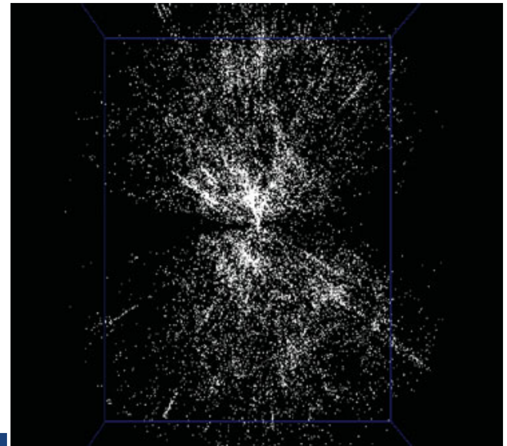


Optical astronomical instrumentation in the State of São Paulo

Claudia Mendes de Oliveira

Instituto de Astronomia, Geofísica e Ciências Atmosféricas
Departamento de Astronomia

Rafael Ribeiro will talk about GMACS,
in general and its optical design

Institutions of the State of Sao Paulo joined GMT in December 2014 with FAPESP being a GMT founder member

NEW opportunity for instrumentation, this time for the Sao Paulo State

- 42 Million people (20% of Brazil's population
- 32% of Brazil's GDP
- 45% of Brazilian science
- 39% of the PhDs graduated in Brazil (7,252 in 2016)
- 13% of State budget for HE and R&D
- 1.7% GDP for R&D (2014)

From Brito-Cruz 2017

Brazil - Overview

- Main Research Institute in Brazil with Instrumentation
  - LNA (Laboratório Nacional de Astrofísica, MG)

- Main Research Institutes with Astronomy
- 61 institutes or universities in Brasil have 1 or more astronomers
  - INPE (Inst. Nacional de Pesquisas Espaciais, SP)
  - ON (Observatório Nacional, RJ)
  - + dozens of Universities

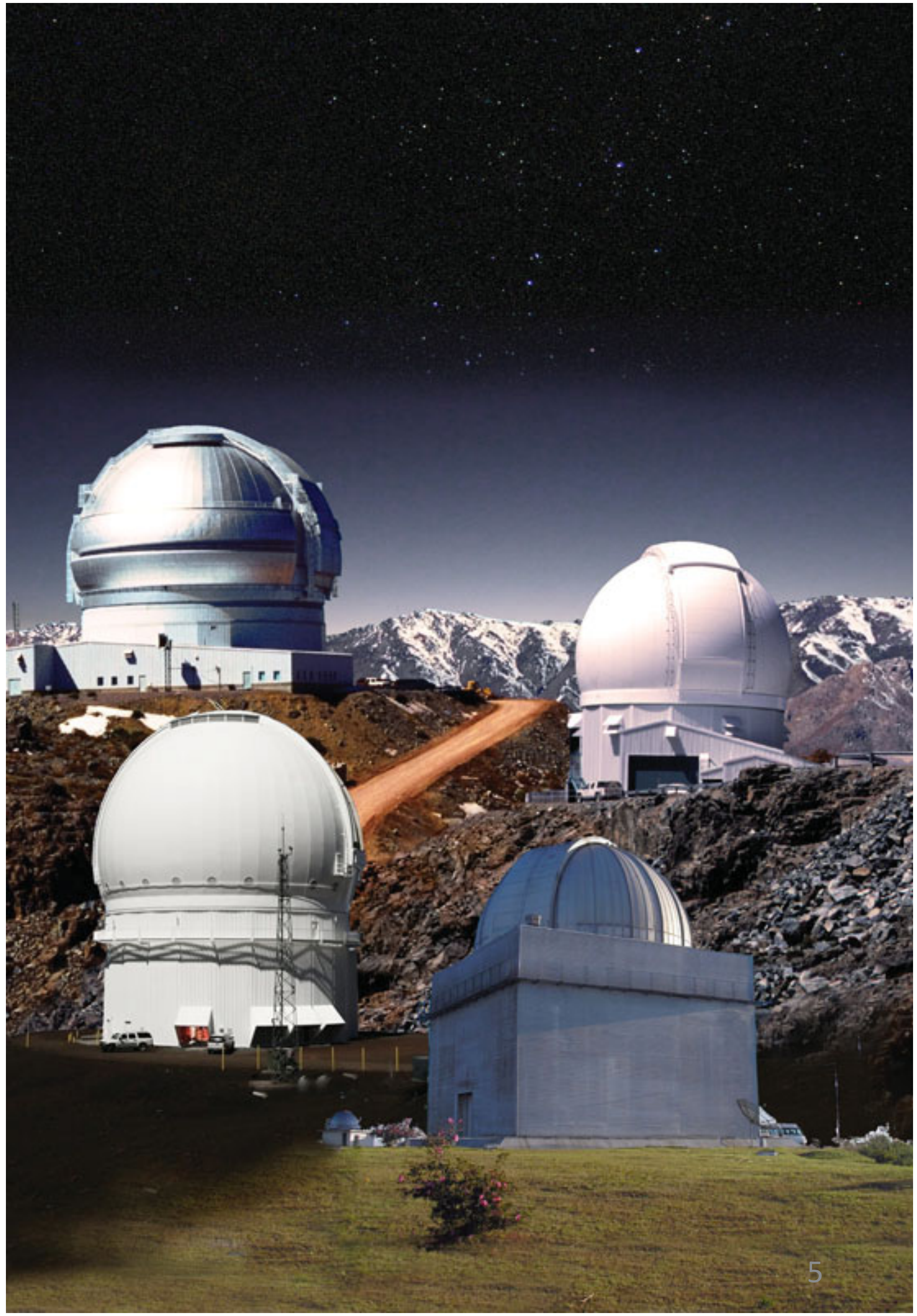
- National Telescope Facilities:

  6.5% Gemini (N/S)
  SOAR (4.1m), 34% (and Blanco – time exchange)
  OPD (1.6m + 0.6m, Brazil)
  T80-South robotic telescope (S-PLUS)
  T100 robotic telescope (ABRAS telescope)

Laboratório Nacional de Astrofísica

- Observational Infrastructure for Brazilian Optical and Infra-red Astronomy
- Telescope operations and instrumentation

Has infrastructure for Astronomy instrumentation. Fine fiber lab and metrology lab.



Instruments by leading institution

- LNA

- - 1.6 and 0.6m tel. of LNA:
- - Echarpe
- - SOAR: SIFS and Stelles
- - CFHT: Spirou
- - VLT: Cubes (Phase A)
- - JMU Liverpool: Frodospec
- - Subaru: PFS (fiber cable)

- INPE

- - Sparc4

- IAG

- - Survey telescopes: J-PAS/J-PLUS/S-PLUS
- - South-Pol (polarimetric mode of T80-South)
- - SAMplus (AO)
- - SAM-FP
- - Optics Lab
- - Workbench Spectrograph
- - Characterization of dispersive elements
- - GMT
- - G-CLEF (AO)
- - GMT (SE)
- - GMACS (SE+Optics)
- - MANIFEST (SE+Mech)

- IMT

- - ESO/ESA
- - Embebbed Software
- - Software Engineering
- - GMT
- - GMACS (SW)

SIFS and STELES

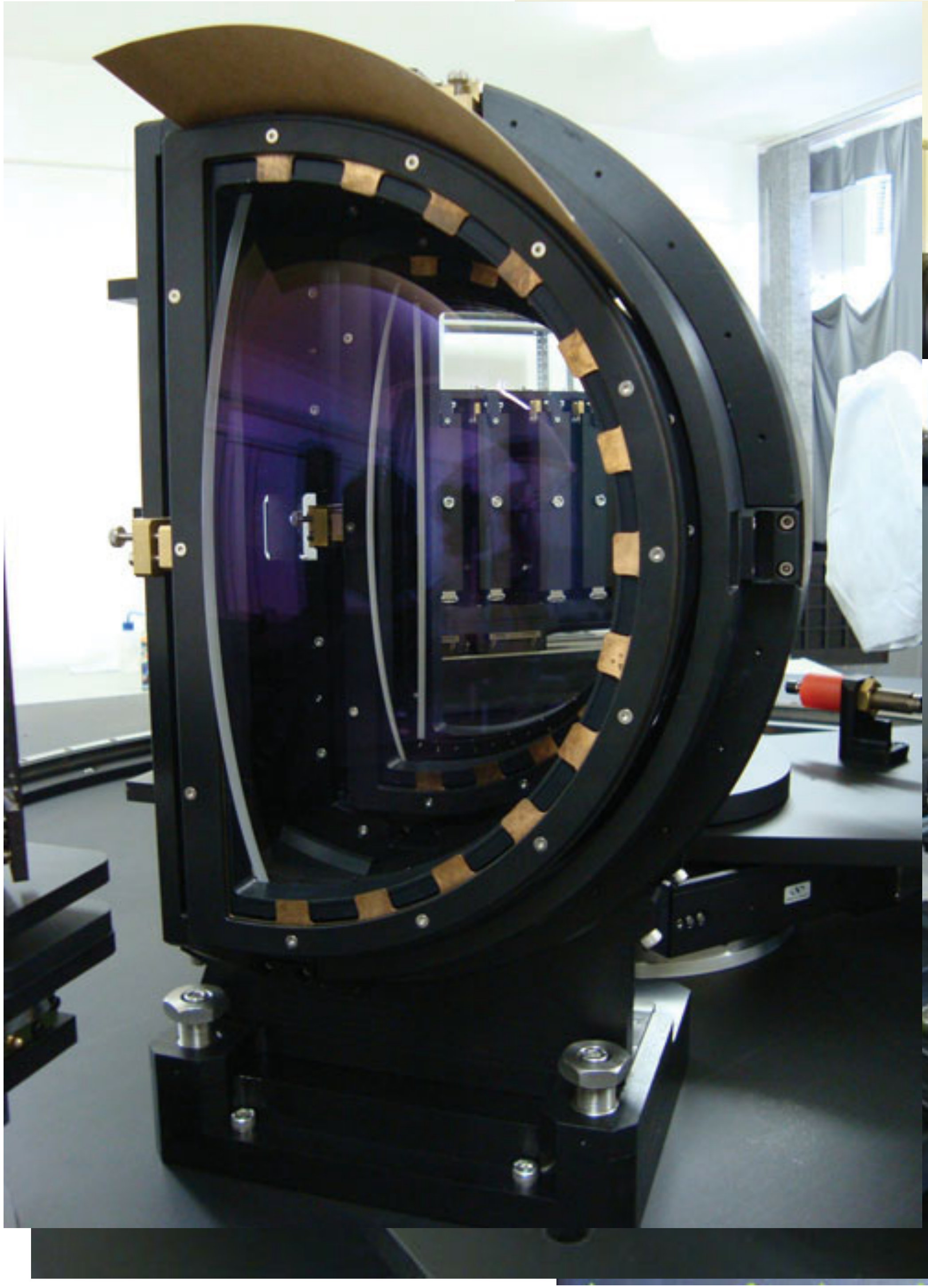
Spectrographs built in Brazil which will become community instruments at SOAR

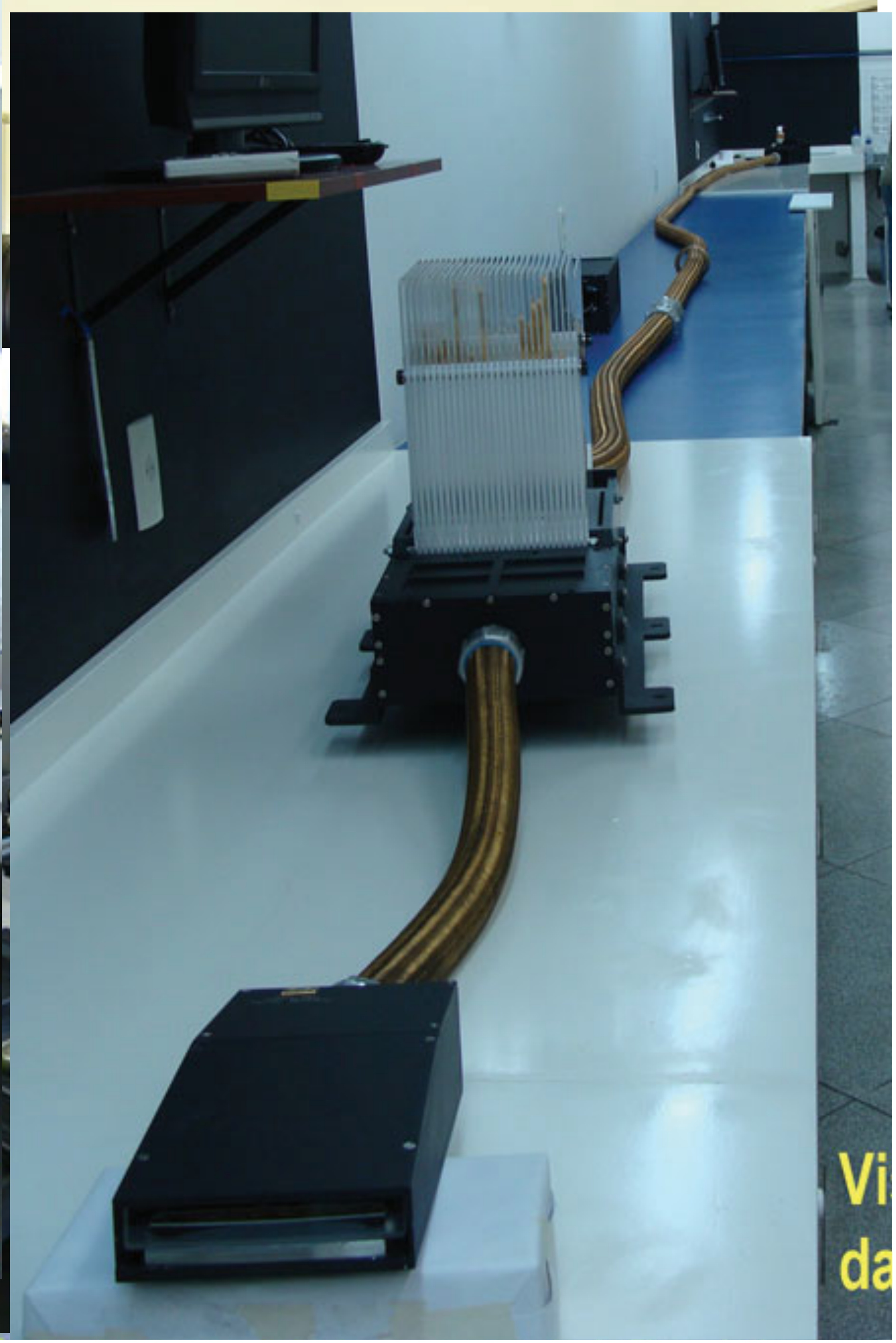
SIFS (1999 – 2017)

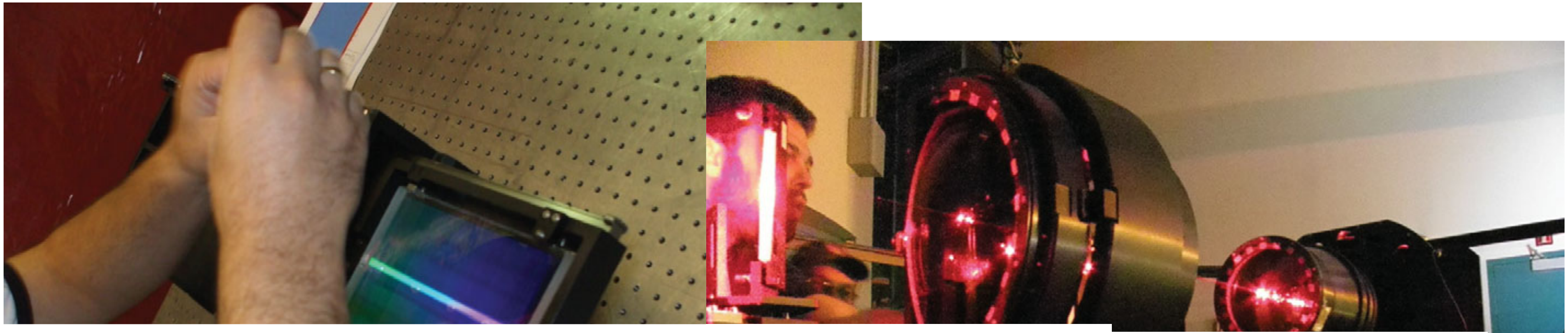
a fore-optics module mounted at the optical Nasmyth focus + a 14-m long optical fiber bundle and a bench spectrograph

1300 fibers, 400-1000 nm, 10 x 5” field, Res power of 5 – 30k, VPH gratings

- 1999 – SOAR meeting at IAG decides that an IFU instrument may be constructed by the Brazilian community. The original proposal was lead by Jacques Lepine, IAG professor.
- Construction of such an instrument in Brazil without appropriate labs and people was a major challenge.Two new engineers were selected for training and sent to AAO, to work with optical fibers and one other to CTIO to work on the development of the Instrument Selector Box. Both were subsequently hired by LNA.
- 2001 – first international review of the instrument – it was clear that major modifications in the concept we re necessary and the coordination of the project was moved from IAG to LNA. Returning from AAO, and hire d by LNA, the optical engineer Cesar de Oliveira became the PI and the instrument Eucalyptus (a path finder for SIFS was built) and the fiber labs and other labs at LNA were installed.
- The phase of construction and installation was very long because people had to be formed, labs had to be co nstructed and there were innumerous problems with importation of parts.
- 2009 – the instrument was sent to SOAR for tests
- 2010 – first observations of an astronomical object – problem of glue of microlenses and fiber cable
- 2011 – the cold weather in the winter caused problems with the glue of the optics
- 2017 – comissioning of the instrument and early-science run







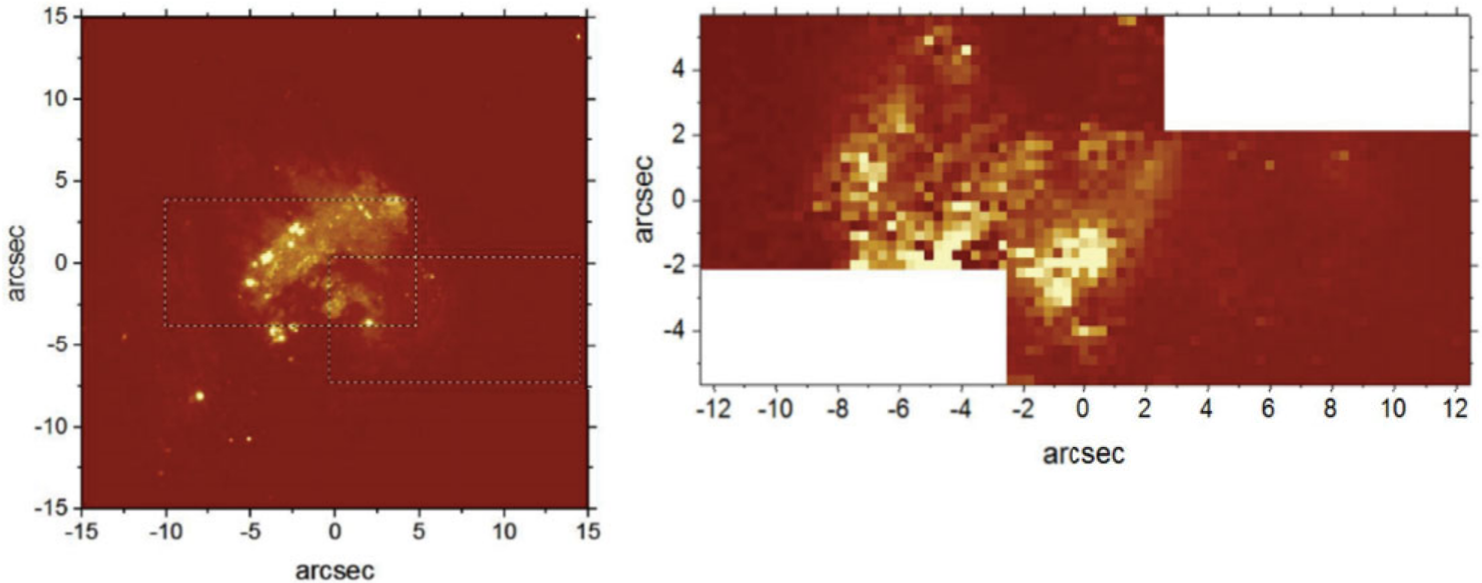
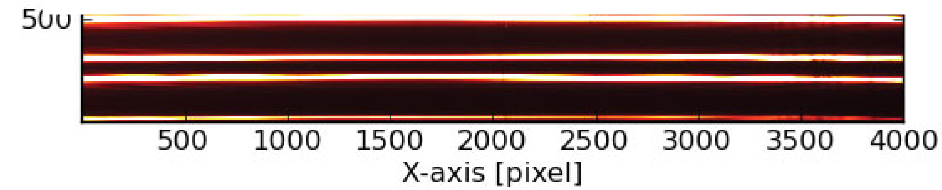


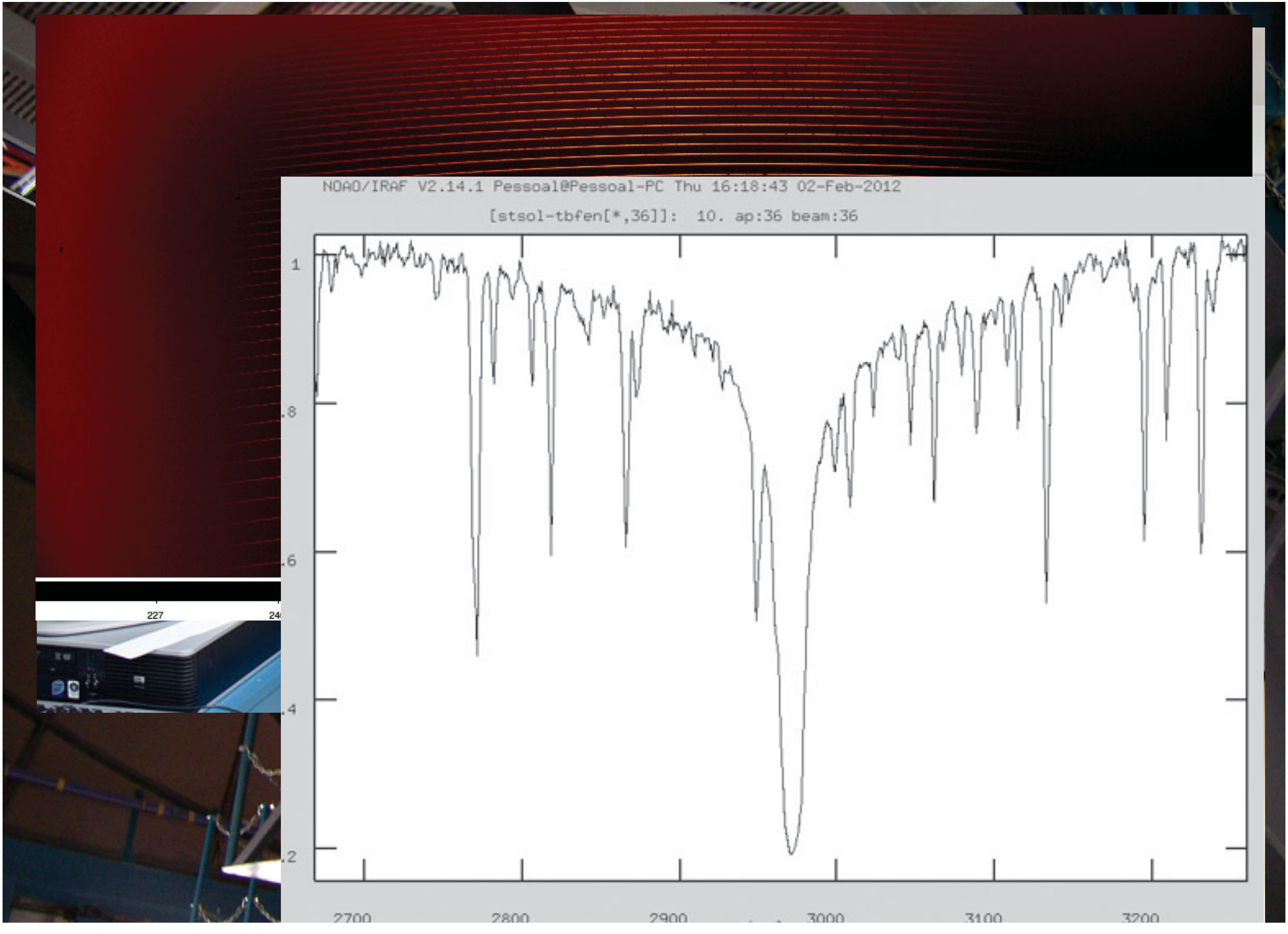
Figure 3. Left: HST FoV of the central 30"x 30" region of the LINER galaxy M83. The dashed rectangles show the region covered by SIFS using two different pointings made on July 7, 2017. Right: Mosaic made from the two datacubes of M83 in the Hα line as imaged by SIFS.



STELES

- SOAR Telescope Echelle Spectrograph
  - R = 50k (80k max)
  - 300 – 900nm in one shot - UV
  - Nasmith fed – flux calibration
  - Fixed configuration - stability
  - No moving optical parts
  - 1.8 x 1.5m
  - 800kg

- LNA / USP


NOAO/IRAF V2.14.1 Pessoal@Pessoal-PC Thu 16:18:43 02-Feb-2012
[stsol-tbfen[*,36]]: 10. ap:36 beam:36
1
.8
.6
.4
.2
2700
2800
2900
3000
3100
3200
227

Status of SIFS and STELES

SIFS - SOAR integral field unit spectrograph -

- Had its **first science verification** and data were sent to PIs

- It may be offered in shared-risk mode to the community in the near future.

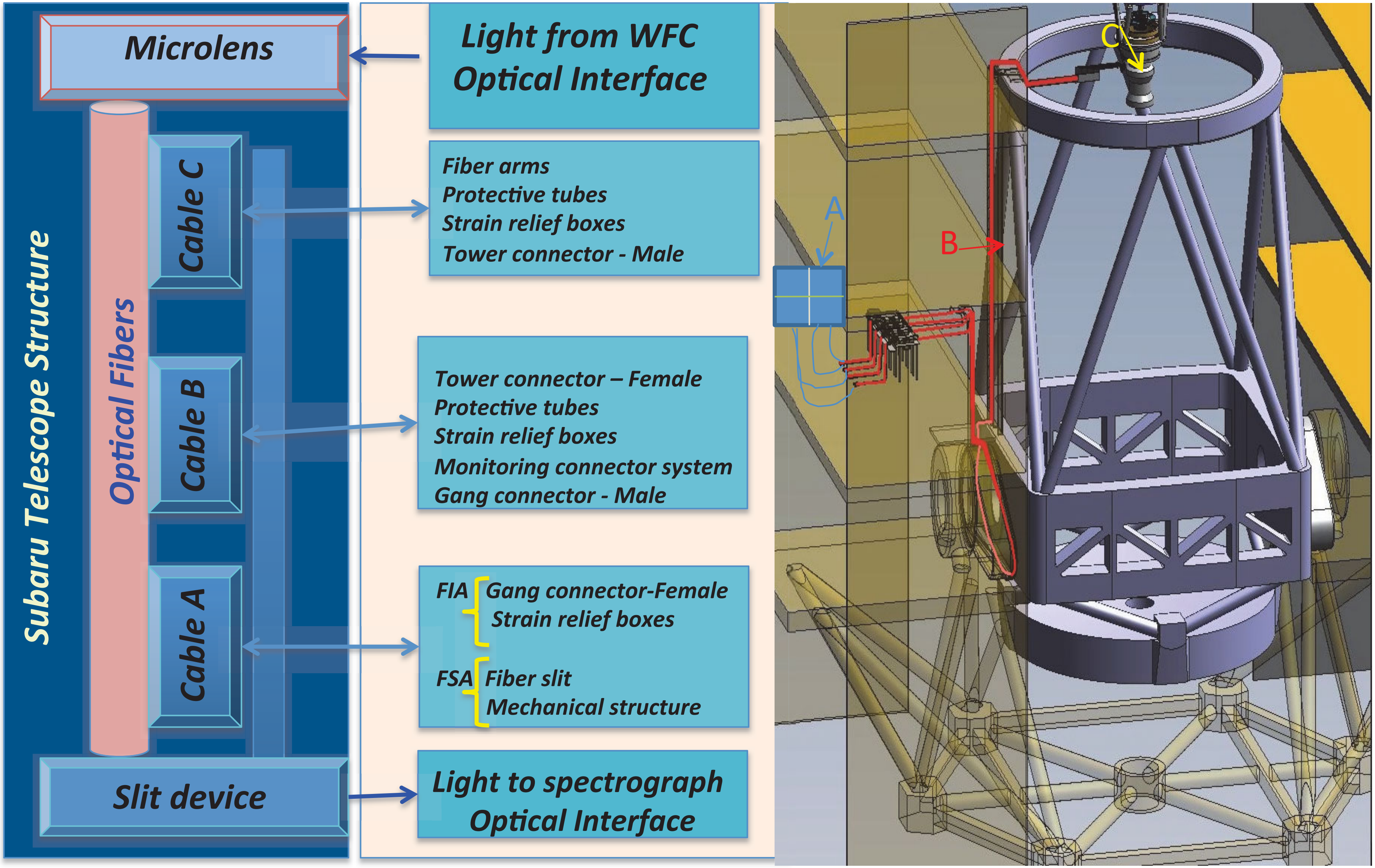
STELES

- Mounted and aligned at SOAR lab
- Not on the telescope yet because a new calibration unity had to be built
- Ready to be mounted on telescope and tested.

Fiber cable for the Prime focus spectrograph

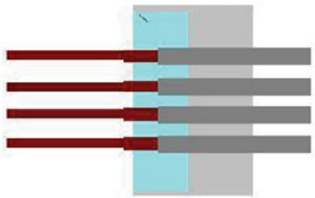
8m - Subaru instrument

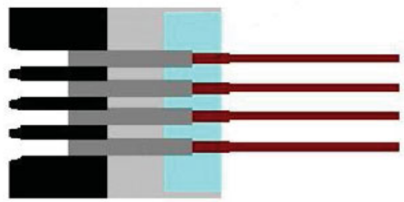
FOCCoS will provide connection between 2394 positioners with four spectrographs by an optical fiber cable.

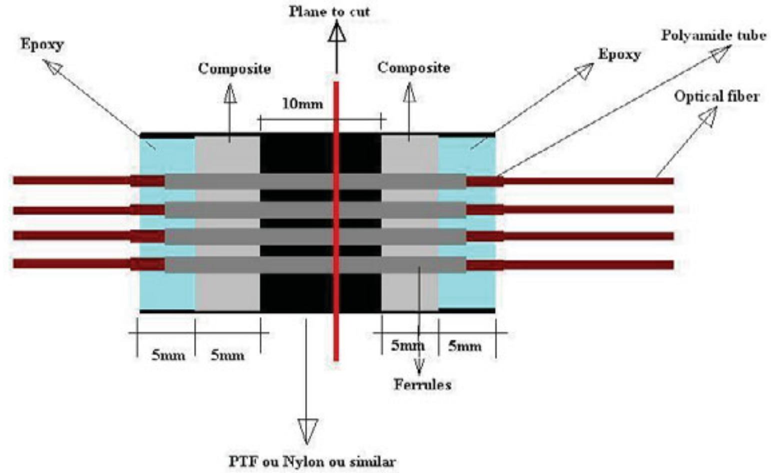


2500 fibers that go from the top to the 4 spectrographs

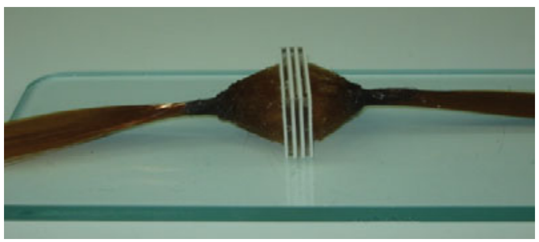
Fiber connectors
(critical to PFS performance)

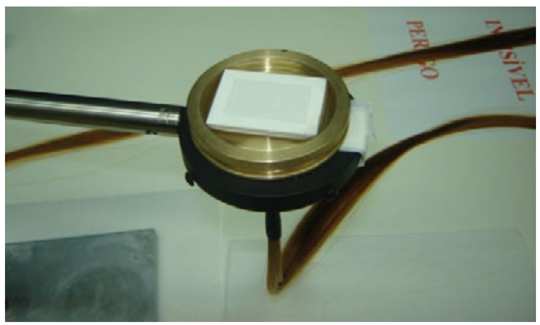


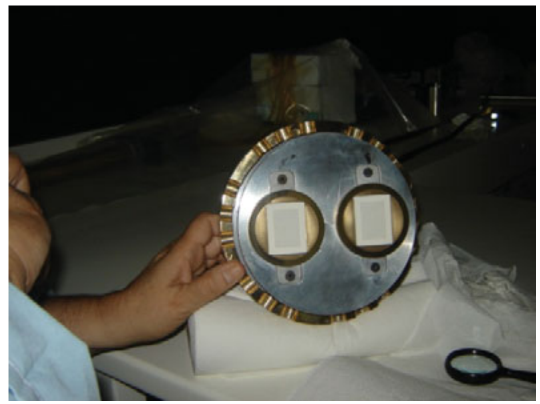




~3,200 fibers: ε ~90%



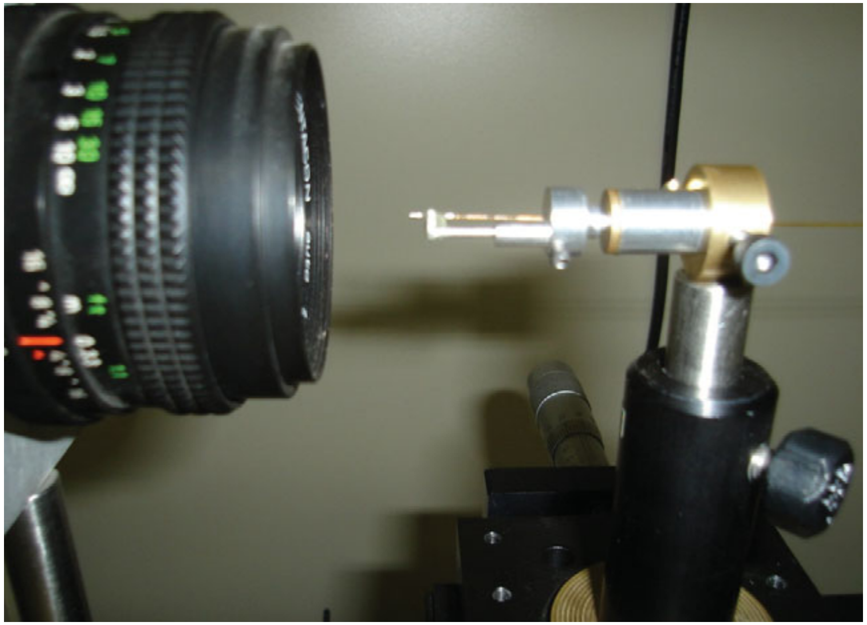




Prototype ***dynamic*** connector with >600 fibers achieved 87% throughput (ε), using new technologies - water jet cutting; new composite materials and precision engineering.

COBRA positoner (JPL)

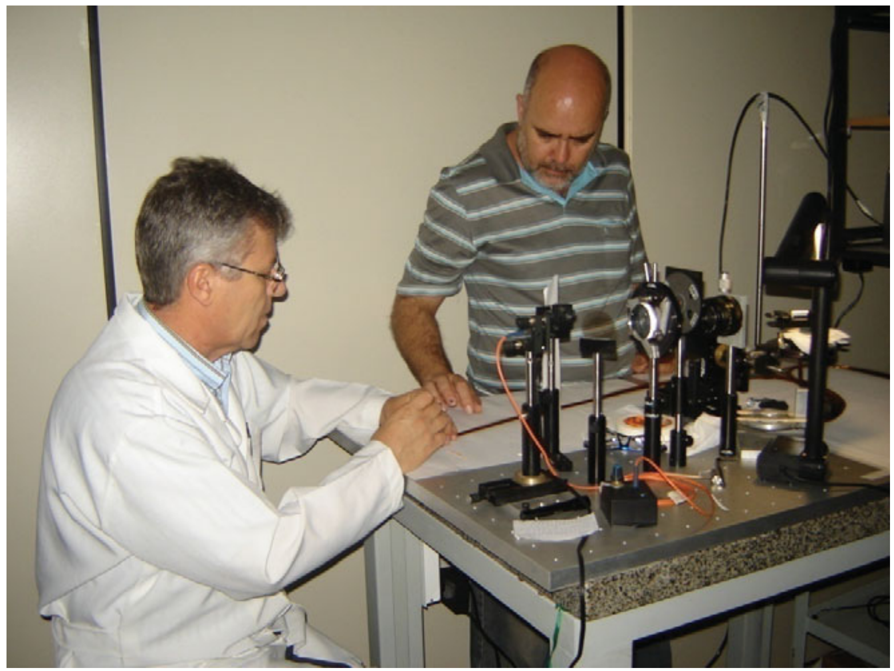
Fiber evaluation tests (@ LNA)



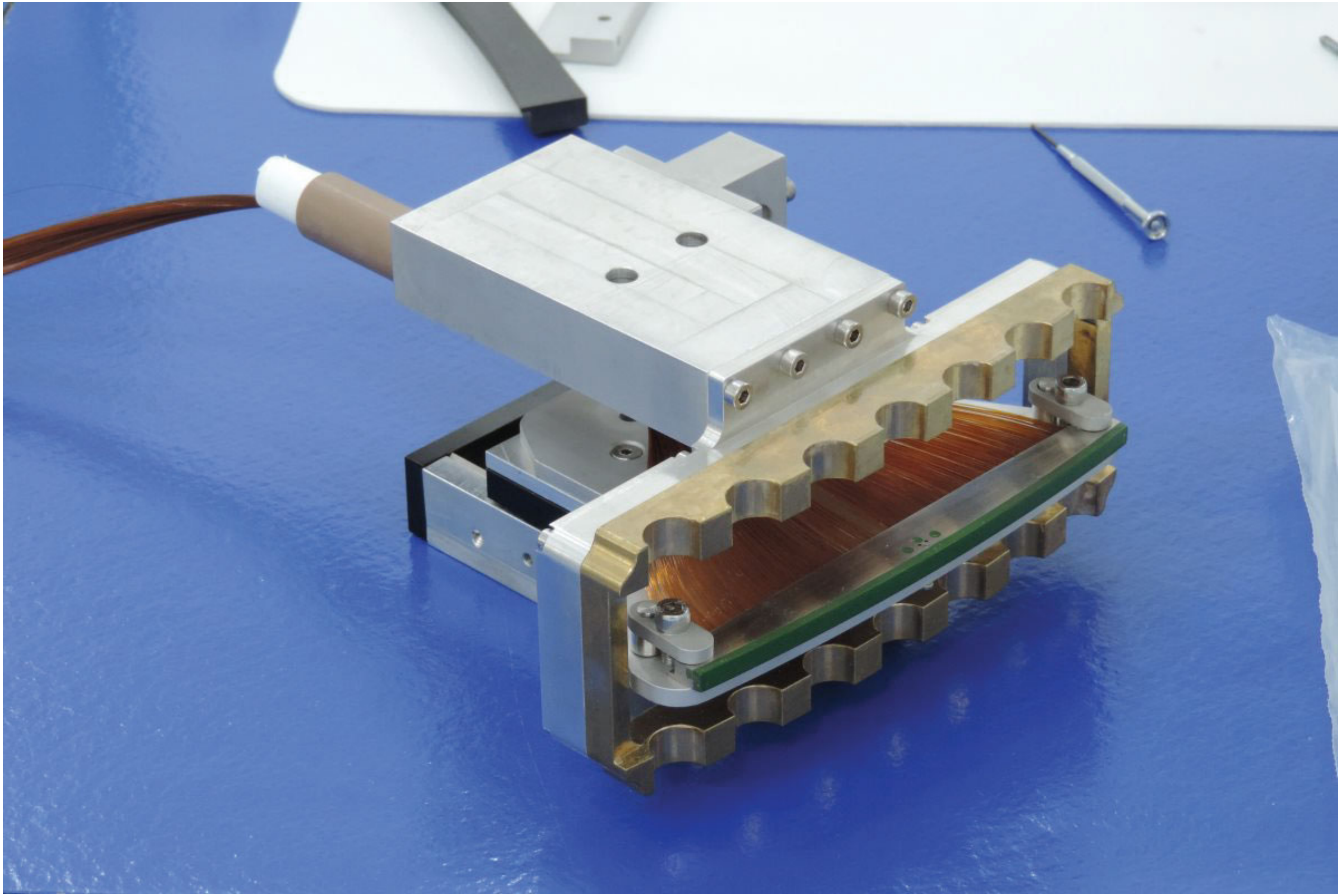
COBRA fiber positioner squiggle motor with attached fibre.

Facilitates tests of the micro components of the positioner using a variety of test materials.

FRD twisting & torsion tests simulating expected conditions



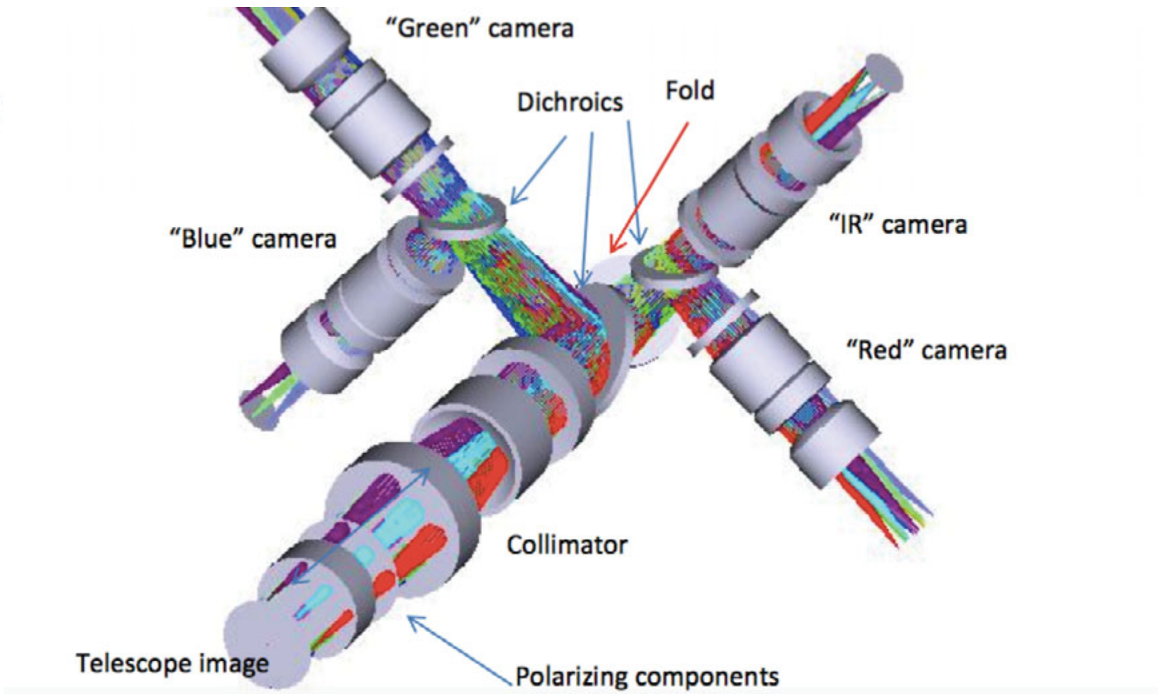
Curved slit



SPARC 4
instrument for OPD 1.6m telescope

SPARC 4, for 1.6m telescope
Claudia Vilega, INPE

- Simultaneous Polarimeter And Rapid Camera in 4 bands
  - ✓ simultaneous imaging in four bands (griz SDSS)
  - ✓ polarimetry as an option
  - ✓ sub-second time resolution
- at 1.6-m telescope



Institutions of the State of Sao Paulo joined GMT in December 2014 with FAPESP being a GMT founder member

NEW opportunity for instrumentation, this time for the Sao Paulo State

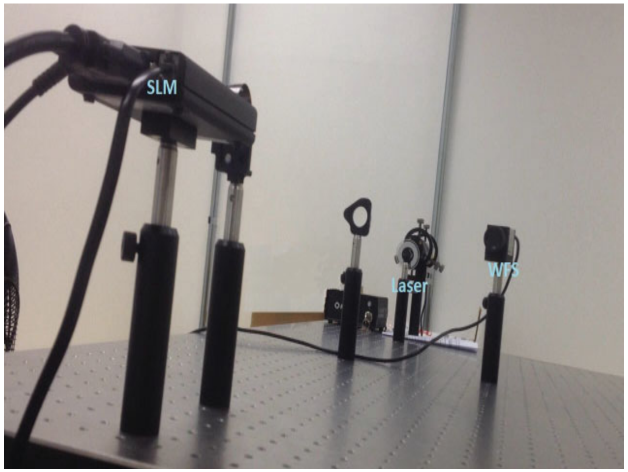
- 42 Million people (20% of Brazil's population
- 32% of Brazil's GDP
- 45% of Brazilian science
- 39% of the PhDs graduated in Brazil (7,252 in 2016)
- 13% of State budget for HE and R&D
- 1.7% GDP for R&D (2014)

From Brito-Cruz 2017

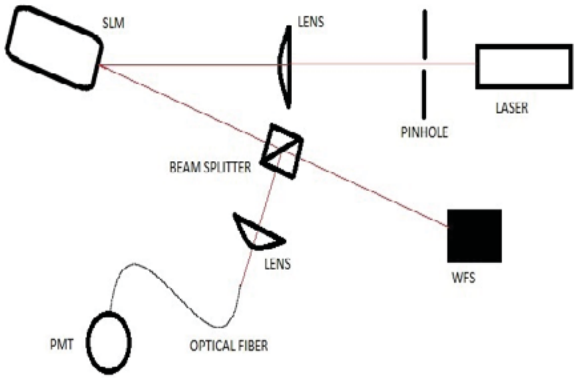
Laboratory for Adaptive Optics for the GMT Project

UFABC

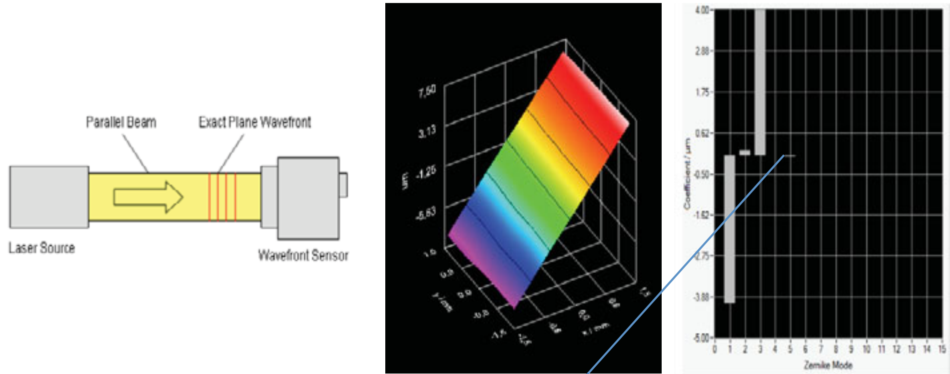
They are characterizing the WF both with WFS and with a photomultiplier



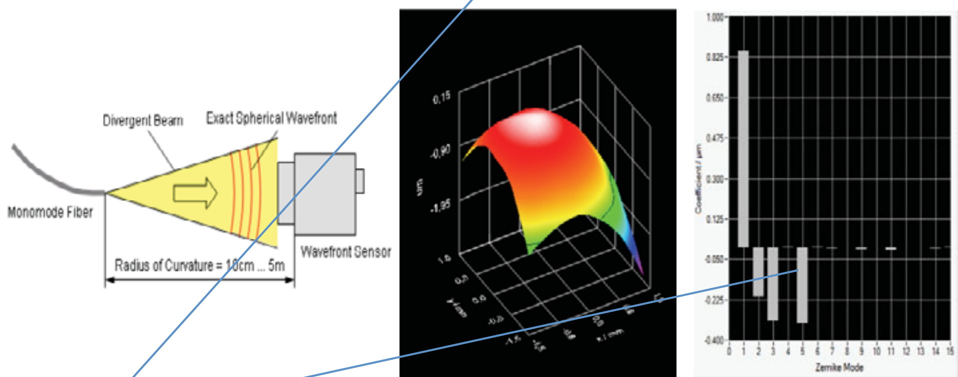
Present setup at the UFABC/LAO (top); diagram of the proposed setup (bottom).



PRELIMINARY RESULTS



Plane wave callibration



Spherical wave callibration

Defocus coefficient

Pictures of the optical lab at IAG
Other labs: Mechanics, eletronics, instrumentation

All inaugurated in the beginning of 2017
Special thanks to Denis Andrade

SAMplus: SAM upgrade to high-order

SAM: SOAR Adaptive Module

- The adaptive module of the 4.1 m SOAR telescope, SAM, corrects ground-layer turbulence using an ultraviolet laser guide star.

- It has been commissioned in 2013 and it is in regular science operation since 2014.

- SAM covers a 3’x3' field of view. It can work with:
  - An CCD imager/speckle camera.
  - An internal Fabry-Perot/tunable filter interferometer
  - External SOAR instrument (e.g., SIFS)

- It operates routinely and stably, delivering resolution in the I-band (856.5nm) equal to the free-atmosphere seeing.

SAM at SOAR

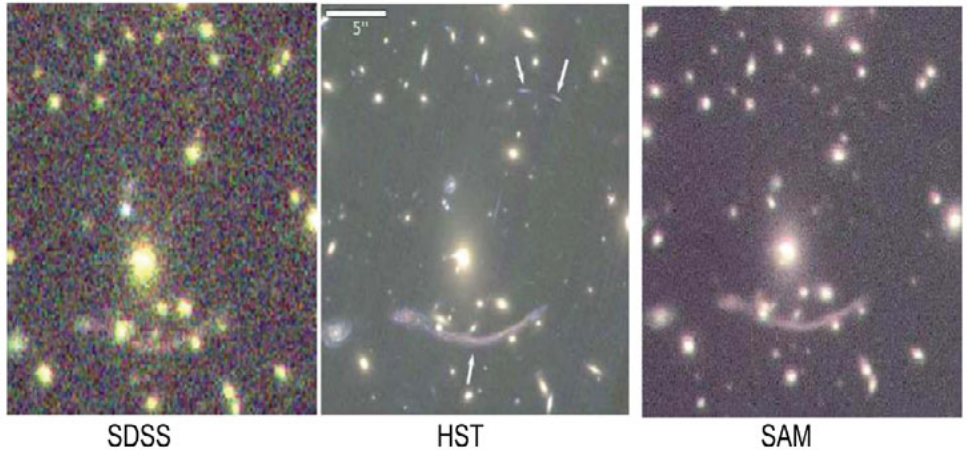


Figure 12. Images of the gravitational arcs in the galaxy cluster Abel 370 from SDSS, *HST*, and SAM. The SAM images were taken on 2013 September 29. Five 5-minute exposures in the SDSS i' and r' filters each are median-combined and presented as a false-color image with a FWHM resolution of $0.''5$.

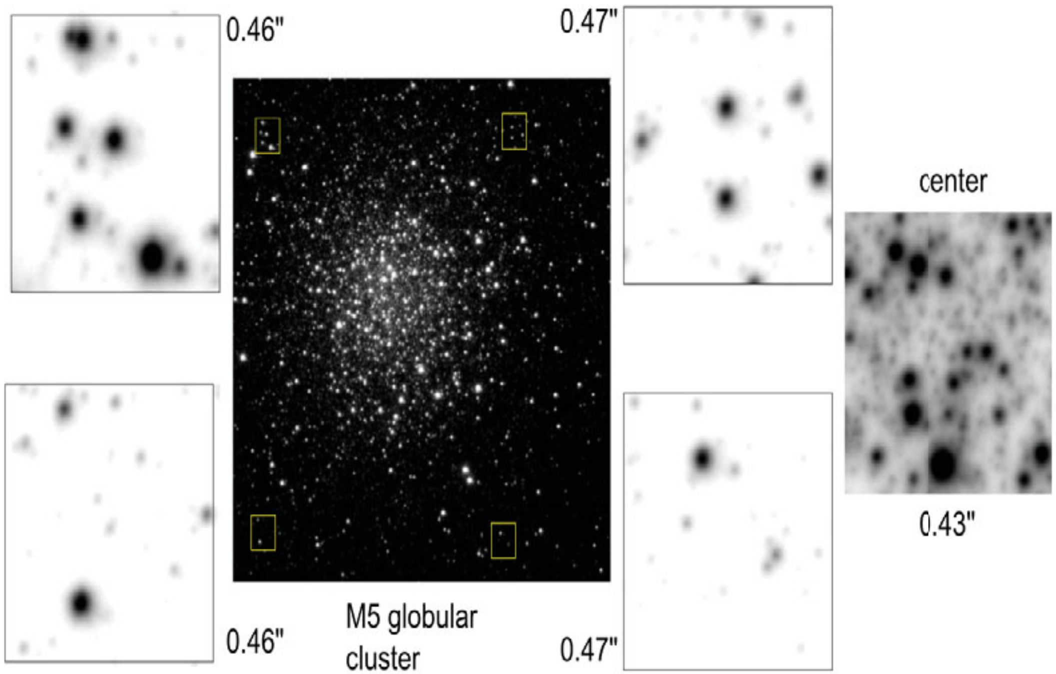


Figure 11. Image of the M5 globular cluster taken on 2013 March 2 (six 10 s exposures in the *I* filter, median-combined). The square fragments of 12″ size in the corners and in the center of the image demonstrate the stability of the PSF over the entire field (the FWHM measured on several stars in each fragment is indicated).

SAMplus: SAM upgrade to high-order

- The concept of the SOAR Adaptive Module (SAM) was developed in 2003, and comissioned on 2013. It was based on AO technology developed in the middle of 1990-s:
  - Bimorph deformable mirror BIM-60 from CILAS;
  - 80x80 pixel CCD-39 from e2v.

- Owing to the limited number of DM actuators, this correction is never perfect. It is better at longer wavelengths and worse at shorter wavelengths. SAM corrects only part of the turbulence.

- The AO technology available today allows us to increase the correction order by using the same laser flux more efficiently. This can be achieved by replacing the DM and WFS with modern AO components.

SAMplus

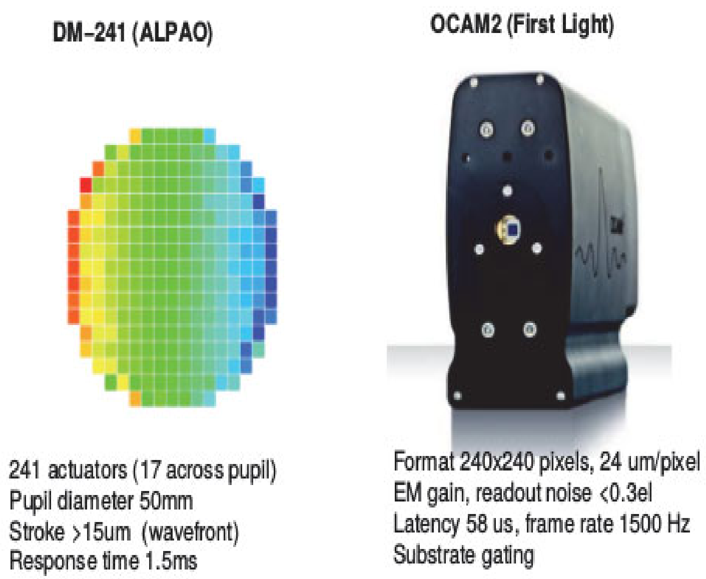


Figure 1: Critical AO components of the proposed SAM upgrade.

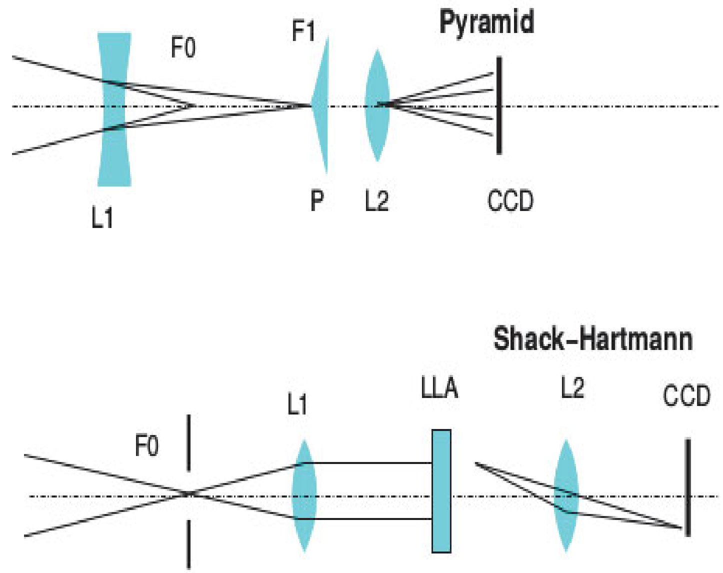
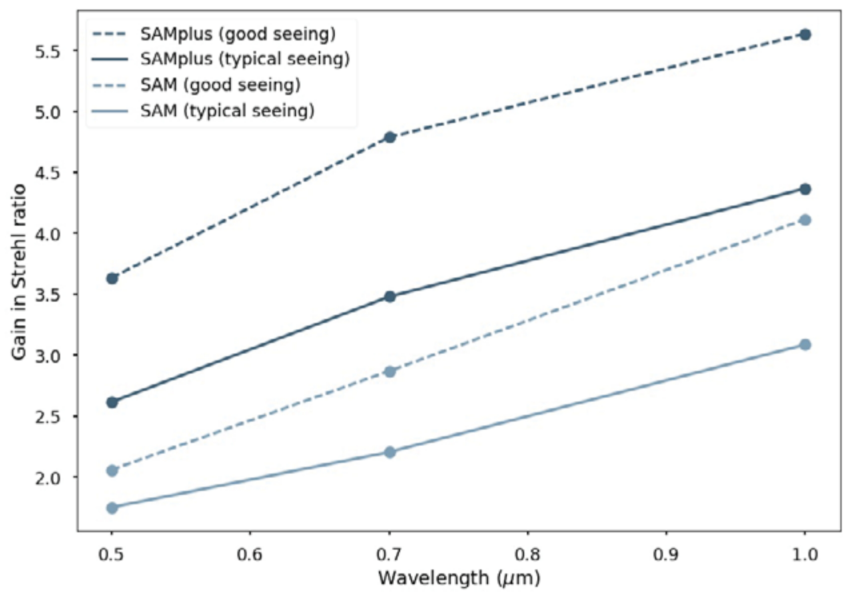


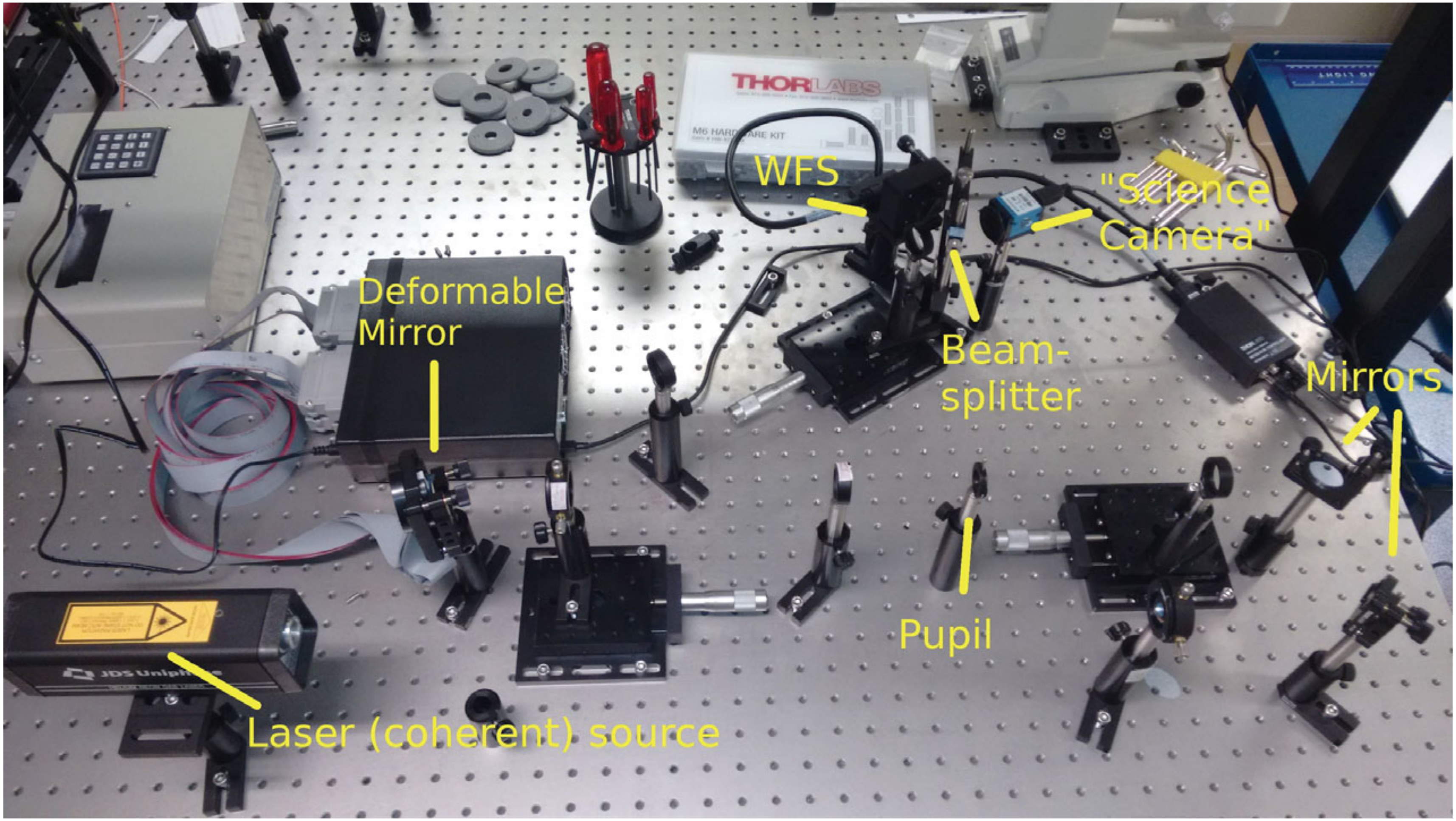
Figure 2: Two concepts of new WFS for SAM: pyramid (top) and Shack-Hartmann (bottom).

These are the components suggested for the SAM upgrade, a larger number of actuators and a gated CCD with more microlenses 14 x 14 = 196 in the WFS and smaller readout noise



Simulated improvement of SAM and SAM-PLUS

CoD Review by late May-early June
Comissioning by late 2020

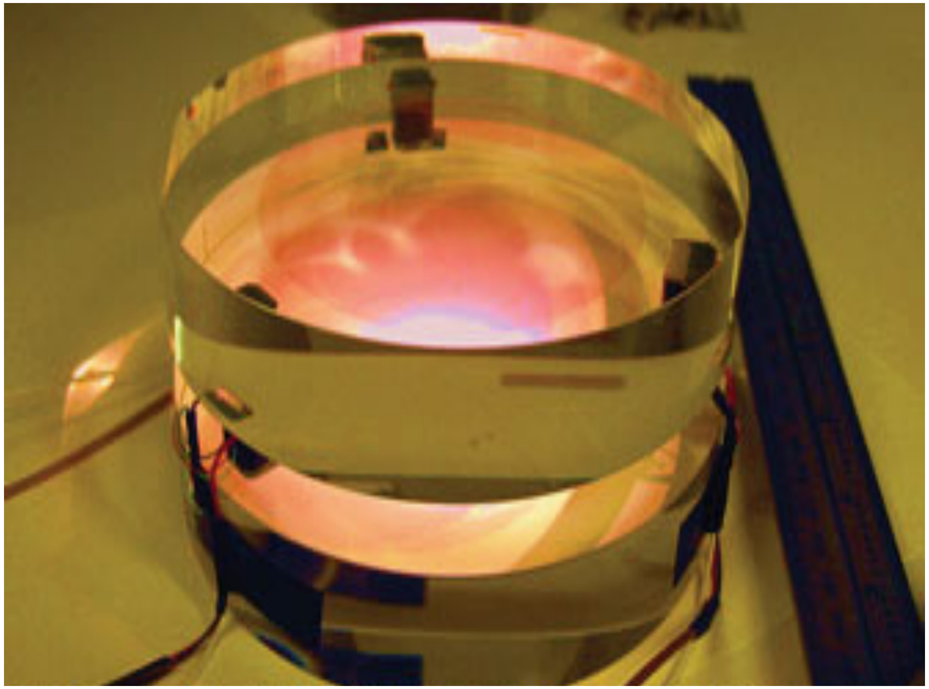


It took 10 weeks for our engineers to go from an empty lab with "no AO" to closed loop using this layout.

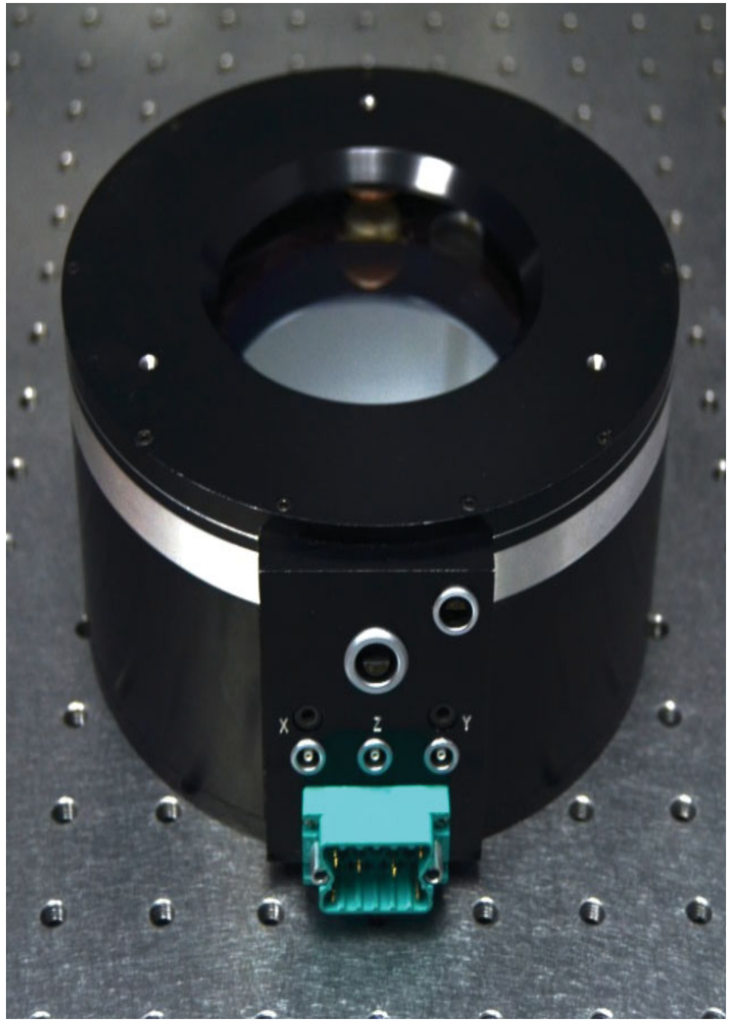
Tour of
The lab
tomorrow
at 10 a.m.

SAM-FP, a Fabry-Perot mode of SAM

SAM-FP uses a Fabry-Perot device inside SAM



Fabry-Perot glass plates
http://www.lumonics.com

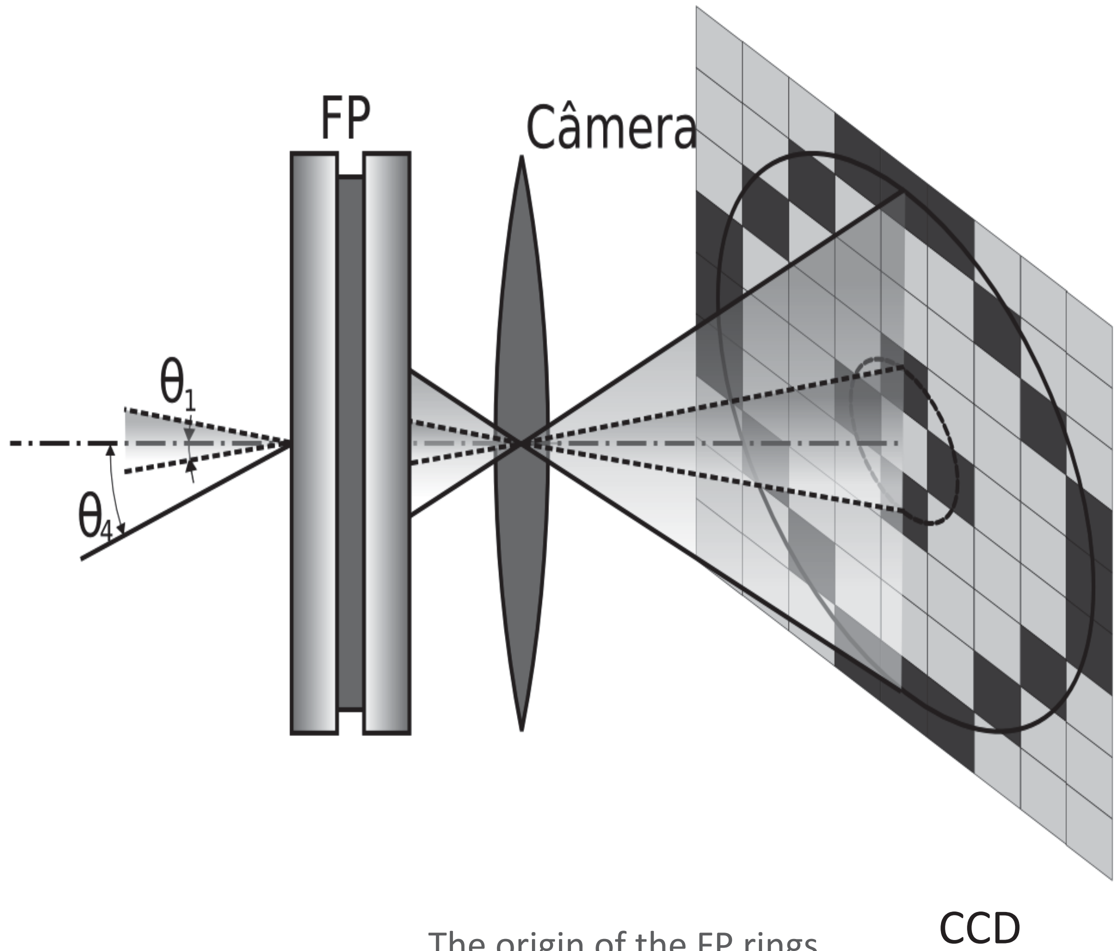


QueensGate Fabry-Perot

Fabry-Perot?

$$m\lambda = 2nd\cos\theta$$

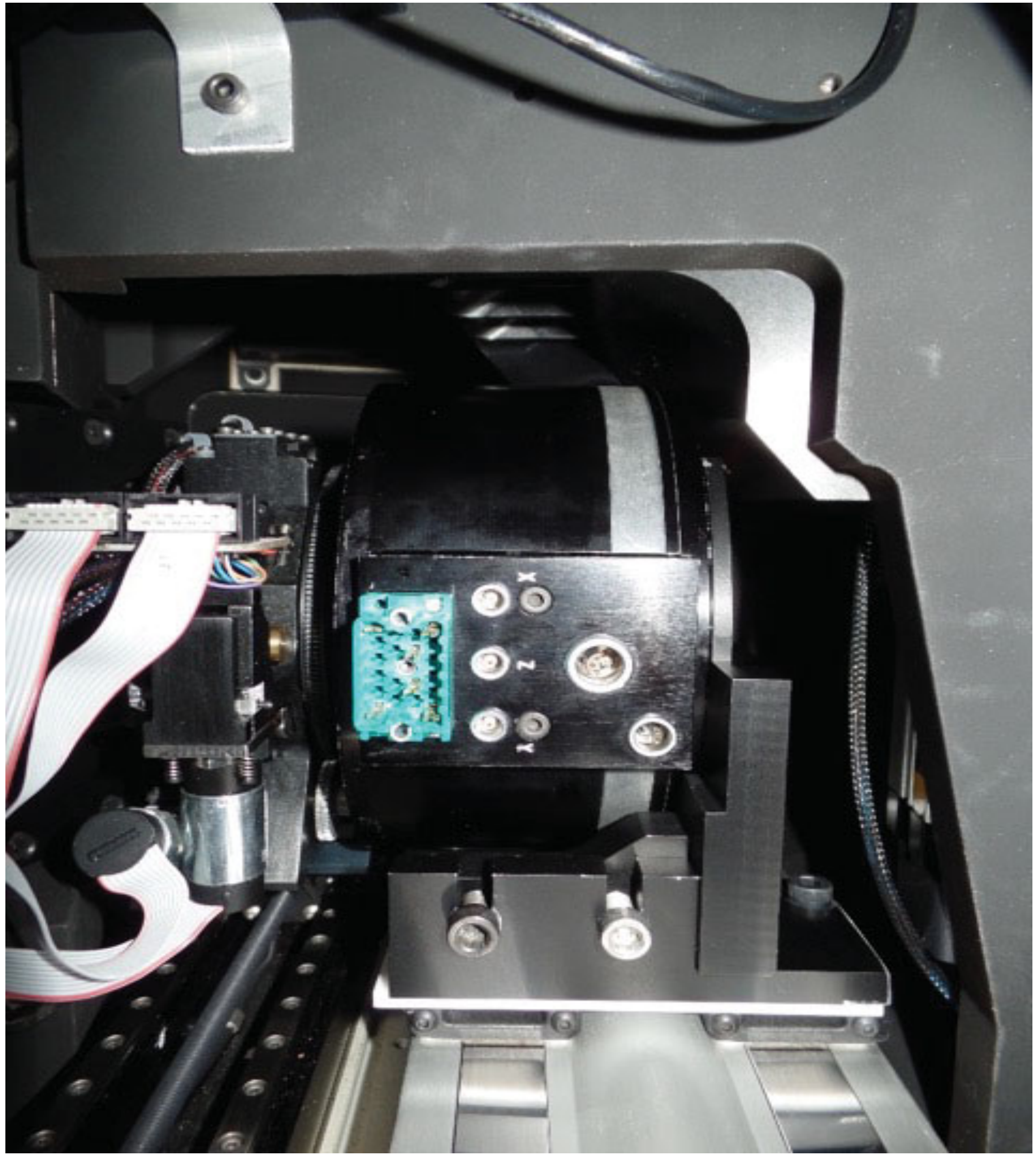
- Axial simmetry
- Single pixels turn rings

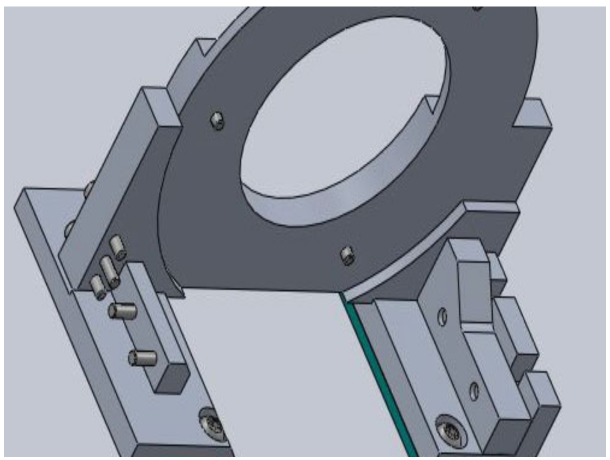


The origin of the FP rings.

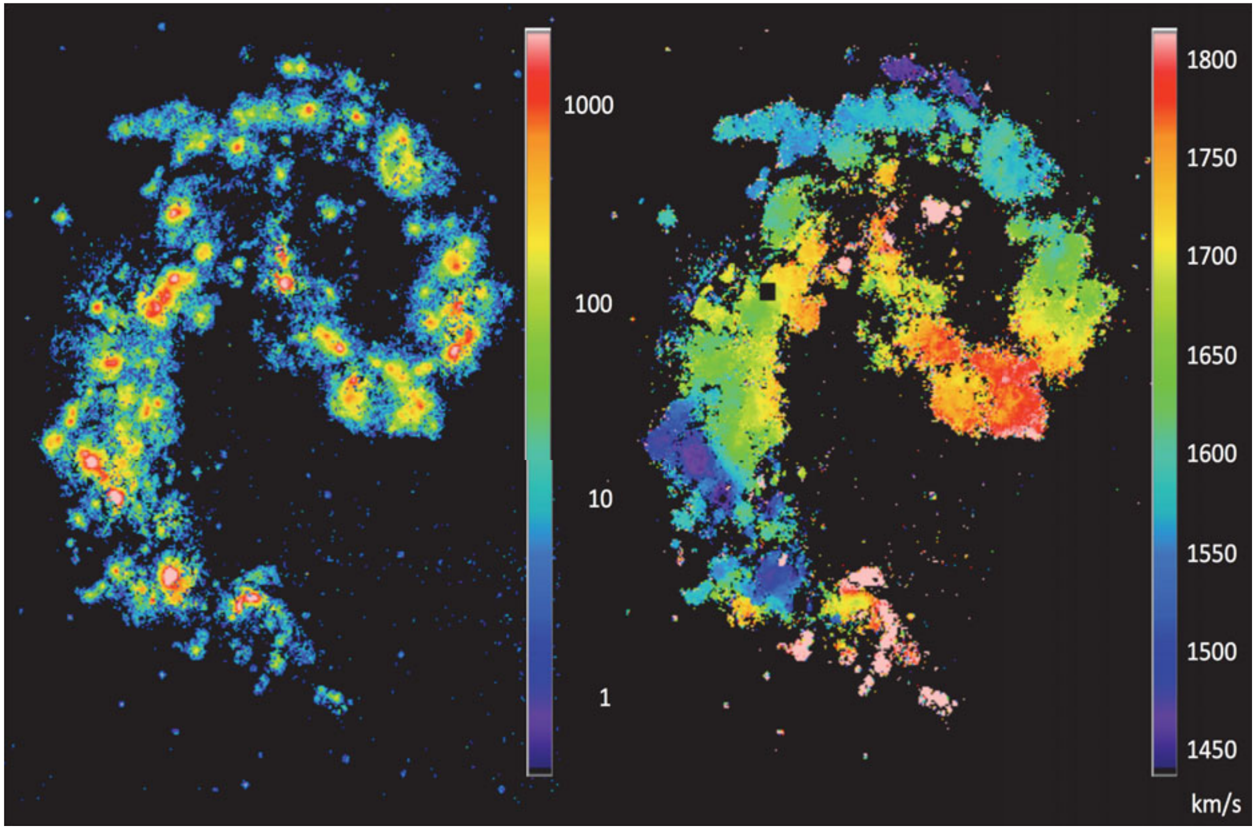
Multiple reflected rays are out of phase by a constant increment, increasing the sharpness of the Interference maximum. Constructive interference happens for some lambdas and not for others.

Fabry-Perot
Inside
SAM

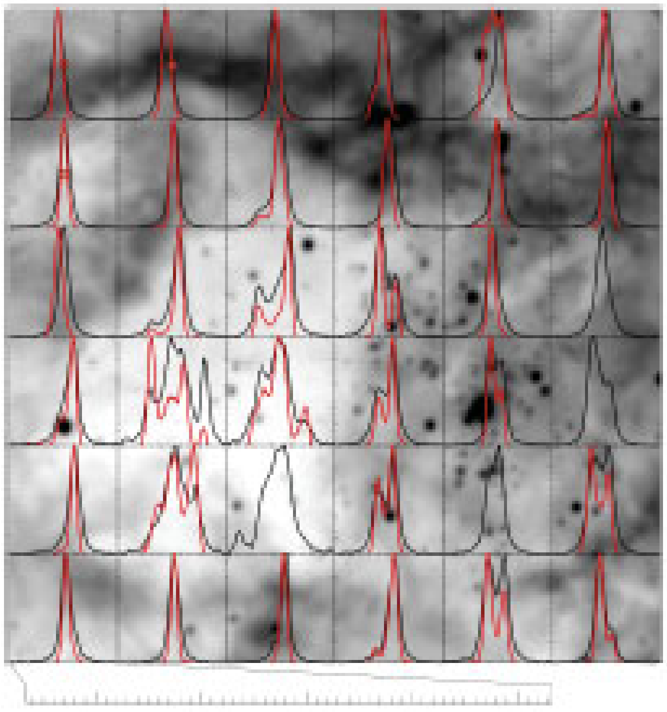




Antenae galaxies – First images taken with SAM-FP



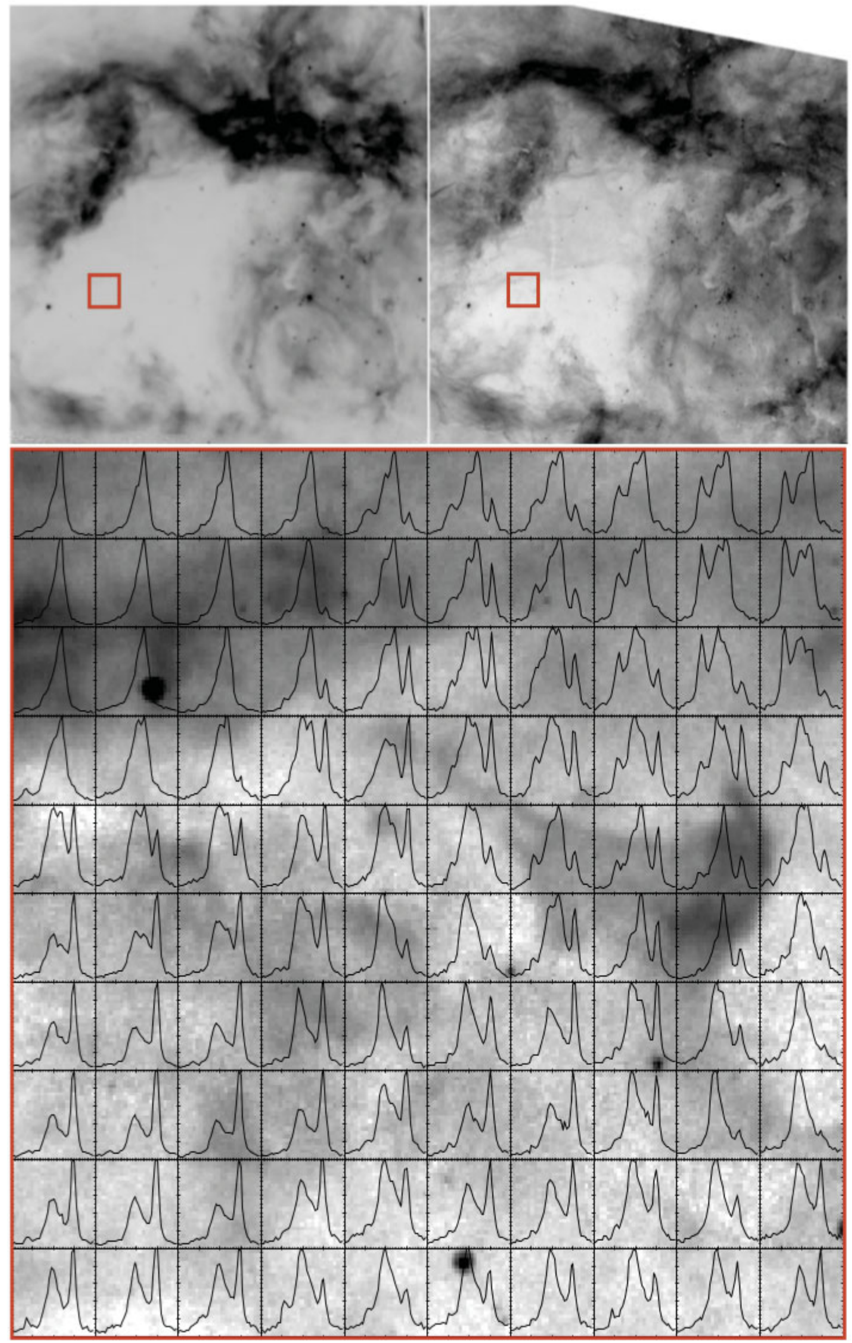
Halpha image **Velocity field**



Tarantula
Nebula

0.5" FWHM

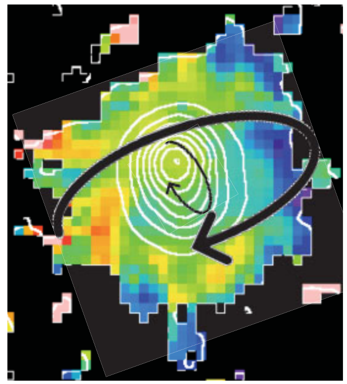
MdO et al. 2017



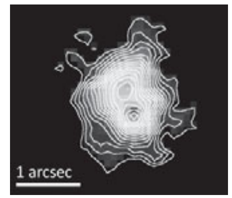
Blue Nuggets in the Local Universe?

blue nuggets = tiny gas-rich starbursts at high redshift; initially prolate like footballs and evolve to oblate; may form in gas-rich mergers or converging gas streams

DECaLS image



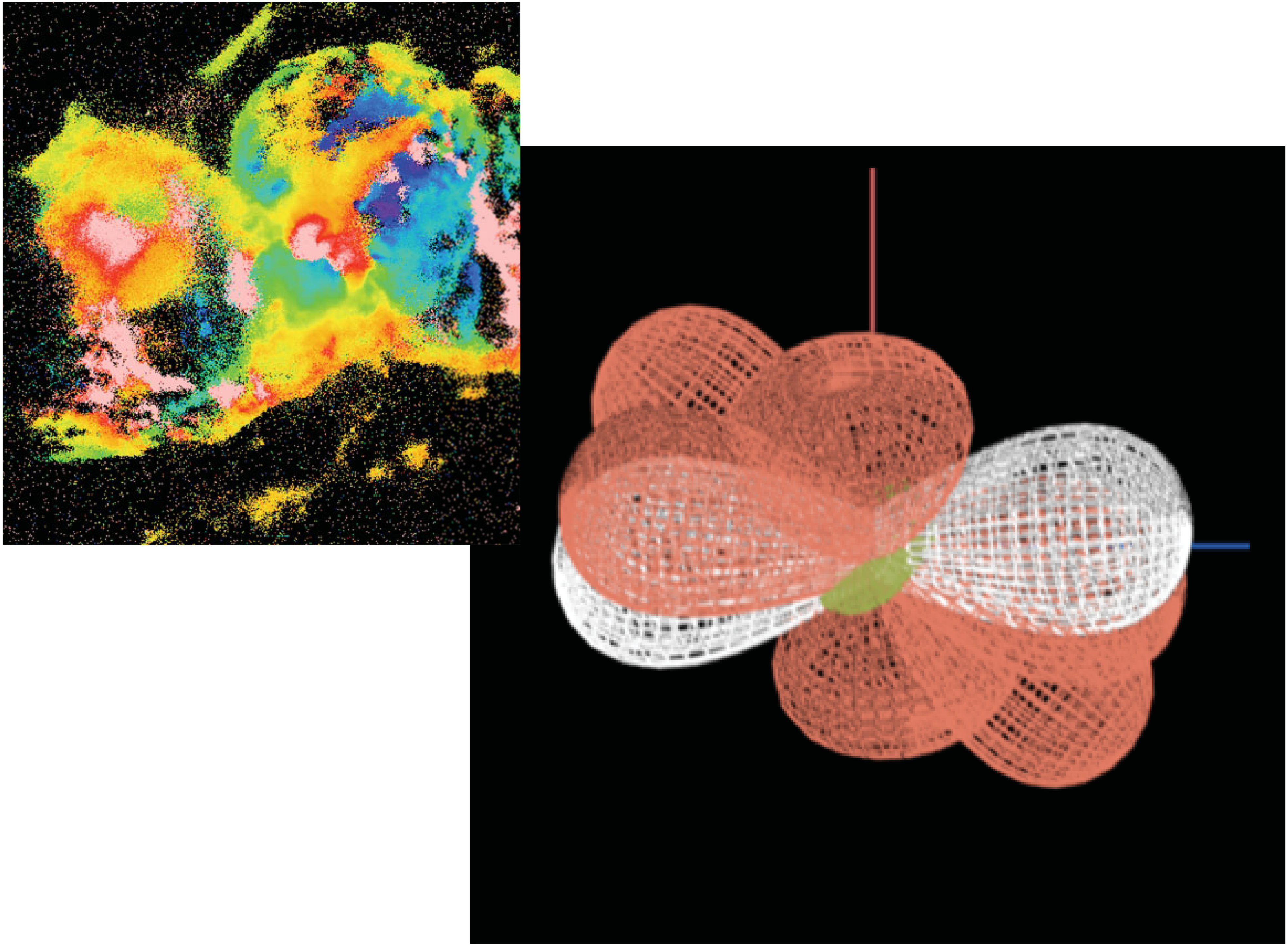
SAM FP vel. field (orientation TBD)



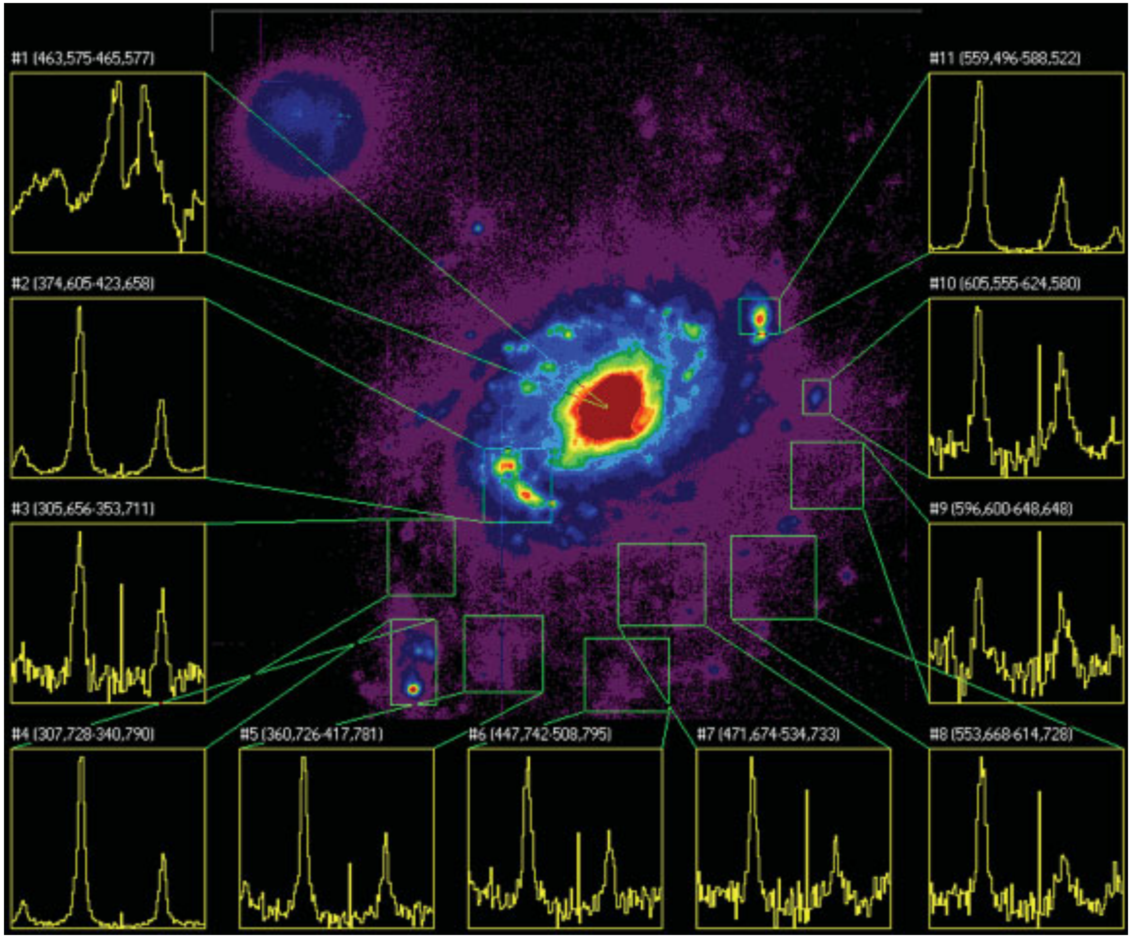
double nucleus found with SAM FP

rf0250 is a gas-rich dwarf starburst in the RESOLVE Survey with stellar mass similar to a high-z blue nugget: our SAM-FP data reveal kinematics possibly consistent with prolateness and a double nucleus suggesting a recent merger

(Palumbo, Kannappan, RESOLVE & SAM-FP teams, in prep)



NGC 1068



#1 (463,575-465,577)
#2 (374,605-423,658)
#3 (305,656-353,711)
#4 (307,728-340,790)
#5 (360,726-417,781)
#6 (447,742-508,795)
#7 (471,674-534,733)
#8 (553,668-614,728)
#9 (596,600-648,648)
#10 (605,555-624,580)
#11 (559,496-588,522)

Multiwavelength survey dedicated telescopes

Participants: ON, IAG, INPE and a number of other institutions.

One 2.5m telescope and two 0.8m telescopes

Spain/Brazil collaboration

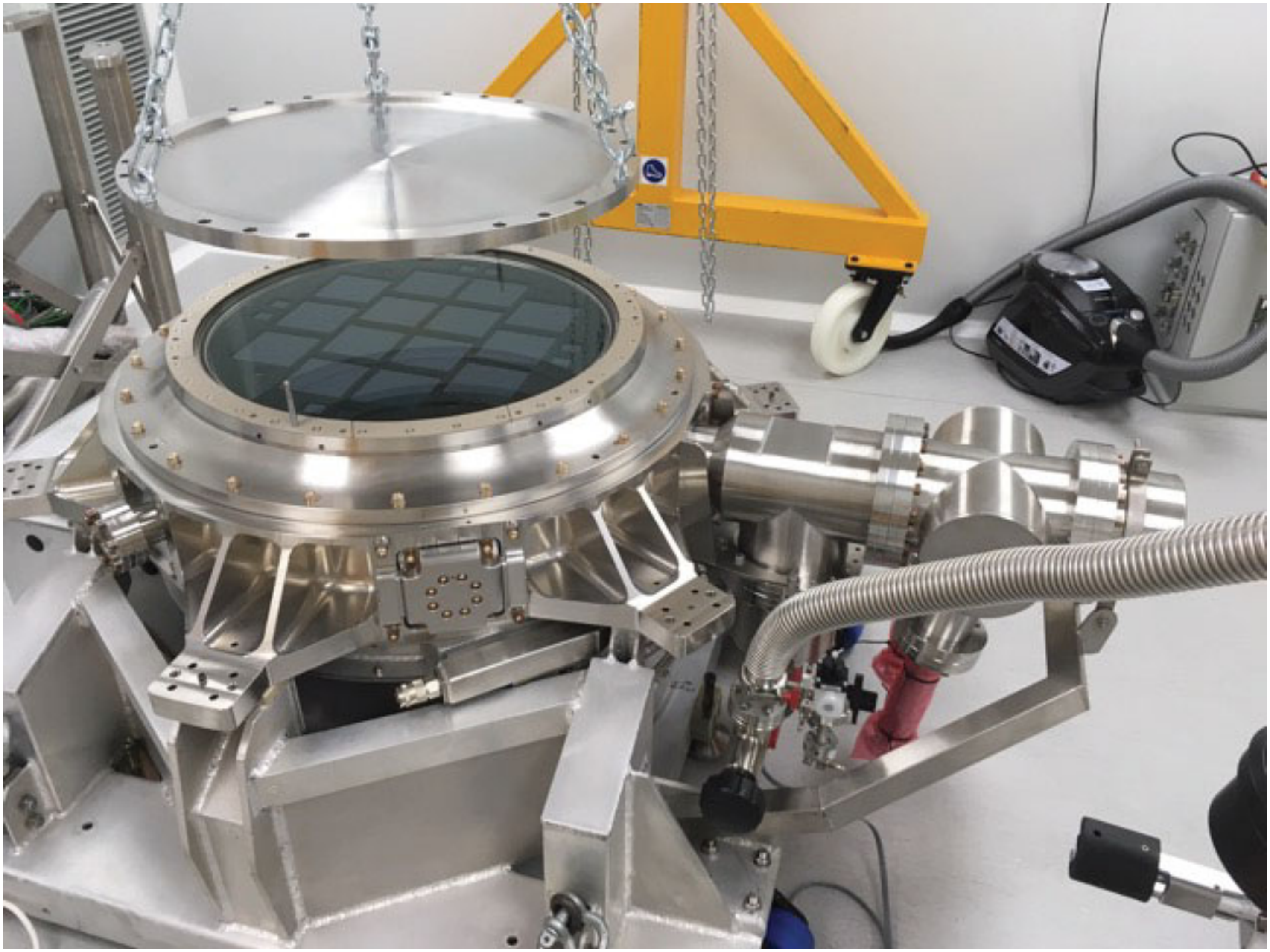
Multiband Surveys:

- **J-PAS: Javalambre Physics of the Accelerating Universe Astrophysical Survey**
  - 8500 sq deg – 2.5m telescope @ OAJ – 59 filters – start: Jan 2017

- **J-PLUS: Javalambre Physics of the Local Universe Survey**
  - 8500 sq deg – 0.8m telescope @ OAJ – 12 bands – going on

- **S-PLUS: Southern Physics of the Local Universe Survey**
  - 8500 sq deg – 0.8m telescope @ Cerro Tololo – 12 bands – start: Dec 2016

JPCam to go on the 2.5m telescope in JAVALAMBRE



J-PAS = ALL SKY IFU

Original motivation: you don't need spectroscopic redshift precision to measure the BAO scale; 0.003(1+z) photo-z are enough (Benitez et al 2009

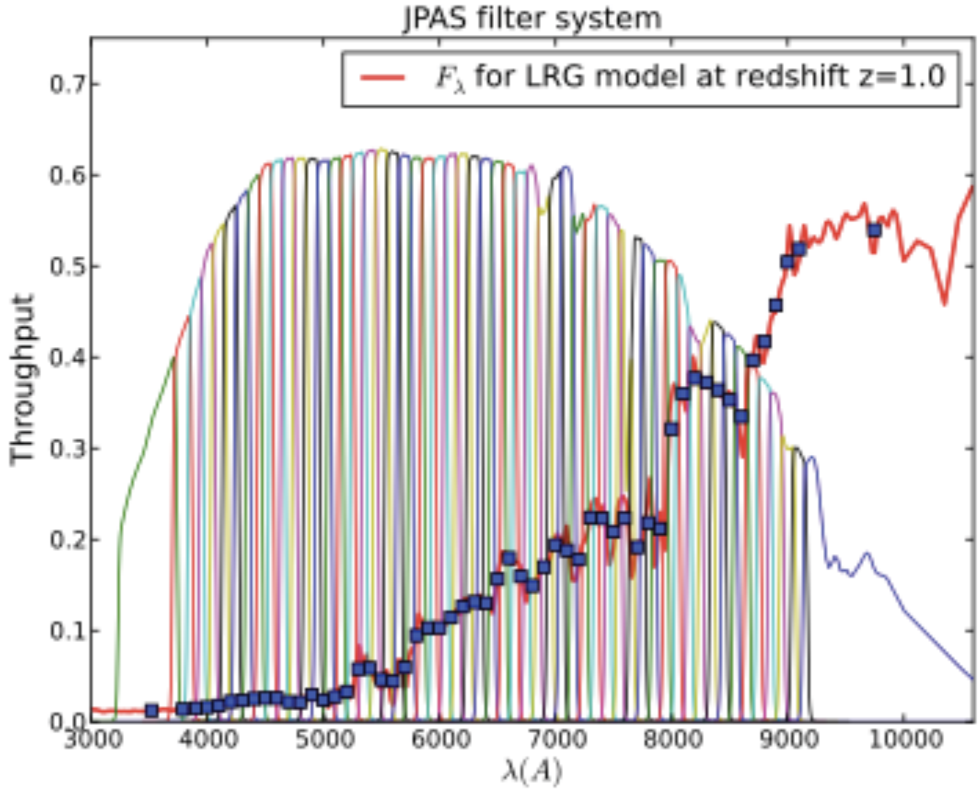
Javalambre Astrophysical Survey:

*Competitive in all "canonical" Dark Energy probes

- BAOs+LSS
- SNIe
- Cluster Counting
- Weak lensing

*Unique data for every other major area in Astrophysics Galaxy Evolution, the Galaxy, Solar System

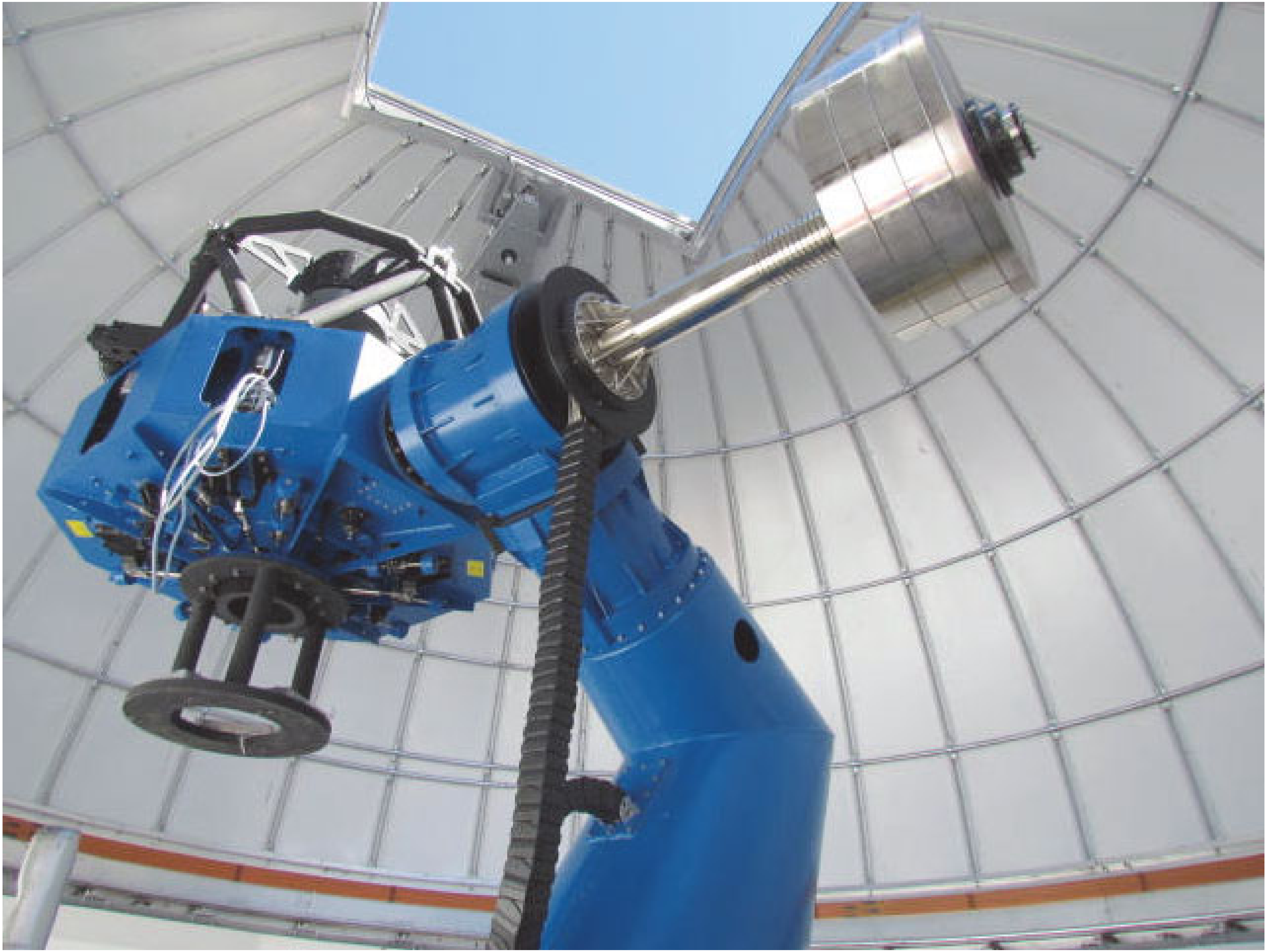
see Benitez et al. 2013



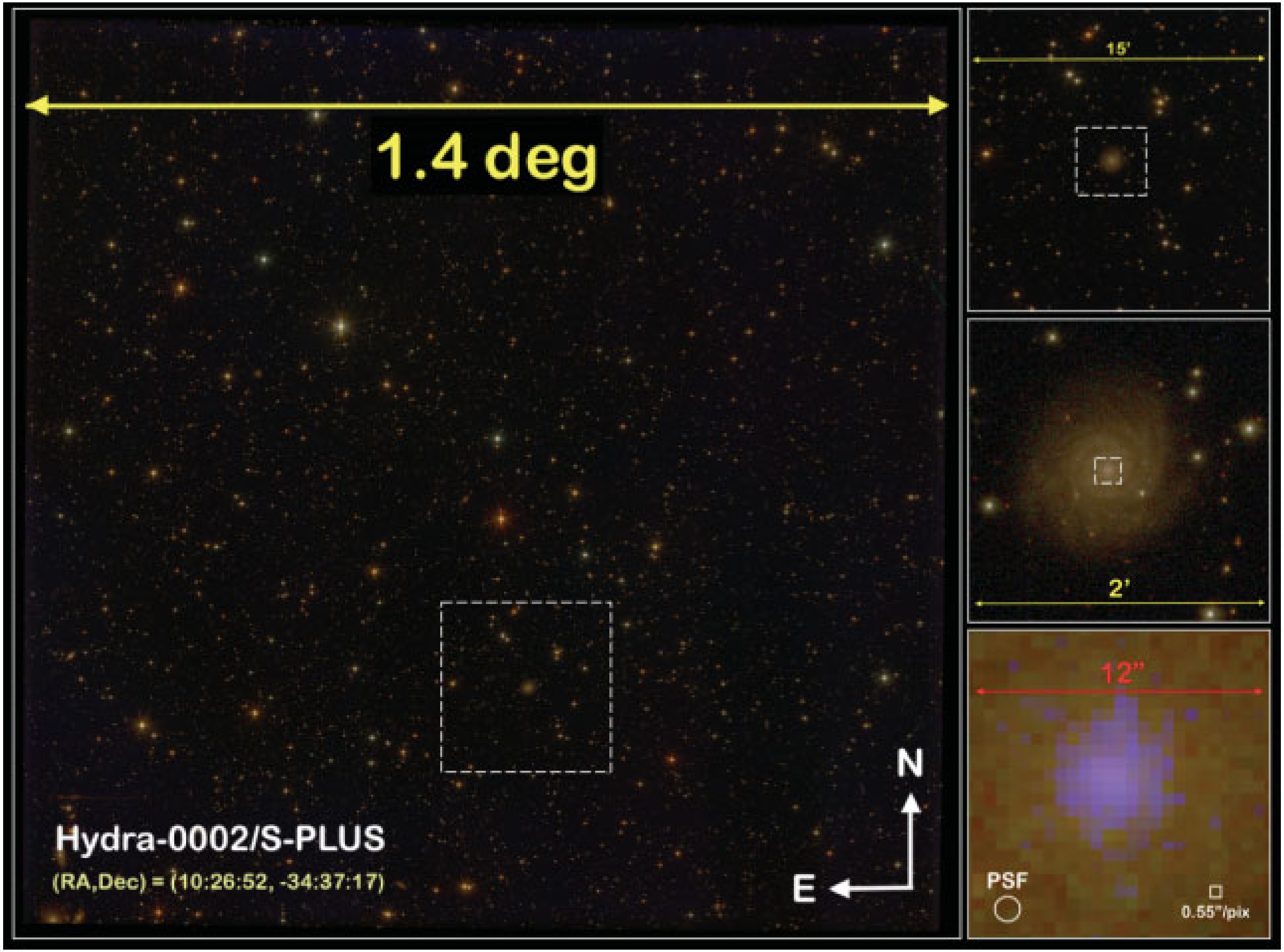
54 NB filters, 5 BB filters
240-480s exposure
8500 sq.deg.

T250 and T80-North
Javalambre - Spain

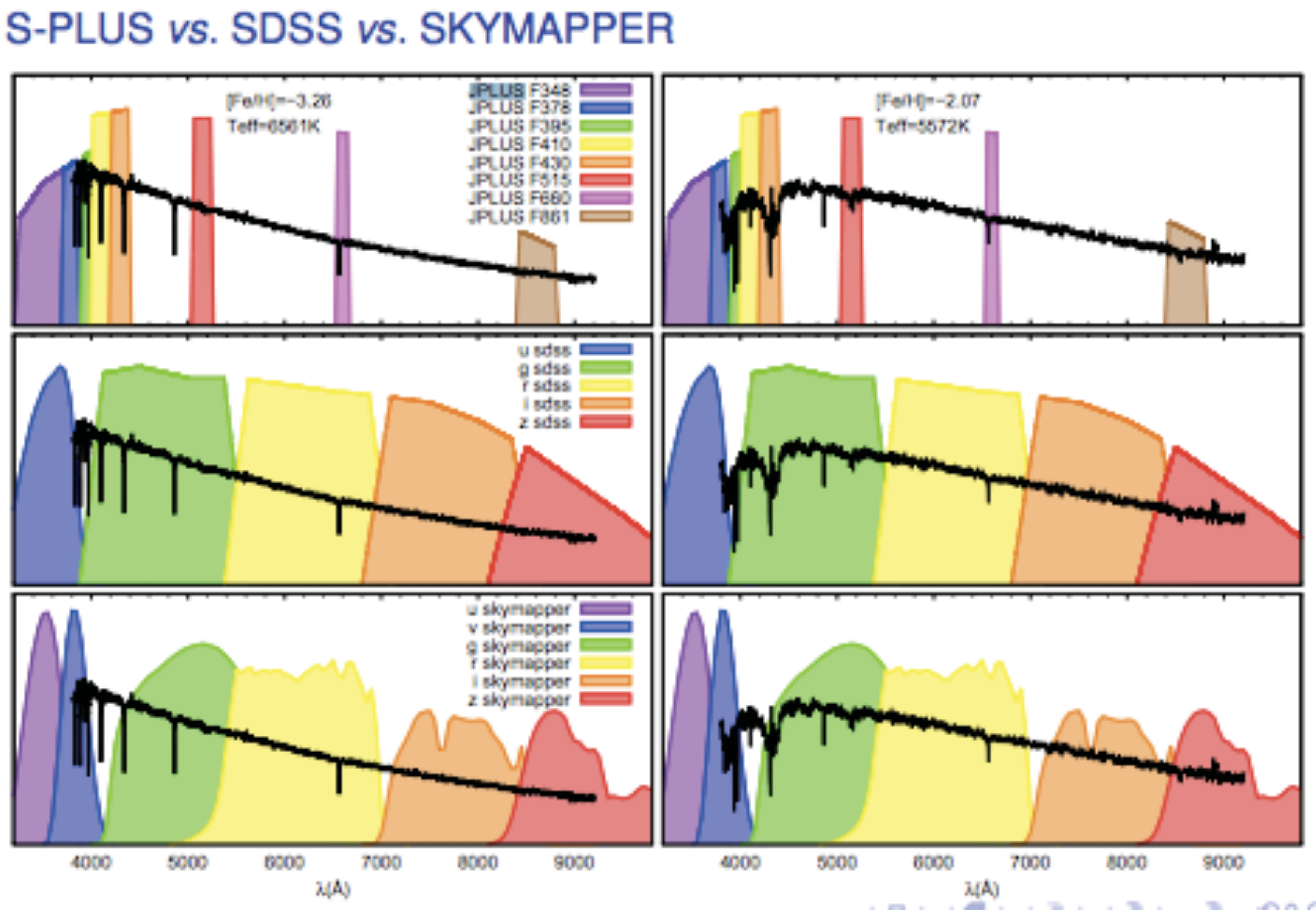

T80-South
-PLUS
survey

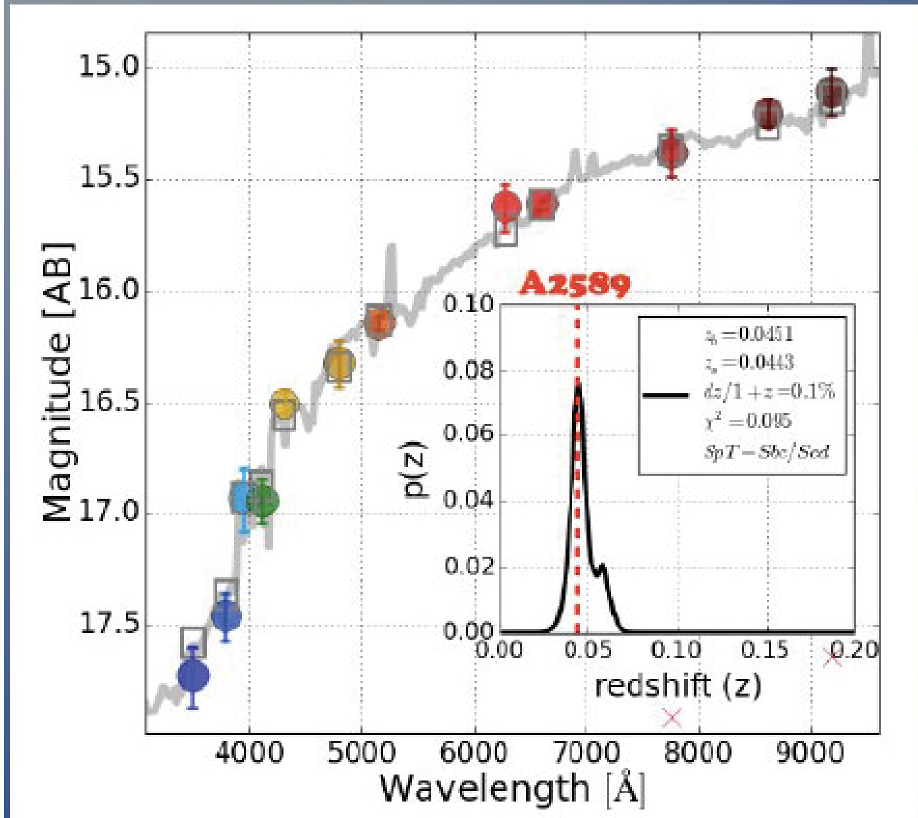


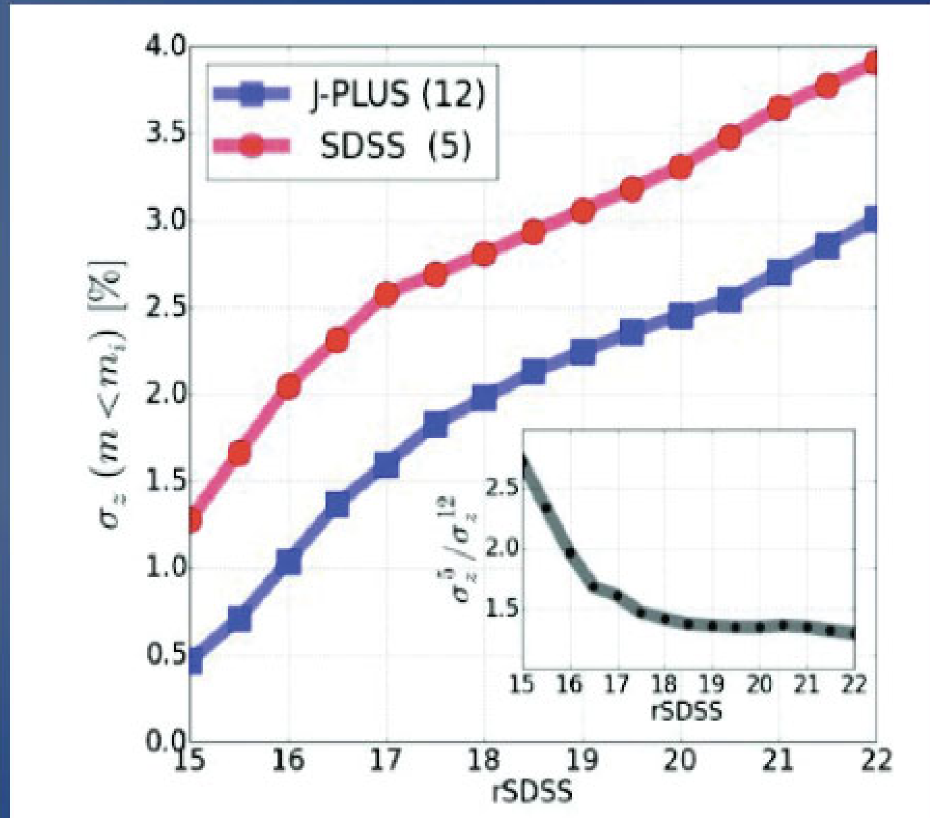
Field of view of T80-South images



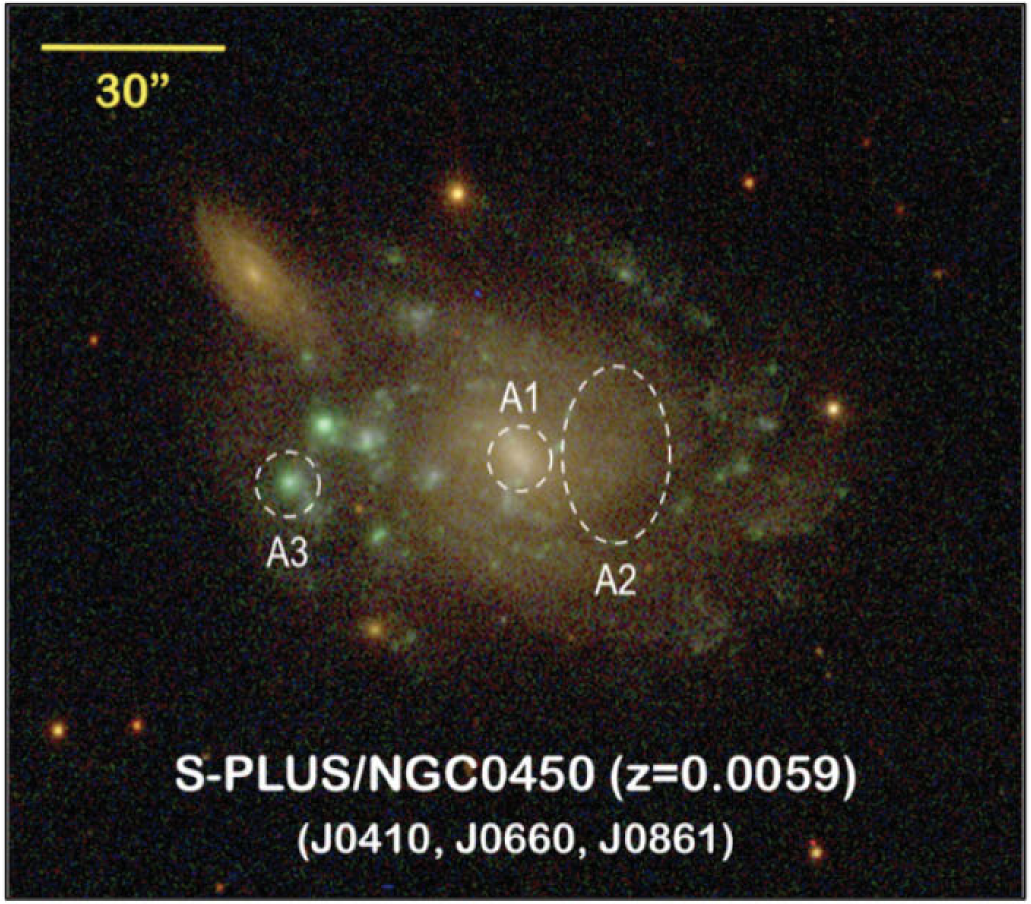
Searching for metal poor stars

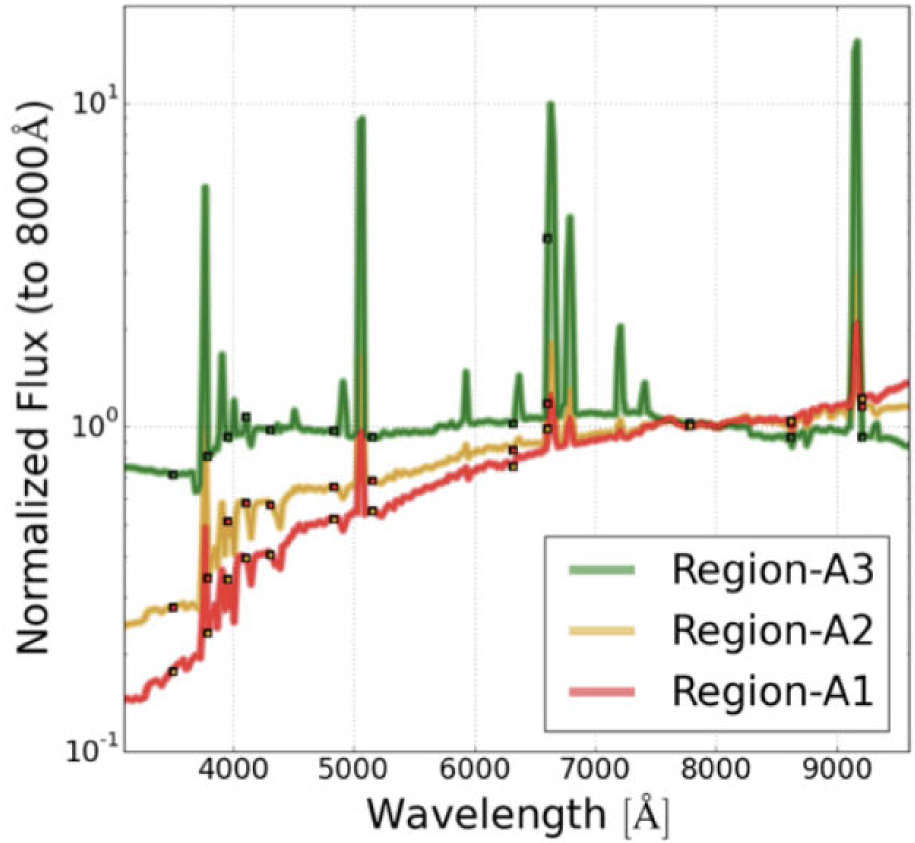



A2589
Magnitude [AB]
Wavelength [Å]
p(z)
redshift (z)
$z_b = 0.0451$
$z_s = 0.0443$
$dz/1+z = 0.1\%$
$\chi^2 = 0.095$
$SpT - Sbc/Scd$


J-PLUS (12)
SDSS (5)
$\sigma_z\ (m < m_i)$ [%]
rSDSS
σ_z^5/σ_z^{12}
rSDSS

IFU Science


30”
A1
A2
A3
S-PLUS/NGC0450 (z=0.0059)
(J0410, J0660, J0861)


Normalized Flux (to 8000Å)
10^1
10^0
10^{-1}
4000
5000
6000
7000
8000
9000
Wavelength [Å]
Region-A3
Region-A2
Region-A1

GMT-related projects

Current instrumentation projects GMT

- SE, GMACS
- Optical design, GMACS
- SW architecture, GMACS
- MANIFEST (GMACS interface)
- AO for G-CLEF (simulations and fiber-optics performance)

GMT Brazil Office
28 people

12 young engineers (SE, optics, optomechanics,software)
2 graduate students
Several undergraduates

1	João Steiner	PI Professor	Astronomer
2	Claudia Oliveira	PI Professor	Astronomer
3	Laerte Sodré	PI Professor	Astronomer
4	Augusto Damineli	PI Professor	Astronomer
5	Eduardo Cypriano	Professor	Astronomer
6	Roderik Overzier	Visiting Professor	Astronomer
7	Priscila Pires	FAPESP fellow	SE + Mech.Eng
8	Renato Borges	FAPESP fellow	SW
9	Beatriz Pereira	FAPESP fellow	SW
10	Tarcio Vieira	FAPESP fellow	Optician
11	Daniel Faes	FAPESP fellow	SE
12	Leonildo Azevedo	FAPESP fellow	SW
13	Aline Souza	IMT fellow	SE
14	Antonio Braulio	IMT fellow	SE + Mech.Eng
15	Daiana Bortoleto	IMT fellow	SE
16	Mario Almeida	UniVap fellow	SE
17	José Paschoal	UniVap fellow	Manager
18	Alexandre Bortoleto	Retired Professor	SE
19	Denis Andrade	USP staff	Elec.Eng
20	José Godoy	USP staff	Adm.Assist
21	Henrique Volpato	USP MSc student	Astronomer
22	Rafael Ribeiro	USP PhD student	Optician
23	Henrique Ortolan	AAO visitor	Mech.Eng
24	Alain Launay	Consultant	Manager
25	Clovis Pereira	Consultant	Ind. Liaison
26	Damien Jones	Consultant	Optician
27	Keith Taylor	Consultant	Optician
28	Amanda Santana	GMTO staff	SE

Main Partner Institutions:

IMT
Univap
UFABC
LNA

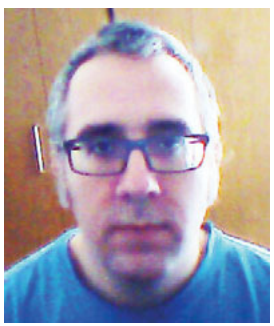
Four very recent hires:

Renato C. Borges is a software engineer, worked for 3 years (till 2017) in LAM, Marseille, and Paris developing reduction software for Fabry-Perot data and Subaru/PFS, to work with Software for one of the GMT instruments (starting with GMACS).

Márcia Beatriz Pereira Domingues has a bachelor in Computer science, Master in Electrical Engineering, PhD in Computer Engineering , and is currently working on SAMPLUS project.

Antonio Braulio Neto is a Mechatronic Engineer with experience in mechanical design, 3D modeling, and finite element analysis. He is a student in master program at USP about computational fluid dynamic, and is currently working on GMACS project.

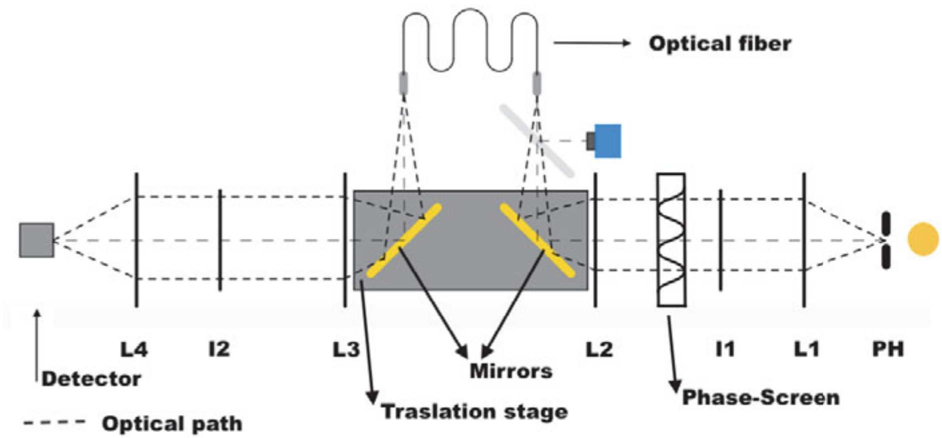
Tárcio A Vieira has a bachelor in Physics. He did Master and Phd degree in Applied Optics. Currently is working in the project of SOAR Adaptive Module (SAM) upgrade from SOAR telescope.

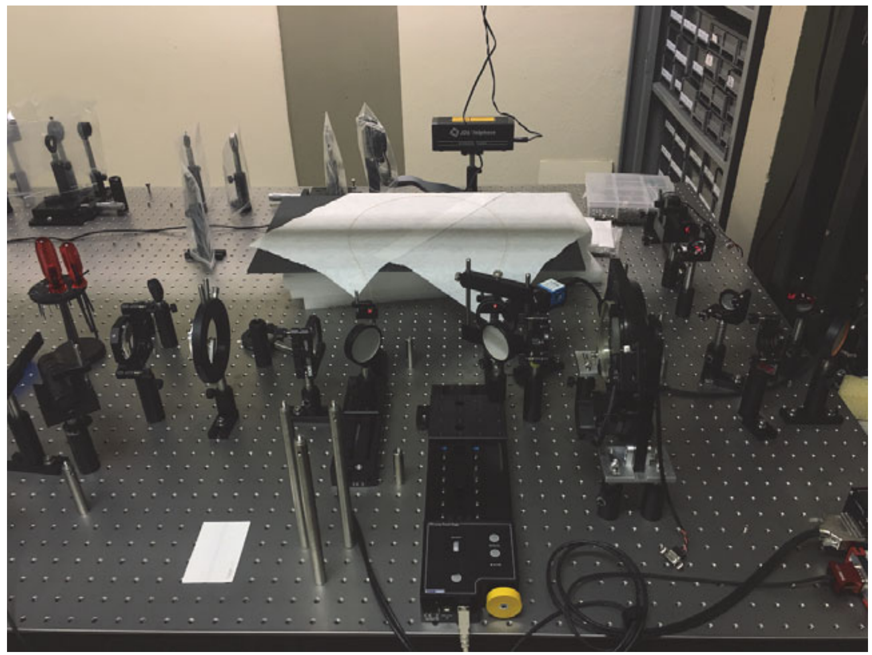


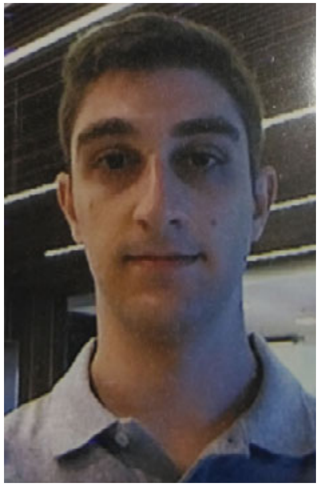

Henrique Volpato

G-CLEF Fiber Focal Ratio Degradation Experiment : Adaptive Optics Impacts

- The ultimate goal is to investigate the capability and advantages of G-CLEF as an Adaptive Optics (AO) instrument;
- Optical bench experiments comparing systems with and without AO;
- All info about atmospheric aberration, with and without AO, lays in two different phase-screens that simulate those conditions;
- Currently measuring FRD (focal ratio degradation) for G-CLEF's fibers response to AO.



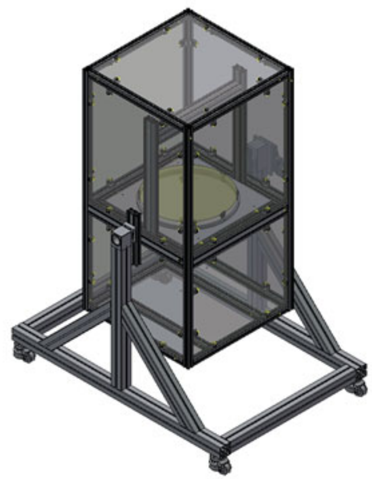




Bachelor in Mechanical Engineering, currently working in IAG – USP and internship in AAO (February to June 2018).

Henrique Ortolan

- Working on the Invert Bug Catcher project (supervisor David Brown).
- Designing a mechanism that accepts replaceable experimental modules that will prototype autonomous inverted adhesion, based on already existent design.
- Install this mechanism in the small test rig, already existent in the AAO.
- Tests with the adhesion of the Bugs on the glass field plate, that simulates the edge of the 1.3m R3275 field plate.



Small Test Rig – Source: AAO

Institute Maua of Technology (software)

- CoRoT mission (2004-2006): flight software validation at Paris Observatory - LESIA - grant from Capes and CNRS.

- CoRoT mission (2006-2010): development of signal processing algorithm applied to the exoplanets channel, developed with the instrument scientist Michel Auvergne - Grant from Fapesp - CNRS.

- Plato Mission (2010 - now): real time camera emulator (software and hardware) - grant from IMT and ESA.

- Hires (2016 - now): software specification for technical cameras (TDCS) - ESO phase A - grant from IMT and ESO.

Systems engineering and Astronomical Instrumentation

- SE is a powerful method to develop complex systems.
- After years used in space astronomy, it is reaching ground-based astronomy.
- It is the standard to improve schedule, cost and requested science for **big experiments**

- **Advantages:**
- **UFMG SE 6-year undergraduate course is a source of excellent professionals**
- **INPE, our space research institute, has used SE and it is a source of professionals and consultants**

System Engineering role

From GTMO SE Management Plan:

The SEMP is the ***foundation*** *document* ***for the technical and engineering activities*** *conducted during the GMT Project.*

[GMTO] strongly recommends that instrumentation groups ***fully integrate into the GMTO SE system****.*

"Systems engineering is an **interdisciplinary field** of engineering and engineering management **that focuses on how to design and manage complex systems** over their life cycles."

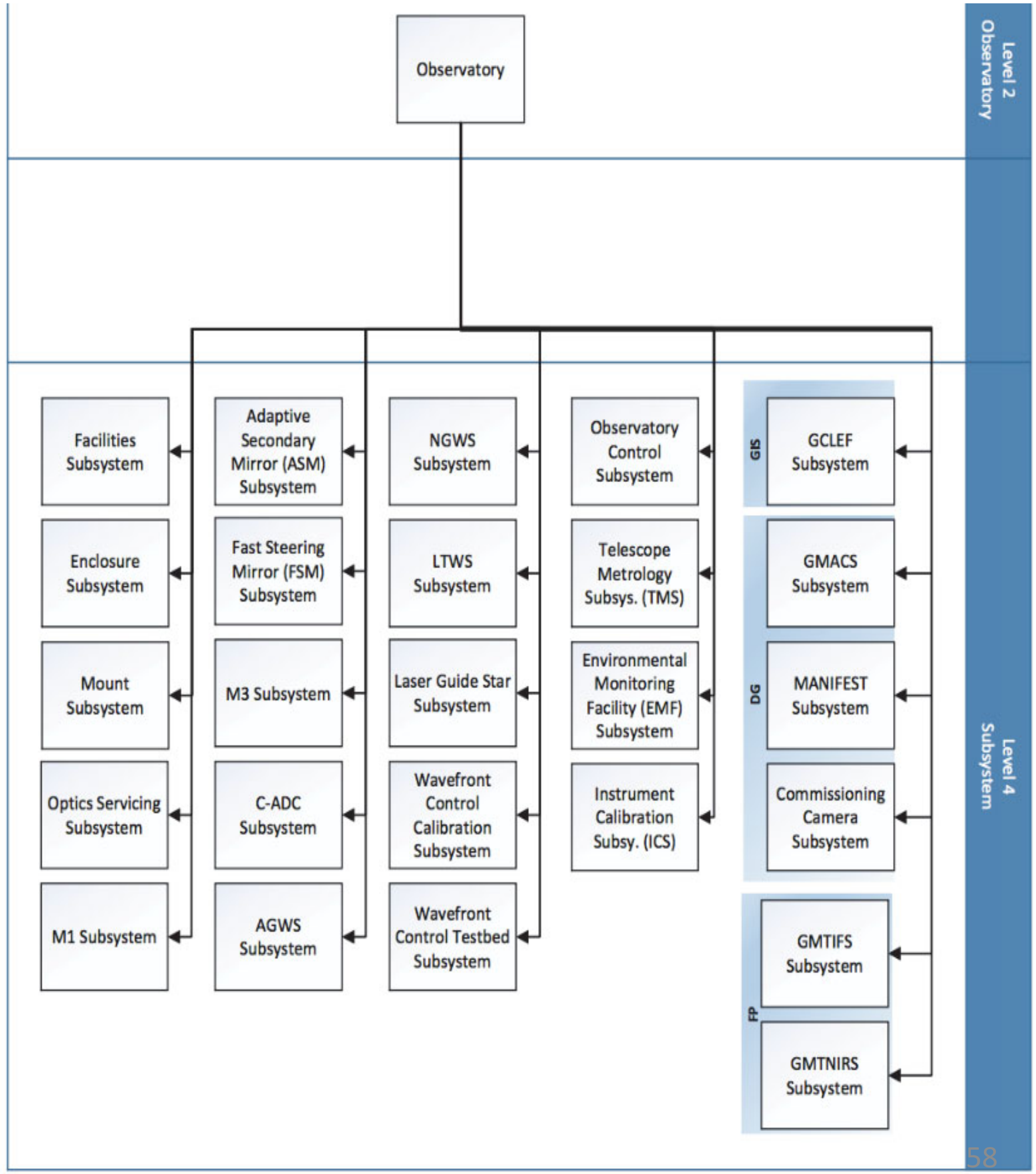


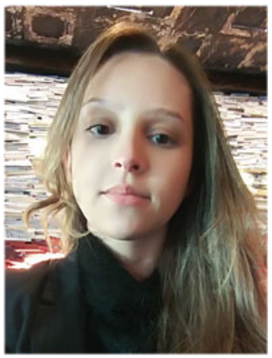
Figure 4-1: GMT-Top-Level Product Breakdown Structure

Current projects involving Systems Engineering (with Brazilian collaboration)

- SAMplus
- GMTO
- GMACS
- MANIFEST

Priscila

Daiana



Aline

Mario

Daniel

These are the members of the SE group which also includes the Mechanical engineer Antonio Braulio and optical physicist Rafael Ribeiro.

Systems Engineering of GMACS

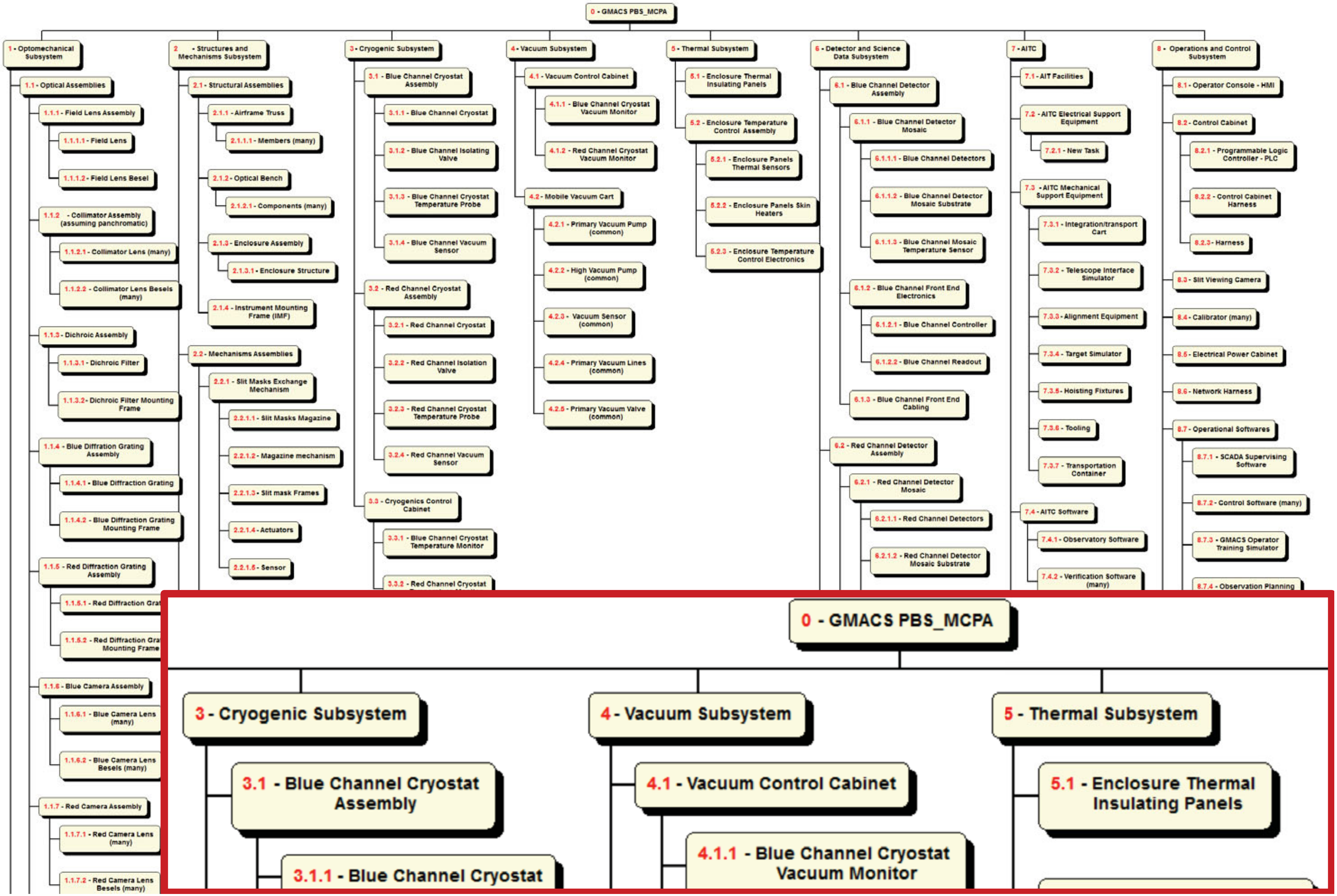
Team responsibilities:

- Application of GMTO's SE Manag. Plan
- Requirements Management
  - Sci-Reqs revision
  - Instrumentation level reqs
    - Follow-down
- Risk Management
- OCDD (Operations Concept Description Document)

Shared responsibilities with PM:

- PBS and WBS definitions
- Information and Configuration Management
- Issues tracking
- Trade-off studies metrics

PBS study for GMACS



WBS study for GMACS