



***Issues for the quantitative  
analysis of Adaptive Optics  
images***

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Gemini*

Workshop on Hokupa'a data acquisition and  
reduction

NOAO, 25-26 February 2001.

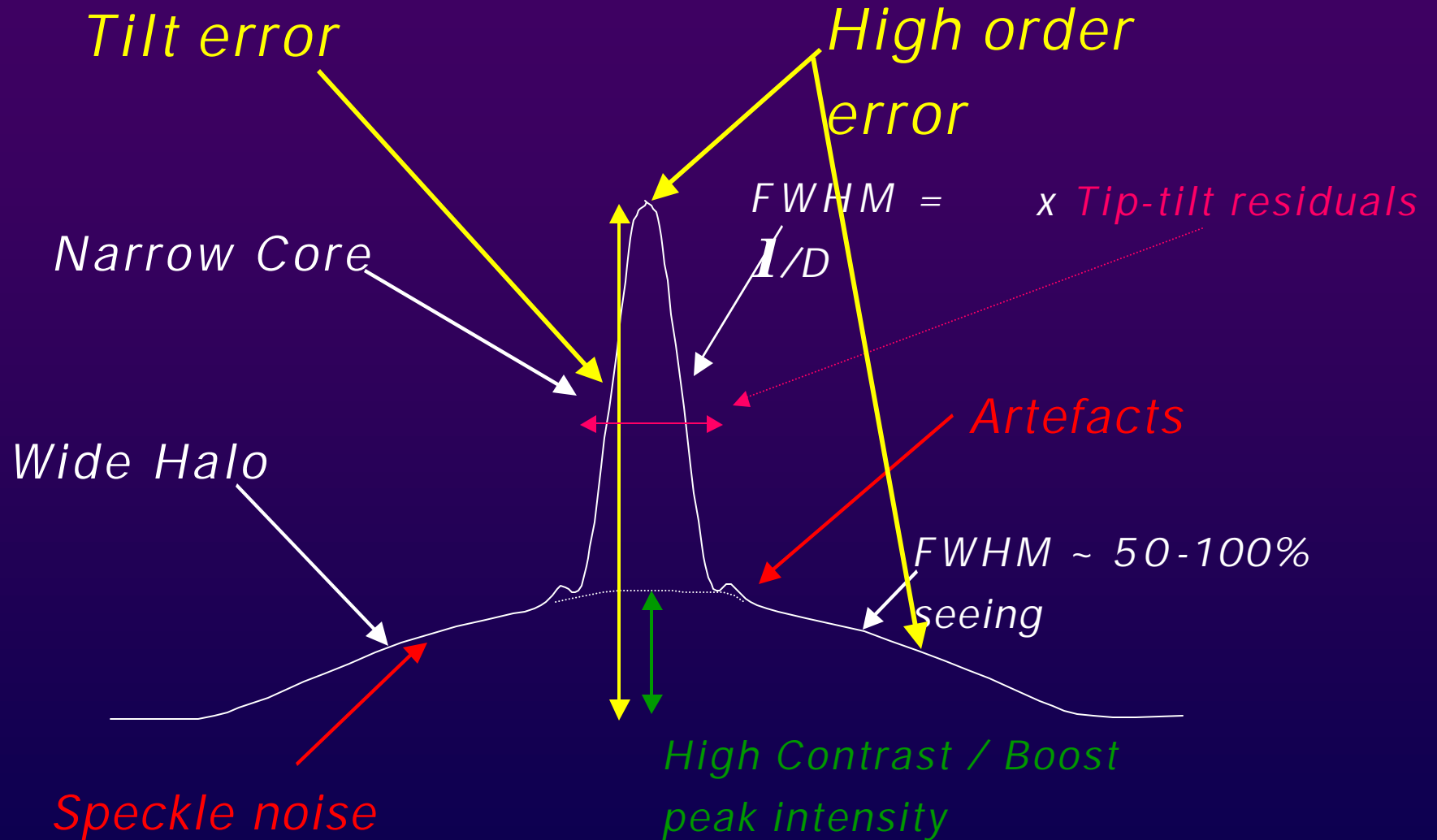


## Presentation "Road-map"

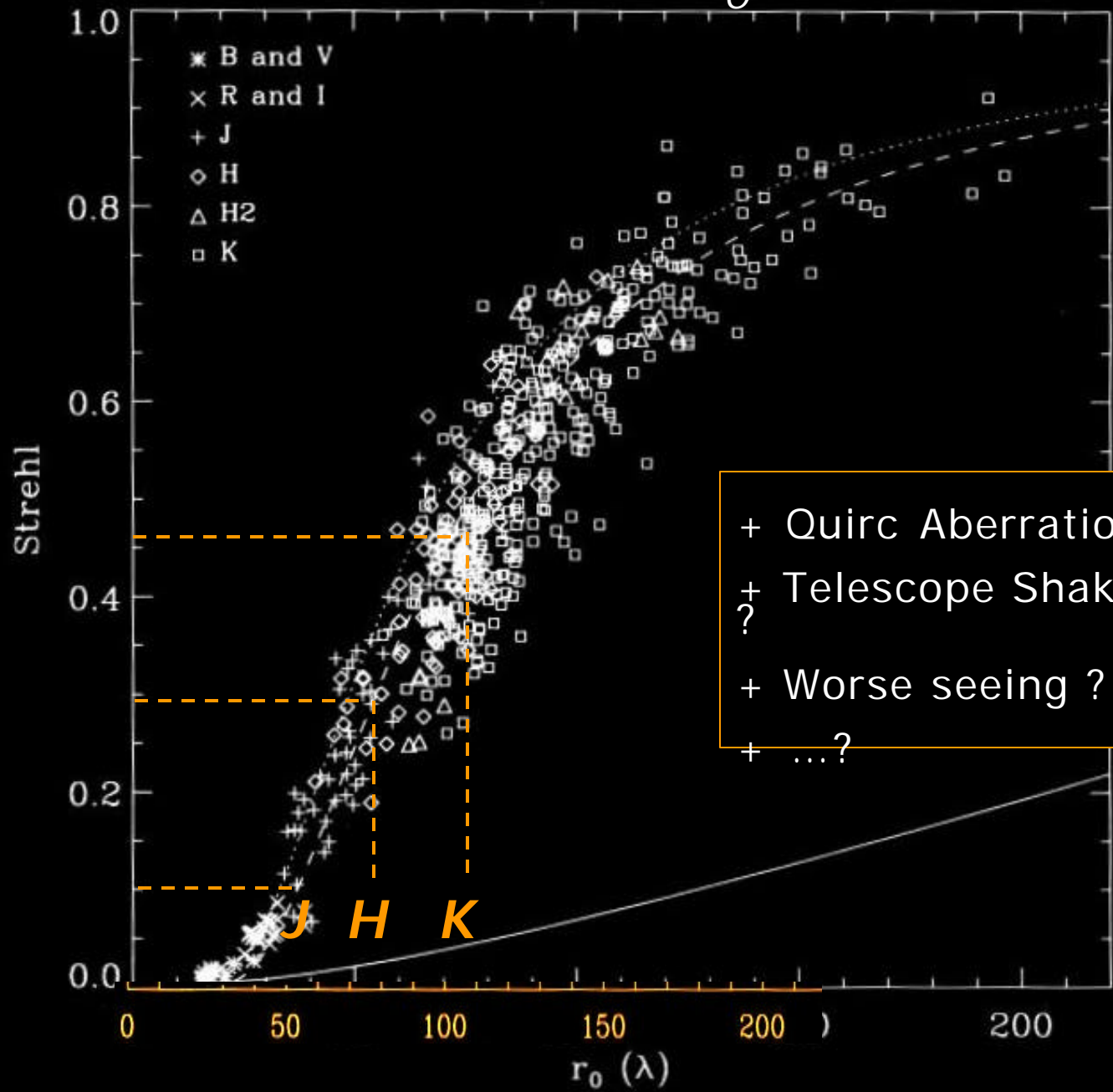
- "Quantitative analysis" of AO images:
  - Photometry, Astrometry, Polarimetry
- Differences with Seeing limited case -> Mostly PSF
- PSF characteristics
  - PSF structure, Halo formation, AO Performance
- PSF variations & calibration issues
  - Variations vs FoV, Temporal, GS magnitude
- Other issues:
  - Speckle noise, Artefacts, Sky modulation, ...
- Limitations of current Data reduction codes



# AO PSF Characteristics



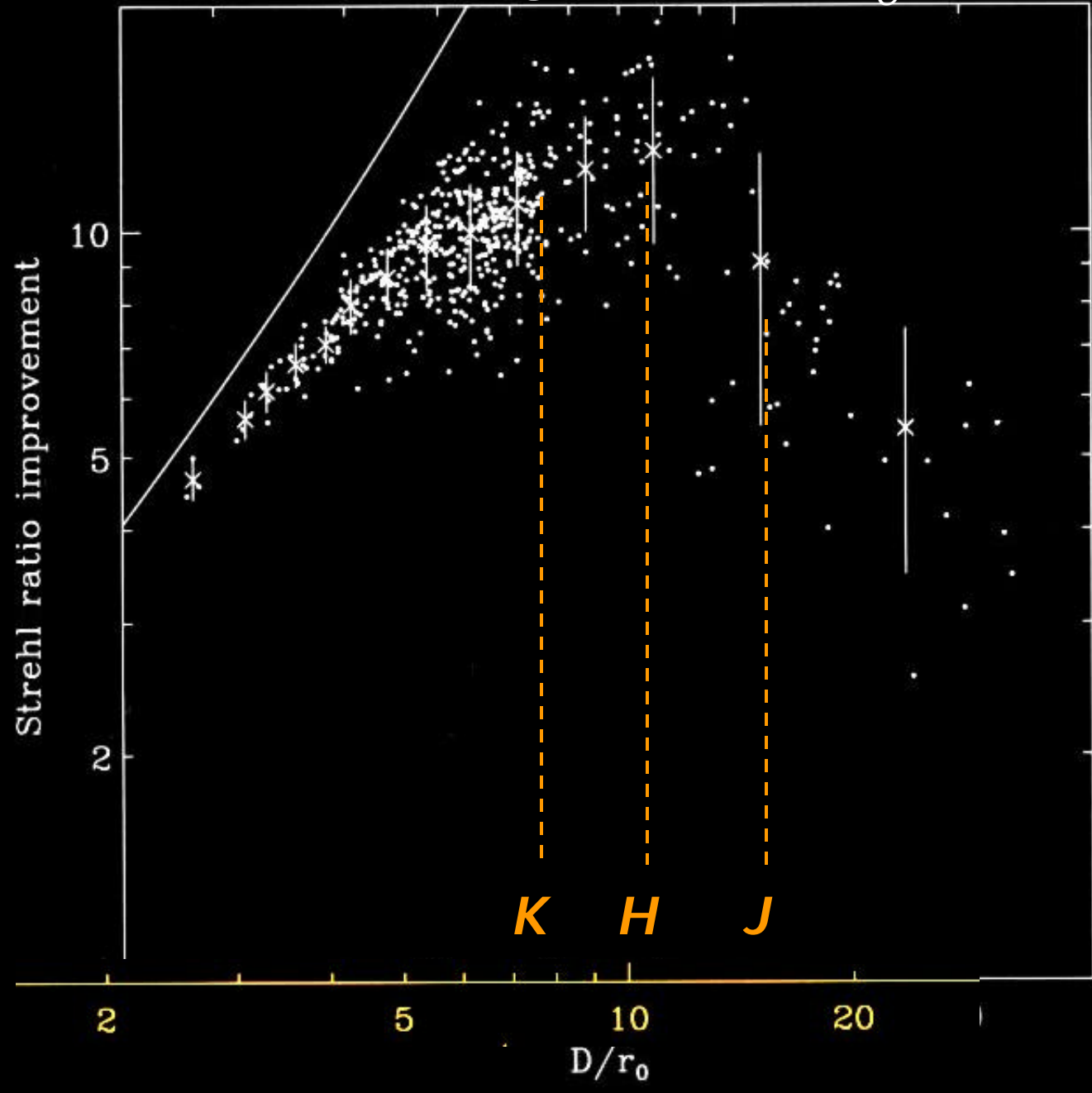
# Strehl vs $r_0$



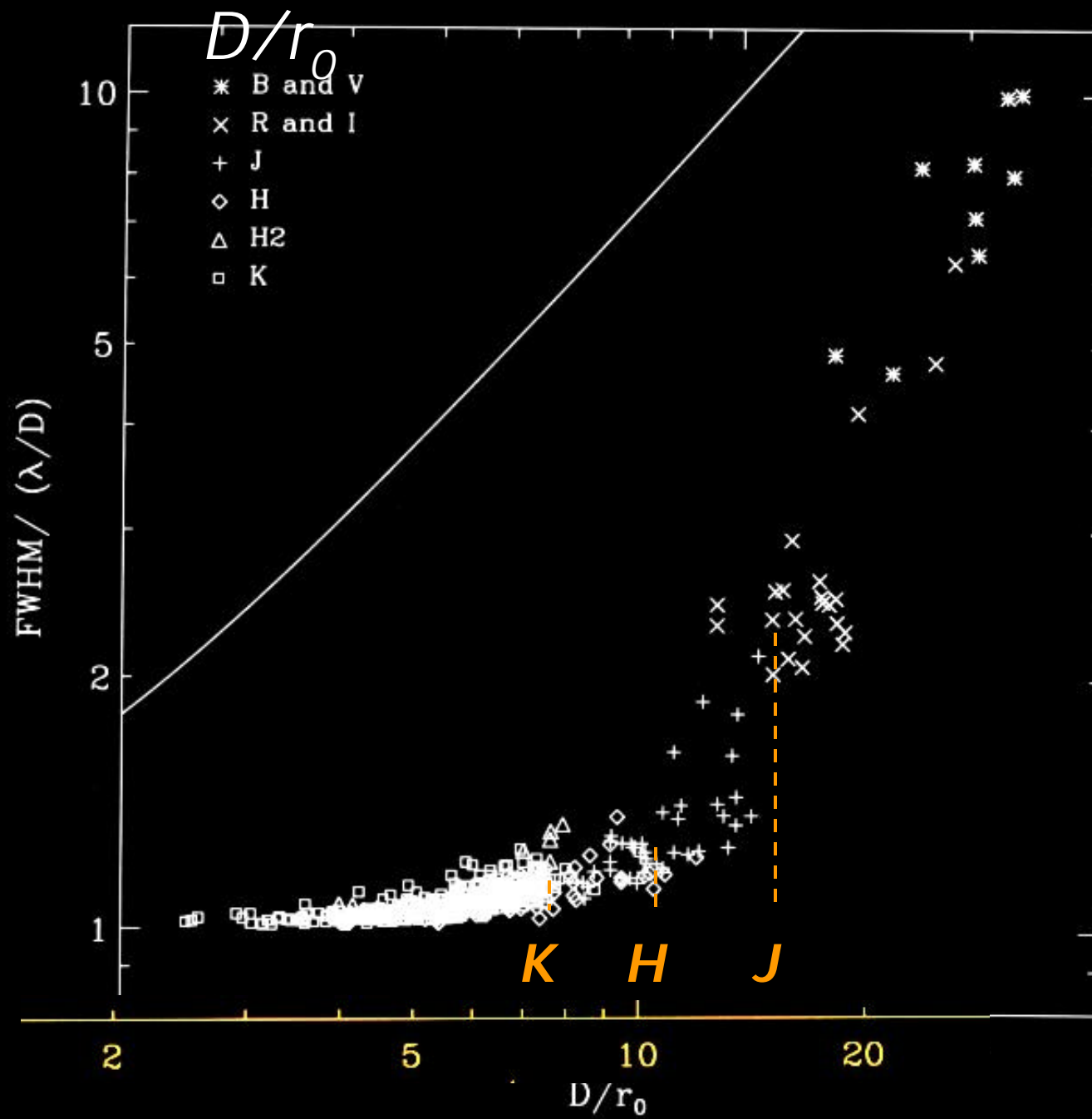
+ Quirc Aberrations  
+ Telescope Shaking  
+ Worse seeing ?  
+ ...?

J H K

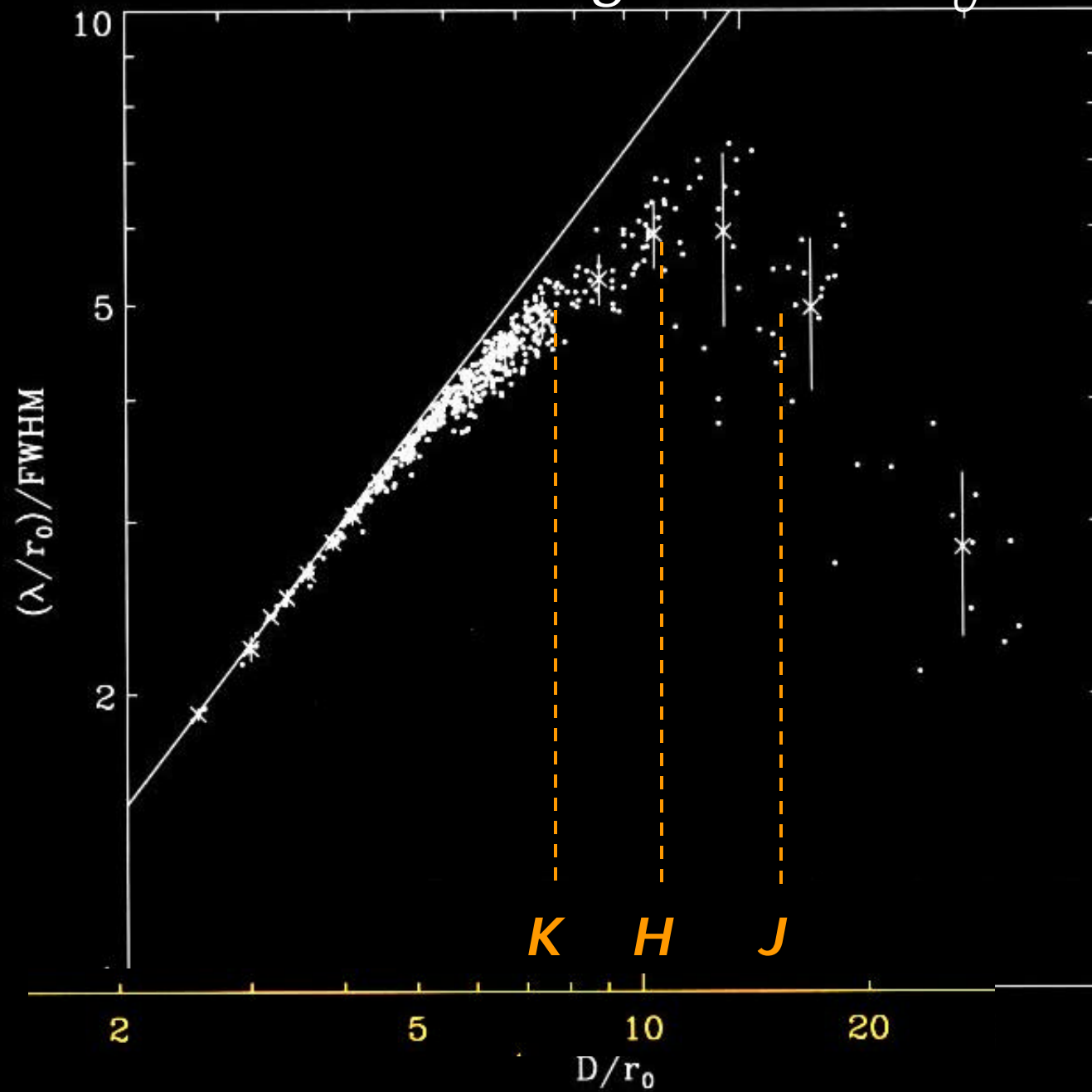
# Strehl gain vs $D/r_0$



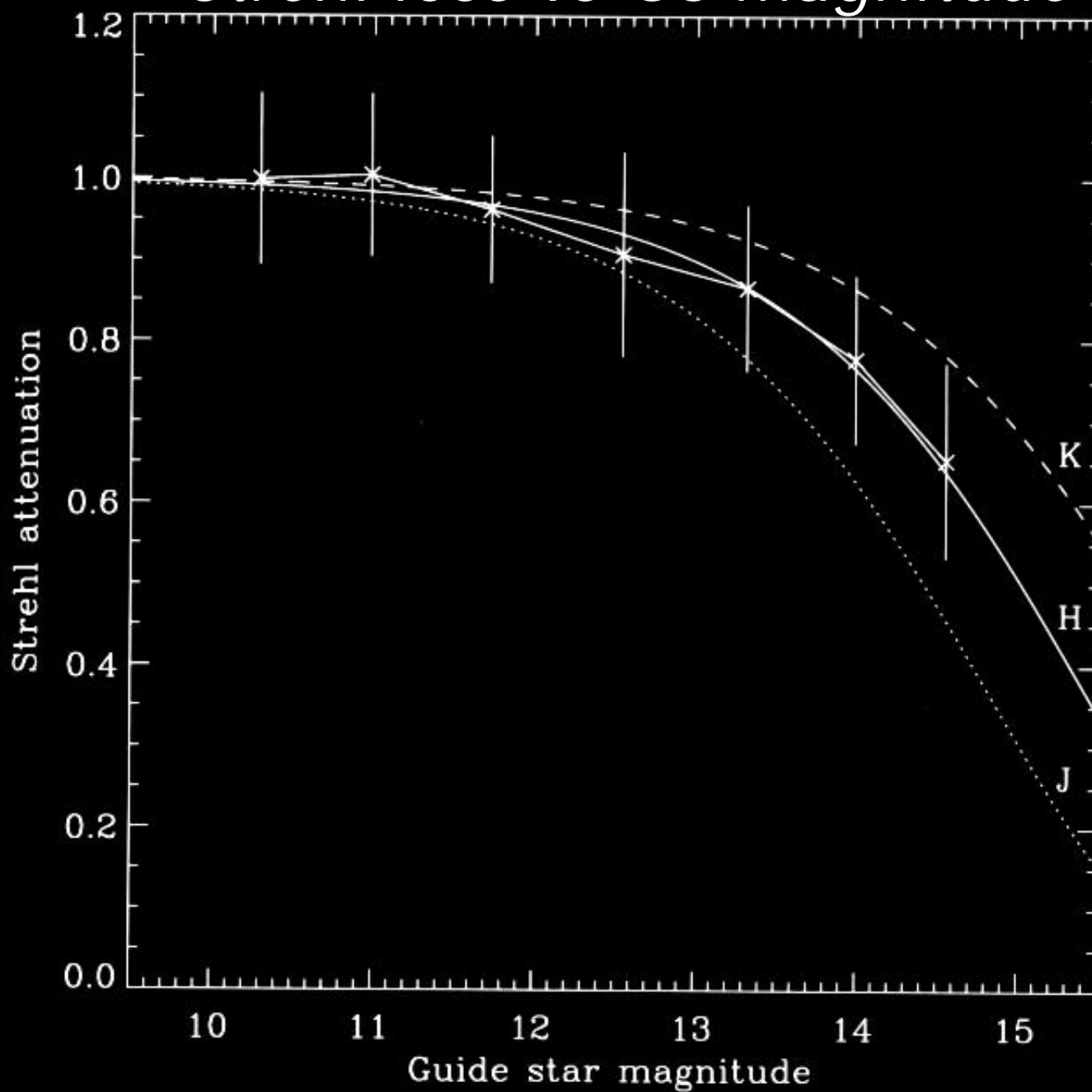
# Normalized FWHM vs



# *FWHM gain vs $D/r_0$*



# Strehl loss vs GS magnitude





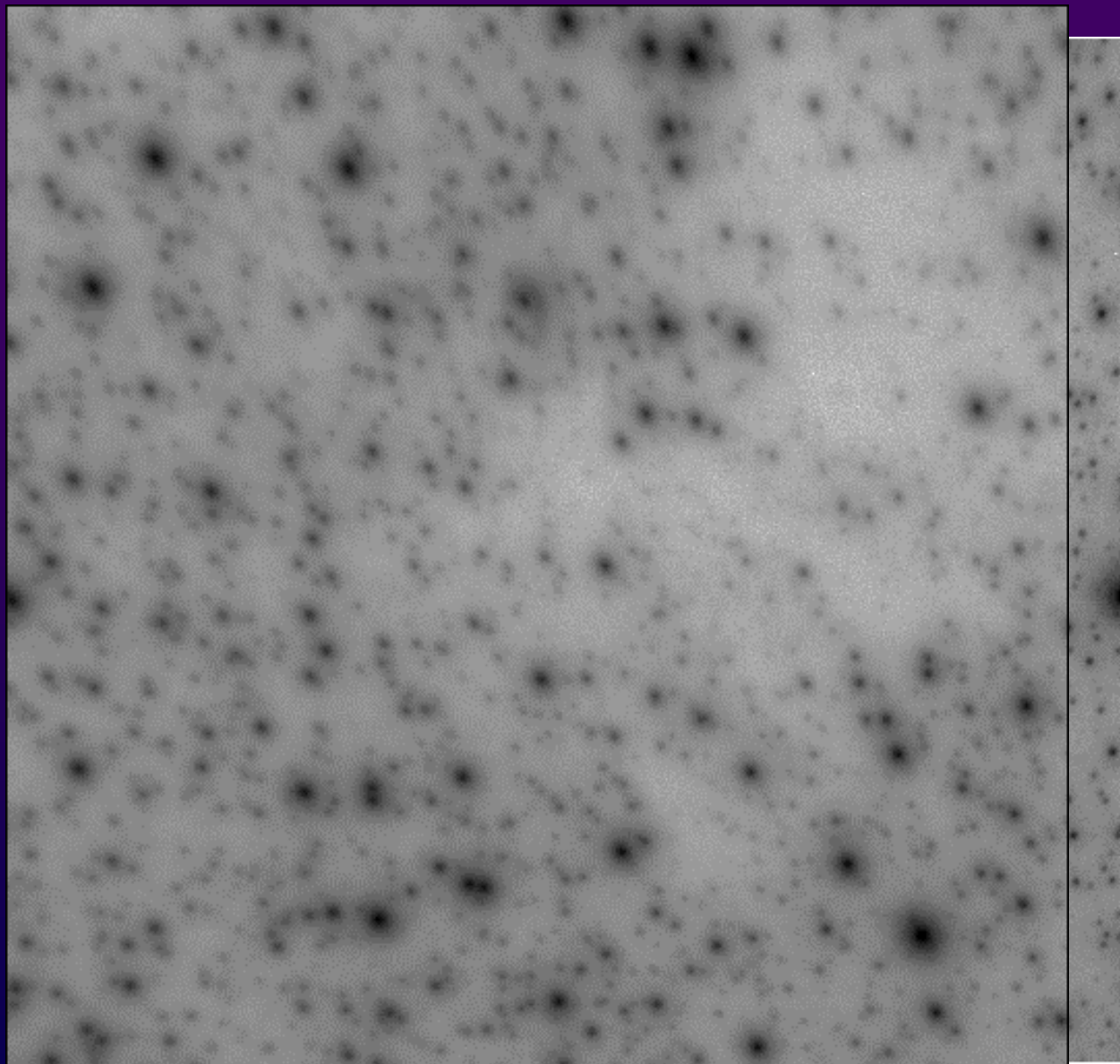
# Anisoplanatism

- Typical Strehl loss of 50% at zenith:

J 17"

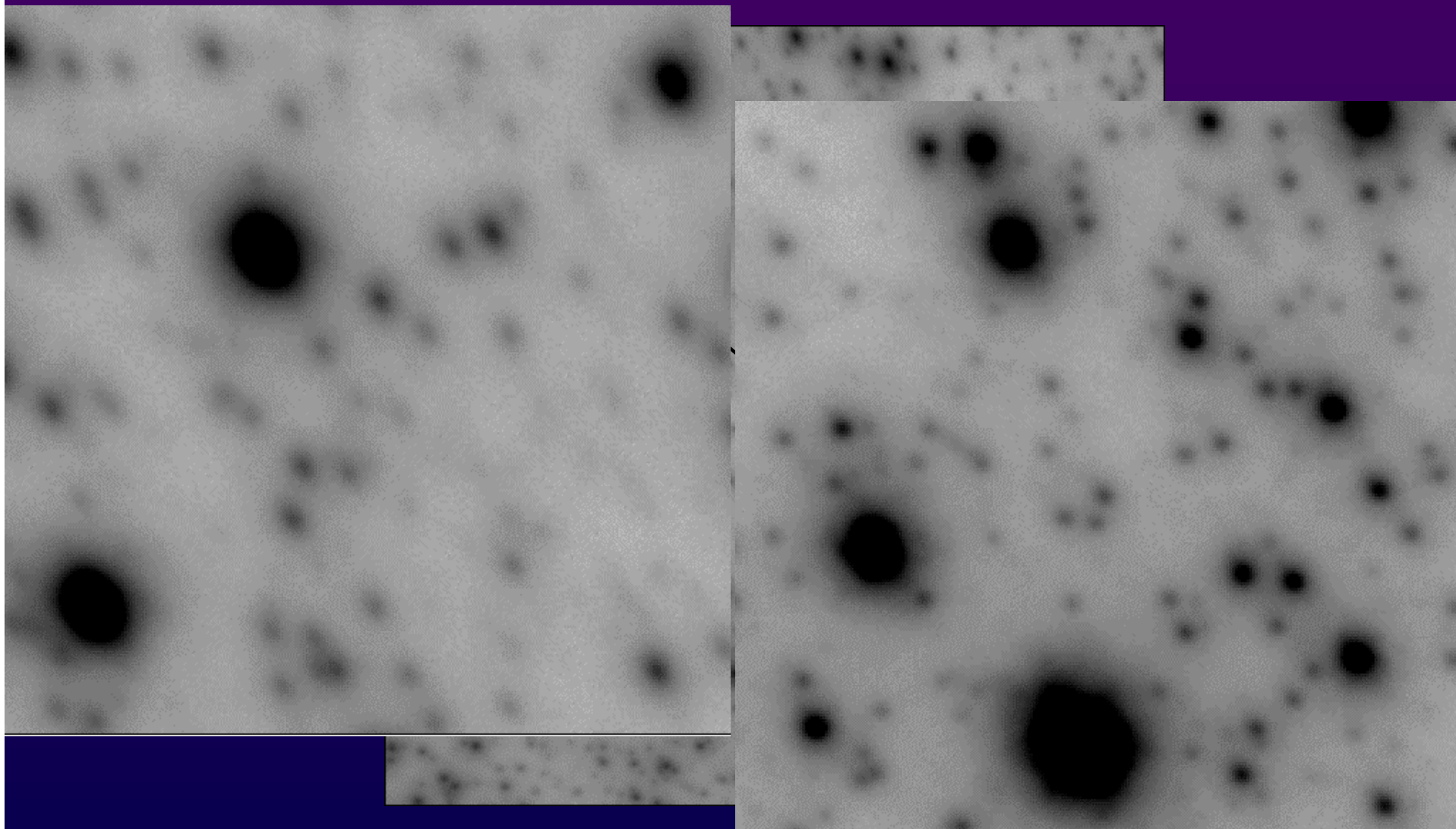
H 25"

K 35"





# Anisoplanatism

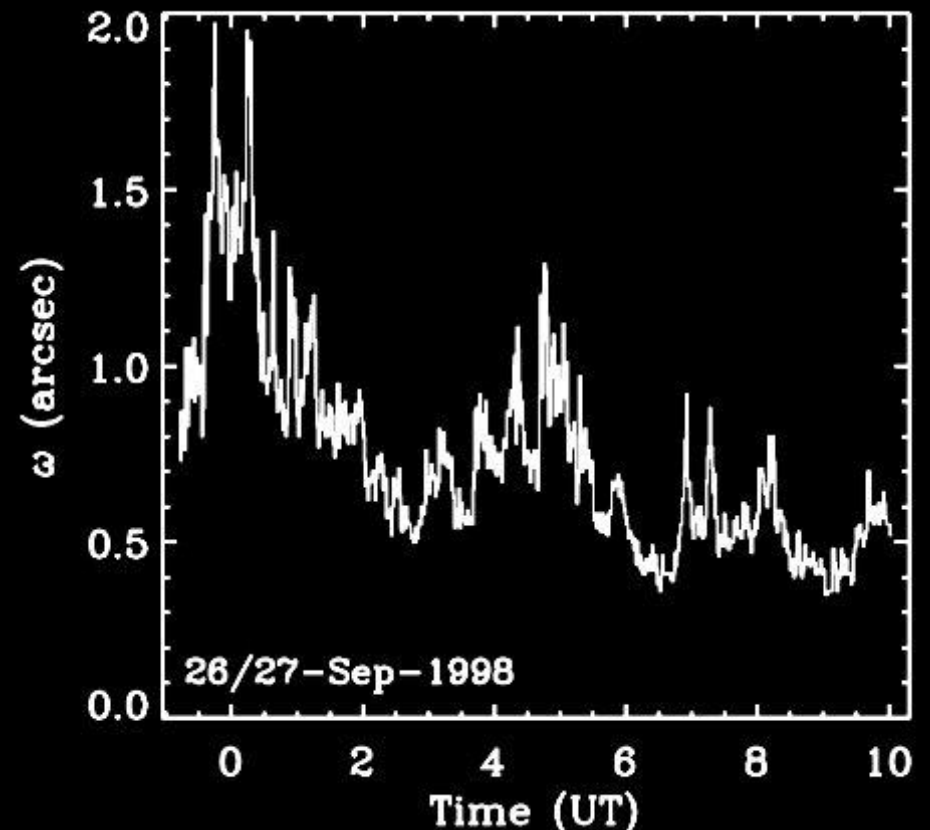
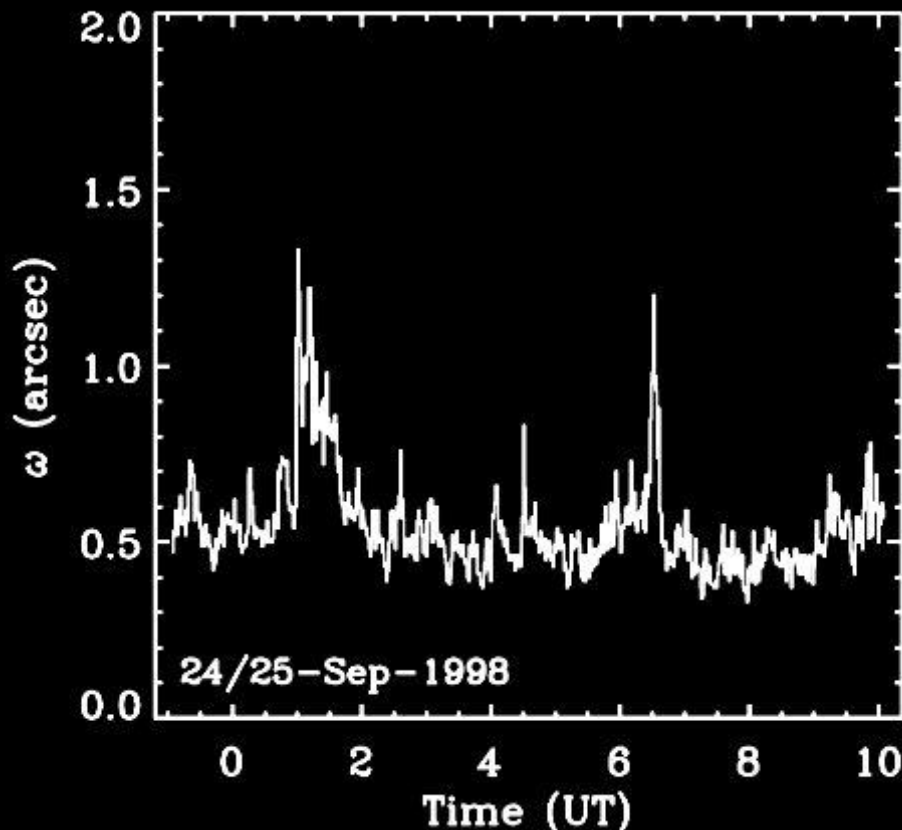


*February 25, 2001*

Hokupa'a Workshop, NOAO

10

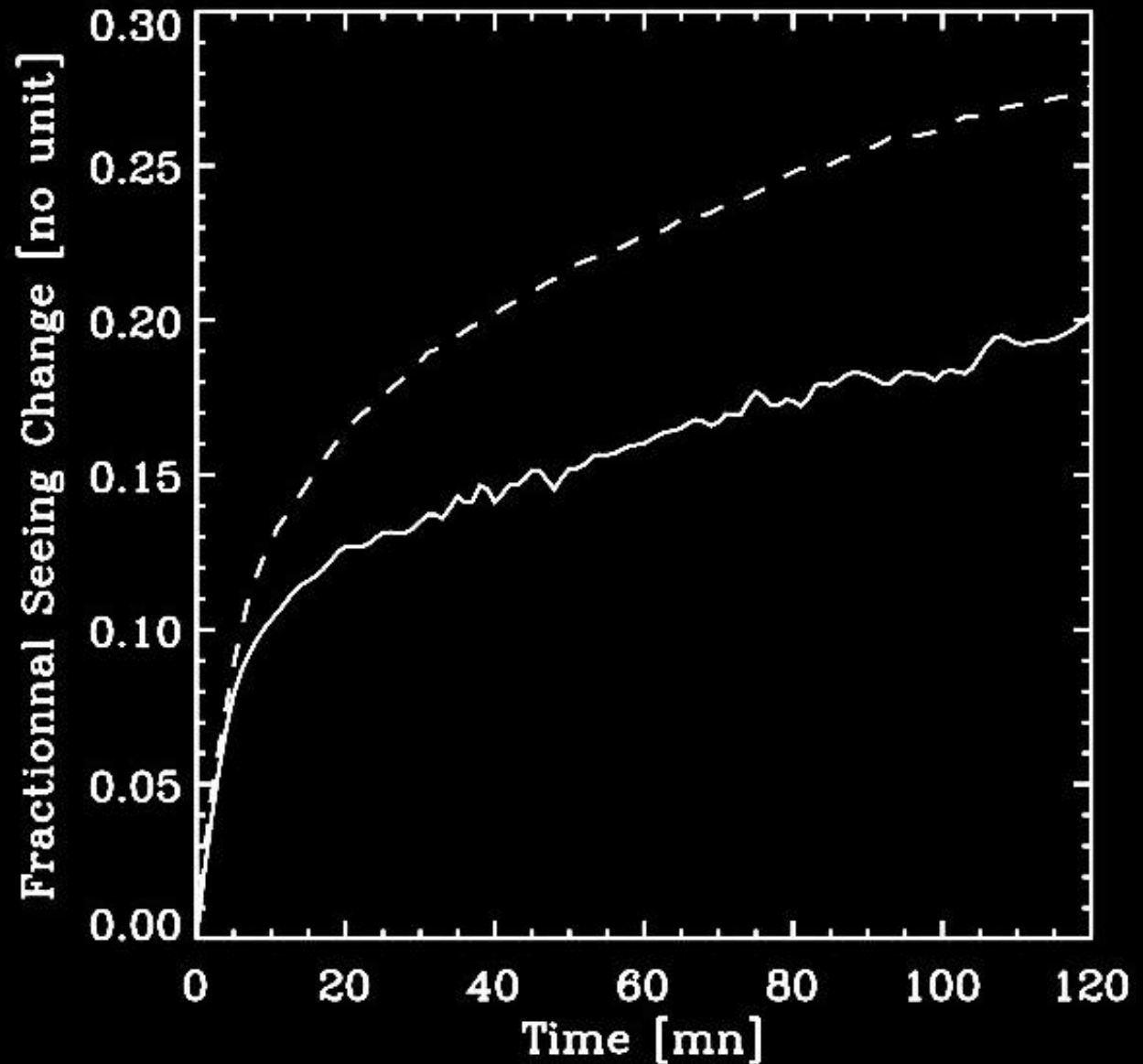
## PSF Temporal Variability



*Example of nightly seeing variations. Data from Paranal, 1998. From ESO Seeing database (Sarazin)*

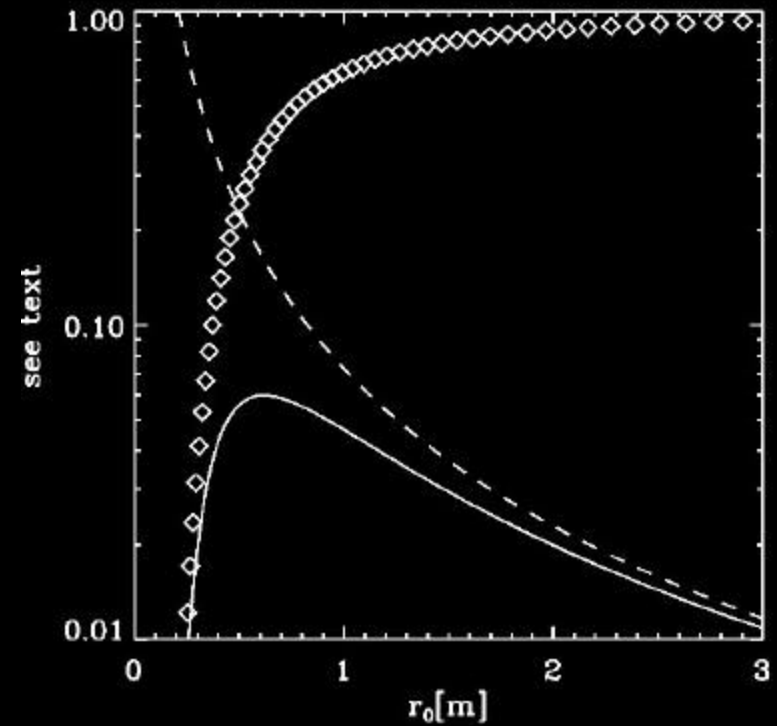
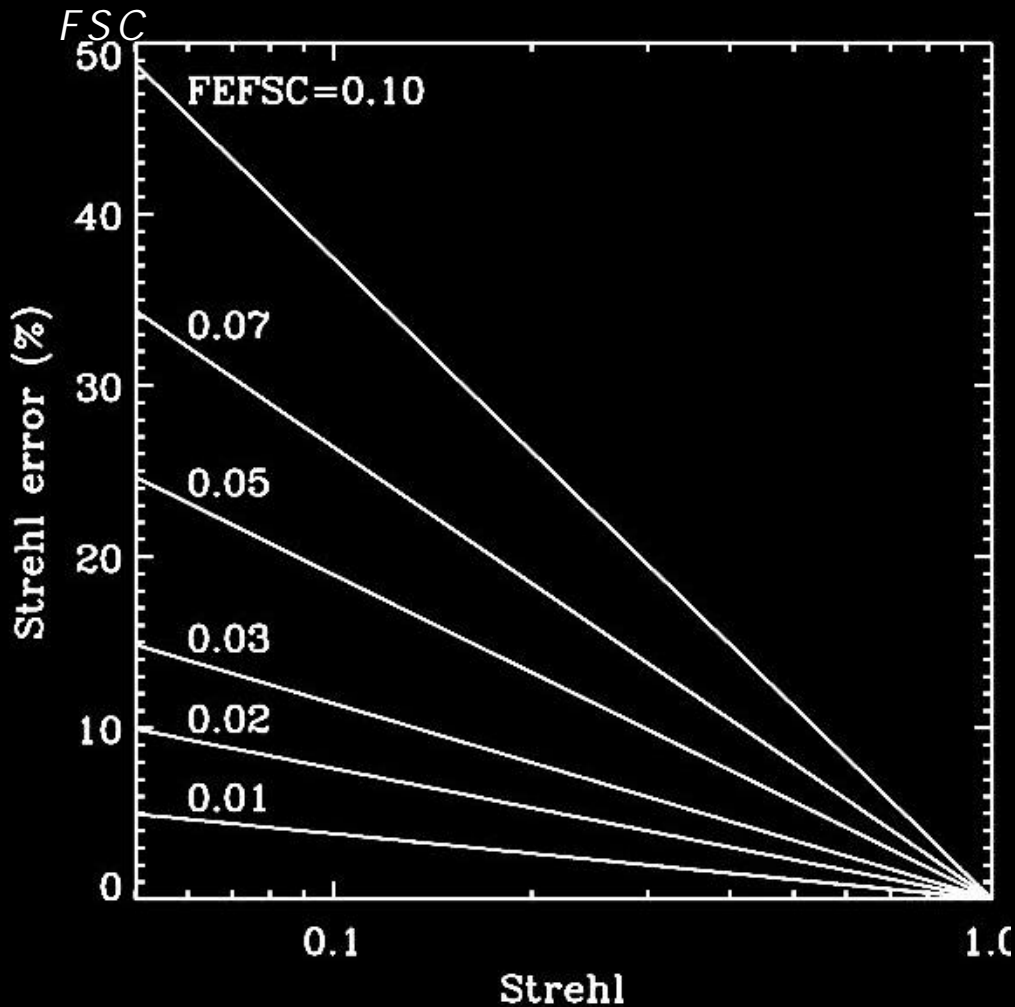
## PSF Temporal Variability

***Seeing variability:  
Fractional seeing change = relative  
variation of seeing.  
Rigaut and Sarazin  
1998. Mauna Kea :  
Racine et al (early  
1990).***



# PSF Temporal Variability

Relative Strehl error vs Strehl for various



***Fractional seeing change vs time + Strehl vs  $D/r_0$  AO behavior gives Strehl error vs time for given Strehl.***



## Other Issues

- **Speckle Noise:**
  - Noise in Halo is dominated entirely by “speckle noise” (and quasi-static aberrations), NOT by photon noise
  - Killer Solution: Dual wavelengths imagers
- **Artefacts:**
  - Source: Static or quasi-static aberrations that vary with time and/or position in FoV
  - Solution: Better designed systems (more stable), better Strehl ratio
- **Sky/FF modulation:** Non Problem (DM in pupil plane)

*Bottom line: Poorly investigated effects, highly statistical phenomena, causes not always*

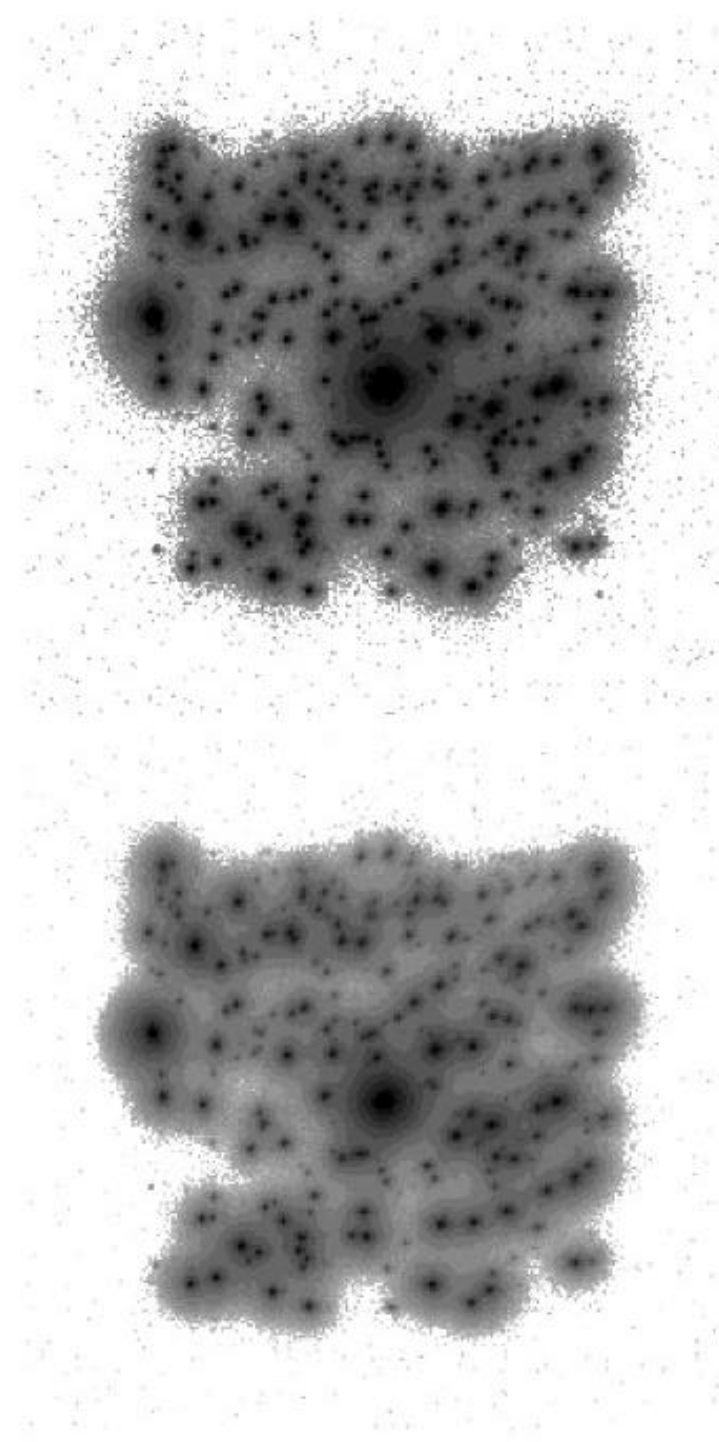
## Photometry with a variable

PSF

*15x15 arcsec<sup>2</sup> J, H and K  
Fields generated using a GC  
type stellar distribution but  
10% of the crowding only.*

*Completed at faint end. 9000  
stars in these images.*

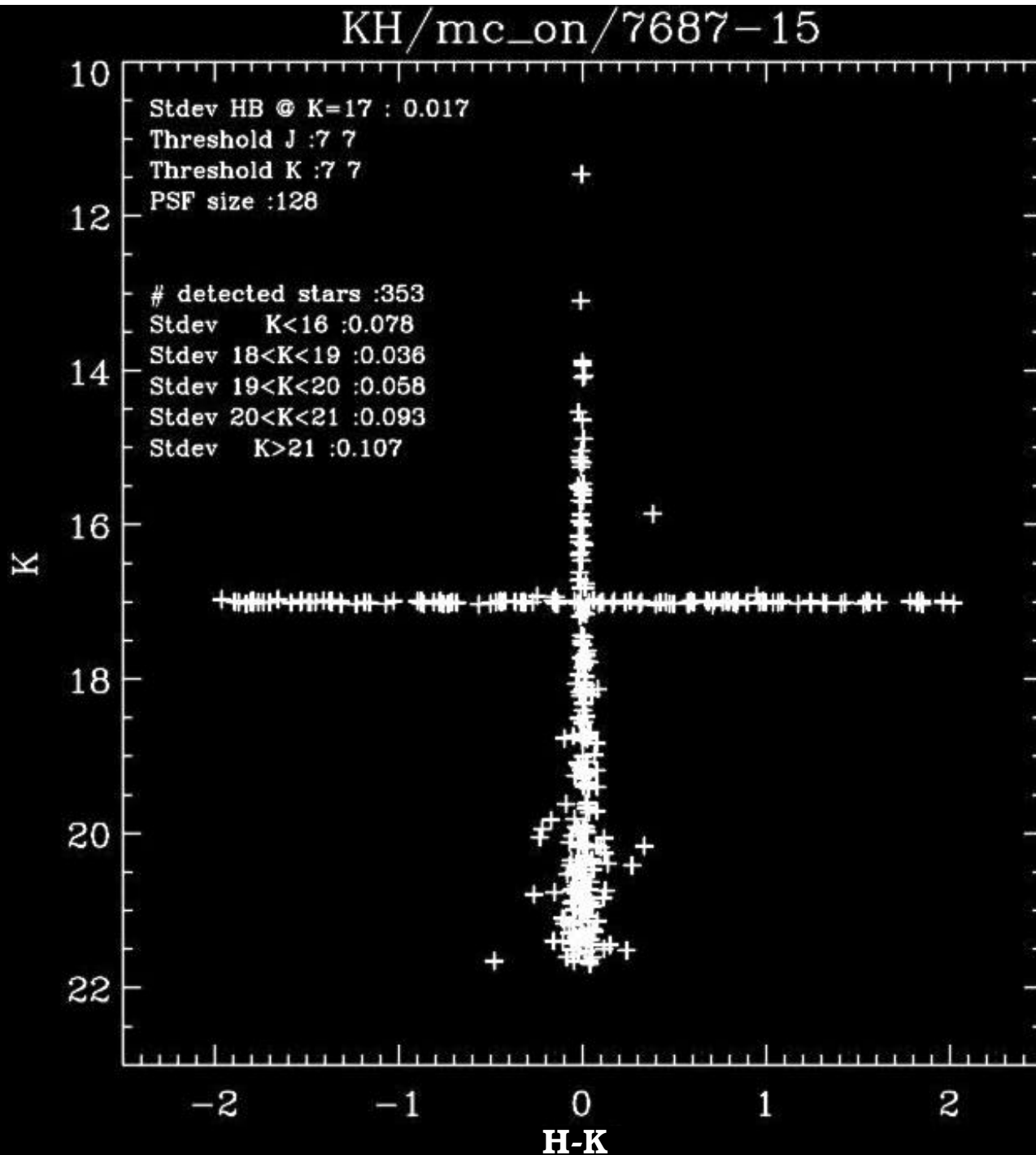
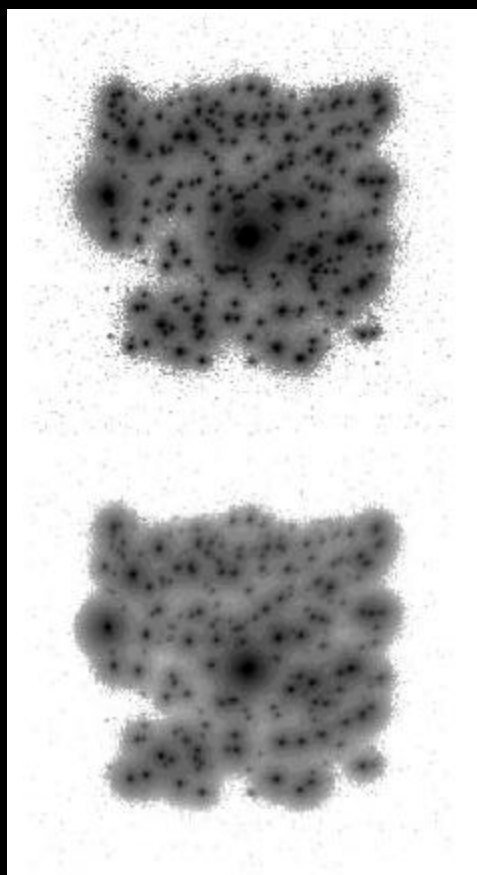
*Classical AO and MCAO at  
1.9 airmass under median  
seeing.*



Photometry  
with a variable

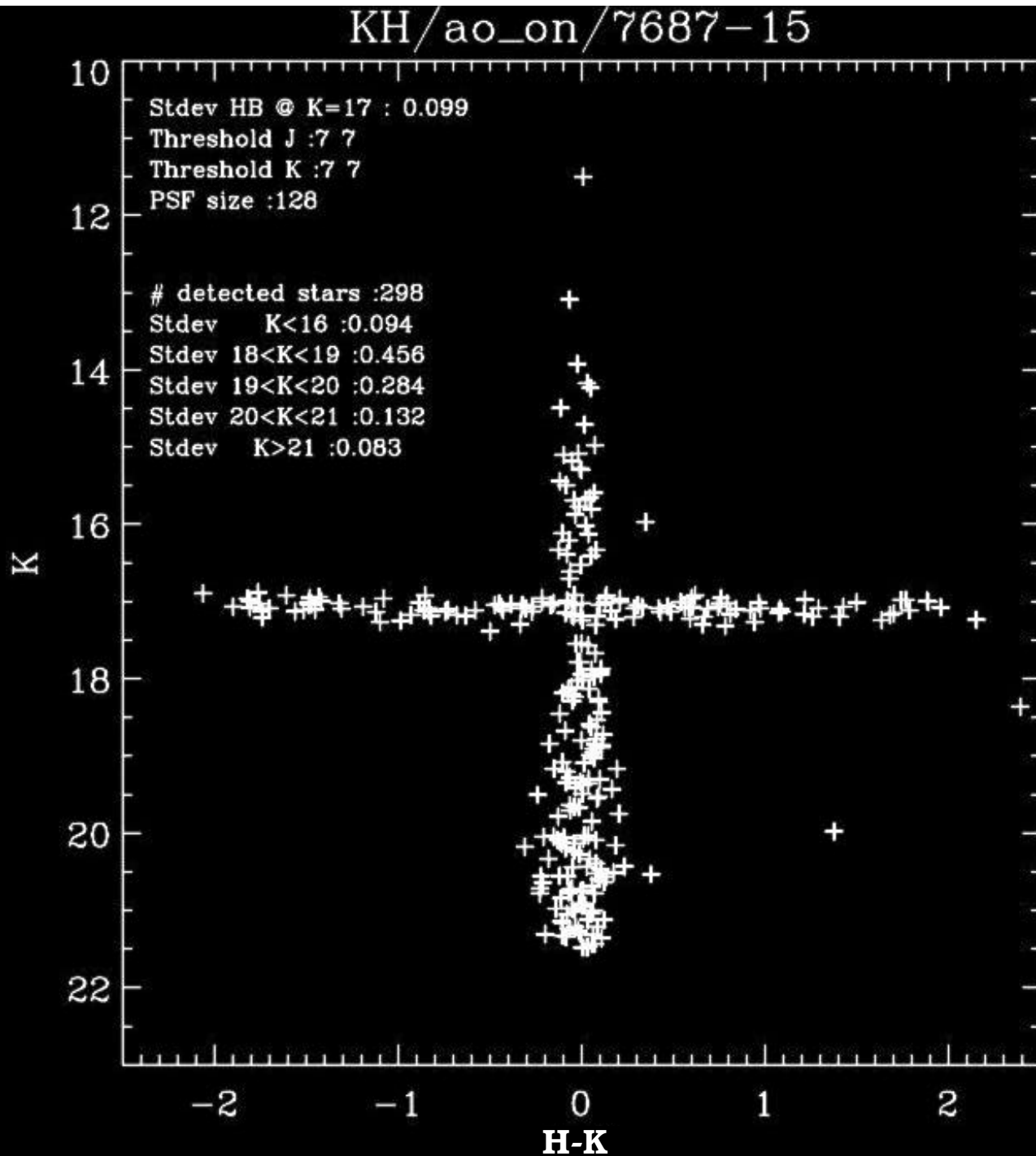
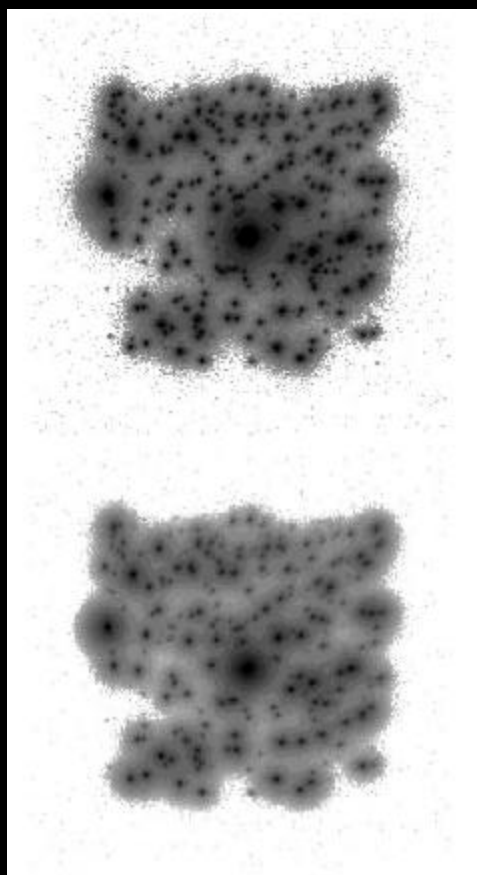
PSF

*H-K / K, MCAO*



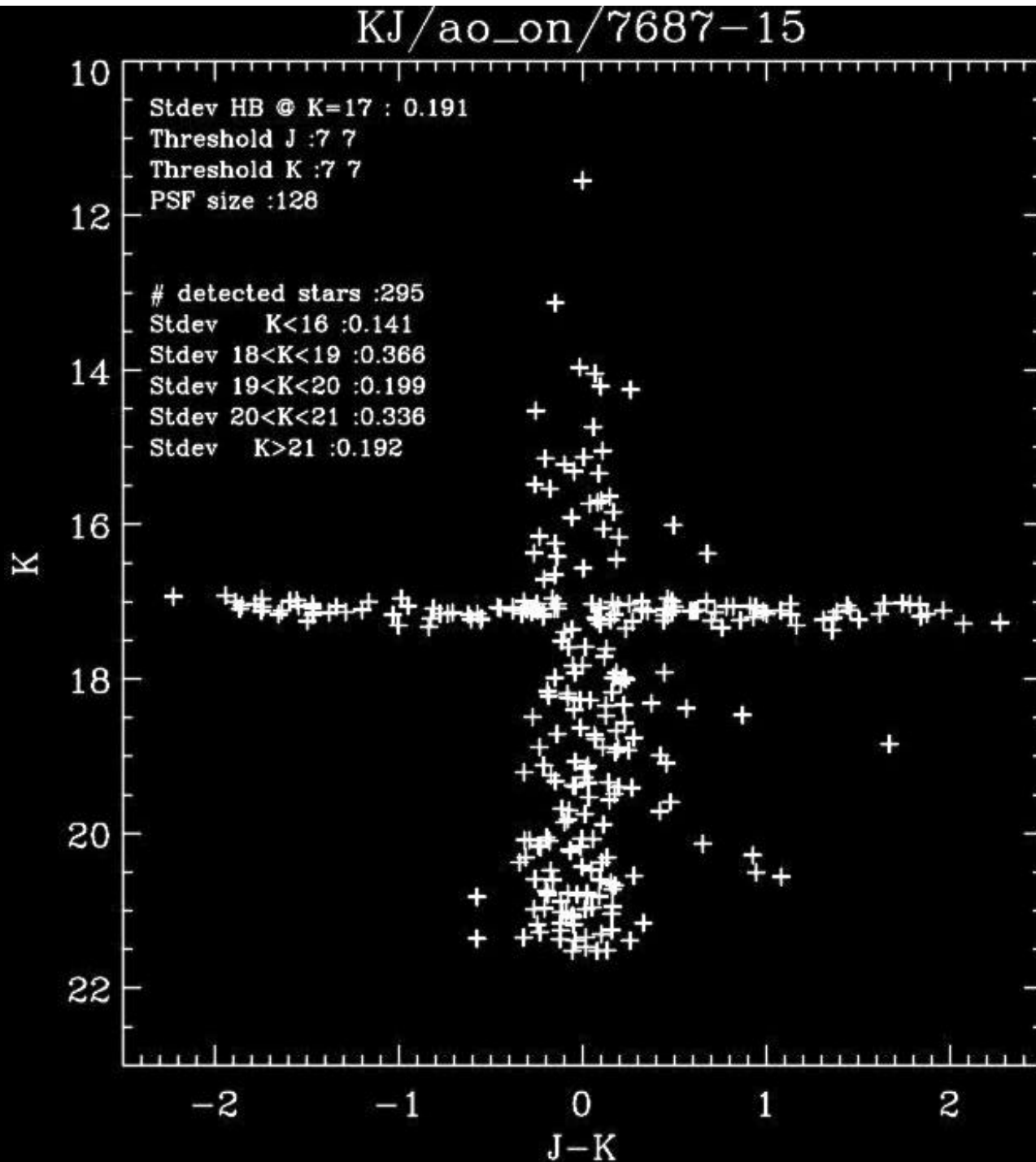
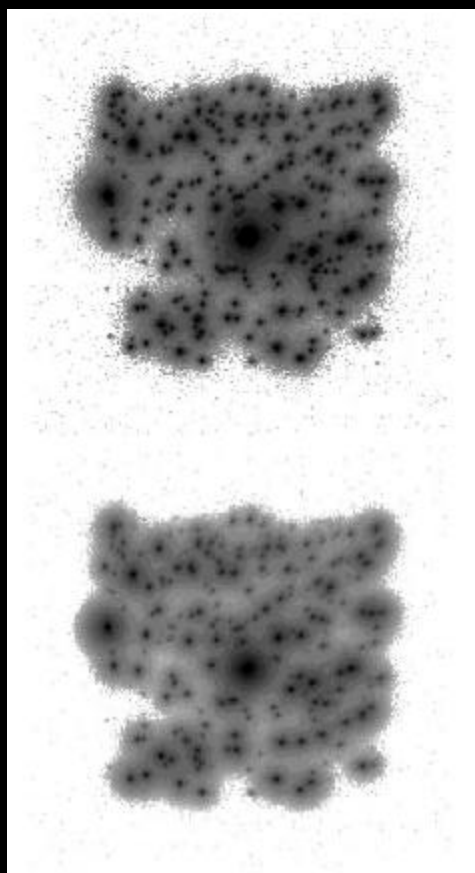
# Photometry with a variable

## PSF $H-K / K, AO$



# Photometry with a variable

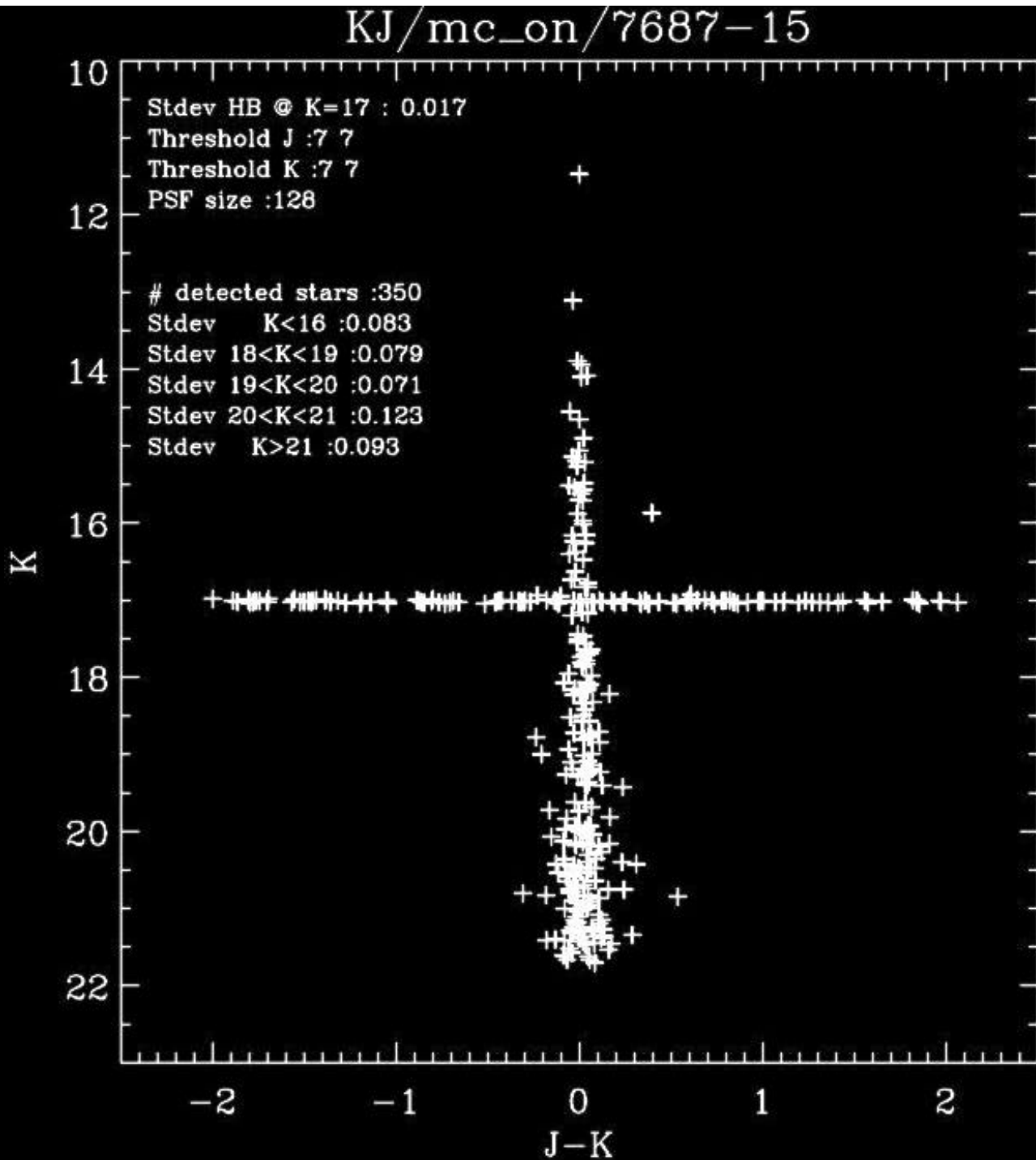
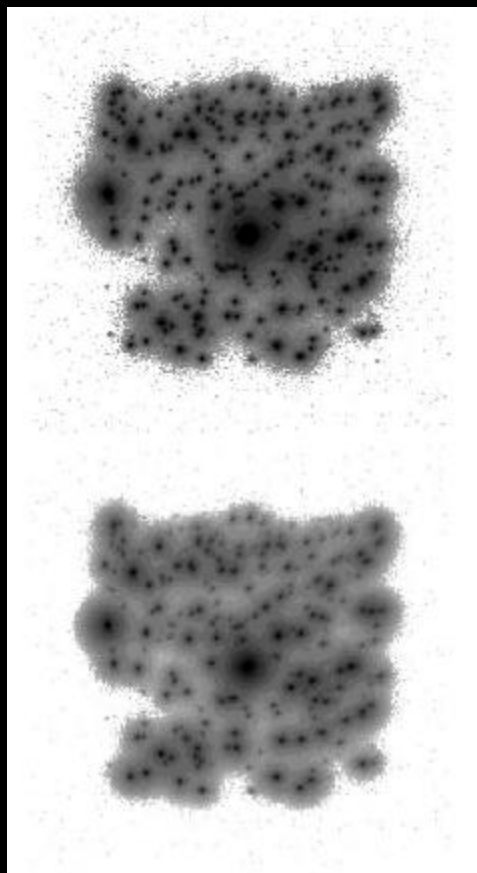
## PSF $J-K / K, AO$



Photometry  
with a variable

PSF

$J-K / K$ , MCAO





## Astrometry issues

- Potential **Field distortion** introduced by Optics can be calibrated out
- **Dynamic Plate Scale effects** unchanged w.r.t seeing limited case -> time averaging required (e.g. 2 mas in one mn for median seeing)
- **Astrometric accuracy** in measurements proportional to FWHM -> 10 x gain w.r.t. seeing limited case
  - Assuming ultimate precision of FWHM/50 -> **mas level**



## Limitation of current Data Reduction Codes

- Code w/ good model for **Field Variable PSF** missing
- Stellar fields: **PSF extraction** from image
- Extended Object: PSF in field or PSF calibration. Deconvolution required ? **Limited photometric accuracy**. >> Model Fitting <<
- New stuff around ?

### Bottom line:

- Hit in SNR due to halo
- a few 1/100 mag photo. possible with heroic efforts on stars
- Blurry situation for blurry objects