PLEIADES
IN-FLIGHT MTF MEASUREMENTS

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Gwendoline Blanchet
Image Quality
***CNES** - Toulouse Space Center*

OUTLINE

- PLEIADES: mission and instrument overview
- MTF measures with stars
- Results

PLEIADES: MISSION & INSTRUMENT OVERVIEW

Main features

- 5 spectral bands : PAN + 4 XS (B, G, R, NIR)
- Spatial resolutions : 70cm (PAN), 2.8m (XS)
- With 2 satellites: daily accessibility
- Lifetime : 5 years
- Launch : PHR1A December 17, 2011
  : PHR1B December 01, 2012

Orbit & geometry

- Near polar sun synchronous orbit
- Repeat cycle : 26 days
- Inclination : 98.2 deg
- Cycle : 14 orbits/day
- Local time : 10.30 AM
- Altitude : 694 km
- Swath : 20 km
- Agile

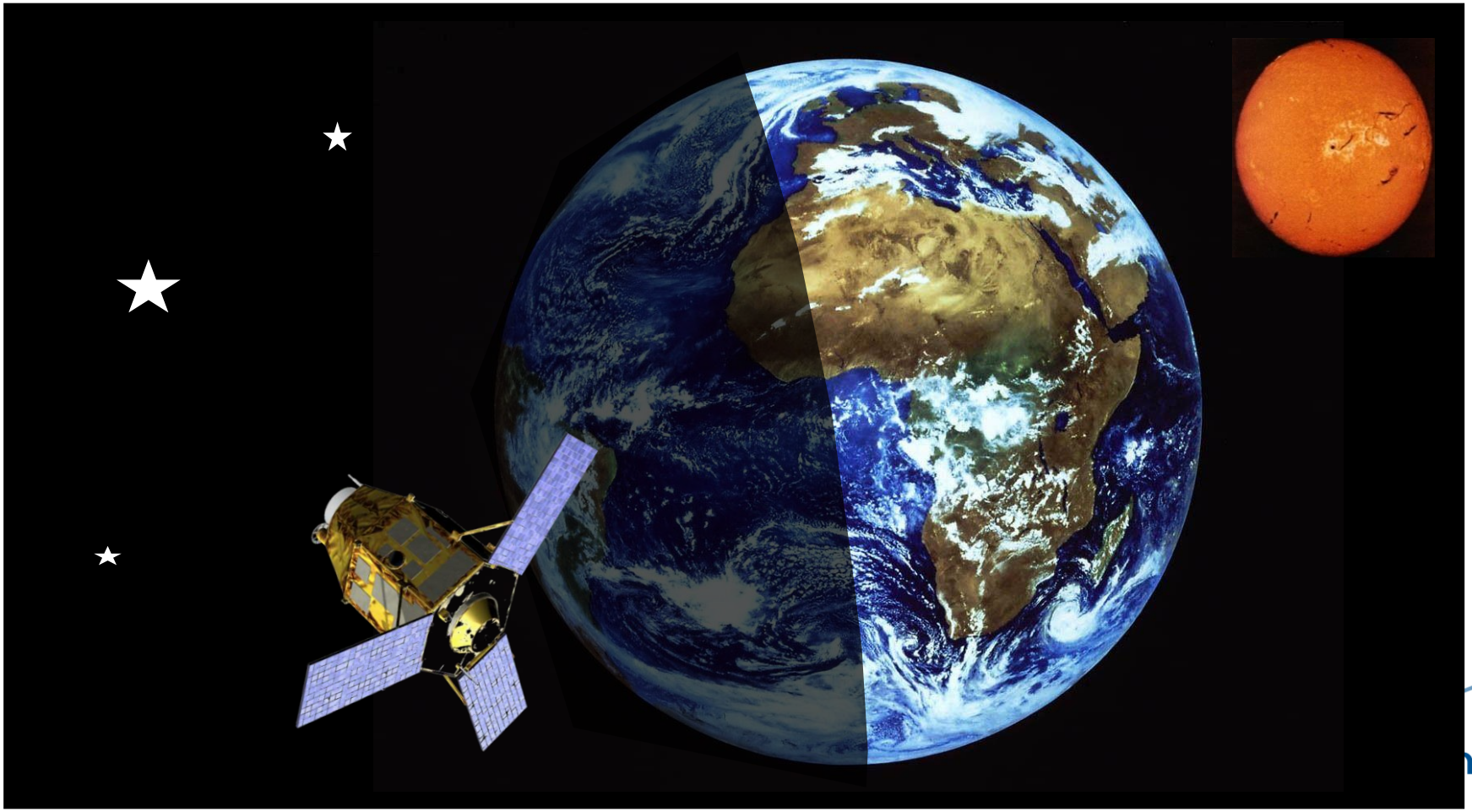
Instrument

- Telescope: Korsch
- Push-broom imager
- Pupil : 65 cm
- Focal length : 12.9 m
- FOV : 1.6 deg
- Focal plane array:
  - 5 detector arrays to cover the total swath
  - Detector size: 13µm(PAN), 52µm(XS)
- Radiometric resolution: 12 bits
- In-flight capacity: refocus , detector equalization and compression ratio

MTF DETERMINATION WITH STARS

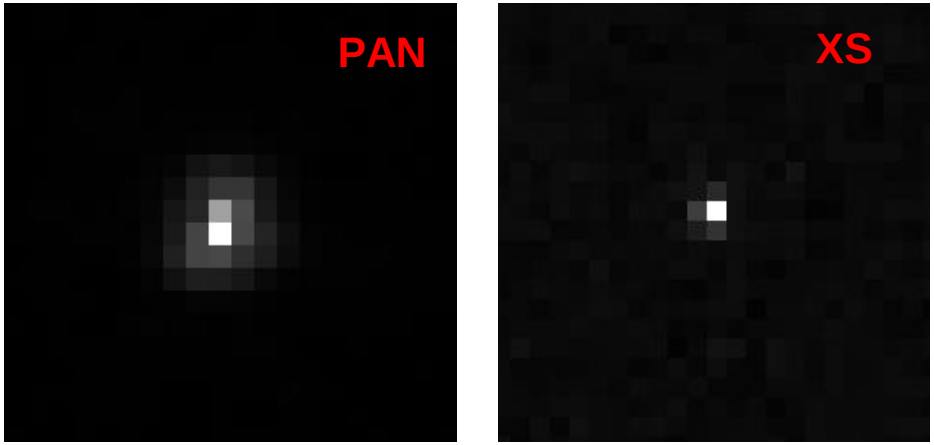
Why stars ?

- Operational interest: night orbits and no weather contraints
- Mathematical interest: motionless punctual objects, well localized and characterized by astronomers



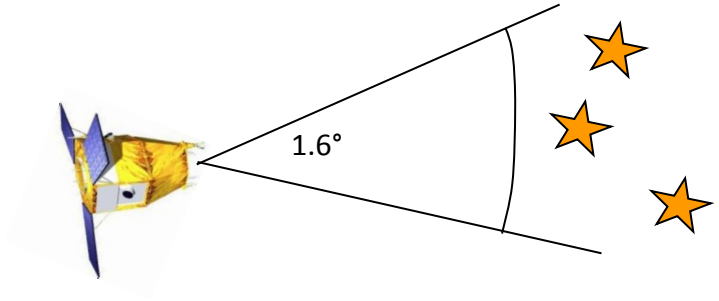
MTF DETERMINATION WITH STARS

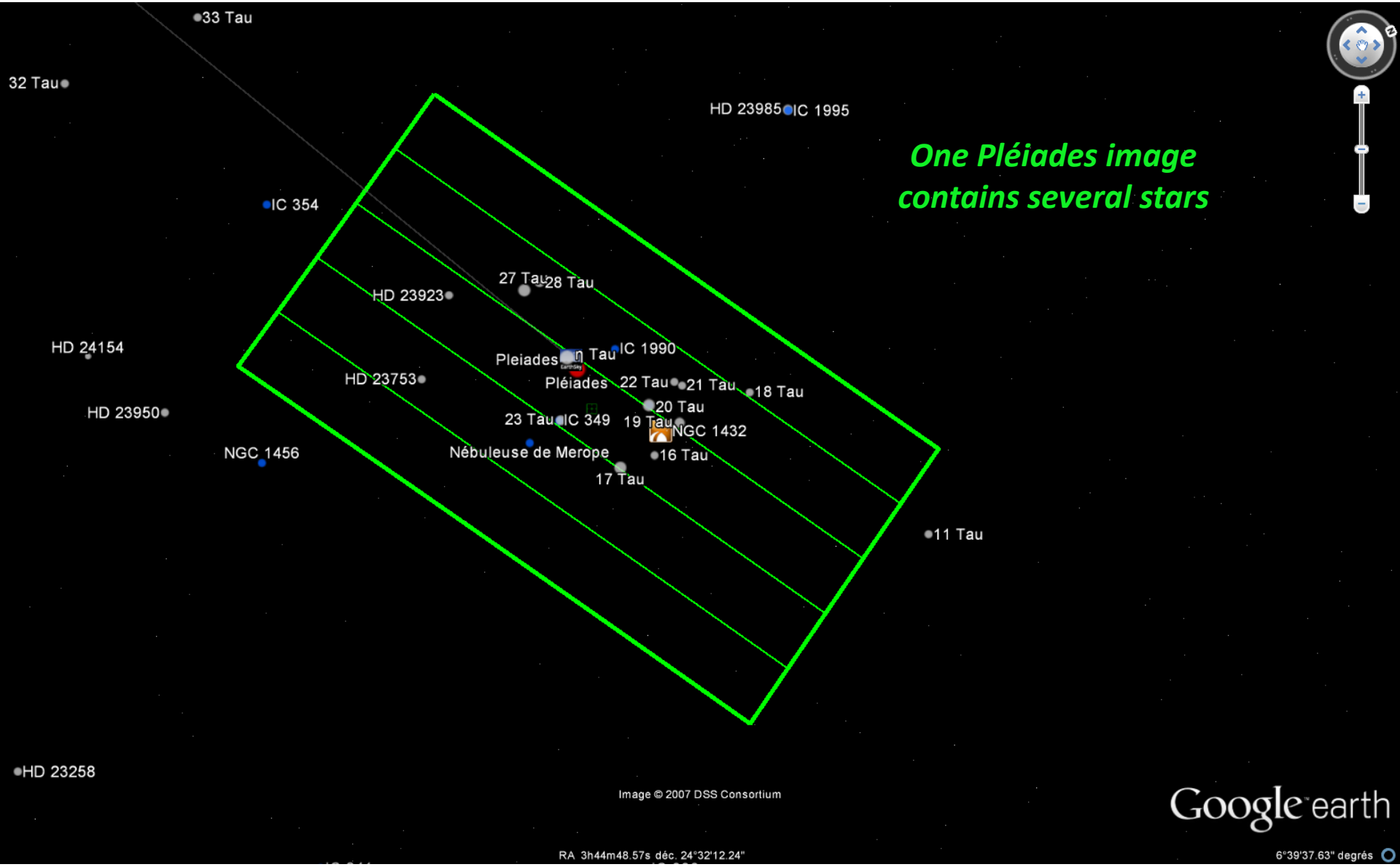
Star images by Pléiades



- Directly the instrument PSF (Point Spread Function) sampled on the acquisition grid
- Spatial resolution:
  - PAN 1µrad
  - XS 4µrad
- Noise + Aliasing → need several star acquisitions to oversample the PSF

- Many stars visible in one Pléiades image

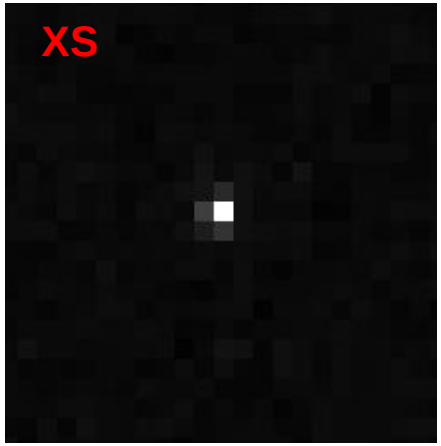


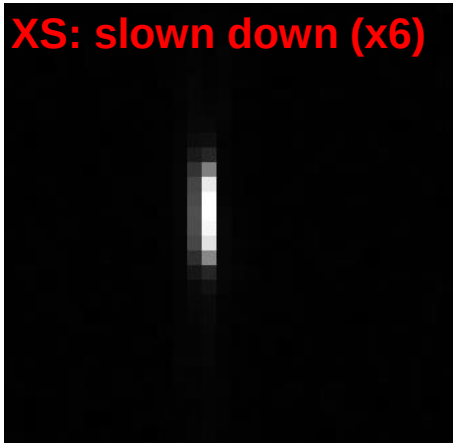

33 Tau
32 Tau
HD 23985
IC 1995
IC 354
27 Tau
28 Tau
HD 23923
HD 24154
IC 1990
Pleiades
Tau
HD 23753
Pléiades
22 Tau
21 Tau
18 Tau
20 Tau
HD 23950
23 Tau
IC 349
19 Tau
NGC 1432
NGC 1456
Nébuleuse de Merope
16 Tau
17 Tau
11 Tau
HD 23258
One Pléiades image
contains several stars
Image © 2007 DSS Consortium
Google earth
RA 3h44m48.57s déc. 24°32'12.24"
6°39'37.63" degrés

MTF DETERMINATION WITH STARS

Agility allows

- 5 acquisitions of the same star in less than a minute.
- Oversampling of the images along one axis by slowing down the satellite





MTF DETERMINATION WITH STARS

Principle:

1. Stars choice
   - » Accessibility
   - » Spectral characteristics
   - » Magnitude

2. Computation of the shift between each star and the sampling grid

3. Computation of the PSF with a mean squares method by interlacing all stars sampled PSF

Assumption:

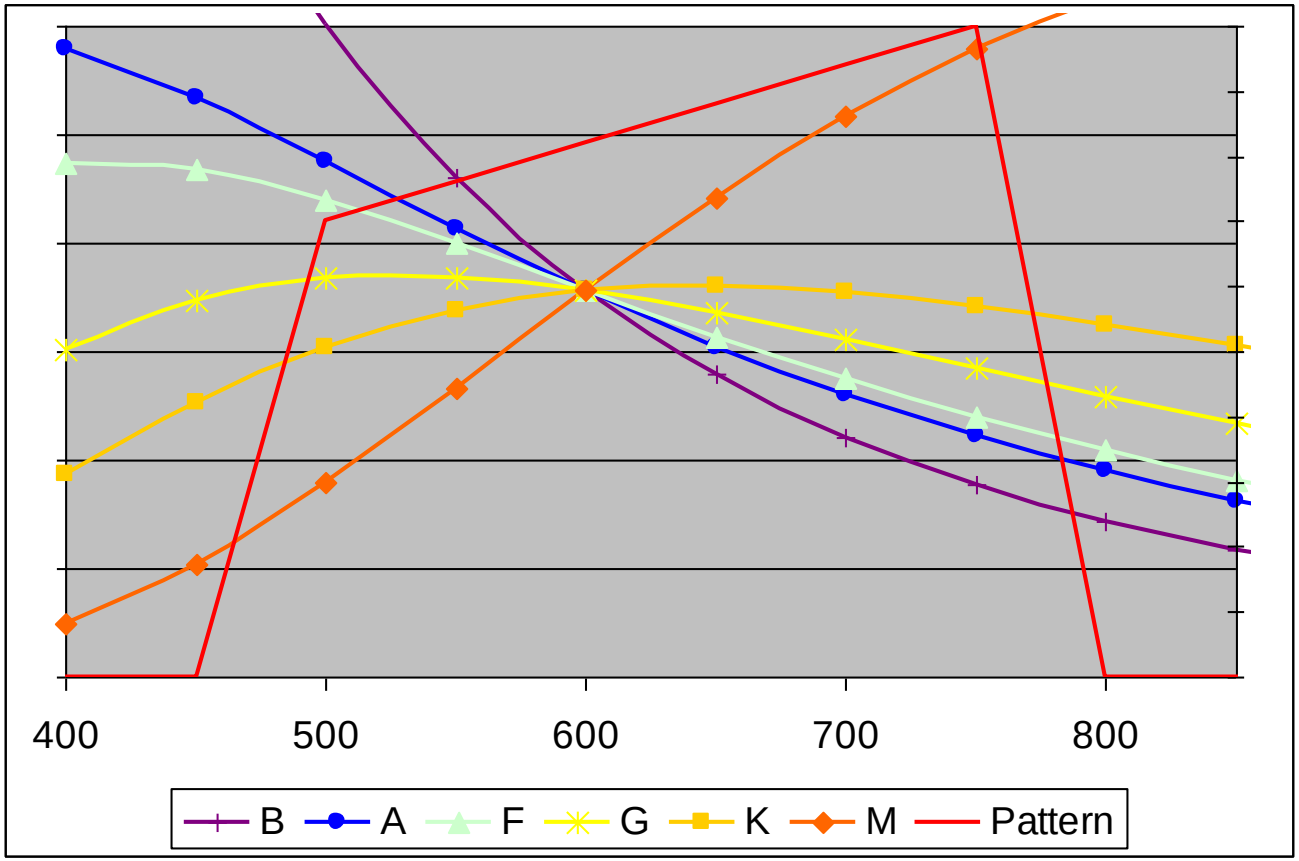
- ✦ MTF real (not complex)

Stars choice

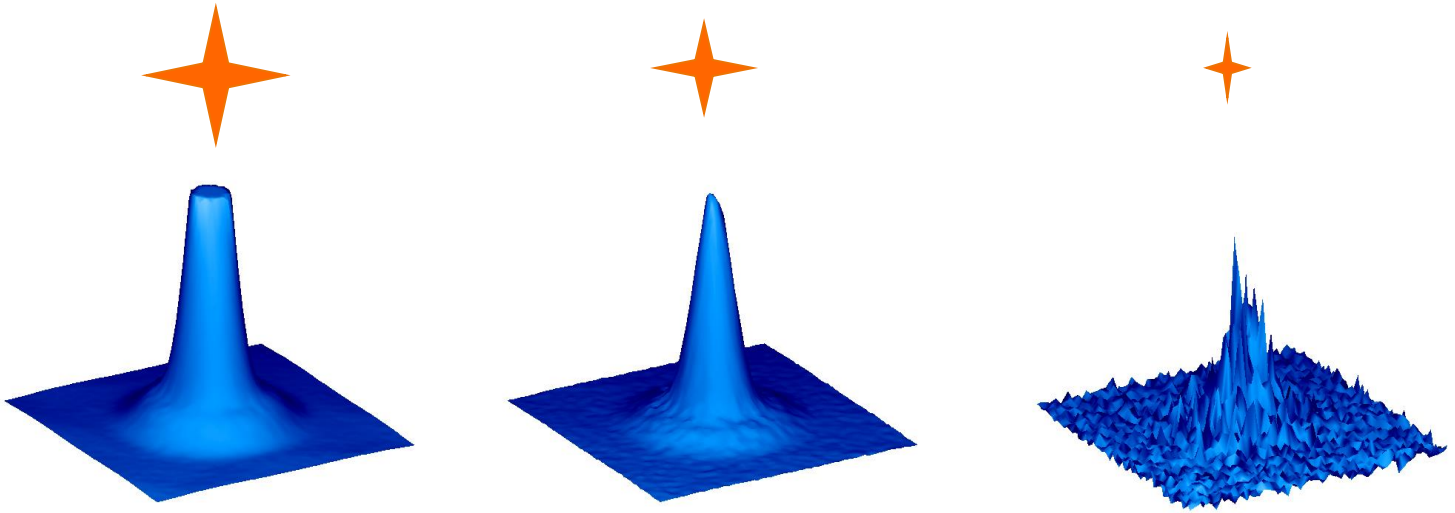
Stars classes, temperature

and spectrum

Class	temperature	color
O	> 25 000 K	Blue
B	10 000 - 25 000 K	Blue-white
A	7 500 - 10 000 K	White
F	6 000 - 7 500 K	Yellow – white
G	5 000 - 6 000 K	Yellow (the Sun)
K	3 500 - 5 000 K	Yellow – Orange
M	< 3 500 K	Red



Stars choice



Saturation

OK

Noisy

Computation of the shift of each star

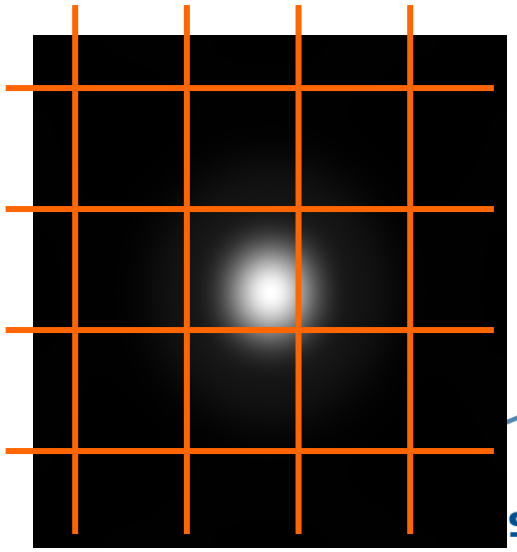
Principle:

- Based on the assumption that the MTF is real
- Shift (dx, dy) obtained when imaginary part of the MTF is equal to 0

$$Find\ \ (dx, dy)\ \ such\ \ that$$

$$\mathrm{Im}\left(FT(image) * \varphi_{ramp}(dx, dy)\right) \equiv 0$$

- With aliasing, this condition is true only at low frequencies.
  - » Phase ramp computation limited to lower frequencies



Computation of the PSF

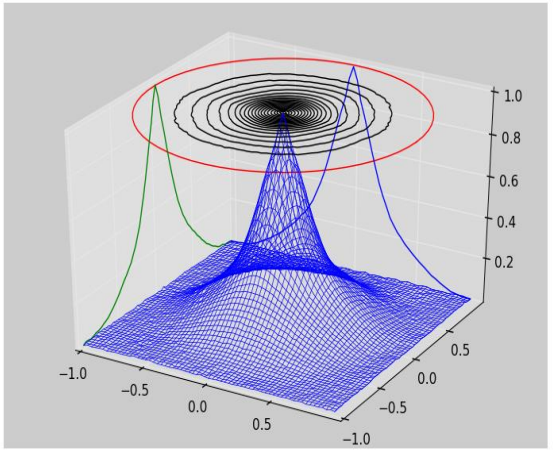
- Linear problem for each star

$$FT(star) = alias(MTF * \varphi_{ramp}(dx, dy))$$

- Problem solved with least squares methods

Inverse problem

$$\begin{bmatrix} FT(star_1) \\ FT(star_2) \\ FT(star_n) \end{bmatrix} = [A].[MTF]$$



RESULTS

PHR1A

MTF	line	column
PAN	0.16	0.15
B0	0.33	0.29
B1	0.31	0.27
B2	0.31	0.25
B3	0.30	0.26

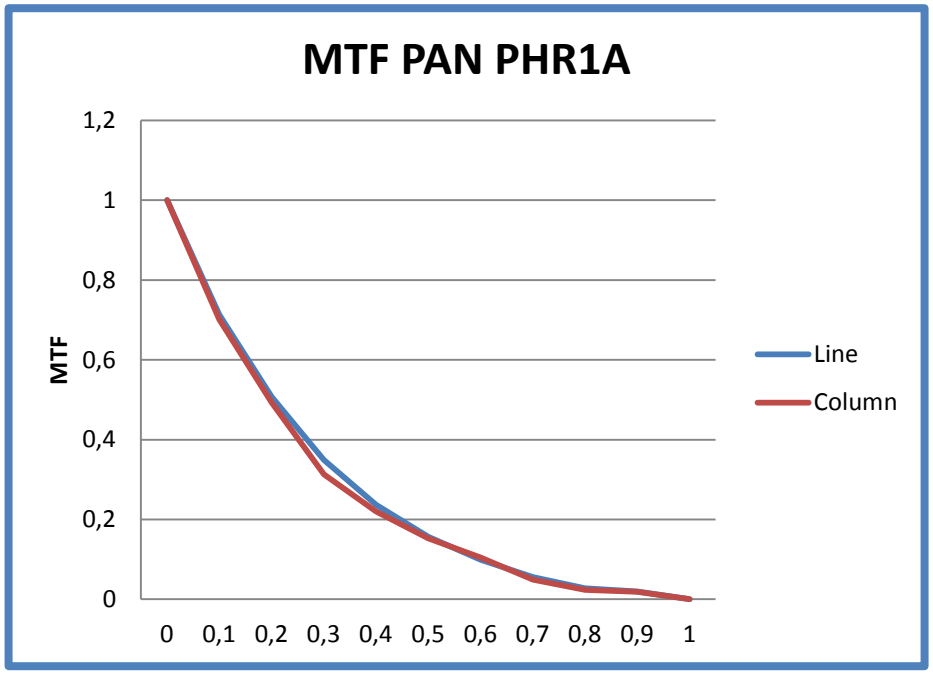
PHR1B

MTF	line	column
PAN	0.16	0.16
B0	0.30	0.27
B1	0.31	0.27
B2	0.31	0.26
B3	0.31	0.26

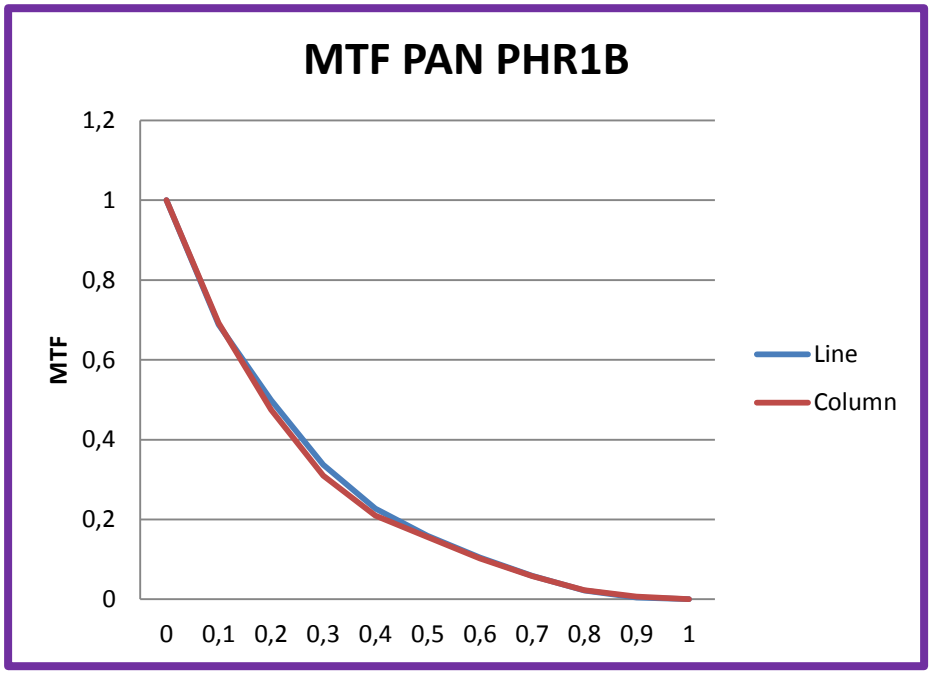
Specifications: MTF > 0.08

RESULTS

PHR1A

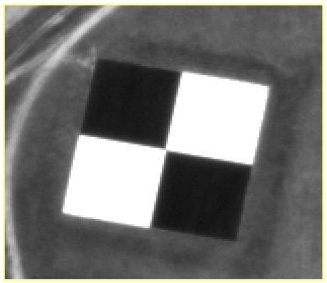


PHR1B



RESULTS

- Cross validated results during in-flight commissioning of PHR with methods based on ground target
  - SPOT family



- Stable results:
  - one measure per satellite each year
  - 2D MTF measure (not only along axis)
  - estimation for each detector array

Consequently, this star-based method has become **operational.**

CONCLUSION

- Star-based method is **the operational method** on Pléiades.
  - » Operational interest: lower impact on the mission wrt image acquisition
  - » Methodological interest: robust and accurate 2D MTF estimation within the focal plane
  - » Method coded in the « ASTral and EaRth Image calibration toolboX » which regroups calibration methods for EO satellite CNES is in charge of

- Method well adapted to next generation satellites as long as they have star acquisition capacity (agility).