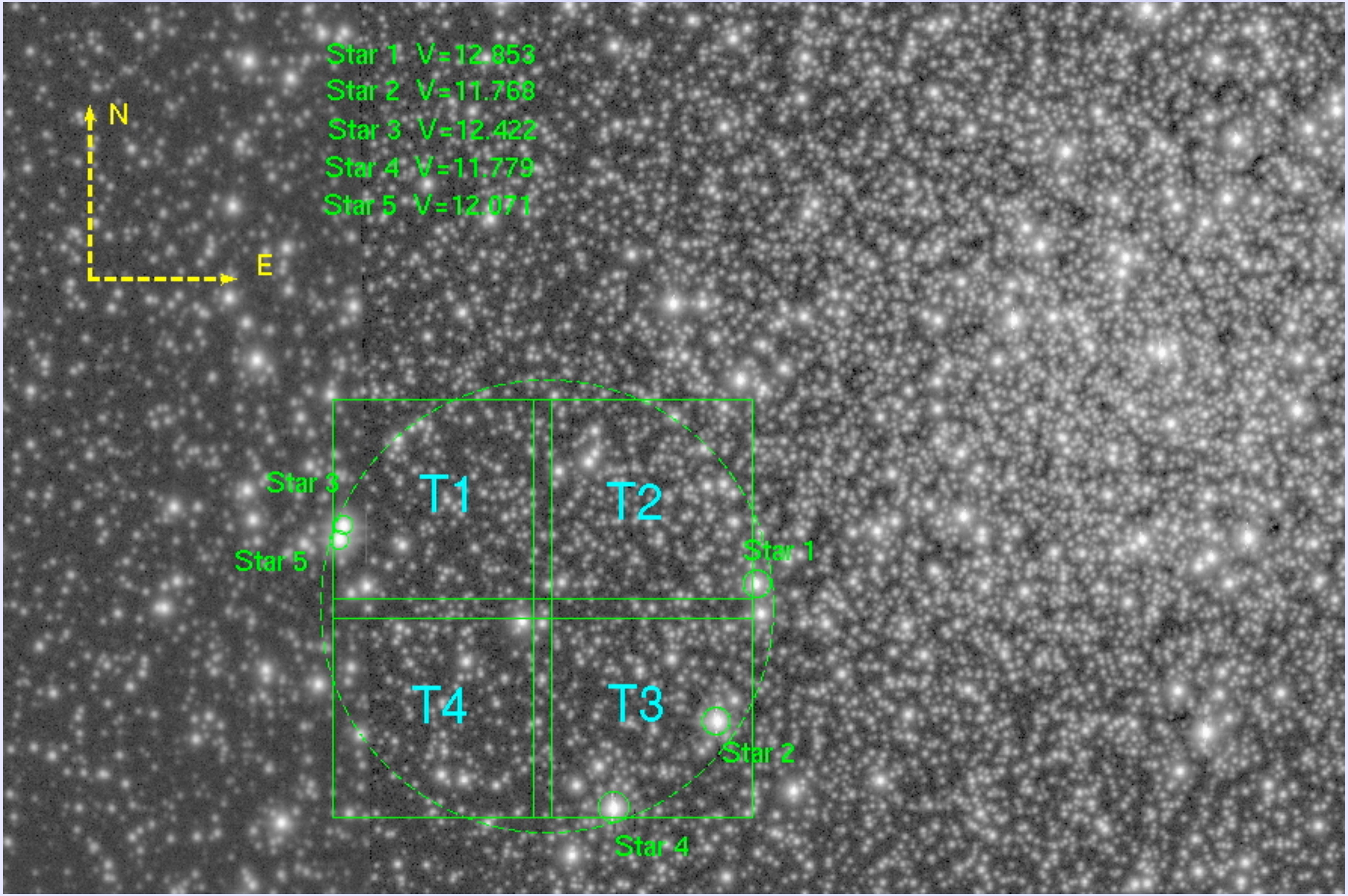
Four pointings (T1,T2,T3,T4) :
J-band: seeing from 0.6” to 0.9”
Ks-band: seeing from 0.8” to 1.3” (T3)
3J+5Ks per pointing = 12(J) + 20(Ks) min=0.5 h

→5 guide stars V~11.7-12.9

→FWHM on images ≤0.07-0.10” [Ks, J]

→FOV 2’X2’, pixel scale 0.028”
Significant improvement in sky subtraction
[Marchetti et al. 2007, The Messenger, 129, 8]

MAD J,K Images of NGC3201



Reduction Strategy

PSF Photometry on Individual Images

Simultaneous reduction of NIR and optical images

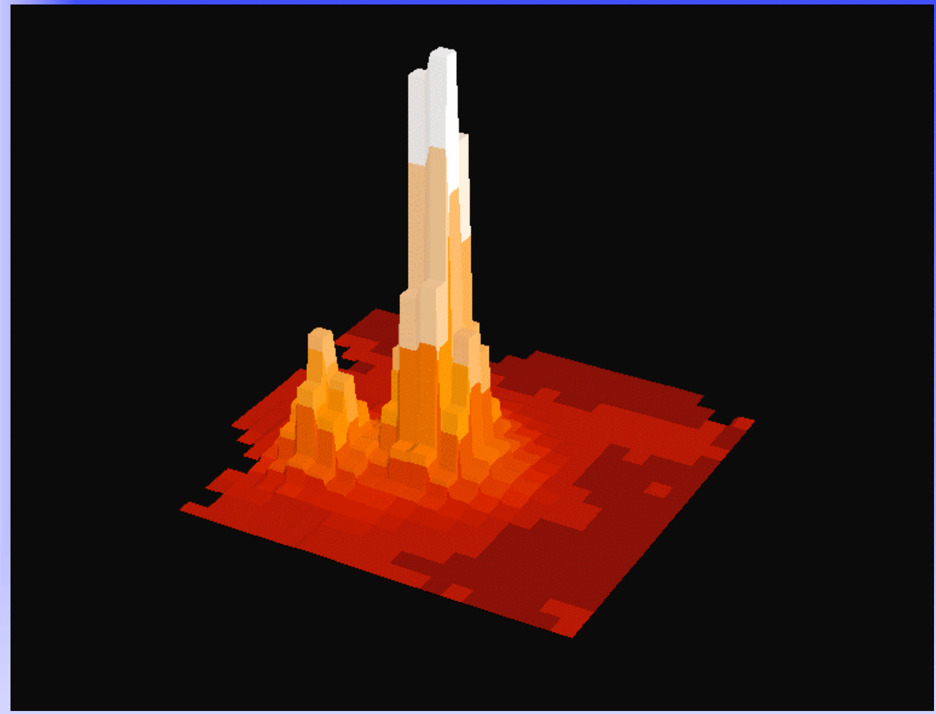
DAOPHOT → ALLSTAR → DAOMASTER → ALLFRAME

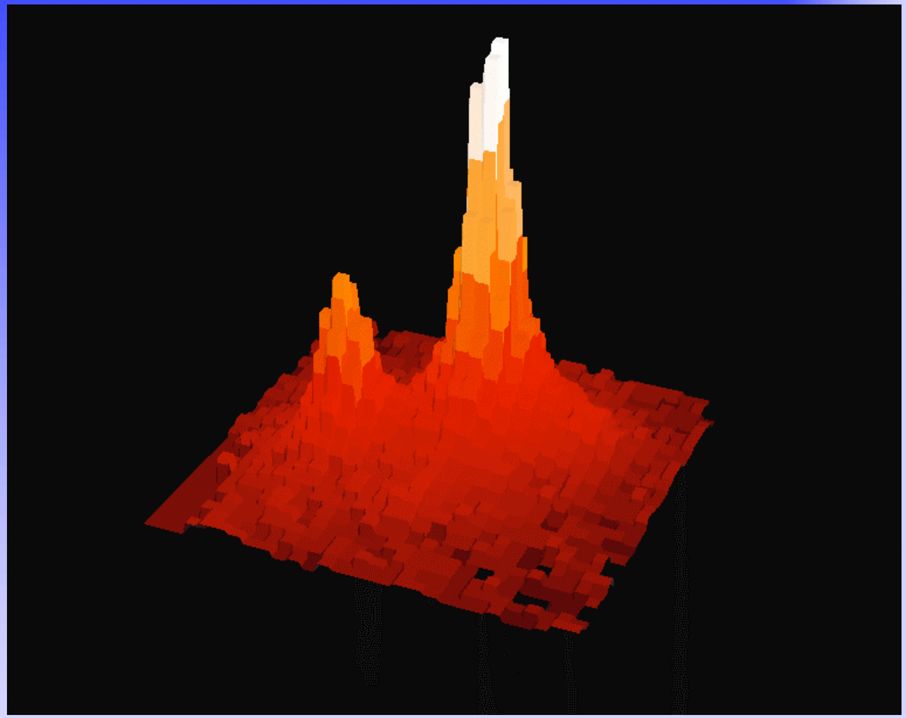
Specific Targets (WDs in ω Cen) → ROMAFOT →
visual check one-by-one

Reduction strategy: data

MS located two magnitudes below the TO region

ACS **MAD**

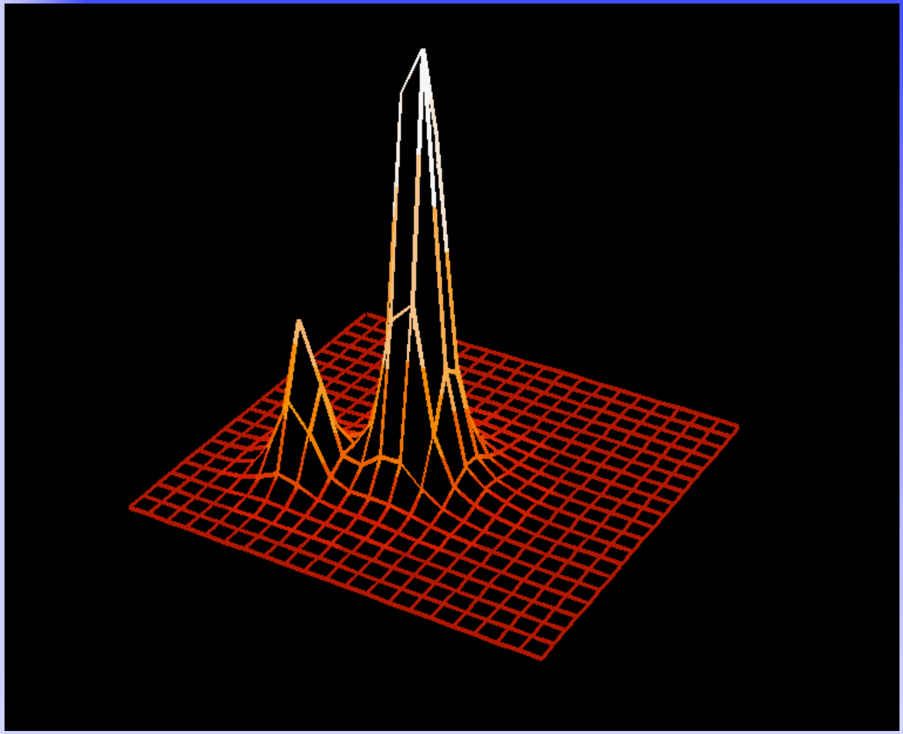


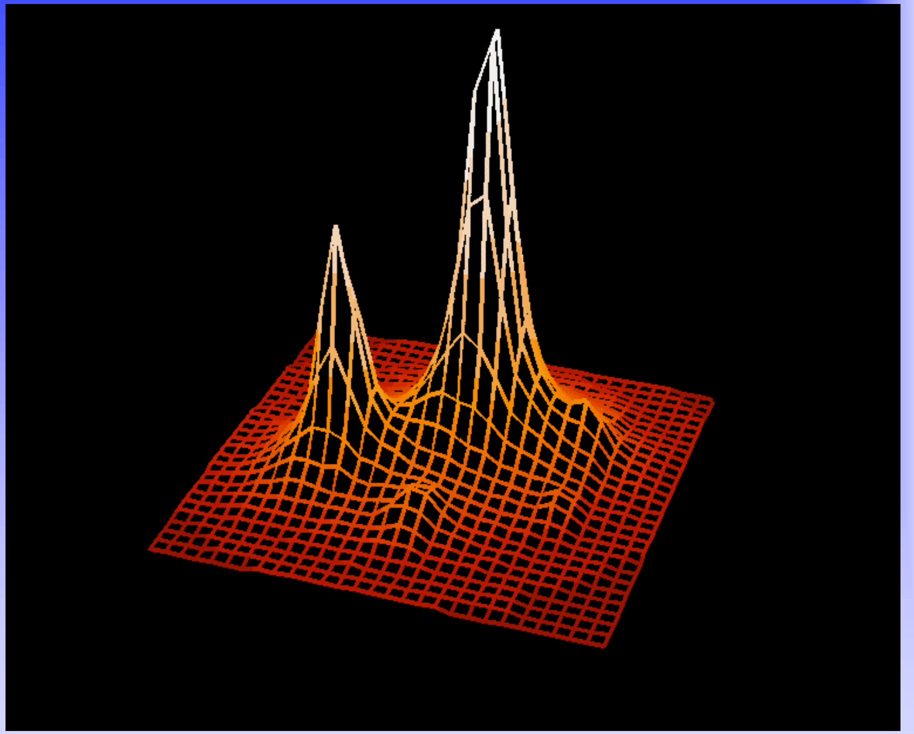


Smaller FoV, lower dynamical range but better sampling 0.05” vs 0.028”

Reduction strategy: Analytical PSF

ACS **MAD**





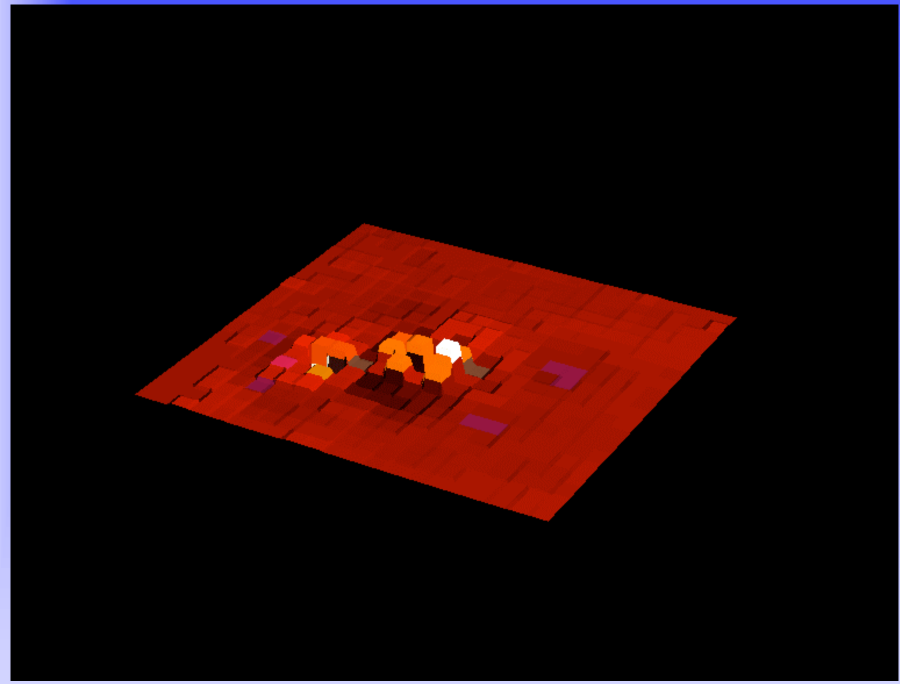
ALLSTAR

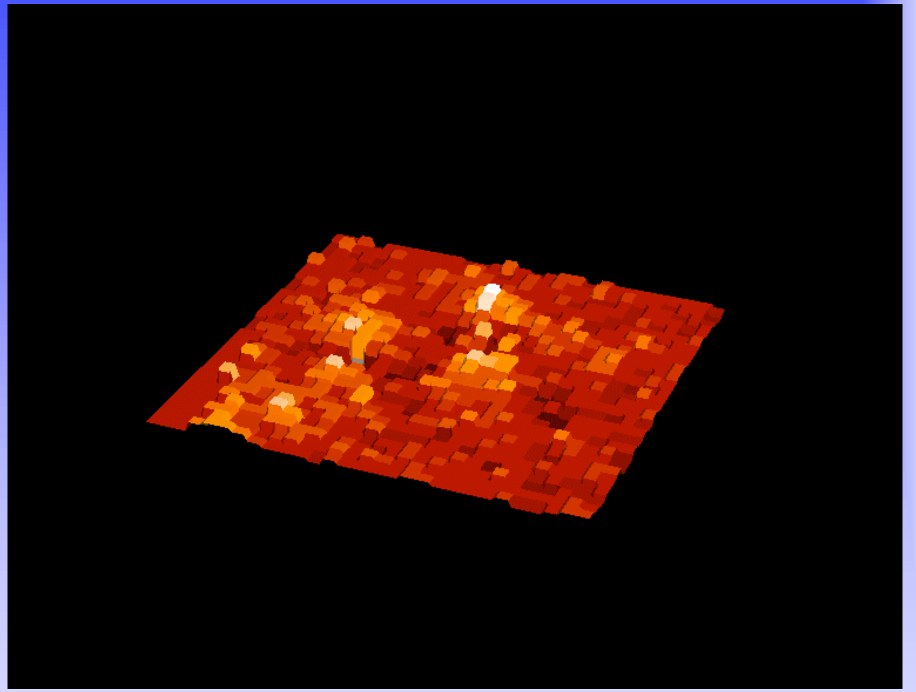
→ PSF(Ks): quadratic Moffat function β=2.5

→ PSF(J): linear Moffat function β=1.5 or Lorentian

Reduction strategy: residuals

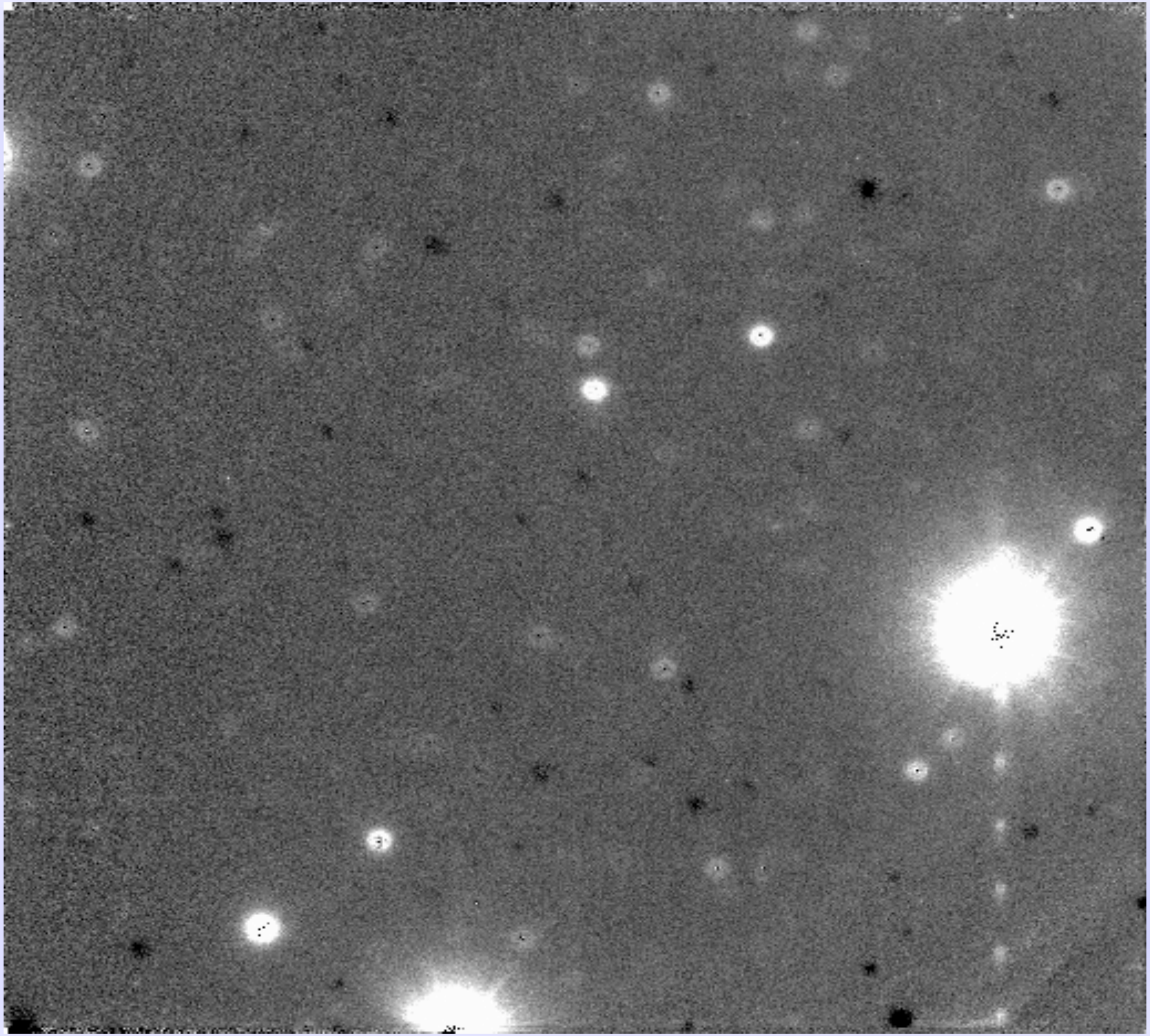
ACS **MAD**





DAOMASTER/ALLFRAME/DAOMASTER

Simultaneous reduction of optical & MAD (J,Ks) images [→ NO IMAGE STACK ←]



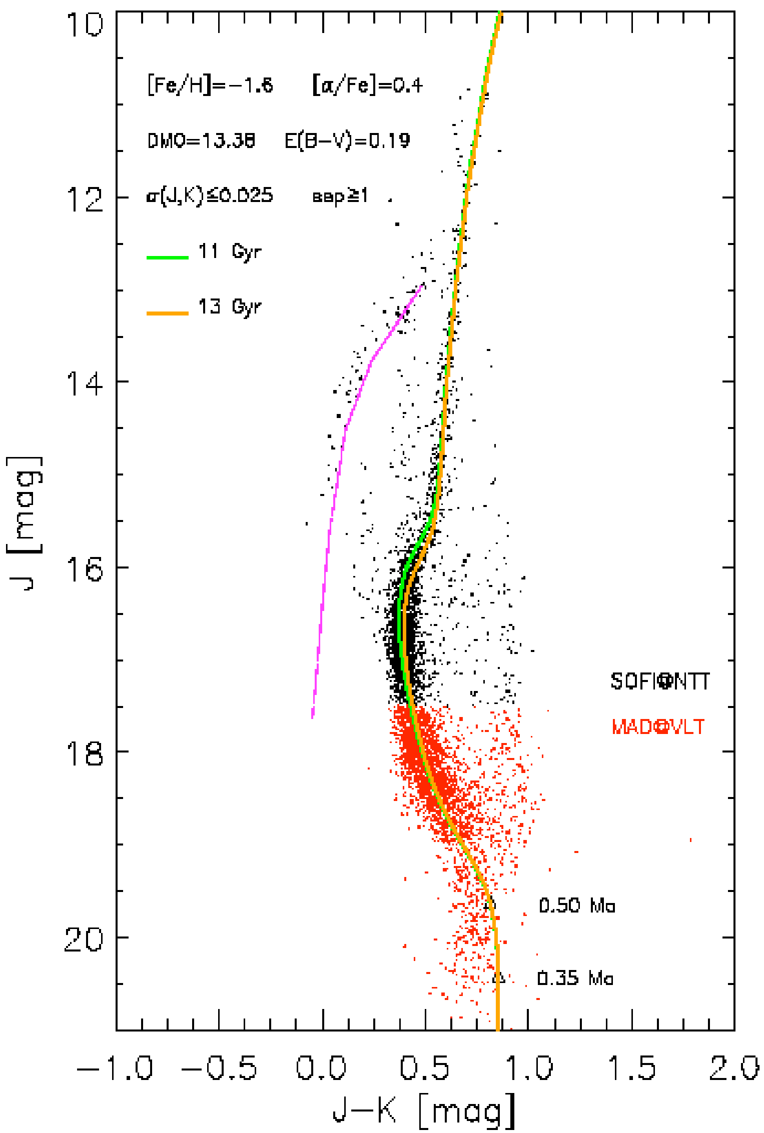
Data show expected evolutionary features
J~21 and K~20.5

Cluster age t=12±1 Gyr

Tested ZΘ and all available CT transformations

Problems:

- Reddening is 30% lower
  Culprit: Reddening law
- Isochrones are redder than observations in the lower MS
  Culprit: NIR CT transformations



All current packages deal with symmetric analytical PSFs

Once the shape of the PSF and the residual matrix have been fixed we are left with three unknowns per stars:

→Moffat function (fixed σ & β): x_i, y_i, h_i

→This is the crucial reason why accurate PSF photometry needs at least 2X2 and possibly 3X3

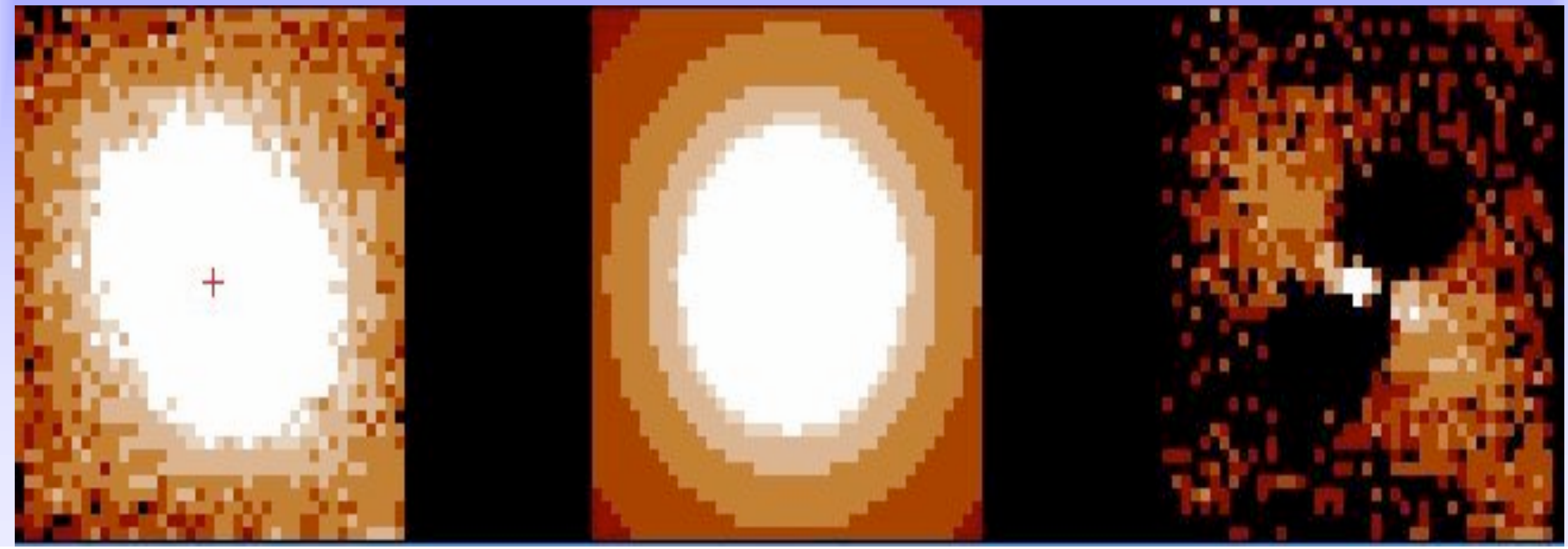
→Recent NIR images from AO systems are (quite) far from being symmetric (circumstantial evidence!)

NACO images of Omega Centauri

9 K-band images t=40 sec (DIT=4, NDIT=10)
FOV=28x28 "^2 pixel scale=0.027 "/px
FWHM=0.36 " (13 px) **Moffat Function (fixed σ,β)**

TOP VIEW

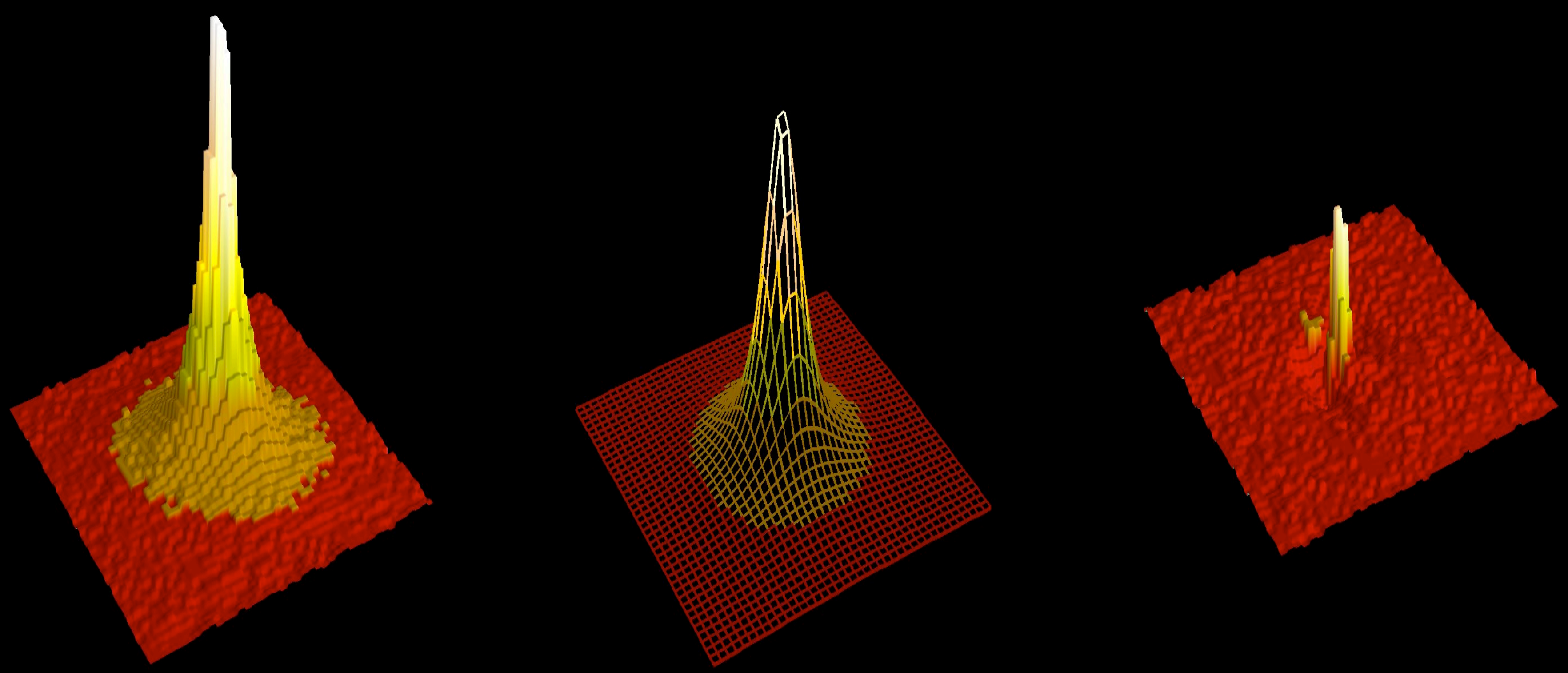
Datum PSF Residuals



NACO images of Omega Centauri

3D view

Datum PSF Residuals $\Delta m \sim 0.9$



EGG PSF

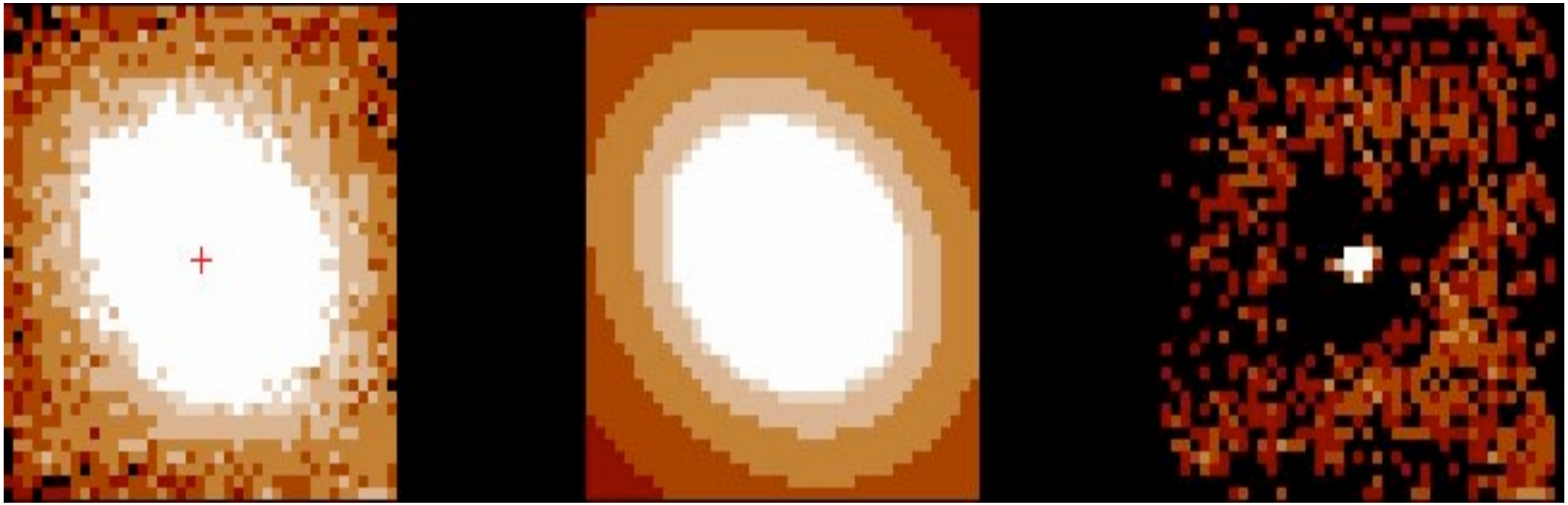
Ballerina PSF

EGG PSF

Fixed σ & β

Unknowns:
x, y, a, b, Θ, ω, h

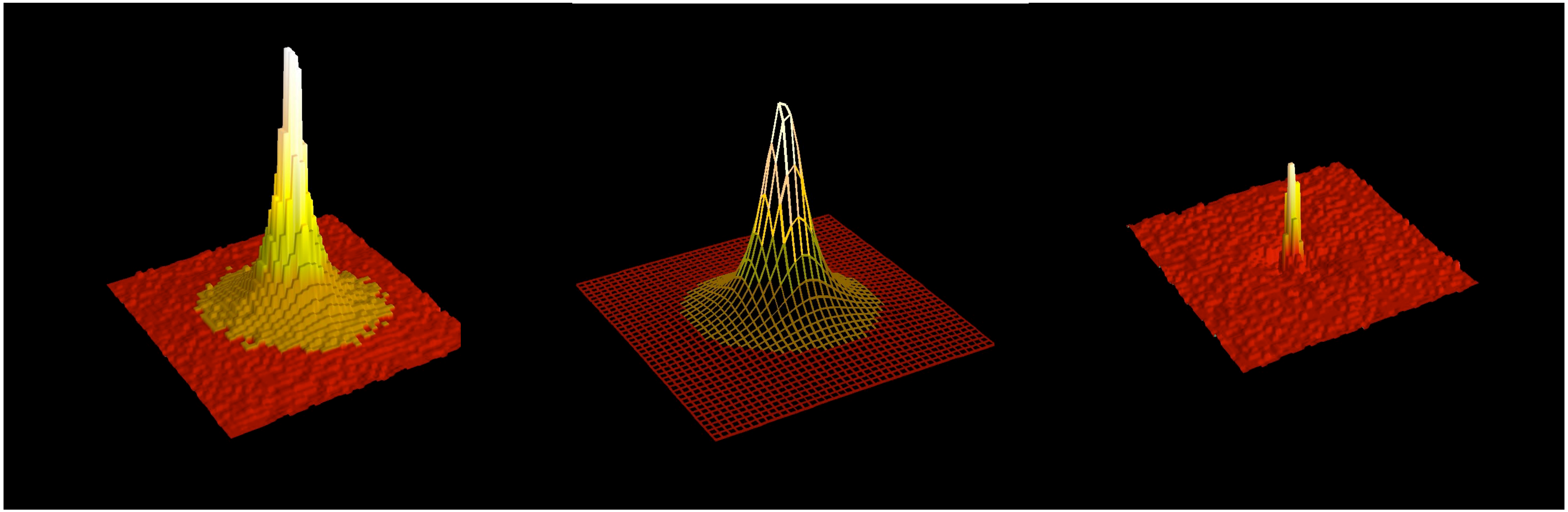
Residuals
Δm~0.1



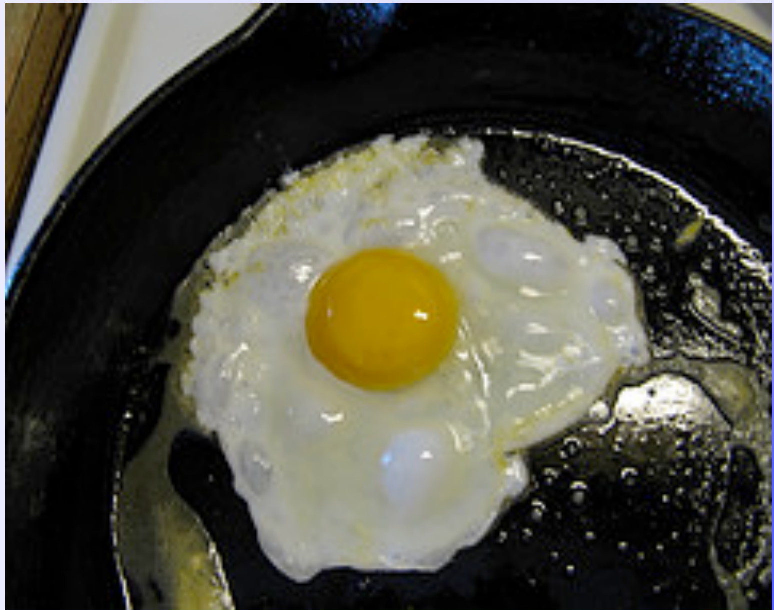
EGG PSF

Fixed σ & β

Unknowns:
x, y, a, b, Θ, ω, h



EGG yolk & white



PSF = M1 (x, y, a, b, Θ, ω, h1) + M2 (x, y, σ=b, h2)

M1 = wings → asymmetric → white

M2 = core symmetric → yolk

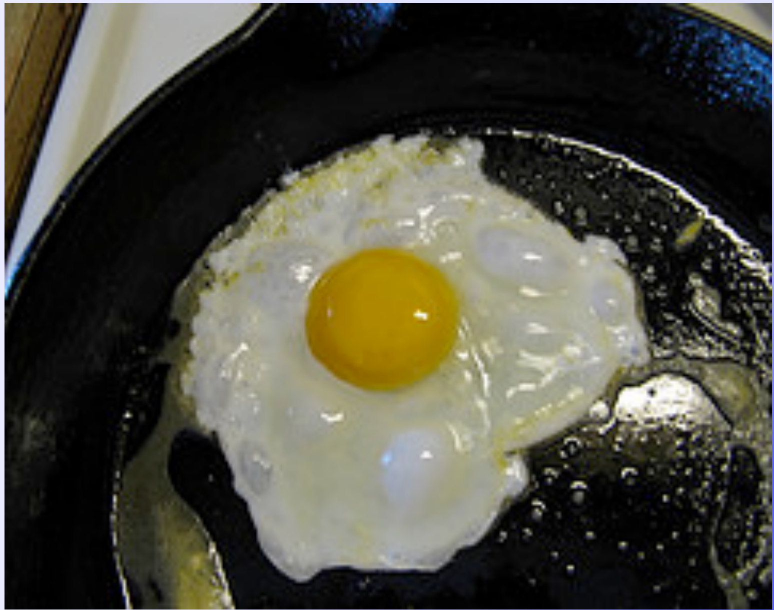
Unknowns (Fixed β for M1 & M2):

x, y, a, b, Θ, ω, h1,h2

Residuals

Δm~0.09

EGG yolk & white



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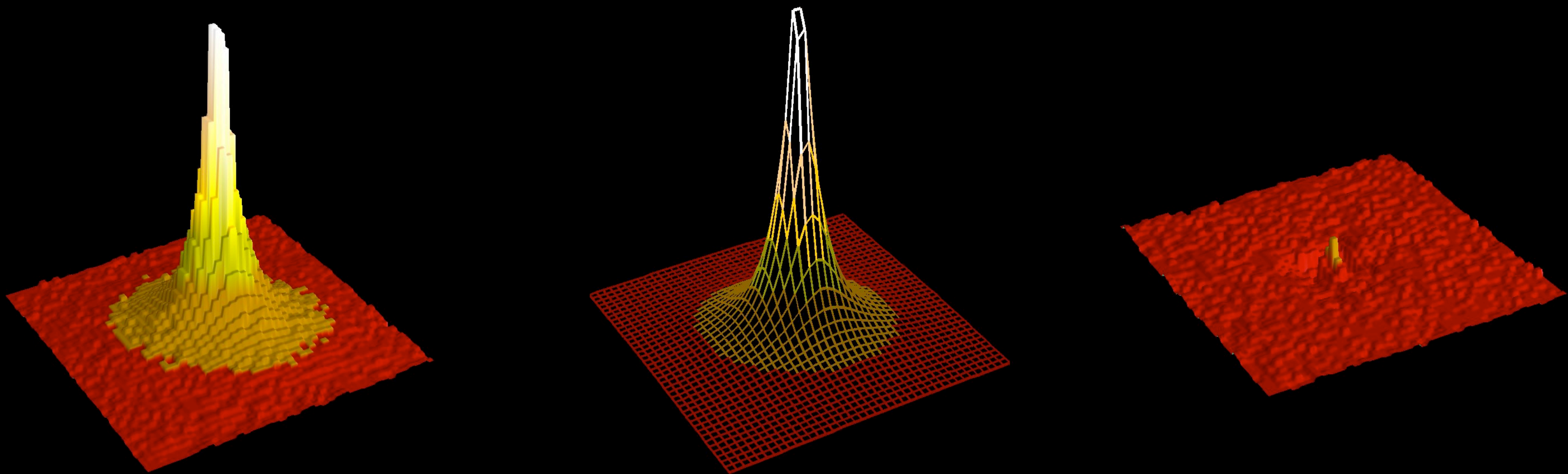
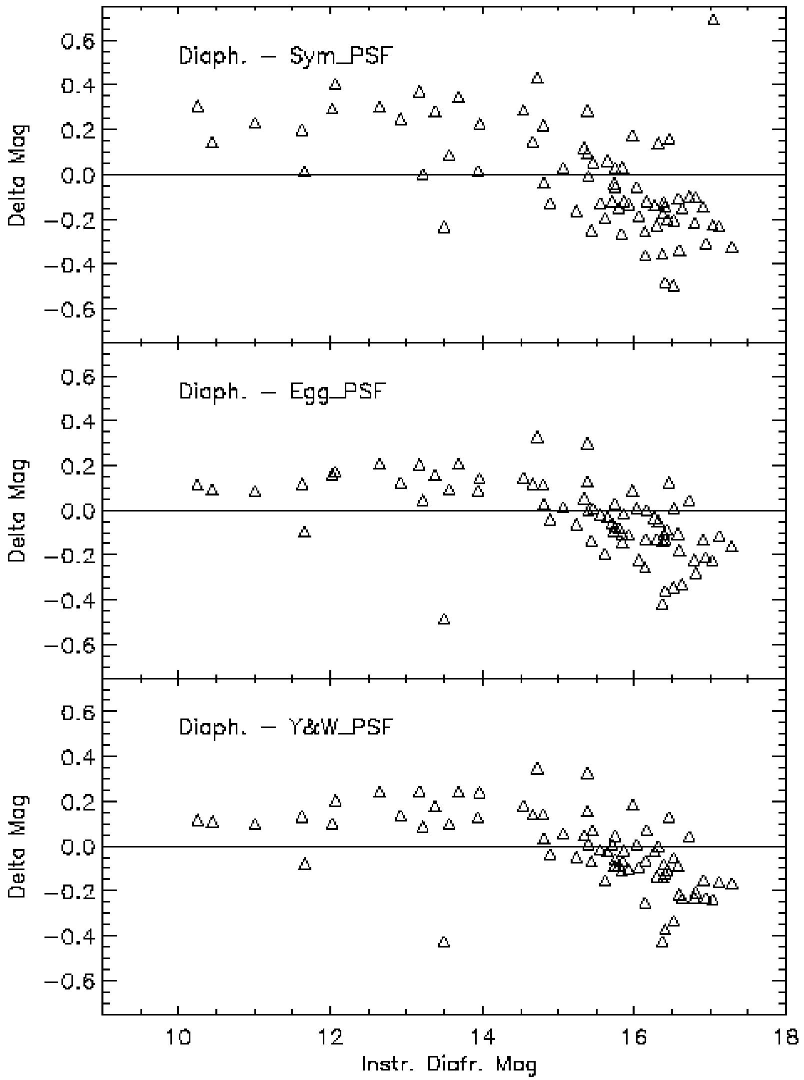


Difference between Diaphragm and PSF magnitudes



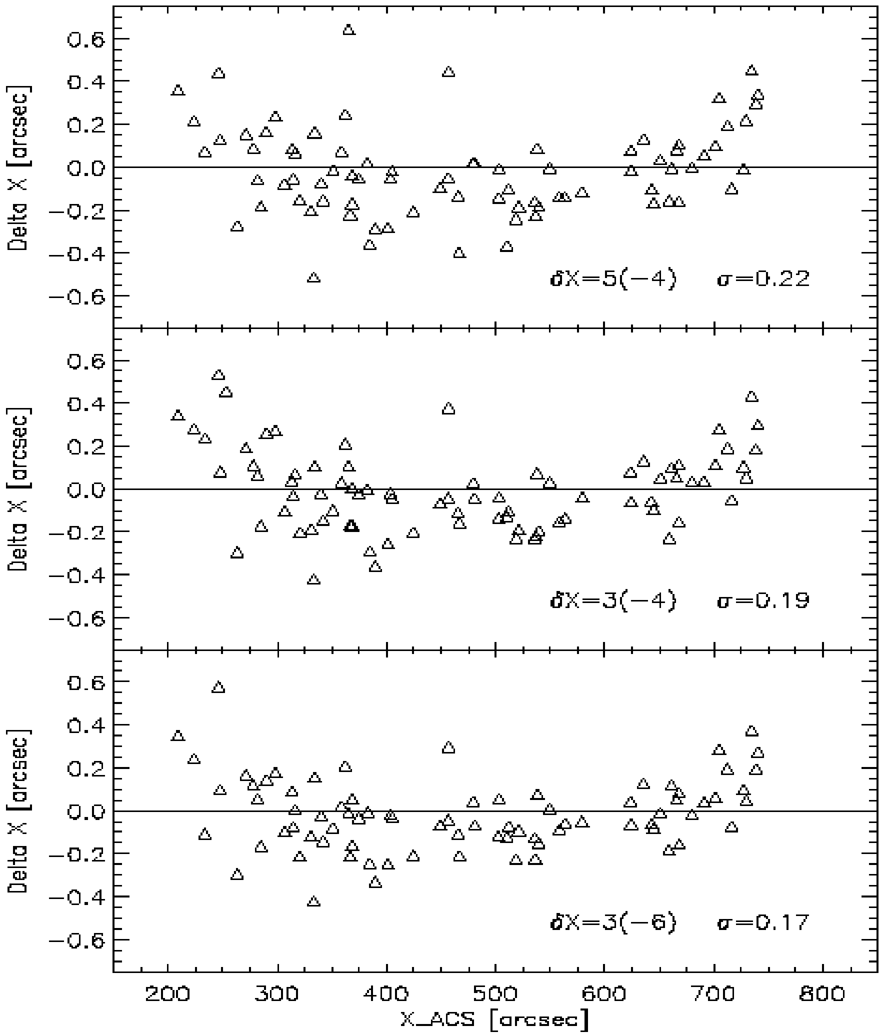
$<\delta M>=0.77 \quad \sigma=0.22$

$<\delta M>=0.03 \quad \sigma=0.16$

$<\delta M>=0.01 \quad \sigma=0.16$

Difference in centroid positions

Along X-axis

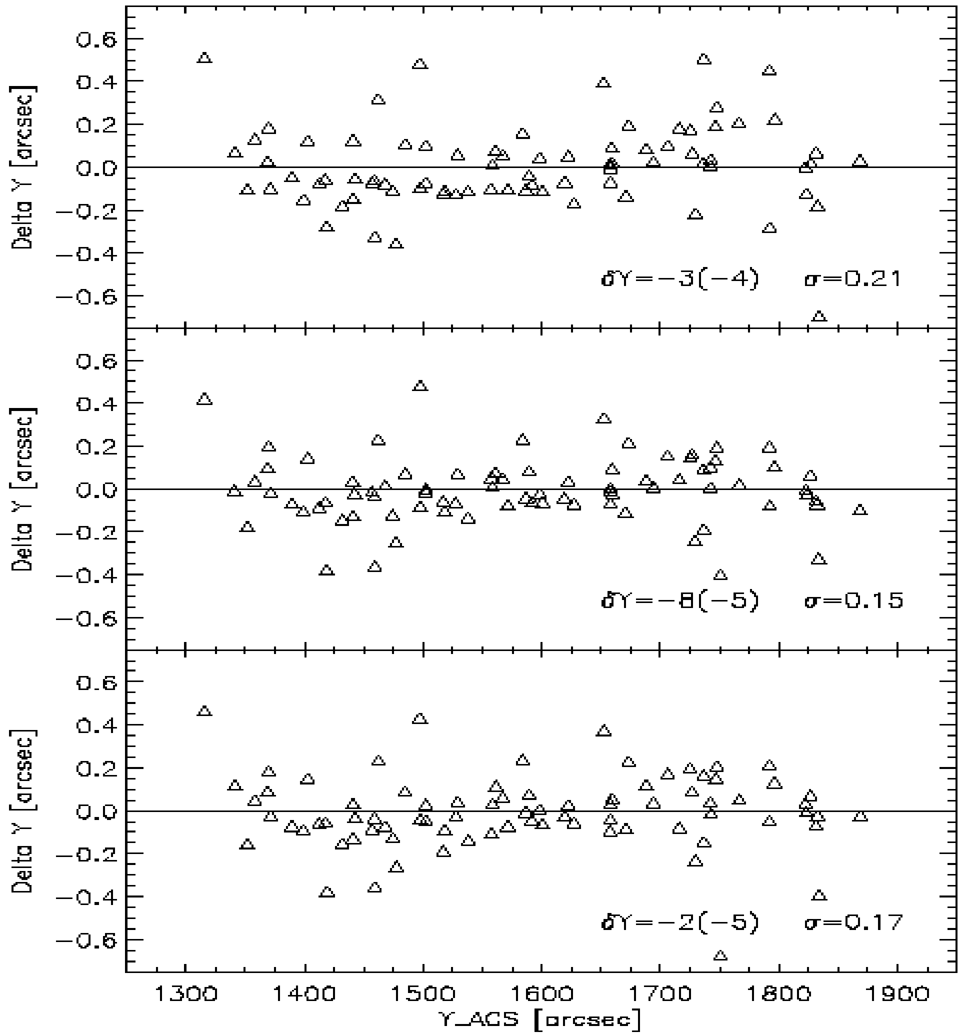


Difference around zero but dispersion decreases ~30% when moving to

Asymmetric PSF

Difference in centroid positions

Along Y-axis



Difference around zero but dispersion decreases ~30% when moving to

Asymmetric PSF

OPEN ISSUES:

→ CROWDING

→STATISTIC J,K images

→CMD evolutionary features

→Independent parameters:
ω - Θ – $\beta 1$, $\beta 2$

Comparison with MAD JK images of the same region collected during the same nights (same external seeing)

On route to use asymmetric PSFs

PROS

→ Photometric precision (smaller residuals)
→ Astrometric precision (smaller dispersions)

CONS

→ Larger number of pixels
→ Deconvolution less stable

TWO POSSIBLE ROUTES

→High Strehl factor
small FoVs → symmetric PSF ~3x3

→ Low Strehl factors
large FoVs → asymmetric PSF ~4x4

CONCLUSIONS

- **E-ELT is a fundamental step for stellar astrophysics and it is around the corner …**

- The use of this instrument is opening new **significant problems**

- **The crucial issue is: on one side FoV vs Strehl on the other pixel cost vs optics**

- **Preliminary good news concerning asymmetric PSF**

Credits

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