

SEA Prize PhD in Instrumentation, Computing and Technological Development in Astronomy and Astrophysics (2017-2018)

"PANIC, una cámara infrarroja de gran campo para el Observatorio de Calar Alto"



Dr M. Concepción Cárdenas Vázquez

Max-Planck-Institut für Astronomie, Germany

INSTITUTO DE ASTROFÍSICA DE ANDALUCÍA M. Concepción Cárdenas Vázquez

Supervisor: Dr Julio F. Rodríguez Gómez (IAA-CSIC)

PhD thesis:

"PANIC, una cámara infrarroja de gran campo para el Observatorio de Calar Alto"

(PANIC, a wide-field infrared camera for the Calar Alto Observatory)



Defence: December, 2018



Outline

- 1. Introduction
- 2. Objectives
- 3. Requirements and Specifications
- 4. Design of PANIC



5. Implementation and Verification of PANIC



6. PANIC's Performance



Max-Plank-Institut für Astronomie

1.Introduction

- 2. Objectives
- 3. Requirements and Specifications
- 4. Design of PANIC
- 5. Implementation and Verification of PANIC

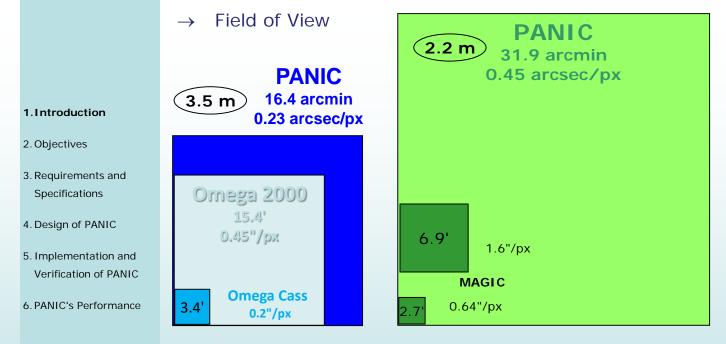
6. PANIC's Performance







- A wide-field infrared camera for the 2.2 m and the 3.5 m telescopes
- 1st instrument in the Program of development of new instrumentation in collaboration between IAA and MPIA
- PI: Matilde Fernández (IAA-CSIC)
- PI: Klaus Meisenheimer (MPIA)



Instrument	Spectral range (µm)	Pixel scale (arcsec/pix)	FoV (arcmin ²)	Operation started	Telescope / Location	Science community
NEWFIRM	1-2.4	0.4	780 / (28×28)	2010	Mayall (4 m) / Kitt Peak (USA) Blanco (4 m) / Cerro Tololo (Chile)	USA
WFCAM	1-2.5	0.4	780 / (28×28)	2005	UKIRT (3.8 m) / Hawaii (USA)	USA / Hawaii / NASA
WIRCAM	0.9-2.5	0.3	460 / (21.5×21.5)	2006	CFHT (3.6 m) / Hawaii (USA)	Canada / France / Hawaii
Omega 2000	0.8-2.4	0.45	235 / (15.4×15.4)	2003	CAHA (3.5 m) / Almería (Spain)	Germany / Spain
PANIC	0.8-2.5	0.45 0.23	940 / (30.7×30.7) 240 / (15.6×15.6)	2015	CAHA (2.2 m) / Almería (Spain) CAHA (3.5 m) / Almería (Spain)	Germany / Spain



- General purpose wide-field imager
- Useable for surveys
- Not tailored to a special application

· Solar system: Comets, searches for transneptunians & minor bodies.

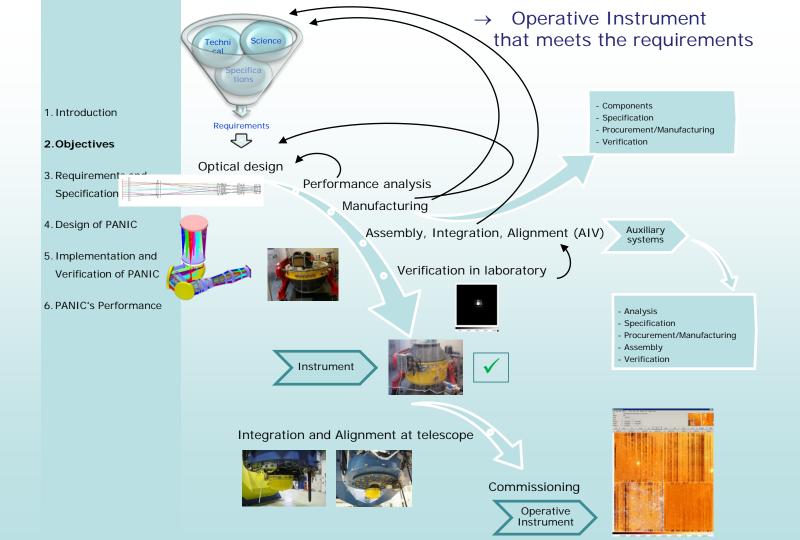
• Stellar evolution: Brown dwarfs, accretion disks of young stars, post-AGBs, exoplanets, supernovae searches, asteroseismology.

- Galactic astronomy: Large-scale structure of the Milky Way and the Galactic components in hidden areas.

• Extragalactic astronomy: Cosmic evolution in the z range 1.5 – 2.0: photometric redshifts in the redshift desert (narrow band filters in clean windows of z and J reducing the background sky, GRBs at high redshift, GRB host galaxies.

 \cdot Clusters and Superclusters of galaxies at intermediate redshift: Search for objects with strong IR excess, Selection of candidates for supermassive starbursts, Broad band + narrow band filter imaging matching the redshifted H α line.

Morphology of nearby galaxies



Project timeline

10/2006 Kick-off **Requirements Collection and Specifications definition** 11/2007 • PDR **Preliminary Design Phase** • FDR Optics 09/2008 • FDR Mechanics 12/2009 **Final Design Phase** Cryo, Electronics FDR Software 02/2010 05/2009-08/2014 Subsystems Manufacturing and Acceptance MAIV AIV phase and Final tests at laboratory • First light 10/2014 Instrument alignment with telescopes Instrument verification at both CAHA • Commissioning 10/2014-03/2015 telescopes

\rightarrow High Level Requirements

-		quirements	2.2 m
	Parameter	Requirement	Techni Science
	Telescope	T22	Specifica
	Focal Station	Cassegrain Focus	tions
	Operation mode	Direct Imaging, over the whole FoV	
	Wavelength range	(0.8 – 2.45) μm	Requirements and Specifications
	Filters	Broad band: Z Y J H K_s Narrow band: ~1%	specifications
nd	Pixel scale	0.45 arcsec/px	
	FoV	(32×32) arcmin, for 0.45 arcsec/px	
	IR Detector	4K x 4K mosaic of 2x2 HAWAII-2RG 18 μm pixel 2.5 μm cut-off	B.
nd	Entrance pupil	Telescope primary mirror	31.9' 0.45"/px
IC	Pupil image available	Cold stop	
nce	Thermal background	S/N maximum, specially in K band	
	Operating conditions	80 K (liquid nitrogen) vacuum	
	System focusing mechanism	Telescope secondary mirror	
	Second pixel scale	0.25 arcsec/pixel / FoV 18 arcmin	
	Camera optics solution	Mono-beam/Refractive/non-collimated stage	

M2

M1

RC focus

1. Introduction

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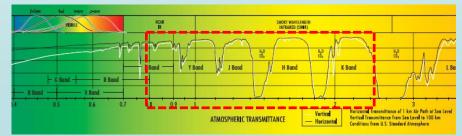


Imagen: Raytheon Vision Systems

High Level Requirements \rightarrow

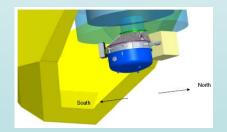
System Specifications \rightarrow

	Parameter	Requirement		
1. Introduction	Image Quality, for 0.45 arcsec/px	$D_{EE80} \le 0.9 \text{ arcsec}=2 \text{ px}$		
	Image Quality, for 0.25 arcsec/px	$D_{EE80} \le 0.75 \text{ arcsec}=3 \text{ px}$		
2. Objectives	Distortion	≤ 1.5 %		
3.Requirements and Specifications	Ghosts: Relative intensity Size at the detector	≤ 10 ⁻⁴ ≥ 10 arcsec		
	Narrow-band filters: max λ_c shift	≤ 0.3 %		
4. Design of PANIC	Optical Transmission	Maximize		
5. Implementation and	Instrument Weight	≤ 400 kg		
Verification of PANIC	Instrument length from the telescope focal plane	≤ 110 cm		

1. Introductio

4. Design of P

6. PANIC's Performance





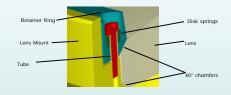
- → High Level Requirements
- → System Specifications

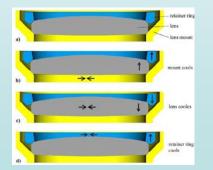
\rightarrow Other Requirements

- Maximization of the S-N in K band
 - · Field Stop: cold
 - Aperture Stop: cold
 - Stray light: Baffling, optics manufacturing.
- Pupil re-imager

Detailed Specifications

- Optical materials [$n(\lambda,T)$, CTE(T)]
- Tolerances: manufacturing, positioning, integration
- Interfaces with other subsystems
- Lens mounts: mechanical design
- Iterations with manufacturers
- Cryostat window
- Space between lenses
- Packing: folding



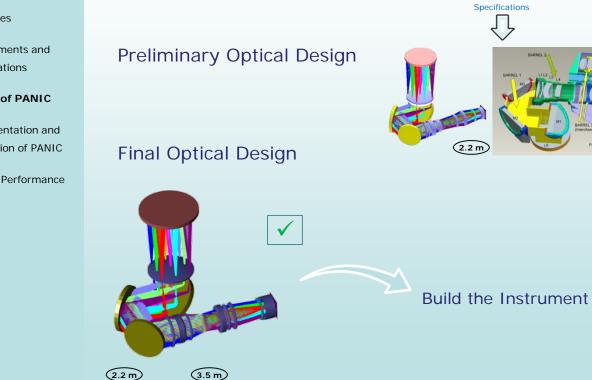


1. Introduction

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- Specifications
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Optical System Implementation

Science

FILTER WHE

Techni

Requirements and

1. Introduction

- 2. Objectives
- 3. Requirements and Specifications

4. Design of PANIC

- 5. Implementation and Verification of PANIC
- 6. PANIC's Performance

A) Optical Design Approach

U					
Parameter	0.45 arcsec/px	0.25 arcsec/px			
Infrared detector	рх	4096;	(4096		
Space between detectors	рх	14	17		
Pixel size	μm	18			
Plate scale	arcsec/px	0.45	0.25		
Plate scale	arcsec/mm	25.0	13.9		
	рх	4096+147			
FoV	mm	76.374			
	arcmin	31.82	17.68		
Lateral Magnification	adim	0.4685	0.8433		
Effective focal length	mm	8251	14851		
Focal ratio, F#	adim	3.750	6.75		

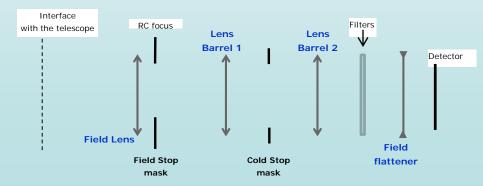
M1

(2.2 m

Foco RC

M2

B) The Initial Optical System



1. Introduction

2. Objectives

3. Requirements and Specifications

4. Design of PANIC

- 4.1. Optical system development
- 4.2. Preliminary Optical Design
- 4.3. Final Optical Design
- 5. Implementation and Verification of PANIC
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A) Optical Design Approach

C) Optical system Model

- Object
- Entrance Pupil: localization and size
- FoV
 - Wavelength range
 - Magnification
 - Plate Scale
 - Optical materials:
 - n (λ, T)
 - CTE (T)
 - Constrains: Temperature, telescope, focus mechanism.
 - Field Stop and Aperture Stop: localization and size

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1. Introduction

- 2. Objectives
- 3. Requirements and
 - Specifications

4. Design of PANIC

4.1. Optical system development

4.2. Preliminary Optical Design

- 4.3. Final Optical Design
- 5. Implementation and Verification of PANIC
- 6. PANIC's Performance

B) The Initial Optical System

D) Optical System **Optimization**

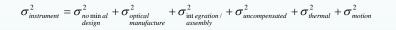
- Variables set up
 - \rightarrow RoC, Thickness, Materials
- Merit figures
 - \rightarrow Image Quality
 - $\rightarrow\,$ Optical Distortion
- Constrains Set up
 - \rightarrow Mechanical
 - \rightarrow Optical

- A) Optical Design **Approach**
- C) Optical system **Model**

E) Optical system **Evaluation**

- Merit figures: Performance
- Constrains fulfilment
- Mechanical
- Optical
- Margin for errors

- B) The Initial Optical System
- D) Optical System **Optimization**
- F) Error Budget



- Sensitivity \rightarrow worst offenders \rightarrow compensators
- Tolerances \rightarrow Budget
 - Manufacturing Errors
 - Assembly and alignment Errors
- Final performance Prediction \rightarrow Montecarlo analysis

Error	σ (μm)	Verification
Nominal Optical Design	5.22	Optical Design: nominal (T22+PANIC)
Lenses manufacturing	4.33	200 Montecarlo (PANIC+ lenses manufacturing) rms spot radius: 5.22 to 6.78 (μm)
Assembly/Integration /Alignment	6.10	200 Montecarlo (PANIC+subsystem) rms spot radius: 5.22 to 6.37 (μm)
Non compensable	0.66	200 Montercarlo (PANIC+indix+Abbe) Numerical model (glasses inhomogeneity) rms spot radius: 5.22 to 5.26 (μm)
Thermal	1.72	Numerical model (thermal gradient) rms spot radius: 5.22 to 5.50 (μm)
Movement	0.92	200 Montercarlo (PANIC+mechanical flexions) rms spot radius: 5.22 to 5.30 (μm)
Margin	0.50	
Total	9.36	≤ 10.03 μm

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4.1. Optical system development

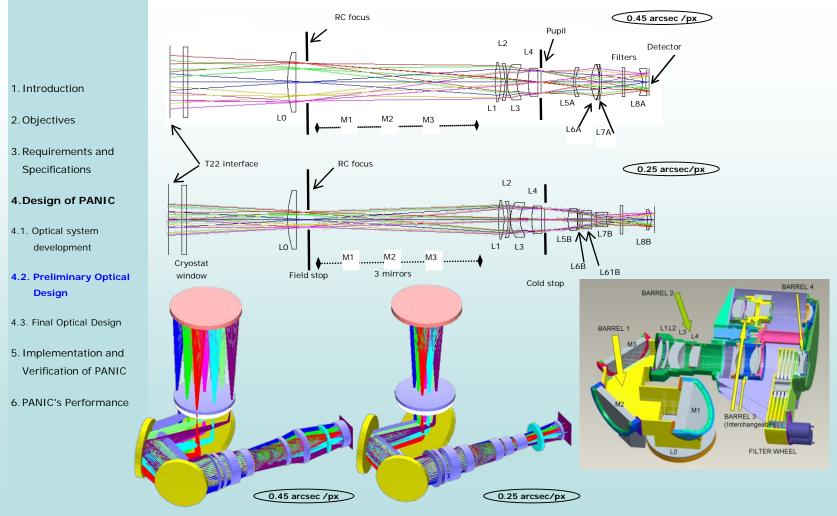
4.2. Preliminary Optical Design

4.3. Final Optical Design

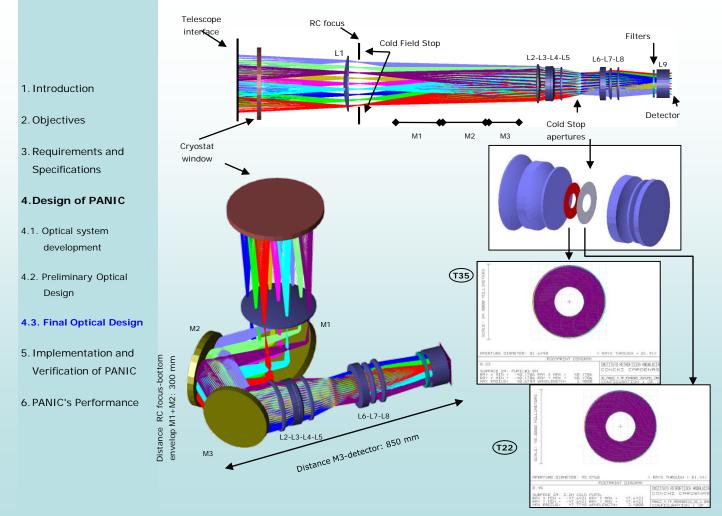
5. Implementation and Verification of PANIC

6. PANIC's Performance

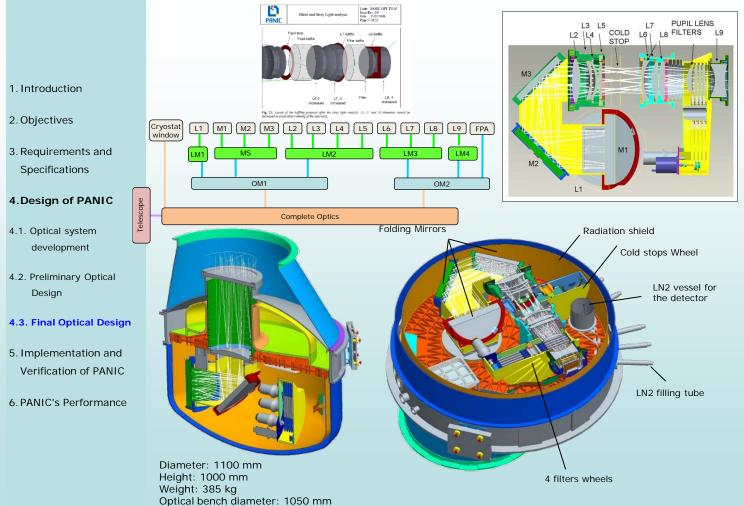
• PDR Optical Design



• FDR Optical Design



• Interaction between Optical Design and Mechanics-Cryogenics





Requirement: $D_{EE80} \le 2 \text{ px}$

λ range

D_{EE80} (pix)

Image quality

2.2 m telescope

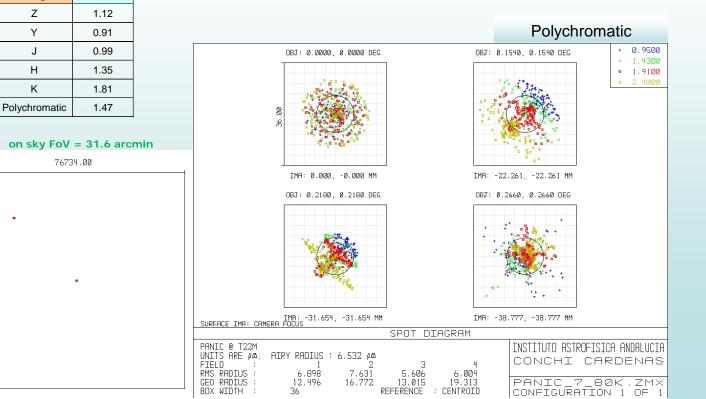
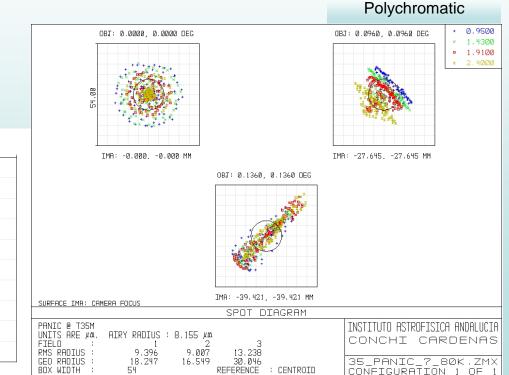




Image quality

3.5 m telescope



 Requirement: DEE80 ≤ 3 px

 λ range
 DEE80 (pix)

 Z
 1.72

 Y
 1.72

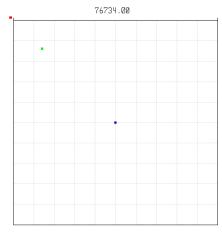
 J
 1.80

 H
 1.94

 K
 2.18

 Polychromatic
 1.97

on sky FoV = 15.9 arcmin



	Dorformonoo	Parameter	Requirement	PANIC
	Performance	Wavelength range	(0.8 – 2.42) μm	~
		System	Within a cryostat	~
		Temperature (liquid nitrogen)	~ 80 K	✓
		Pressure	10 ⁻⁶ mbar	✓
		Focus mechanism	Telescope secondary mirror	✓
1. Introduction		Optical system solution	Refractive	✓
2. Objectives		Optical surfaces	Spherical and flat Minimize number of aspherics and conics	Spherical and flat ✓
3. Requirements and		Elements	2 barrels for cold stop re-imaging 2 flat-fields	✓
Specifications		Lenses mechanical constrains	Implementation of chamfers at the edge Edge thickness \geq 6.5 mm	~
4.Design of PANIC		Broad-band filters	Z, Y, J, H у K _s	\checkmark
n besign of France		Narrow-band filters	$FWHM/\lambda_c 100 \sim 1\%$	✓
4.1. Optical system		Narrow-band filters, λ_c shift	≤ 0.3 %	✓
development		Re-imagined System Entrance Pupil	Physically available to introduce a cold stop within the camera optical track	~
4.2. Preliminary Optical		Image quality for the re-imagined System Entrance Pupil	Flux loss in K band: < 10%	< 2% ✓
Design		Aperture stop	Cold	✓
4.3. Final Optical Design		Cold stop diameter degradation	≤ 3 % in K band	✓
		Field Stop	Cold	✓
5. Implementation and		Stray Light reduction	Optimized for K band	\checkmark
Verification of PANIC		Ghosts: relative intensity	< 10 ⁻⁴	\checkmark
6. PANIC's Performance		Ghosts: size on the detector	> 10 arcsec(in case of relative intensity violation)	~
		Back focal distance	> 10 mm	✓
		Length focal plane - bottom	≤ 110 cm	✓
		Weight	≤ 400 kg	385 kg ✓
		Transmission	> 45 % (complete wavelength range)	~ 50.6 % 🗸
		Distortion	\leq 1.5 % (complete wavelength range)	< 1.42 % ✓
		Lateral magnification	0.4685 ± 0.0025	0.468 ± 0.003 ✓

• Performance

2.2 m

M2		T22	
	Parameter	Requirement	PANIC
	Plate scale	(0.450 ± 0.007) arcsec/px	(0.445 ± 0.003) arcsec/px ✓
	FoV, square	(32.0 ± 1.0) arcmin	(31.6 ± 0.3) arcmin ✓
м1	Image quality, D _{EE80}	\leq 2 px = 36 μm = 0.900 arcsec	≤ 1.5 px = 26.4 μm = 0.65 arcsec ✓

Foco RC

	T35									
	Parameter	Requirement	PANIC							
	Plate scale	(0.226 ± 0.004) arcsec/px	(0.224 ± 0.002) arcsec/px ✓							
	FoV, square	(16.1 ± 0.5) arcmin	(15.88 ± 0.11) arcmin ✓							
	Image quality, D _{EE80}	\leq 3 px = 54 μ m = 0.678 arcsec	≤ 2.0 px = 35.5 μm = 0.45 arcsec ✓							
M1										

1. Introduction

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- 3. Requirements and Specifications

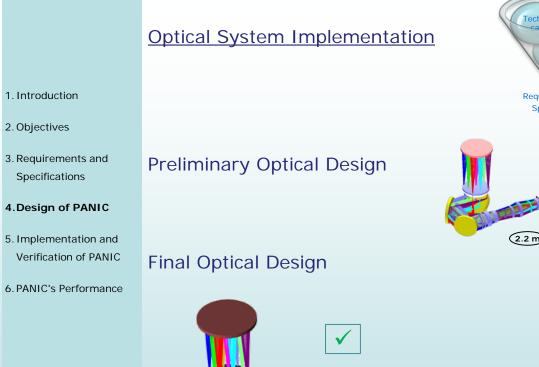
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4.3. Final Optical Design

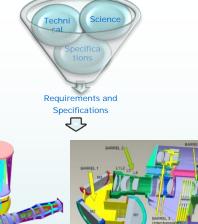
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Foco RC



3.5 m

2.2 m



Build the Instrument

1. Introduction

2. Objectives

Auxiliary systems designed for PANIC

- 3. Requirements and Specifications
- 4. Design of PANIC

5. Implementation and Verification of PANIC

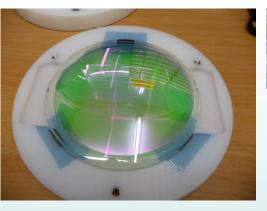
- 5.1. Components: Manufacturing and Acceptance
- 5.2. Instrument in the Laboratory: AIV and Final tests
- 5.3. Instrument at

Telescope: Alignment and Verification

6. PANIC's Performance

November/2008 \rightarrow April/2012

• Lenses and Cryostat window



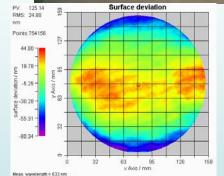


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- 2. Objectives
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- 5. Implementation and Verification of PANIC
- 5.1. Components: Manufacturing and Acceptance
- 5.2. Instrument in the Laboratory: AIV and Final tests
- 5.3. Instrument at Telescope: Alignment and Verification
- 6. PANIC's Performance

- Lenses and Cryostat window
- Folding Mirrors







- 2. Objectives
- 3. Requirements and Specifications
- 4. Design of PANIC
- 5.Implementation and Verification of PANIC
- 5.1. Components:





6. PANIC's Performance



- Lenses and Cryostat window
- Folding Mirrors
- Science Filters

1. Introduction

- 2. Objectives
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4. Design of PANIC

5.Implementation and Verification of PANIC

5.1. Components:

Manufacturing and Acceptance

- 5.2. Instrument in the Laboratory: AIV and Final tests
- 5.3. Instrument at

Telescope: Alignment and Verification

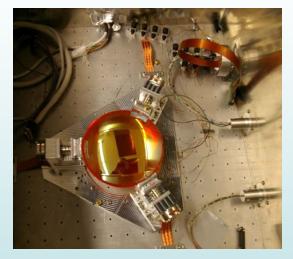
6. PANIC's Performance

Filtro	λ _c (μm)	FWHM (µm)	T (%)		
Z	0.877	0.095	> 80		
Y	1.020	0.100	> 70		
J	1.250	0.160	> 80		
н	1.635	0.290	> 80		
Ks	2.150	0.301	> 80		
H ₂	2.122	0.032	> 65		



- Lenses and Cryostat window
- Folding Mirrors
- Science Filters
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- 5.1. Components: Manufacturing and Acceptance
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- 6. PANIC's Performance



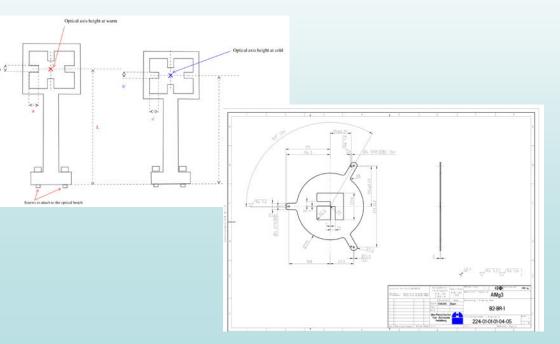


- Lenses and Cryostat window
- Folding Mirrors
- Science Filters

- 1. Introduction
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- 5.1. Components: Manufacturing and Acceptance
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- 5.3. Instrument at Telescope: Alignment and Verification
- 6. PANIC's Performance



• Alignment targets (at warm, alignment DEC X and DEC Y)



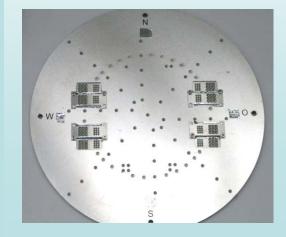
- Lenses and Cryostat window
- Folding Mirrors
- Science Filters

• Pupil Imager Lens

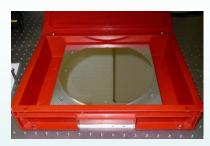
- 1. Introduction
- 2. Objectives
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- 5.1. Components: Manufacturing and Acceptance
- 5.2. Instrument in the Laboratory: AIV and Final tests
- 5.3. Instrument at Telescope: Alignment and Verification
- 6. PANIC's Performance

Auxiliary systems designed for PANIC

- Alignment targets (at warm, alignment DEC X and DEC Y)
- Auxiliary mirrors (at warm, alignment Tilt X and Tilt Y)
- · Auxiliary cryostat exit window (for opto-mechanical axis verification at cold)
- Focal mask (for detector positioning at the instrument focus)





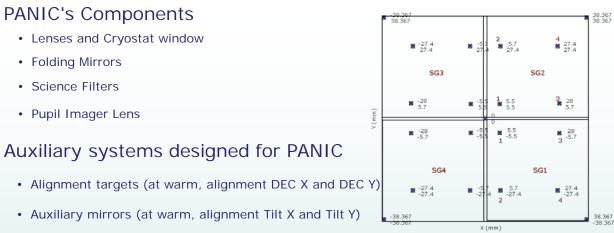




- · Lenses and Cryostat window
- Folding Mirrors
- Science Filters

• Pupil Imager Lens

- 1. Introduction
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- 6. PANIC's Performence: Salida de la fibra monomodo



- Auxiliary cryostat exit window (for opto-mechanical axis verification at cold)
- Focal mask (for detector positioning at the instrument focus)
- Star Simulator (for instrument image quality measurements at laboratory)





Folding Mirrors Structure

$May/2010 \rightarrow August/2014$





- 2. Objectives
- 3. Requirements and Specifications
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- 5.1. Components: Manufacturing and Acceptance
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- 6. PANIC's Performance



Static conditions: Tilt X = (5 ± 1) arcsec Tilt Y = (15 ± 7) arcsec



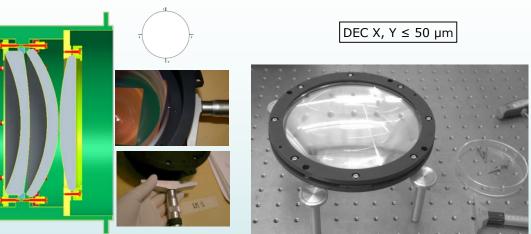
Dynamic conditions: Tilt X,Y \leq 20 arcsec

- Folding Mirrors Structure
- Lenses

$May/2010 \rightarrow August/2014$

1. Introduction

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- Folding Mirrors Structure
- Lenses
- Filters and PIL

- 1. Introduction
- 2. Objectives
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- 5.1. Components: Manufacturing and Acceptance
- 5.2. Instrument in the Laboratory: AIV and Final tests
- 5.3. Instrument at Telescope: Alignment and Verification
- 6. PANIC's Performance





$May/2010 \rightarrow August/2014$



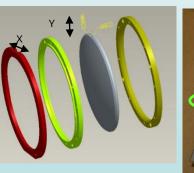
- Folding Mirrors Structure
- Lenses
- · Filters and PIL

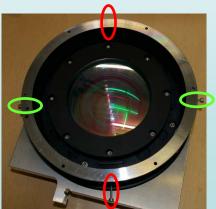
1. Introduction

- 2. Objectives
- 3. Requirements and
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- 4. Design of PANIC

5.1 mplementation and Verification of PANIC

- 5.1. Components: Manufacturing and Acceptance
- 5.2. Instrument in the Laboratory: AIV and Final tests
- 5.3. Instrument at Telescope: Alignment and Verification
- 6. PANIC's Performance







$May/2010 \rightarrow August/2014$

System level

- Operation temperature changed: from 80 K to 95 K
- · Final optical design: Feedback with the optical as-built parameters
 - \rightarrow As-built Optical model
- Calculation of the mechanical compensators: L2-L3 and L7-L8 distances
- Lenses Barrels: mechanical compensators, decentering L2 and L6

- Folding Mirrors Structure
- Lenses
- Filters and PIL

System level

1. Introduction

- 2. Objectives
- 3. Requirements and
- Specifications
- 4. Design of PANIC

5. Implementation and Verification of PANIC

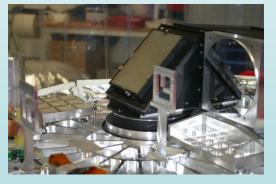
Calculation of the mechanical compensators: L2-L3 and L7-L8 distar

· Final optical design: Feedback with the optical as-built parameters

• Operation temperature changed: from 80 K to 95 K

- Lenses Barrels: mechanical compensators, decentering L2 and L6
- 5.1. Components: Manufacturing and Acceptance
- 5.2. Instrument in the Laboratory: AIV and Final tests
- 5.3. Instrument at Telescope: Alignment and Verification
- 6. PANIC's Performance











Subsystem level

- Folding Mirrors Structure
- Lenses

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Filters and PIL

System level

1. Introduction

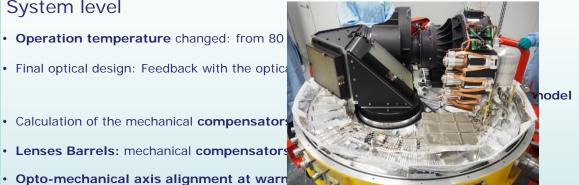
- 2. Objectives
- 3. Requirements and
- Specifications
- 4. Design of PANIC
- 5.1 mplementation and Verification of PANIC
- 5.1. Subsystems: Manufacturing and Acceptance
- Opto-mechanical axis alignment at warn
- · Complete instrument alignment at warm and verification at cold





Common Opto-mechanical axis: DEC X/Y \rightarrow 100 – 50 μ m Tilt X/Y \rightarrow 1 -1.5 arcmin





Subsystem level

- Folding Mirrors Structure
- Lenses
- Filters

System level

1. Introduction

- 2. Objectives
- 3. Requirements and Specifications
- 4. Design of PANIC

5.1. Components:

5. Implementation and Verification of PANIC

Manufacturing and

- Opto-mechanical axis aligitized
- Complete instrument align
- 5.2. Instrument in the

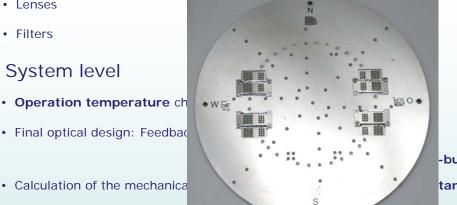
Acceptance

Mosaic of detectors: positi



•

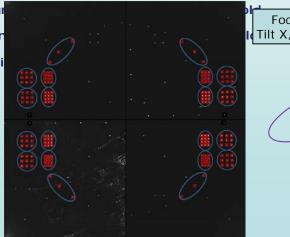
$May/2010 \rightarrow August/2014$

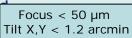


Lenses Barrels: mechanical compensators, decentering L2 and L6

-built Optical model

tances









let

- 1. Introduction
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- 4. Design of PANIC
- 5. Implementation and Verification of PANIC
- 5.1. Components: Manufacturing and Acceptance
- 5.2. Instrument in the Laboratory: AIV and Final tests
- 5.3. Instrument at

Telescope: Alignment and Verification

6. PANIC's Performance

$October/2014 \rightarrow March/2015$

Reassembly after transport







- 1. Introduction
- 2. Objectives
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5.Implementation and Verification of PANIC

- 5.1. Components: Manufacturing and Acceptance
- 5.2. Instrument in the Laboratory: AIV and Final tests
- 5.3. Instrument at Telescope: Alignment and Verification
- 6. PANIC's Performance

• Reassembly after transport

• Image quality tests at laboratory (after transportation)

- 1. Introduction
- 2. Objectives
- 3. Requirements and Specifications
- 4. Design of PANIC

5. Implementation and Verification of PANIC

- 5.1. Components: Manufacturing and Acceptance
- 5.2. Instrument in the Laboratory: AIV and Final tests
- 5.3. Instrument at Telescope: Alignment

and Verification

6. PANIC's Performance





$October/2014 \rightarrow March/2015$

October/2014 \rightarrow March/2015

- Reassembly after transport
- Image quality tests at laboratory (after transportation)

• At 2.2 m telescope: alignment

1. Introduction

2. Objectives

- 3. Requirements and Specifications
- 4. Design of PANIC

5. Implementation and Verification of PANIC

- 5.1. Components: Manufacturing and Acceptance
- 5.2. Instrument in the Laboratory: AIV and Final tests
- 5.3. Instrument at **Telescope: Alignment** and Verification
- 6. PANIC's Performance

1.97e+003

2.06e+003

2.15e+003

2.240+003

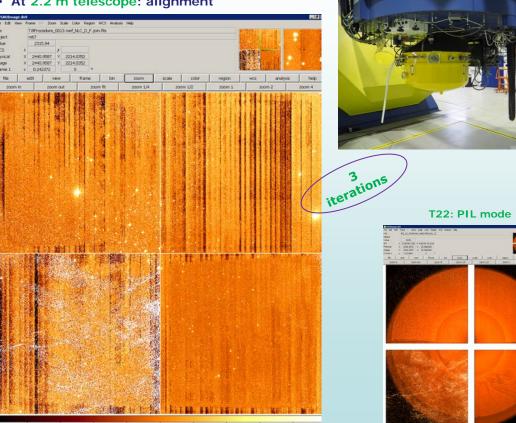
2.338+003

2.41e+003

2.5e+003

2.596+003

2.688+003



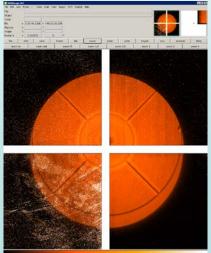
- Reassembly after transport
- Image quality tests at laboratory (after transportation)
- At 2.2 m telescope: alignment
- At 3.5 m telescope: alignment



October/2014 \rightarrow March/2015



T35: PIL mode



1701 38-6 9036 Faith USA 12120 12979 14856 38514

1. Introduction

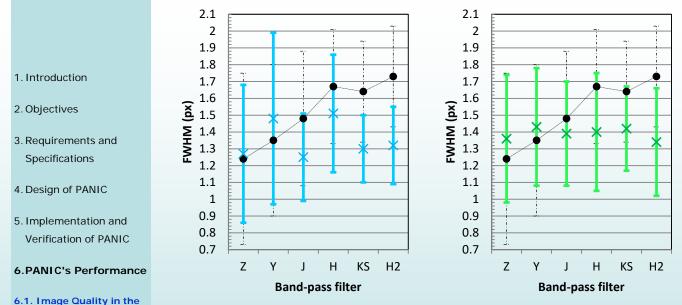
2. Objectives

3. Requirements and Specifications

4. Design of PANIC

5. Implementation and Verification of PANIC

- 5.1. Components: Manufacturing and Acceptance
- 5.2. Instrument in the Laboratory: AIV and Final tests
- 5.3. Instrument at Telescope: Alignment and Verification
- 6. PANIC's Performance



laboratory

6.2. Filters Set

6.3. Commissioning at both telescopes

x Experimental data at laboratory: <u>before</u> transport

• as-built Optical model

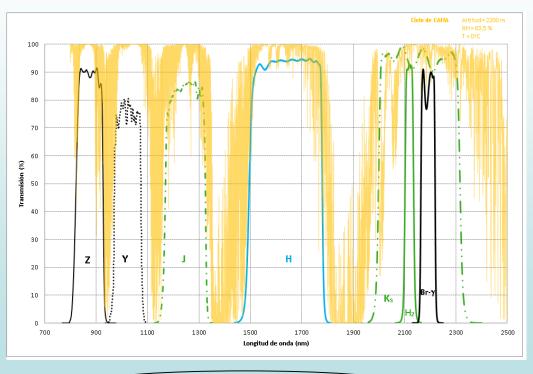
x Experimental data at laboratory: <u>after</u> transport

		Position					
		1	2	3	4	5	6
Wheel	#1	Y	н	PIL	Blank	J	Open
	#2	z	Ks	Blank	H ₂	dummy	Open
	#3	dummy	dummy	Blank	dummy	dummy	Open
	#4	dummy	dummy	Blank	dummy	Br-γ	Open



1. Introduction

- 2. Objectives
- 3. Requirements and Specifications
- 4. Design of PANIC
- 5. Implementation and Verification of PANIC
- 6.PANIC's Performance
- 6.1. Image Quality in the laboratory
- 6.2. Filters Set
- 6.3. Commissioning at both telescopes



Operation temperature: 100 K

	T22				
	PANIC performance	Expected As-built Optical system	Measured (M) Derived from measurements (D)		
1. Justice doubtle in	Lateral magnification	0.4676 ± 0.0014	(D) 0.470 ± 0.020		
1. Introduction	Focal ratio, F#	3.7434 ± 0.0016	(D) 3.76 ± 0.17		
2. Objectives	Plate scale	(0.4456 ± 0.0022) arcsec/px	(M) (0.4484 ± 0.0017) arcsec/px		
3. Requirements and	FoV, square	(31.65 ± 0.15) arcmin	(M) (31.67 ± 0.11) arcmin		
Specifications	Image quality, D _{EE80}	(25.9 \pm 0.6) μm = (1.44 \pm 0.03) px (\leq 2 px)	(D) ≤ 2 px		
	Distortion	≤ (1.332 ± 0.016) %	(M) ≤ 0.73 %		
4. Design of PANIC	Gap between detectors	≤ 167 px = 75 arcsec	(M) ~ 156 px = 70 arcsec		
5. Implementation and Verification of PANIC	Pupil image diameter (on the detector)	(72.4 ± 0.9) mm	(M) ~ 71.5 mm		
6.PANIC's Performance	Performance T35				
6.1. Image Quality in the laboratory	PANIC performance	Expected As-built Optical system	Measured (M) Derived from measurements (D)		
6.2. Filters Set	Focal ratio, F#	4.6744 ± 0.0022	(D) 4.70 ± 0.21		
0.2. There's Set	Plate scale	(0.2239 ± 0.0013) arcsec/px	(D) (0.226 ± 0.009) arcsec/px		
6.3. Commissioning at both telescopes	FoV, square	(15.90 ± 0.09) arcmin	(D) (16.0 ± 0.8) arcmin		
both telescopes	Image quality, D _{EE80}	$(32.4 \pm 0.8) \ \mu m = (1.80 \pm 0.04) \ px \ (\le 3 \ px)$	(M) ≤ 2 px		
	Distortion	(1.381 ± 0.020) %	(D) ≤ 0.73 %		
	Gap between detectors	≤ 167 px = 38 arcsec	(D) ~ 156 px = 35 arcsec		
	Pupil image diameter (on the detector)	(55.7 ± 0.6) mm	(M) ~ 55.3 mm		

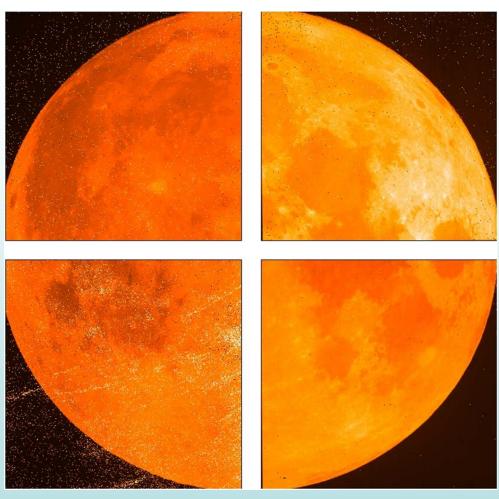
1. Introduction

- 2. Objectives
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- 4. Design of PANIC
- 5. Implementation and Verification of PANIC

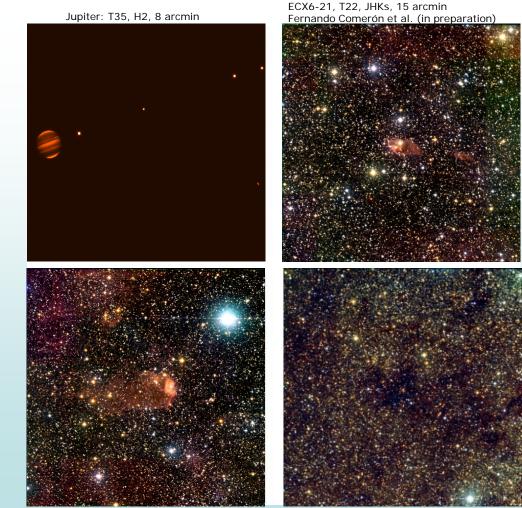
6.PANIC's Performance

6.1. Image Quality in the laboratory

- 6.2. Filters Set
- 6.3. Commissioning at both telescopes



First light image, full Moon: T22, H2, 30 arcmin



DR18, T22, JHKs, 15 arcmin Fernando Comerón et al. (in preparation)

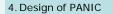
Infrared bright source RAFGL5475, T22, JHKs, 15 arcmin Fernando Comerón et al. A&A 622, A134 (2019)

- 2. Objectives
- 3. Requirements and Specifications
- 5. Implementation and

6.1. Image Quality in the laboratory

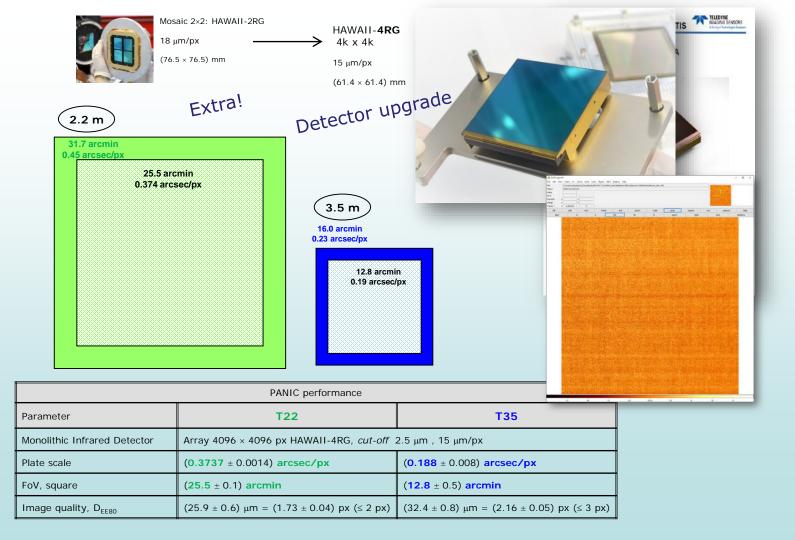
- 6.2. Filters Set
- 6.3. Commissioning at both telescopes

- 1. Introduction



Verification of PANIC

6.PANIC's Performance







¡Gracias!

- · Concepción Cárdenas Vázquez: conchi@mpia.de
- Thesis available at: http://digibug.ugr.es/handle/10481/54456
- · This talk in English at EAS 2020 annual meeting: https://youtu.be/q530WQD87tg?t=3263
- · PANIC web site: http://panic.iaa.es