



High-precision Asteroseismology of Dense stellar fields

PROPOSAL FOR NEXT ESA M8

IP: Andrea Miglio, University of Bologna

Spanish contribution: UV, IAA, UGR, IAC, ICE, ICCUB

Spanish IP: A. Moya (UV)



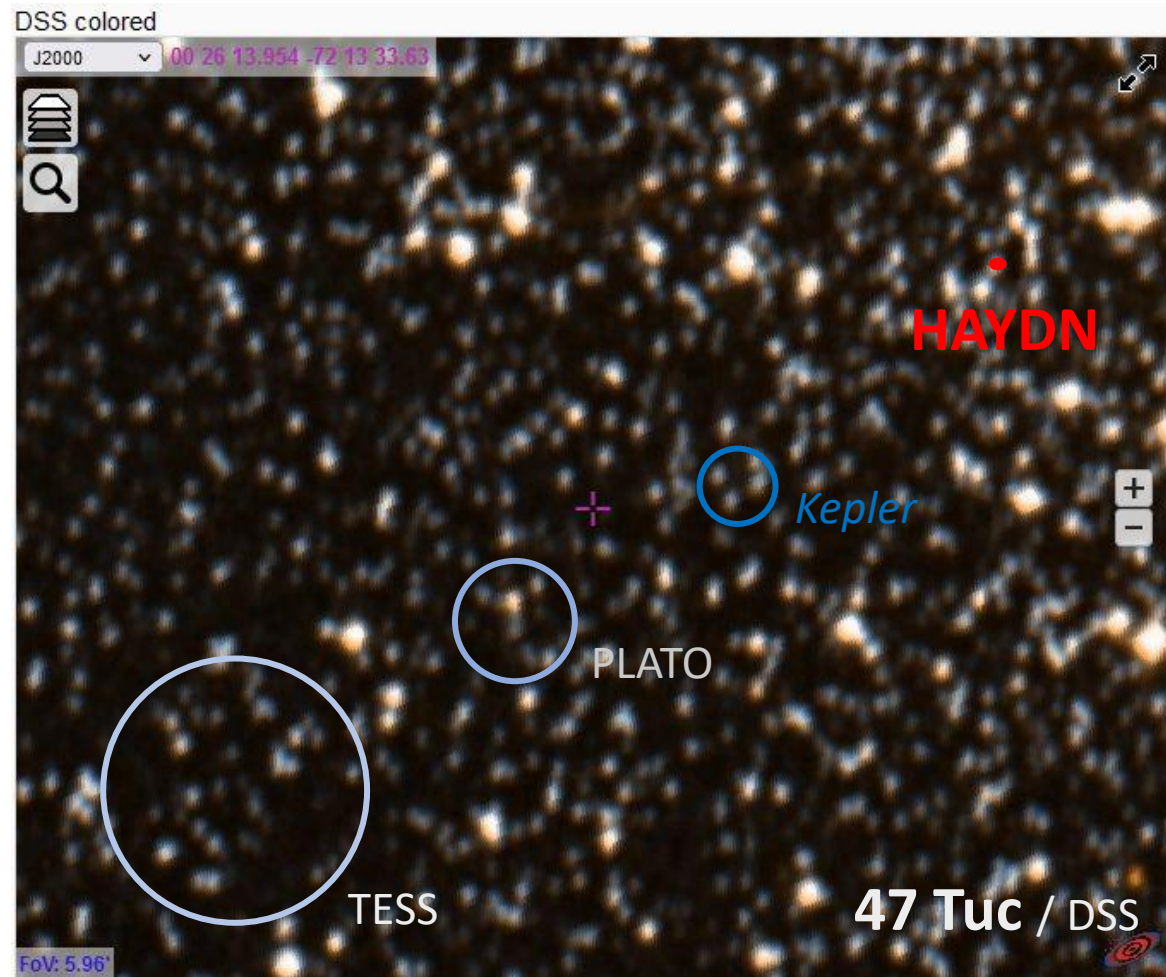
Scientific goals

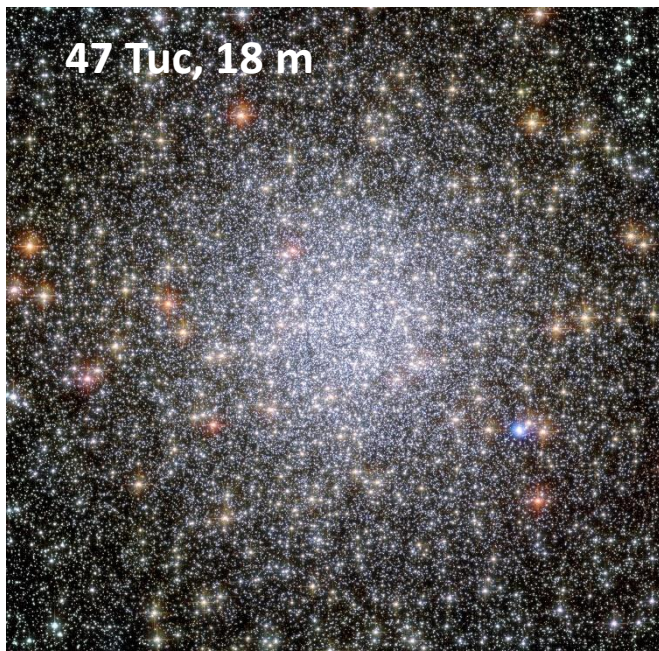
- SO 1: High-precision stellar astrophysics,
- SO 2: Stellar Clusters: formation, evolution, dynamics, and age-scale fundamental calibrators,
- SO 3: Assembly history and chemodynamics of the Milky Way and dwarf galaxies,
- SO 4: The dependence of the occurrence rate of planets on the environment.

PSF

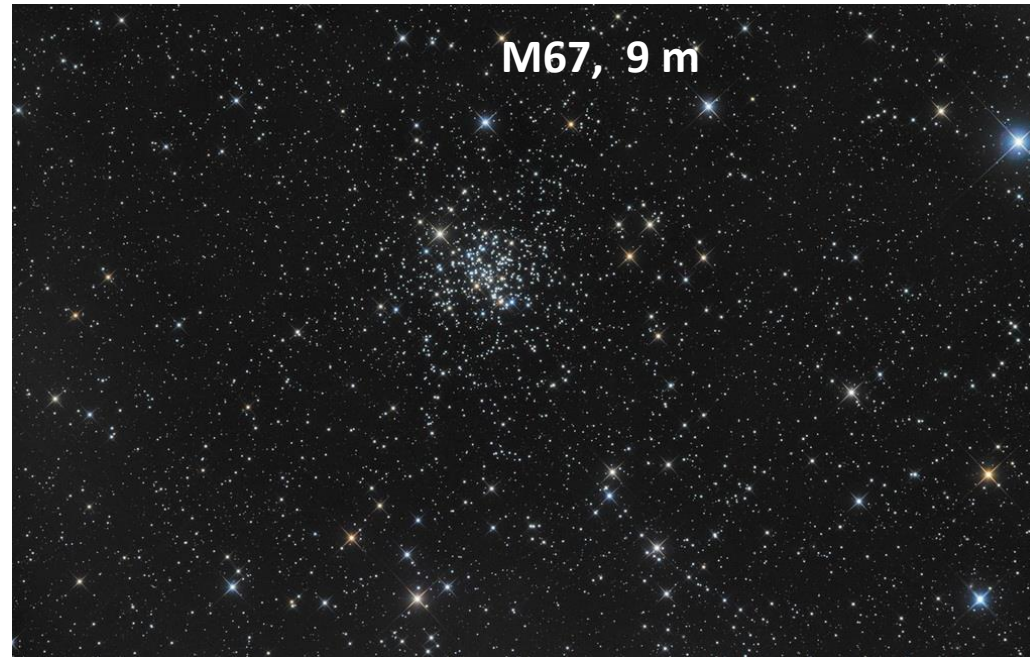
HAYDN benefits from the heritage of CoRoT, Eddington, PLATO, but with a PSF designed for the observation of dense stellar fields

Mission	PSF (arcsec)
CoRoT (seismo)	914
TESS	84
<i>Kepler</i>	21
PLATO	37
HAYDN	1.3

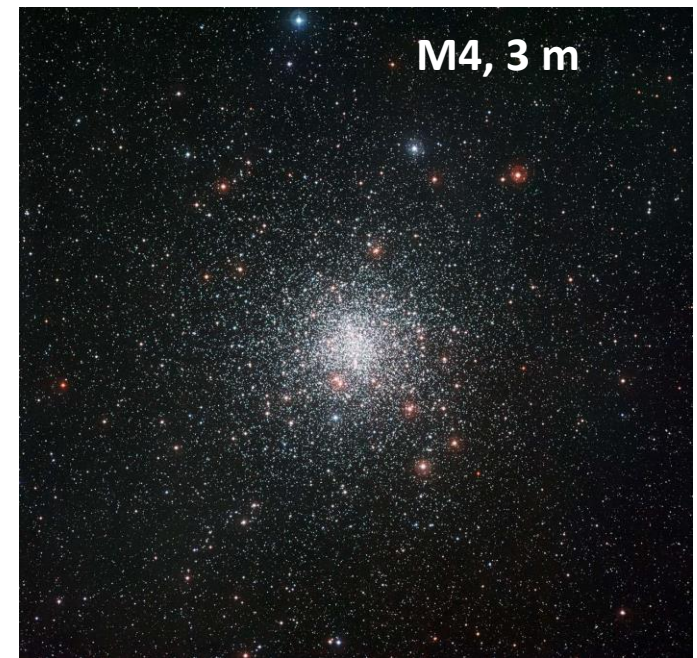




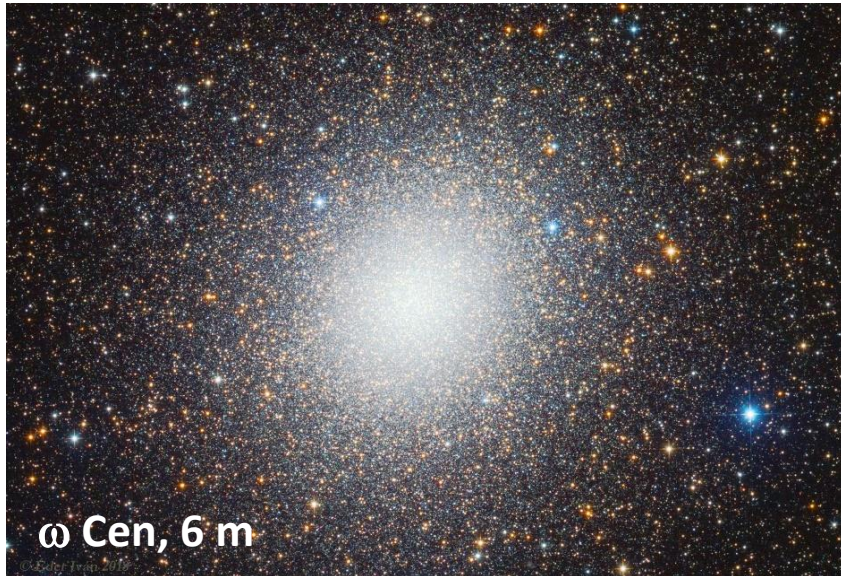
47 Tuc, 18 m



M67, 9 m



M4, 3 m



ω Cen, 6 m



Baade's window, 6 m



Sgr dSph, 7 m (add)

The consortium

International: IT, Fr, UK, Sp, Pt, Hu, Be, Ge, Sw

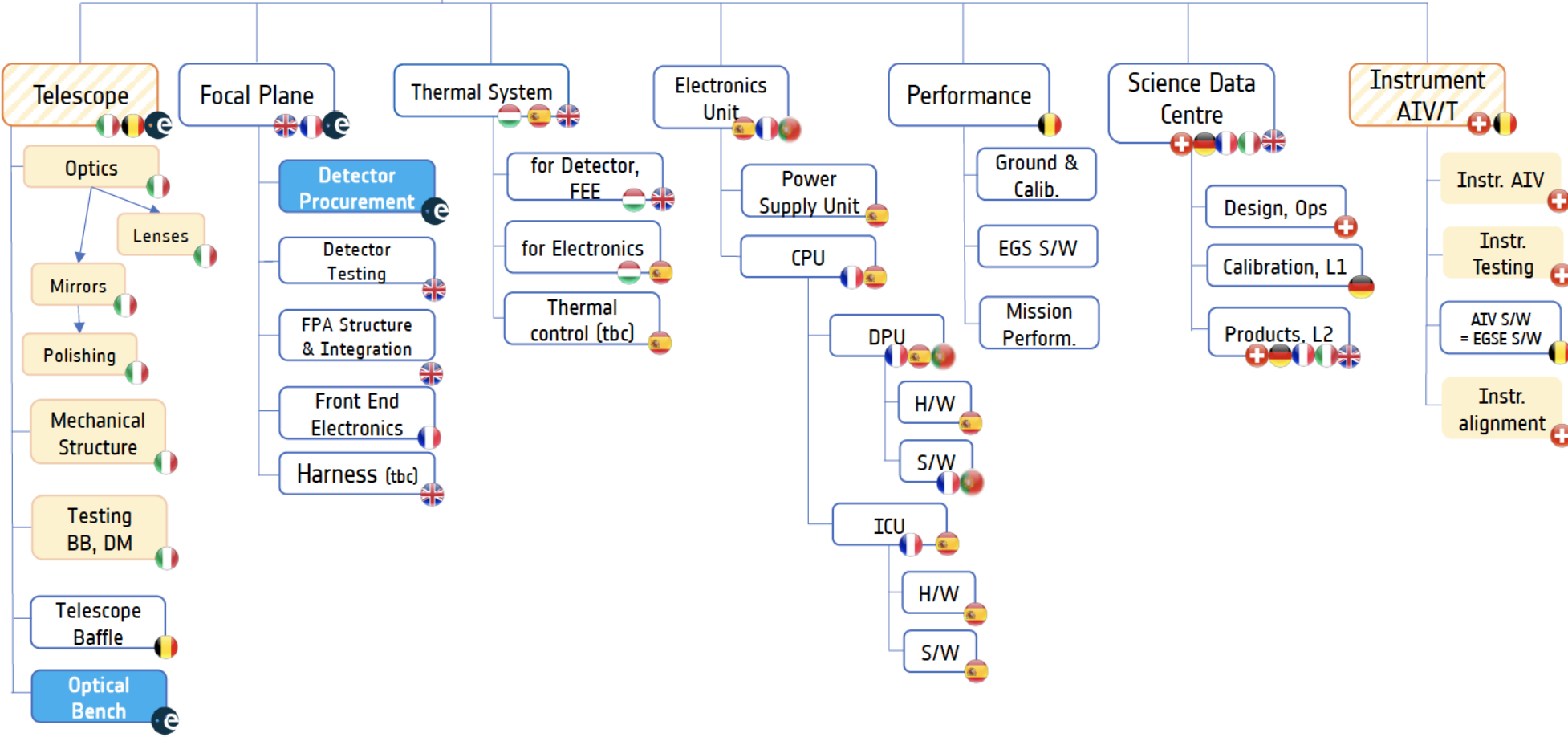
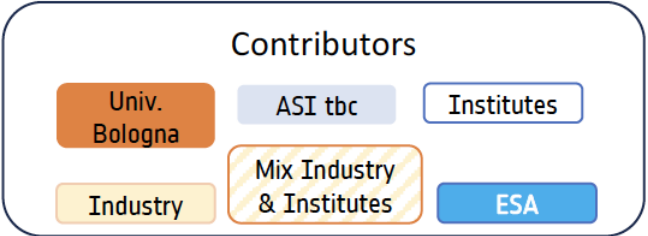
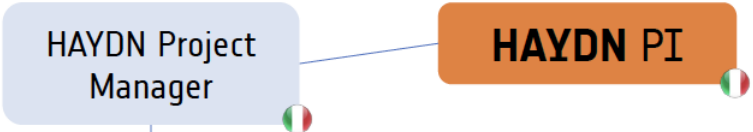


Spain: UV, UGR, IAA-CSIC, IAC, ICE, ICCUB

Scientific Consortium

PI	Andrea Miglio	Italy	Università di Bologna
Co-PI / Deputy PI	Benoît Mosser	France	LESIA - Paris Observatory

Consortium Science Team & National Co-Is	Daisuke Kawata	UK	MSSL UCL
	Andres Moya	Spain	University of Valencia
	Rafa Garcia	France	CEA
	Patrick Eggenberger	Switzerland	University of Geneva
	Marc Antoine Dupret	Belgium	ULiege
	Leo Girardi	Italy	INAF OAPD
	Laurent Gizon	Germany	Max-Planck-Institut für Sonnensystemforschung, Göttingen
	Robert Szabo	Hungary	Konkoly Observatory - Budapest
	Margarida Cunha	Portugal	Universidade do Porto
	Juan Carlos Suarez	Spain	University of Granada
Cristina Chiappini	Germany	AIP	



Spanish consortium

The third largest community in HAYDN consortium in terms of the number of institutions and researchers

UV, IAA, UGR, IAC, ICE, ICCUB

Scientific contribution

Large expertise of the Spanish teams derived from previous projects

- Stellar physics, stellar modeling, stellar evolution, 1D, 3D modeling
- Asteroseismology, seismic data analysis
- Stellar rotation, stellar activity, magnetism
- Galactic stellar populations, cluster population simulations, Galactic archaeology

+ Instrumental contribution

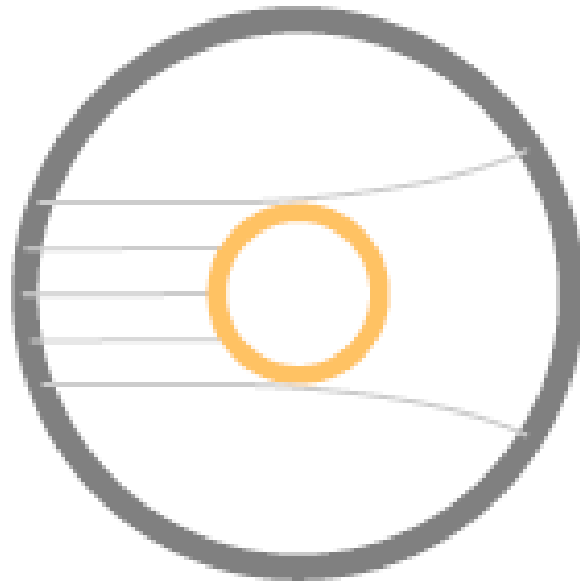
Instrumental contribution derived from previous projects

- DPU, PSU, thermal stability.

Summary

- 1) HAYDN is a low-risk high-gain mission. It harvests one of the remaining low hanging fruits. Ultra-precise photometric time series in clusters.
- 2) All technology at TRL ≥ 6 , except the CCD that is the only challenge.
- 3) High scientific return
- 4) Spain is the third-largest community, just after the two co-IP (Italy and France)

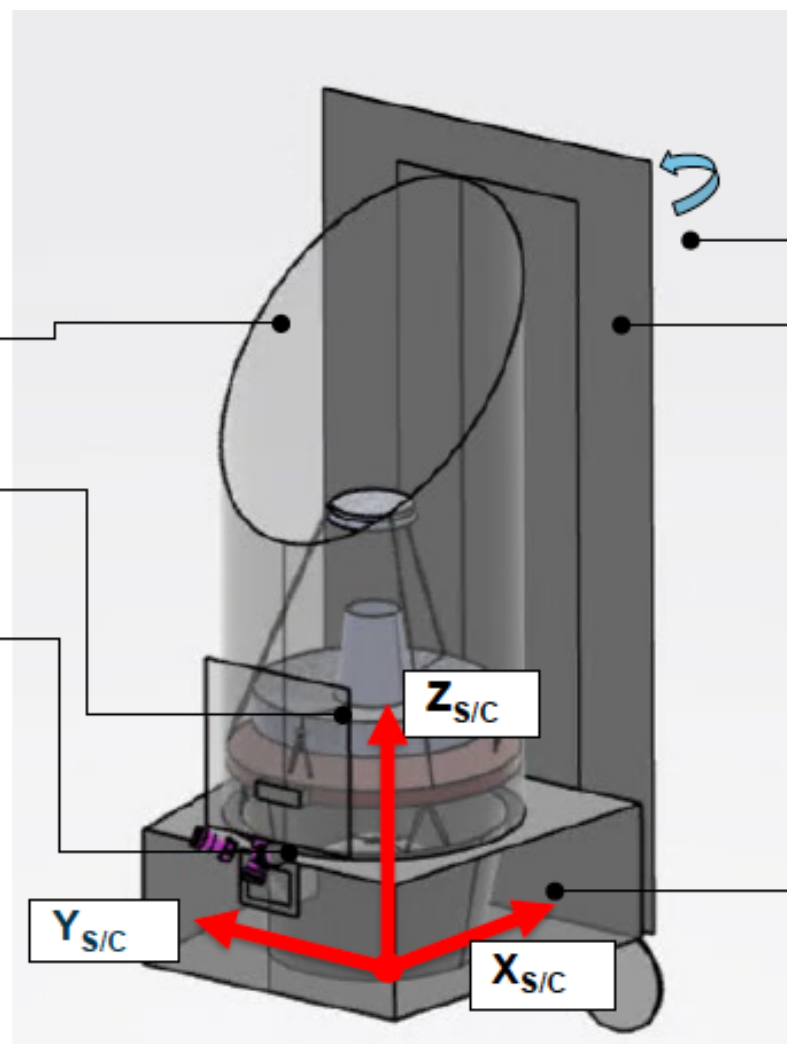
HAYDN



Thank you very much

Instrument

- Payload External Baffle
- FPA, proximity electronics
- Optical Bench

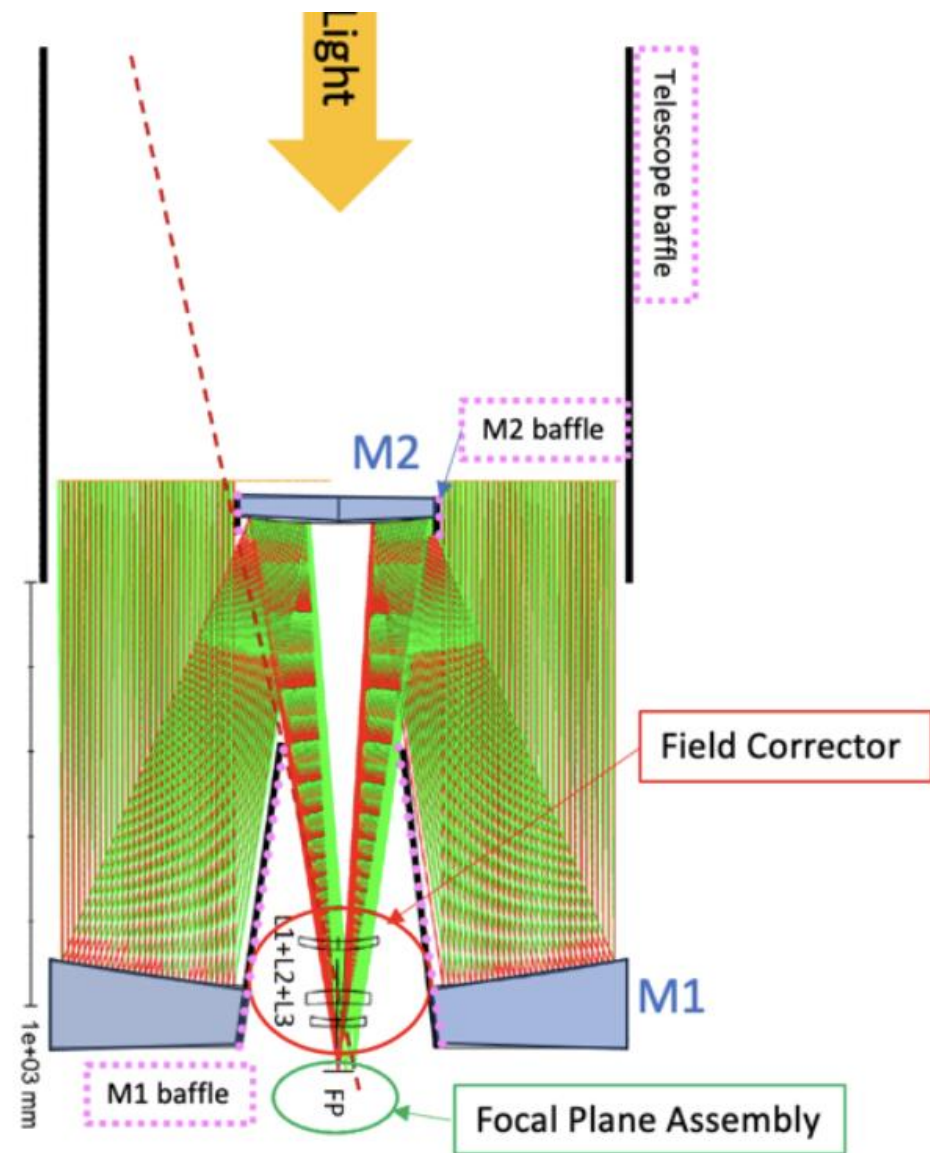
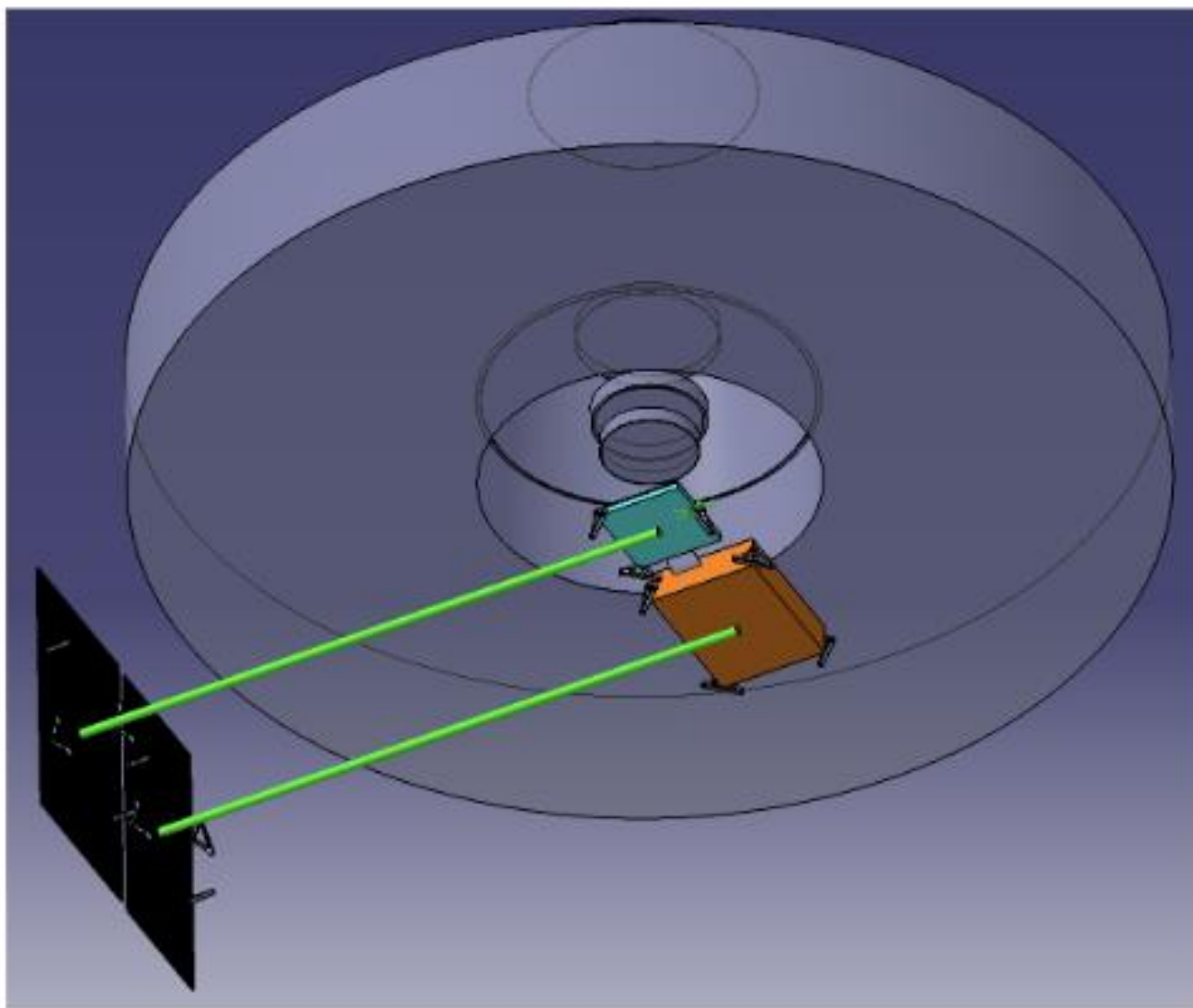


Platform Module

- Sola array
- Sun shield
- Standard platform incl. electronics

Rotation angles

- Roll around X_{SC}
- Pitch around Y_{SC}
- Yaw around Z_{SC}



Heritage

Mass & Power breakdown

Eddington assessment study report
(ESA CDF study team)

Eddington	Mass (kg)	Power (w)
Payload	274	150
Service module	461	370
Launch adapter	50	
Fuel	56	
Margin	169	80
<i>Total</i>	<i>940 kg</i>	<i>600 W</i>

Cost & telemetry

PLATO

PLATO	HAYDN
26 cameras	1 telescope
26 x 4 CCD	2 CCD

HAYDN / PLATO

less demanding in terms of complexity, data transfer

Development plan

Phasing with ESA schedule

Phase A start in 2023

Current design proposed with CCD detectors

CMOS detectors show properties that better fit with the scientific requirements than CCDs

From Teledyne-E2V:

- large area back-illuminated CMOS imager
- 9k x 9k 10- μ m pixels
- 2-3 years for achieving TRL 6

Properties	CCD	CMOS
Pixel size	13 μ m	10 μ m
Dynamic range	x	x
Precise photometry	x	tbc

→ Phase 0-A (2023-2025): verify that CMOS detectors can achieve precise photometry

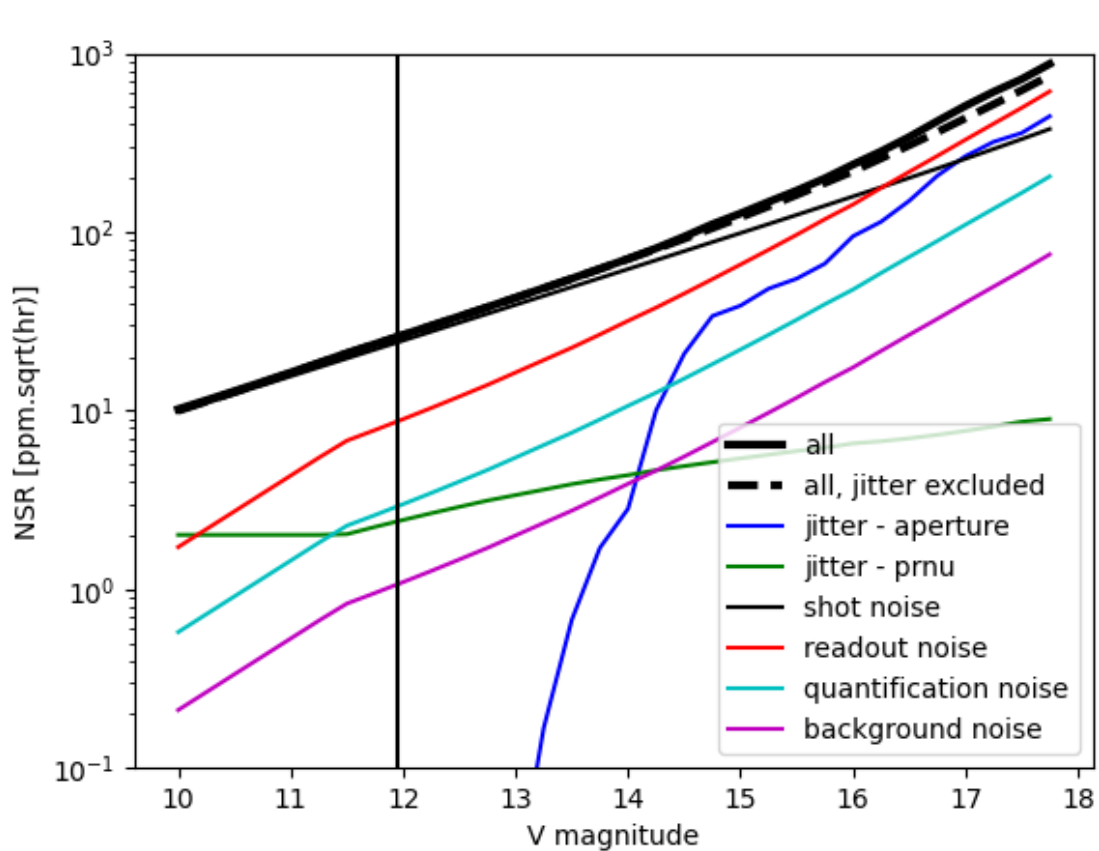
Phase 0 sizing

Parameter	Unit	Value	Comment(s) / origin
Equivalent pupil diameter	cm	120	HAYDN optical design, unobstructed pupil
Focal length	mm	4125	HAYDN optical design
PSF diameter	μm	26 or 52	HAYDN optical design. Diameter of the circle concentrating 90% of the PSF energy. Two options are explored
Integration time	s	6	<i>Kepler</i> technical characteristics
Readout time	s	0.52	<i>Kepler</i> technical characteristics
Pixel size	μm	13	HAYDN design
Pixel scale	arcsec	0.65	HAYDN design
Readout noise	e-	95 (1- σ)	<i>Kepler</i> technical characteristics
PRNU	-	1% (1- σ)	PLATO specifications (typical value: ~0.4%)
Gain	e-/ADU	110	As in <i>Kepler</i>
Full Well Capacity	ke-	1,100	PLATO specifications
Pointing error	arcsec/Hz ^{1/2}	0.07 (1- σ)	<i>Kepler</i> technical characteristics. For each transverse axis
Reference star Teff	K	6,000	The PLATO camera bandwidth is assumed

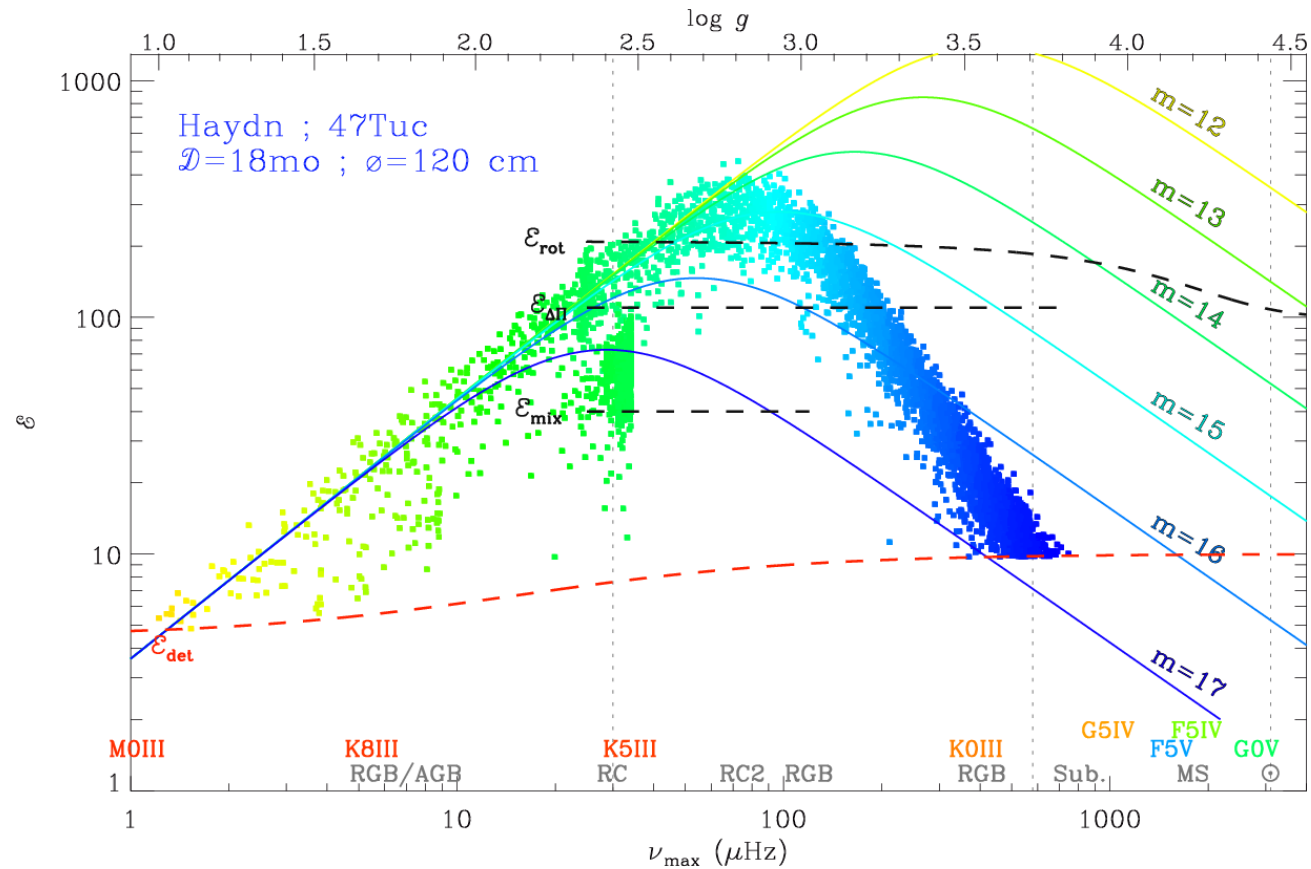
Possible targets

ID	RA, Dec (deg)	age/Gyr, [Fe/H], distance/kpc	# Stars with solar-like oscillations ¹	Time needed (months)	Mode	Comments / reasons to observe
47Tuc/ - NGC104	6.02, -72.08	13,-0.8,4	4192	18	HR	Multiple populations at the same [Fe/H]. Many evolved BSS. SMC stars in the background.
M67/ - NGC2682	132.85, 11.81	4,0,0.9	408	9	HR	Diffusion, solar analogues, stars with small convective cores, BSS.
ωCen/ NGC5139	201.5, -47.5	12,-1.5,5.4	1902	6	LR	Core of a dwarf galaxy, multiple populations ,different [Fe/H], infer star formation history
Baade's Window	270.8, -30.0	10,-0.3 to+0.3, 8	52124	6	LR	Infer the bulge's complex star formation history
M4/NGC6121	245.8, -26.5	12,-1.2,2.2	431	3	LR	The closest globular cluster
M22/NGC6656	279.0, -23.9	13,-1.5,3.2	388	3	LR	A scaled-down ω Cen, with spread in Fe and neutron-capture elements
NGC7789	359.2, +56.7	1.5,0.0,2.1	114	3	LR	Very rich, compact intermediate-age cluster
NGC188	11.8, 85.2	7.1,0.14,1.7	55	3	LR	Very old, metal-rich open cluster
NGC2243	97.39, -31.28	3.5,-0.5,4.4	38	3	LR	Solar age, metallicity $\frac{1}{3}$ solar open cluster
NGC2506	120.0, -10.76	1.6,-0.2,3.5	69	3	AD	Open cluster with many core-He burners
NGC6752	287.5, -60.0	12,-1.5,4.0	1205	7	AD	The classical, well behaved globular cluster at the peak of the GC metallicity distribution
NGC6397	265.0, -53.7	13,-2.0,2.5	149	3	AD	Low-metallicity GC
M54 & Sgr dSph	283.8, -30.5	11,-1.4 ,27	77	7	AD	The closest extragalactic dwarf and its nuclear cluster
M11 - NGC6705	282.75, -6.28	0.32,0.14,1.7	31	3	AD	Open cluster, outskirts of bulge in the background,with intermediate-mass core-He-burners
NGC2818	139.04, -36.6	0.0,0.0,3.1	15	3	AD	Interesting age range, but few core-He-burners

Noise model & seismic performance



Noise model: [Marchiori et al. 2019, A&A 627, A71](#)



Seismic performance: [Mosser et al. 2019, A&A 622, A76](#)