Status & Plans for IFS capabilities at the SPM Observatory

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Galaxy Structure and Evolution through Integral Field Spectroscopy:
the next generation surveys

Tonanzintla, Puebla, July 15-26 2013

Situation in a nutshell

- At present, there are no IFS facilities at SPM
  - just Long-Slit spectrographs and a scanning FP
  - but Mezcal (single-order Echelle) has a MOS mode
- A planed 6.5 m telescope ($SPMT_6$) will have, since day one, a suite of IFS capabilities (existing now on MMT)
  - 300 fiber high and medium R spectrographs and a new low-R MOS instrument
- At the moment, there is no plan for IFUs for this or any other SPM telescope
- So, let´s start here to contemplate such an idea

Contents

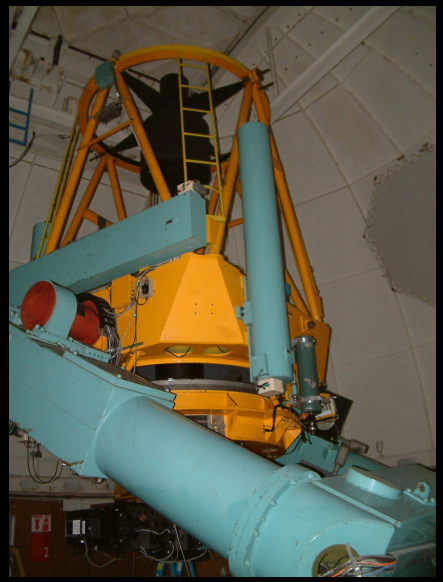
- The San Pedro Mártir site & Observatory
- SPM development with respect other sites
- Ongoing projects
- The 6.5 m Telescope Project

- Discussion on IFS Science niches for instruments perspectives at SPM

San Pedro Mártir Site

Developed & operated as observatory by IA-UNAM over the last 40 yrs

OAN 135 yrs:
Chapultepec (1878) -> Tacubaya (1909)
Tonanzintla (1942) -> SPM (1967)

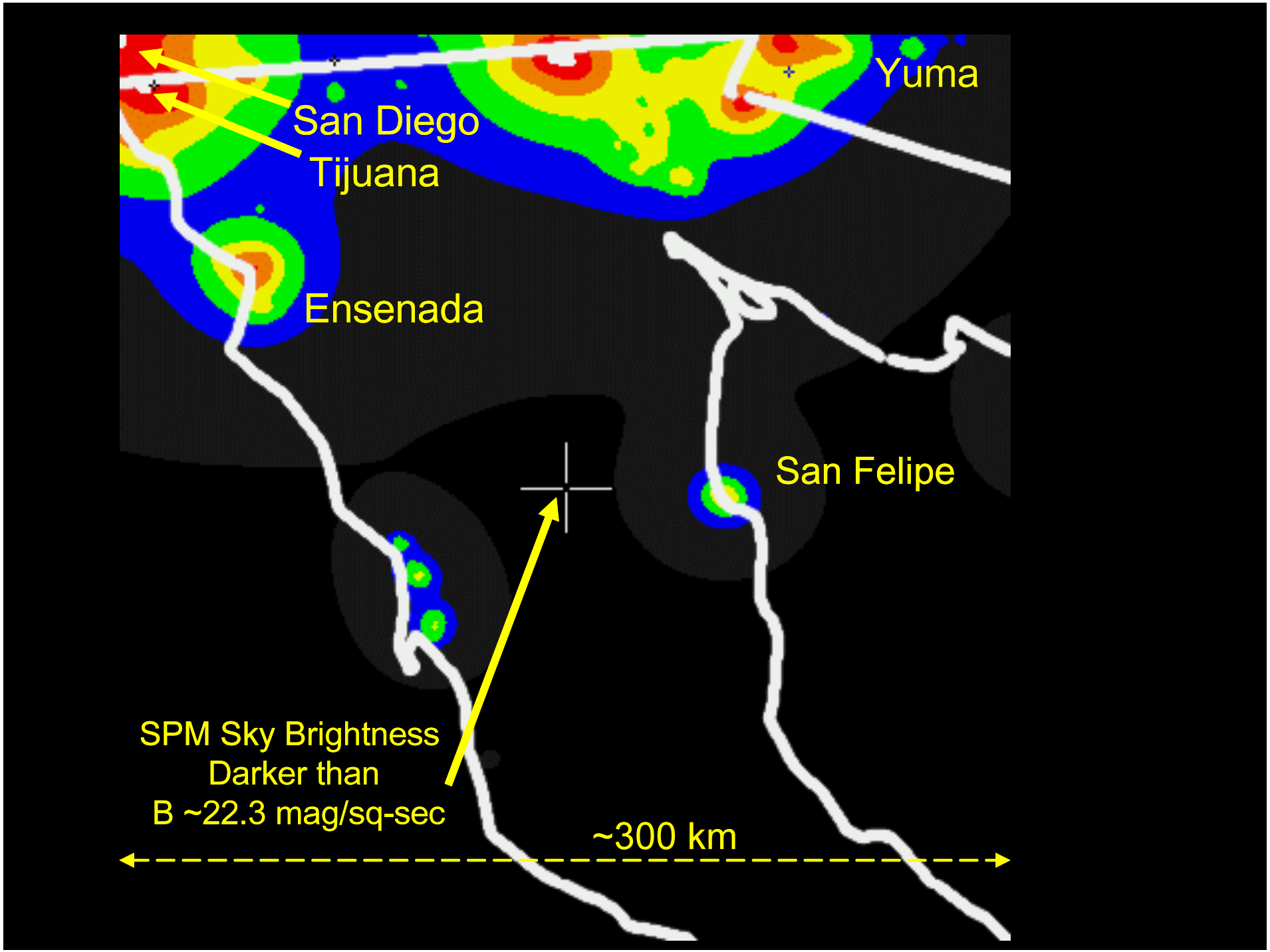


3 main telescopes (2.1m, 1.5m, & 0.84m)

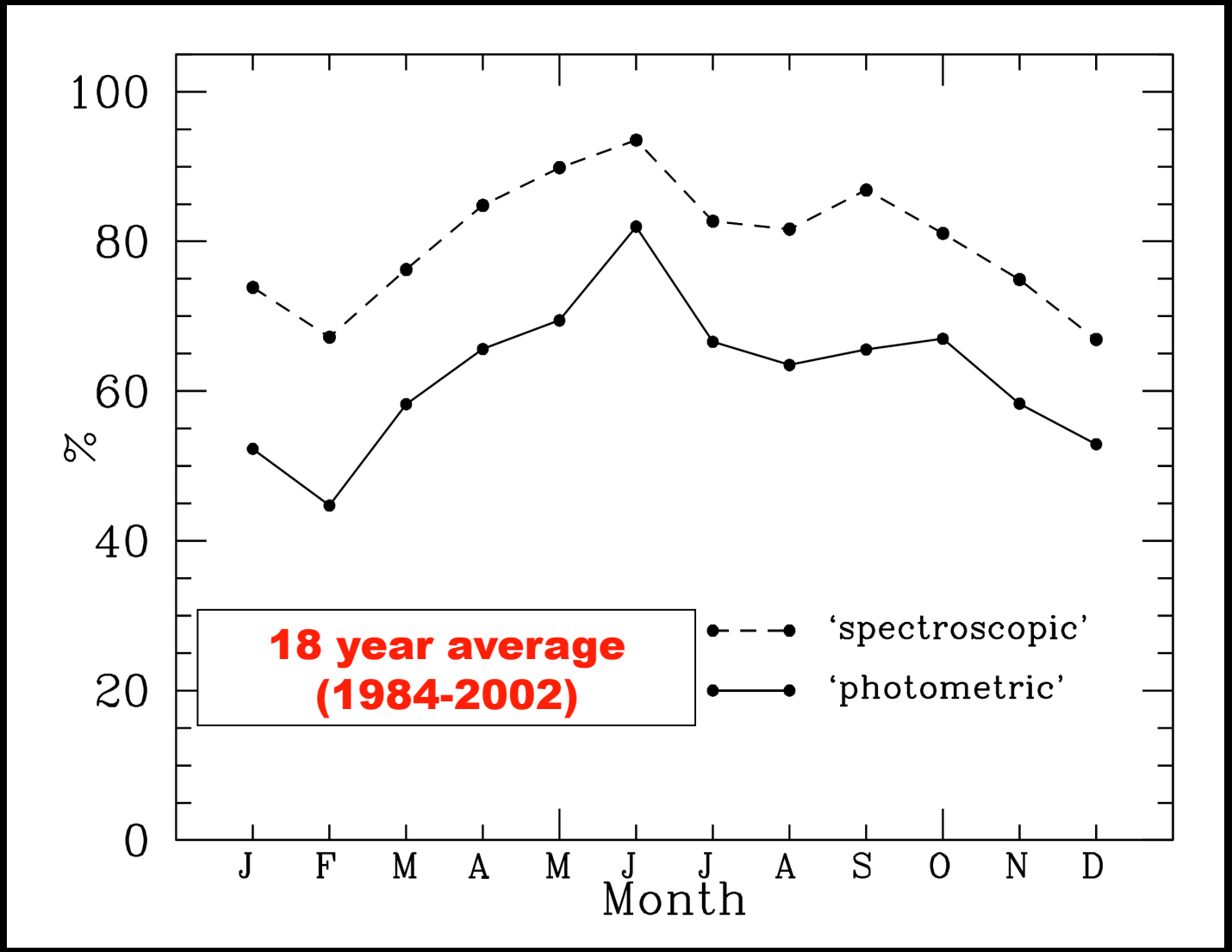
Well equipped with a good battery of instruments (Optical to 25 μm)

SPM: Privileged Astronomical Site

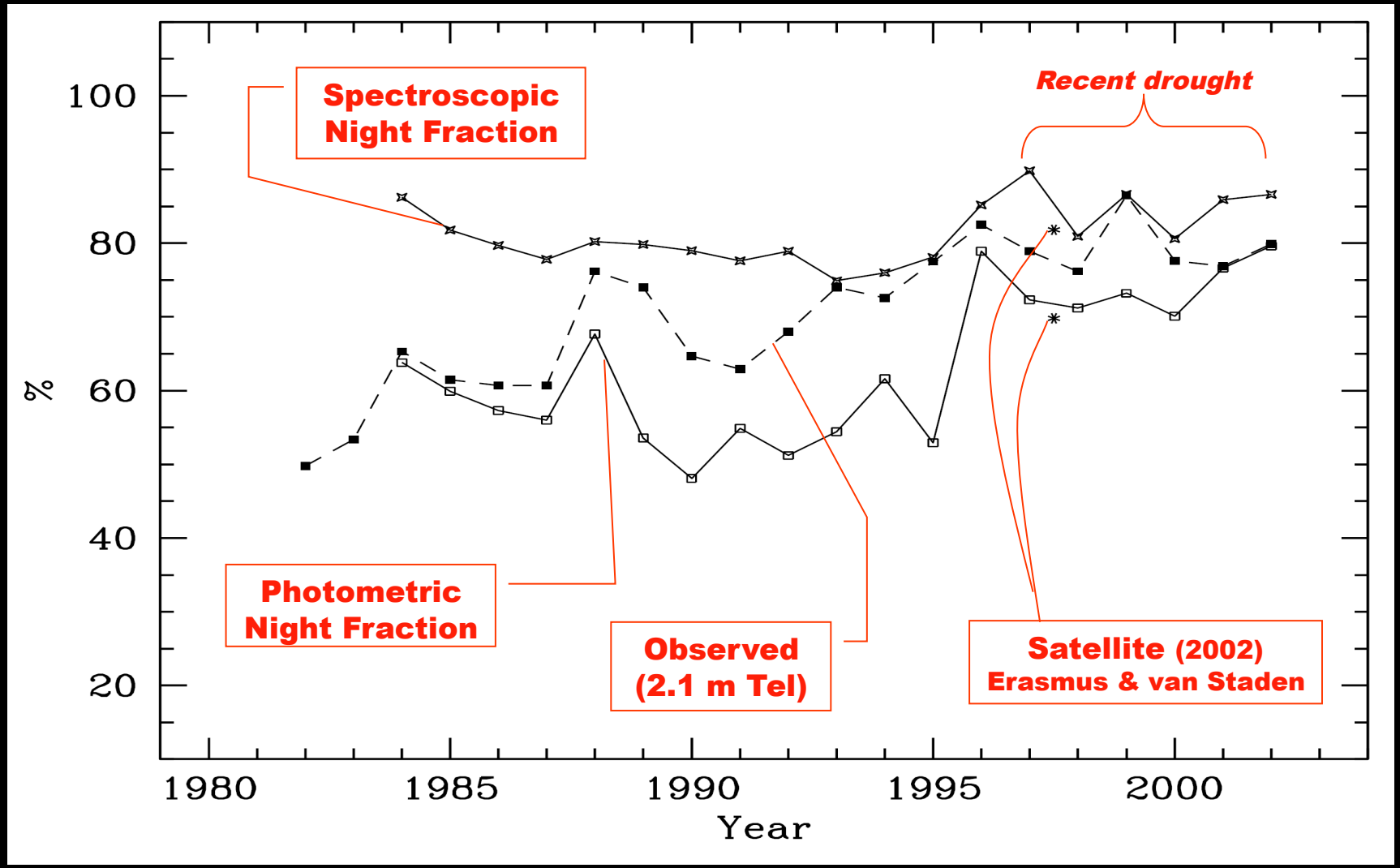
- ✓ Excels in several relevant aspects
  - ❖ Sky transparency and percentage of clear nights
  - ❖ Image quality (seeing) and stability
  - ❖ Sky darkness
- ✓ Reliability:
  - ❖ Statistics baseline spans over 4 decades
  - ❖ Site characterized by independent groups
- ✓ More recently considered and studied by international projects (LSST & TMT)
- ➢ Yet to host new-generation telescopes


Yuma
San Diego
Tijuana
Ensenada
San Felipe
SPM Sky Brightness
Darker than
B ~22.3 mag/sq-sec
~300 km

Seasonal transparency



SPM: Sky Transparency over 18 years



SPM Site Characteristics

Sky Transparency Annual Statistics [a,b]	
Usable nights	80.1 %
Clear nights	73.2 %
Photometric nights	61.3 %

Seasonal Seeing [c]	
Median annual	0.61”
Spring	0.58”
Summer	0.58”
Autumn	0.68”
Winter	0.69”

Sky Brightness [f]	Dark	Bright
U	21.5	19.3
B	22.3	19.8
V	21.2	19.7
R	20.7	19.6
I	19.2	19.4
J	16.4	
H	14.1	
K´	14.9	

Optical Turbulence [g]	
Altitude [km]	Seeing
2-4	0.44”
4-9	0.17”
9-16	0.24”
16-21	0.08”
21-25	0.02”
Surface Layer [h]	0.11”

Mean Water Vapor Content (PWV)	2.63 mm Satellite	2.40 mm Radiometer
Mean Atmospheric Extinction [e] [mag/airmass]	0.14 @ 549 nm	0.055 @ 800 nm
Mean wind velocity [i]	27 +/- 3.6 m/s (GGUAS)	26.5 +/- 1.7 m/s (NCEP)

a) Erasmus & van Staedel 2003, A Satellite Report of Cloud Cover and Water Vapor in the Southwestern U.S.A. and Northern Mexico, Second Report.
b) Tapia 2003, RMxAA(SC), 19, 75: 1984-2002 period.
c) Echevarría 2003, RMxAA(SC), 19, 41; Michel et al. 2003a, RMxAA(SC), 19, 37; Michel et al. 2003b, RMxAA, 39, 291.
d) Hiriart 2003, RMxAA(SC), 19, 90: zenith atmospheric opacity at 210GHz
e) Parrao & Schuster 2003, RMxAA(SC), 19, 81 : 1973-1999 period
f) Richer 2005 in http://haro.astrossp.unam.mx/indexspm.html: 2004-2005 period, units are mag/arcsec.
g) Avila et al. 2003, RMxAA(SC), 19, 11:Generalized Scidar measurements, SPM 2000 campaign.
h) Sánchez et al. 2003, RMxAA(SC), 19, 23 : 15 m mast & simultaneous DIMM, SPM 2000 campaign.
i) Carrasco & Sarazin 2003, RMxAA(SC), 19, 103: 1980-1995 GGUAS & NCEP data sets.

Privileged Optical/Infrared Sites

Northern Chile

Antu	8.2m	Europe
Kueyen	8.2	Europe
Melipal	8.2	Europe
Yepun	8.2	Europe
Gemini	8.1	USA UK Canada Brazil Chile Australia Argentina
Baade	6.5	USA
Clay	6.5	USA
Soar	4.1	Brazil USA
Blanco	4.0	USA 74
"360"	3.6	Europe 77
NTech	3.5	Europe
duPont	2.5	USA 75
MPG-E	2.2	Europe

Construction: 1,200 M$
Operation: 71 M$/yr

Hawaii Island

Keck I	10m	USA
Keck II	10	USA
Subaru	8.3	Japón
Gillet	8.1	USA UK Canadá Brasil Chile Australia Argentina
UKIRT	3.8	UK 79 Canada, Holland
AEO	3.7	USA-AF
CFHT	3.6	Canada France USA 79
IRTF	3.0	USA
UH	2.2	USA 70

Construction: 1,000 M$
Operations: 76 M$/yr

Canary Islands

GTC	10.4m	Spain México USA
Herschel	4.2	UK Spain Netherland
Galileo	3.6	Italy Spain
Newton	2.5	UK Spain Netherlands
Nordic	2.5	Denmark Island Norway Finland Sweden
Liverpool	2.0	WW Us

Construction: 300 M$
Operations: 15 M$/yr

San Pedro Mártir

SPM	2.1m	México 79
SPM	1.5	México
SPM	0.8	México

Construction: 5 M$
Operations: 1.0 M$/yr

Construction Investment: Telescope plus building <u>without instrumentation</u>
Operation costs (based on 2006 annual reports) : Only Optical/IR telescopes considered
Excluded radio, Solar, High-Energy, etc, as well as budget & developments away from observatory or at administrative or research centers of the consortium or partners

Telescopes at other sites (Optical/Infrared)

Continental USA

HET	9.2	USA Germany
LBT	2x8.4	USA Italy Germany
MMT	6.5	USA
Hale	5.0	USA 48
Mayall	3.4	USA 73
ARC	3.5	USA
WIYN	3.5	USA
Starfire	3.5	USA Military
Shane	3.0	USA 59
H. Smith	2.7	USA 68
Hooker	2.5	USA 17
SLOAN	2.5	USA Europe Japan
CHARA	2.4	USA France
MRO	2.4	USA
Hiltner	2.4	USA
WIRO	2.3	USA
Bok	2.3	USA 69
KP2.1	2.1	USA 61
Struve	2.1	USA 69

Construction: ~800 M$
Operations: ~60 M$/yr

Other sites

SALT	9.8	S. Africa UK USA Germany Poland N. Zeeland
Bolshoi	6.0	Russia 76
LZT	6.0	Canada USA France
LAMOST	4.2	China USA
AAT	3.9	Australia UK 75
MPIA	3.5	Germany, Spain
ByAO	2.6	Armenia 76
Shajn	2.6	Ukraine 76
duPont	2.4	France
Lijiang	2.4	China
ANU	2.3	Australia
V. Bappu	2.3	India
MPIA	2.2	Germany Spain
Beijing	2.2	China
Sahade	2.2	Argentina
HCT	2.1	India
Lyot	2.0	France
Faulkes-S	2.0	Australia

Construction: ~310 M$
Operations: ~40 M$/yr

More Recently

VLT-Int	4+x8.4m	Europe (in Chile)
Keck-Int	2x10	USA (in Hawaii)
LSST	8.0	USA (in Chile)
Lamost	6.4	China USA UK
DCT	4.2	USA (in USA)
VISTA	4.0	Europa (in Chile)
VST	2.6	Europe (in Chile)
Aristarcos	2.5	**Greece**
APF	2.4	USA (in USA)
Pan-STARRS	4x1.8	USA (in Hawaii)
MRO-I	2.4+10x1.4	USA (in USA)

Investment: ~730 M$

Planned

E-ELT	42m	Europe (en Chile o Canarias)
TMT	30m	USA (en Hawai, Chile o SPM)
GMT	24m	USA (en Chile)

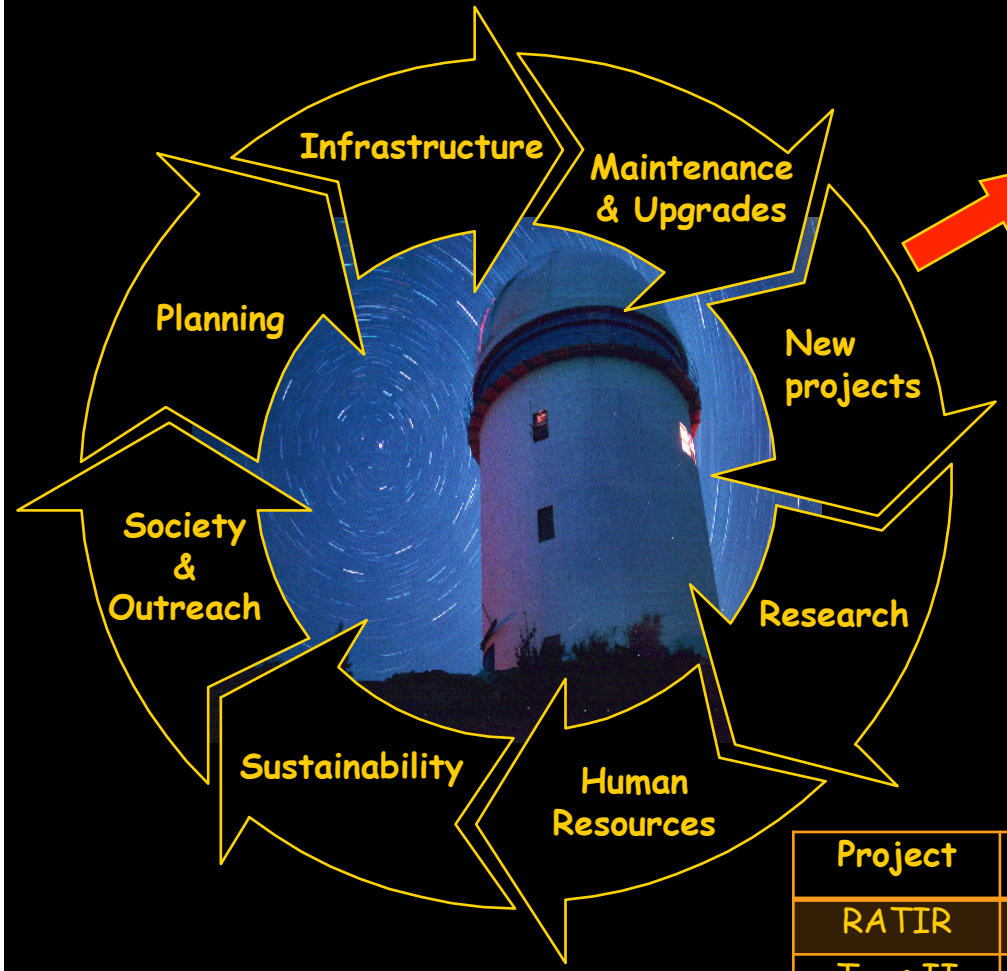
Investment: ~2,700 M$

Infraestructura y Desarrollo en Observatorios Astronómicos

	Sitios de Excelencia				Otros
	SPM	Canarias	Hawai	Chile	(22)
Telescopios grandes (diámetro mayor a 2m)	1	6	11	15	37
Inversión en grandes Tels	5 M$	350 M$	1,000 M$	1,300 M$	1,110 M$
Inversión Acumulada (durante últimos 20 años)	30 M$	3,500 M$	7,000 M$	10,000 M$	3,500 M$
Instrumentos Modernos (desarrollados en última década)	3	15	40	80	100
Presupuesto Anual	1 M$	30 M$	100 M$	150 M$	150 M$
Artículos Científicos por año	10	150	500	800	?
Países Involucrados	1	16	15	25	40

SPM is a Top-Class Astronomical site yet to be exploited...

Action Manifold



World-Class Telescope Scales Considered fot SPM

a) Small Robotic Telescope (1-2m)
- Investment: 1-15 M$
- Timescale: 1-5 yrs

b) Mid-size International Project (4m)
- Investment: 10-30 M$
- Timescale: 2-5 yrs

C) Large International Facility (6-10m)
- Investment: 80-200 M$
- Timescale: 6-10 yrs

d) Giant International Telescope (25-40m)
- Investment: > 1,000 M$
- Timescale: 8-12 yr

Planning,
Infrastercure y Modernization

New International Projects

Project	Status	Partners	Cost	Operate
RATIR	In Opertns	NASA, U. California	1.2 MU$	2012-15
Taos II	Development	Taiwán, EUA	15 MU$	2012-20
Bootes	Development	España, China, Nueva Zelanda	0.5 M€	2013-23
GTF/SVOM	Negotiation	Francia	5 MU$	2014-
CTA	Proposal	27 contries	50 M€	TBD
6.5m Tel SPMT	Planning	INAOE, U. Arizona, SAO, U. California	50 MU$	TBD

- We require upgrading infrastructure to consolidate international projects with external partners (Spain, France, Taiwan, USA, among others)

Present conditions

- In situ energy production with diesel generators
  - -Limited capacity (up to ~250kW)
  - -Environmental risk in transport

- Microwave 2Mbit/s connection.
  - - Limited bandwidth
  - - Stability issues

Joint solution for energy/telecommunications

- Installation of a medium voltage line (~85km)
- Installation of fiber optic along the same structures
- Estimated cost: ~100M pesos (8MUSD)
  - -UNAM
  - -CONACyT
  - -FUNAM (Fundación UNAM)
  - -CFE (Federal Electricity Commission)
- UNAM/CFE contract signed in October 2012 for construction.
- Environmental and technical studies underway
- Planned conclusion for late 2014.

Ongoing and planned projects

- TAOS-II: 3 robotic telescopes. Taiwan-Mexico, 15MUSD. Under construction (groundbreaking last May).
- BOOTES-5: 1 robotic telescope. Spain-Mexico, 1MUSD. Under construction.
- SVOM/GFT: 1 robotic telescope. France-Mexico, 5MUSD, in planning.
- San Pedro Mártir Telescope. Design, construction and operation of a 6.5m. USA-Mexico. 100MUSD. In planning.

- Cerenkov Telescope Array. Design, construction and operation of an array for high energy astrophysics. 28 countries (incl. Mexico), 50MUSD. Site selection in process, SPM is a candidate site.

The 6.5 m SPM Telescope

- Long effort through three initiatives:
  - SPM-Twin (2004-2008), México, Korea, Princeton, UK
  - SASIR (2008-2011), México, California, Arizona
  - $SPMT_6$ (2011-), México, Arizona, Harvard-SAO

SPM-Twin (2004-2008): Complementary 6.5 m Telescope Pair

Wide Field Telescope (WFT)
(Modified Magellan/MMT)

- Optimized for massive multi-object Spectroscopy (MOS)
- Field of view: Φ ~1.5° diameter
- Operation: 0.36 -1.8 µm

- Spatial resolutions:
  - Seeing limited (NB imaging)
  - ~ 1"-3" Spaxel sampling
- Spectral resolutions:
  - R>~4000 (MOS/IFS)
  - R<~1000 (NB imaging)

- 1st - Generation Instrumentation:
  - Full MOS set: WF+ADC, dIFUs and spectrographs, for maximal field sampling (~10^4 spaxels)
  - Wide-Field Narrow-Band imager (Tunable Filter FP)

AO-IR Telescope (SFT)
(Optimized Magellan/MMT)

- General Science with IR Optimization and AO ready
- Fields: Φ~15' and Φ ~1' (AO)
- Operation: 0.4 - 24µm

- Spatial resolution:
  - Seeing limited to
  - Diffraction limited (AO)
- Range of spectral resolutions

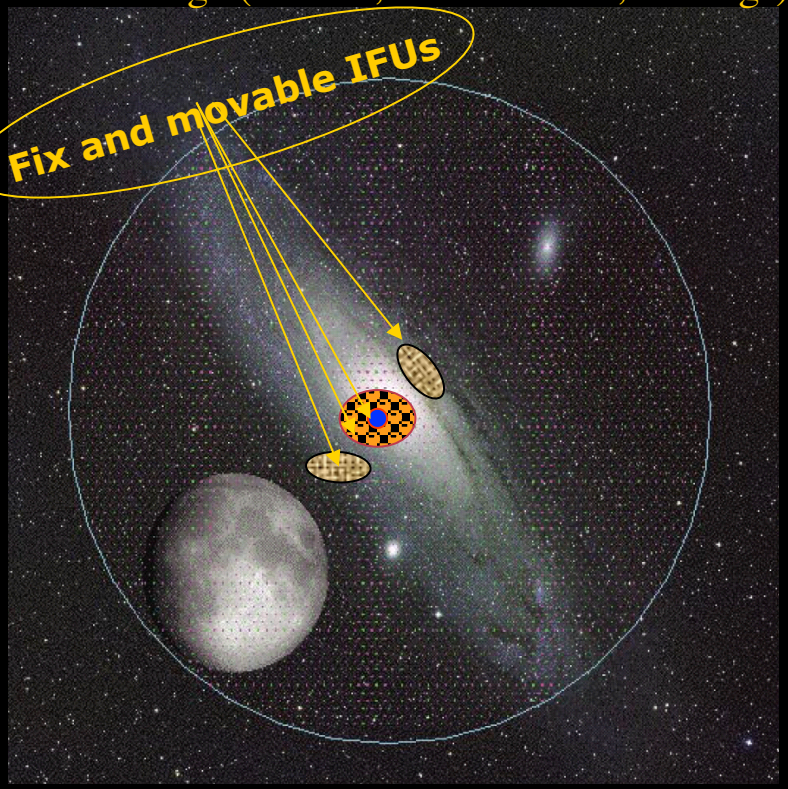
- 1st - Generation Instrumentation:
  - Secondary set (Nas, Cass, AO)
  - High-R optical & NIR spectrographs
  - NIR/AO science instrument
  - Mid-IR New-generation instrument

- Guest & replicated instruments

SPM-Twin (2004-08): Wide-Field Sampling & Integration (complementary limitations)

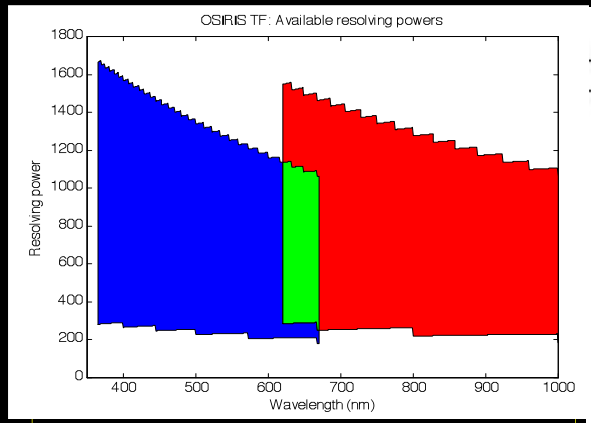
1.5° Field of View (5400") = 1.77 square degrees
Lots of sampling elements ("spaxels"): 2.4×10^7 squared arcsecs

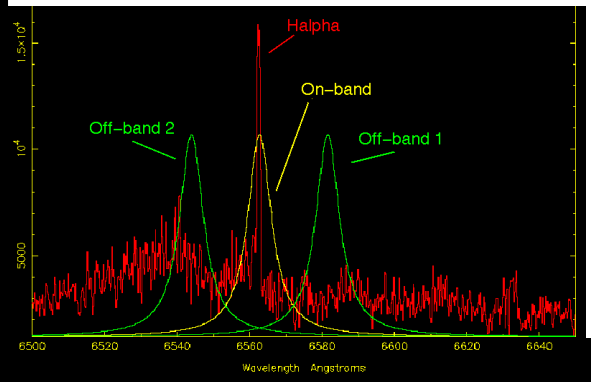
a) Full wavelength range with well-chosen spatial coverage (d-IFUs, fiber-bundles, starbugs)

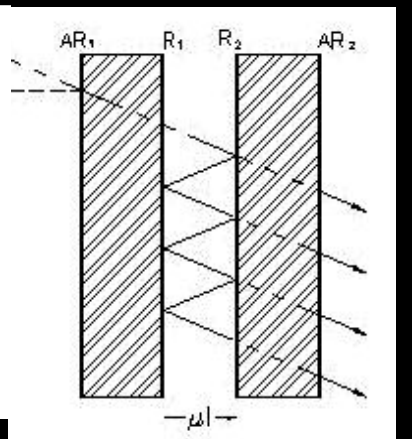


K.A.O.S. Purple Book 2002

b) Full spatial coverage with a finite wavelength range (WFT tunable imager)







$m\lambda = 2\mu l \cos\theta$

$R = mN$

$dR/R = dm/m = dl/l$

R: 100 - 1000

m: 4 – 40

l : 1.5 – 15 μm

GTC-OSIRIS

SPM-Twin WFT:

3 Spaxel Distributions for Spectroscopy

High-Z & Stellar objects

a. *Super sloan-like surveys (DE, LSS, etc. basically redshifts)*
b. *Stellar surveys (thick disk, Local Group systems)*
c. *GC & PN systems*
d. *HII Regions in local galaxies*

Very large number of individual spaxels (sparse sampling) with limited patrol fields each)

The Intermediate-z Universe and semi-crowded fields

a. *Indicative galaxy dynamics, gradients and size*
b. *Indicative structure (notches, pair interaction, etc)*

A number of relatively small IFUs (sparse with limited-continuous sampling), relatively large patrol fields

The "local" 150 Mpc Universe

a. *Large galaxies*
b. *galactic extended sources*

Single Large IFU (continuous sampling), fixed patrol field

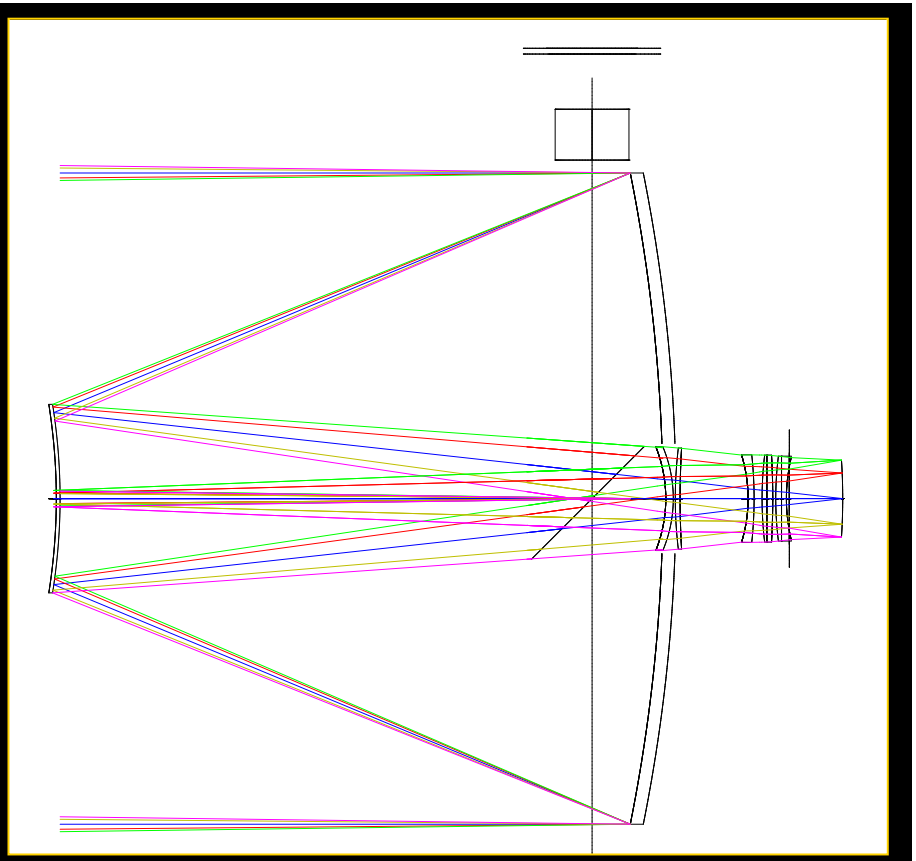
SPM 6.5m f/4.5 WFT

Effective aperture: 6.2 m
M1 to M2: 6.02 m
Plate scale 0.142 mm/arcsec

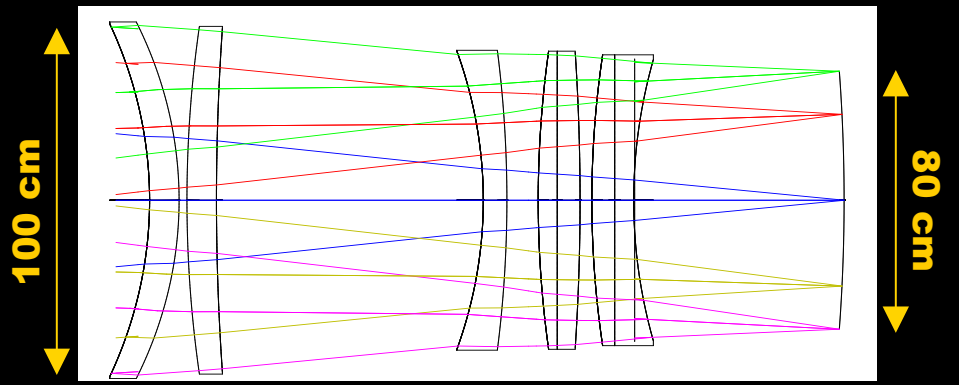
Primary mirror
Conic = -1.07198
Curv. radius = 16,255 mm
Hole diameter ≥ 1,100mm

Secondary mirror
Conic = -3.78412
Curv. radius = 5,813 mm
Diameter: 1.9 - 2m (1.°5 - 2° fields)

WF+ADC Field
3 silica lenses
(all-spherical surfaces)
ADC: 2 double prisms
Largest lens (Silica meniscus)
Aperture: 1.03 m (1.°5 field)
1.25 m (2° field)
Thickness: 75 to100 mm
Curv. radii: 1.5 m & 4.0m (front, back)



WFC Lenses: 3 Silica (all spheres)



ADC Double prisms: 2 (K10 + N-Pk52A)

Proyecto y Consorcio Internacional

Inversión: 160 Millones de dólares

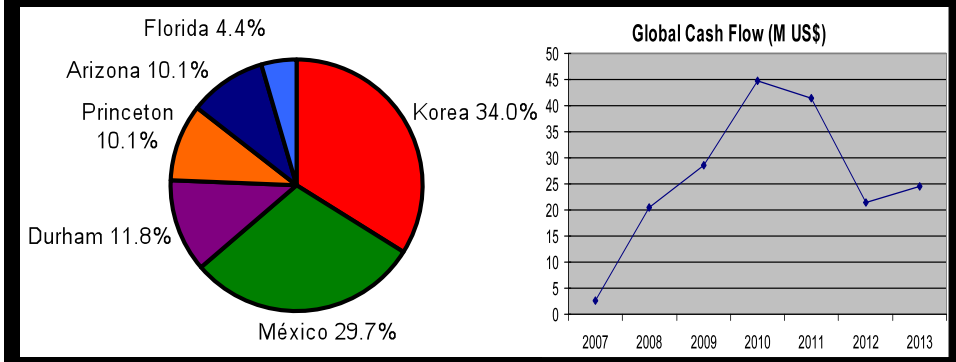
Desarrollo: 2007-2013

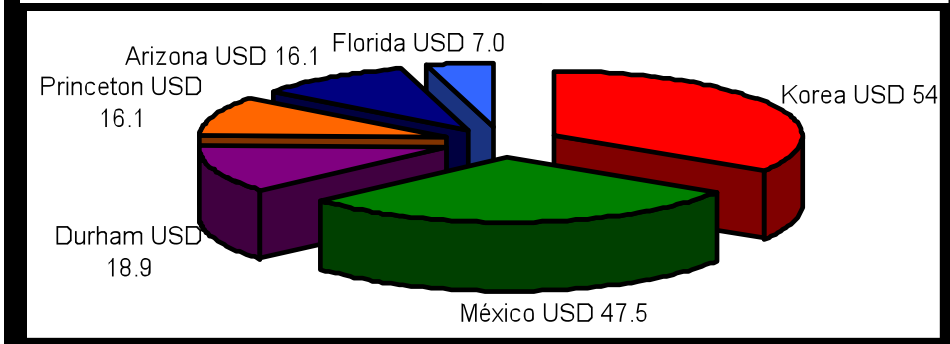
Vida operativa: >30 años (revisión por década)

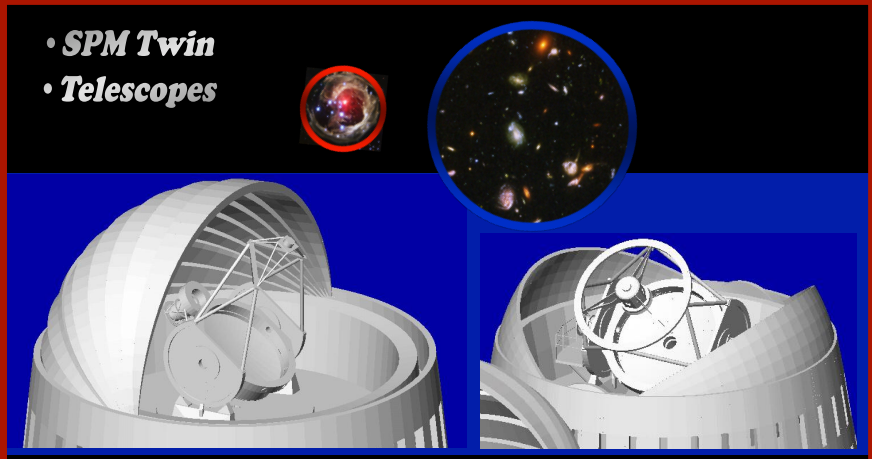
Solicitado: 48 millones de dólares

Concurrente: 112 millones de dólares

Consorcio Internacional: México, Corea y Universidades de EEUU e Inglaterra







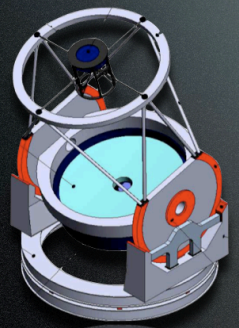
SFT Budget	
Feasibility Study	0.125
Conceptual Design	0.300
Science definition	0.500
Management	2.770
System Engineering	2.750
Civil Engineering	10.700
Telescope	10.290
Optics	16.390
Coating	0.750
Control System	8.000
Instruments	23.250
Total	75.825
Contingency (15%)	11.374
TOTAL	87.199

WFT Budget	
Feasibility Study	0.125
Conceptual Design	0.300
Science definition	0.500
Management	2.770
System Engineering	2.750
Civil Engineering	10.700
Telescope	10.290
Optics	22.990
Coating	0.750
Control System	8.000
Instruments	25.000
Total	84.175
Contingency (15%)	12.626
TOTAL	96.801

SASIR (2009-2011)

SASIR Vision in a Nutshell

6.5 meter telescope (Magellan inspired)



- **site:** San Pedro Mártir (SPM), Baja California
- **Filters:** *Y, J, H, K* (3 dichroics)
- **Detectors:** 124 2k × 2k IR arrays
- ~1.05° diameter field of view
  - ➡ 2 sq. deg. on-sky
- autonomous/robotic surveying
- **Survey:** cover entire sky in ~2-3 months; 4 year survey
  - "shallow" (~2.5 π; 6-12 visits)
  - "medium" (0.5 π; ~200 visits)
  - "deep" (~1000 sq deg; 10^3+ visits) surveys
- $195M (15% contingency)
  (includes $29M for 2nd generation instrumentation)

New Phase Space:
Aperture + wavebands + Field of View + Time

Multi-threaded Science Goals

"Static" Sky
- **Unveiling the Lowest Temperature Neighbors:** finding the local brown dwarf & Y dwarf population (candidates for exoplanet imaging)
- **Probing the Epoch of Reionization w/ Quasars**

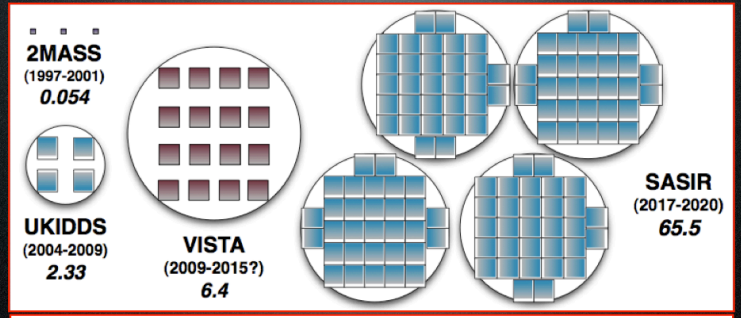
"Transient" Sky
- **Multi-messenger Probe:** Gravity Wave & Particle Counterparts
- **IR cosmology/distance ladder:** supernovae, RR Lyrae, Mira, etc.

[*also: IMF studies, dwarf/dark matter problem & Galactic structure, galaxy evolution studies, galaxy clusters $z > 1$, obscured quasars, fast transients phase space, high-redshift transients (e.g. GRBs), exoplanet transit survey*]

Science Synergies
- adaptive optics grid
- photo-z improvement over optical-only
- discovery engine for GSMTs, JDEM
- high-resolution dust maps (esp. in the Galactic Plane)

SASIR es único en su tipo

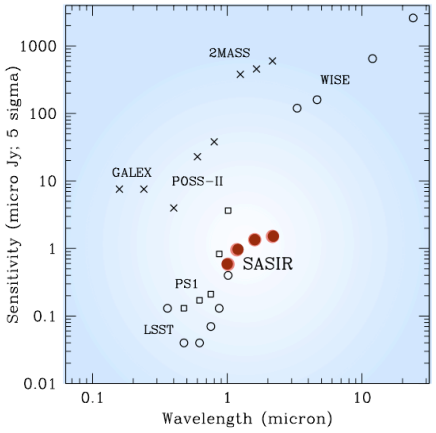
étendue-couleur© (m^2 deg^2 × number of simultaneous bands)

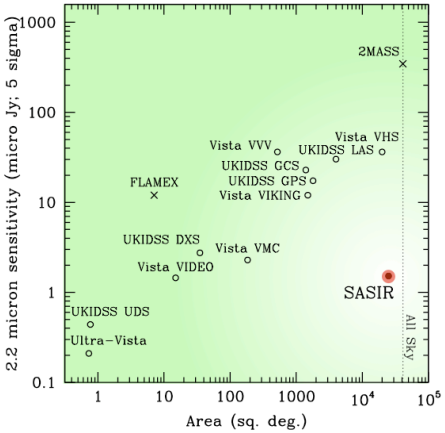


Velocidad de muestreo (Etendué-coleur) Apertura, Campo y Bandas Simultaneas: SASIR es 1200 veces superior a 2MASS, 28 a

El poder de un telescopio es una conjunción de Tamaño, Campo, Colores cubiertos, Tiempo de dedicación y Eficiencia

Campo cubierto:
$(0.14°)^2$ 2MASS ; $(0.455°)^2$ UKIDSS ; $(0.77°)^2$ VISTA ; $(0.72°)^2$ SASIR





SPMT$_6$ Initiative (2012)

- Built and operate a binational observatory around a 6.5-mts telescope in San Pedro Mártir, Baja California México

- Partners:
  - México:
    UNAM, INAOE, U.Sonora, U. Guadalajara, CIDESI, a full set of universities/institutions with Astronomy-related interests
  - USA:
    U. Arizona & Smithsonian Institution (MMT Consortium), potentially others

- Complete the SPMT$_6$ combining existing resources:
  - Site & its facilities (OAN-UNAM)
  - Primary mirror (UA/INAOE)
  - Secondary mirror (f/5) and field-correcting optics (MMT)
  - MMT instrumentation suite (f/5) for initial operations

  - Just need to develop the building and the telescope structure
  - Contemplates joint operations of both SPMT$_6$ & MMT facilities

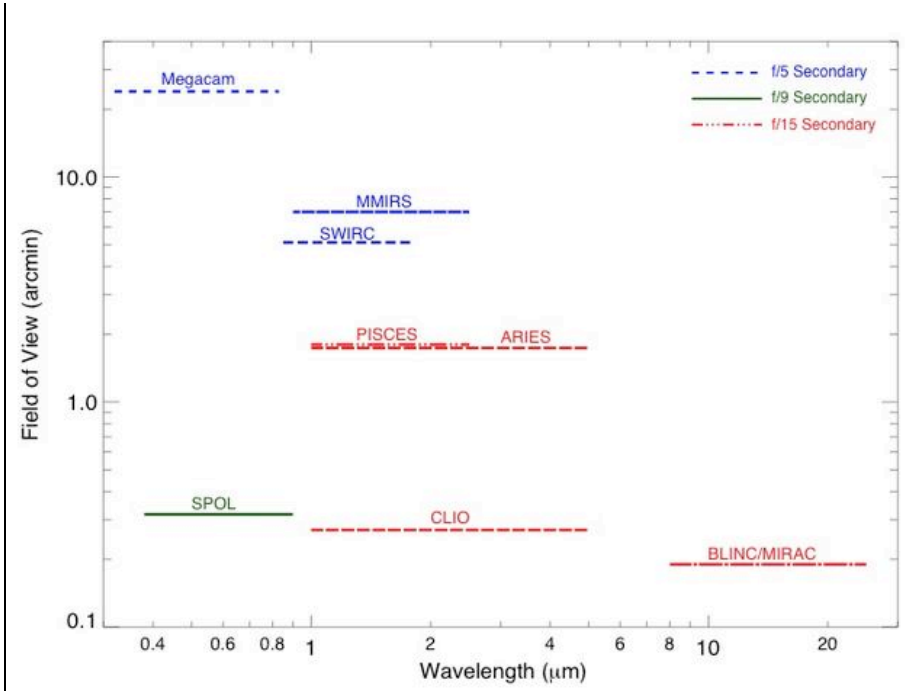
MMT Instrumental suite

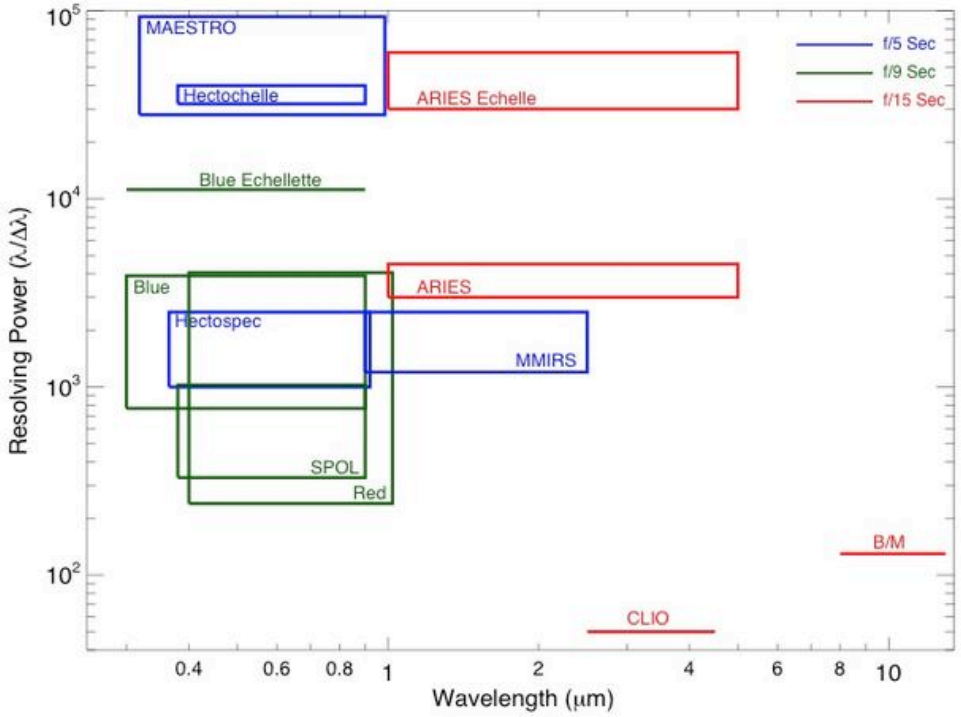
f/5 Existing Suite

+ Binospec

	NAME	BRIEF DESCRIPTION	Spectral Range	Resolving Power/ pixel scale	Field of FOV	PI Contact
f/9						
	Blue Channel	Optical single-slit spectrograph	3000 – 9000Å	R = 770 – 3900 & 11200	/	MMTO
	Red Channel[1]	Optical single-slit spectrograph	4000Å – 1.02μm	R = 240 - 4050	/	MMTO
	SPOL	Imaging spectropolarimeter	3800 – 9000Å	R = 330 – 1025 0.19"/pix	19"	P. Smith (SO)
f/5						
	Hectochelle	Optical fiber-fed multi-object echelle spectrograph	3800 – 9000Å	R = 32,000 – 40,000	1°	A. Szentgyorgyi (SAO)
	Hectospec	Optical fiber-fed mulit-object spectrograph	3650 – 9200Å	R = 1000 - 2500	1°	D. Fabricant (SAO)
	MAESTRO	Single-slit echelle spectrograph	3185 – 9850Å	R = 28,000 – 93,000	/	J. Bechtold (SO)
	Megacam	Wide-field optical imager	3200 – 8300Å	0.08"/pix	24' x 24'	B. McLeod (SAO)
	MMIRS	IR mulit-object spectrograph and imager	0.9 – 2.5μm	R = 1200 – 3000 0.20"/pix	7' x 7'	B. McLeod (SAO)
	SWIRC	Wide-field IR imager	0.85 – 1.8μm	0.15"/pix	5.12' x 5.12'	W. Brown (SAO)
f/15						
	ARIES[1]	IR imager & single-slit echelle spectrograph	1 - 5μm	R = 3000 – 60,000 0.019 – 0.1"/pix	20" – 104.4"	D. McCarthy (SO)
	CLIO[1]	Thermal IR camera	1.5 - 3μm	0.027 – 0.048"/pix	8.7" x 7" or 15" x 12"	P. Hinz (SO)
	MIRAC-BLINC[1]	Mid-IR camera and IR nulling interferometer	8 - 25μm	0.09"/pix	11.5"	P. Hinz (SO)
	PISCES[1]	Wide-field IR imager	1 – 2.5μm	0.026"/pix or 0.11"/pix	26.4" or 1.9'	D. McCarthy (SO)

Instrumental Parameter Space



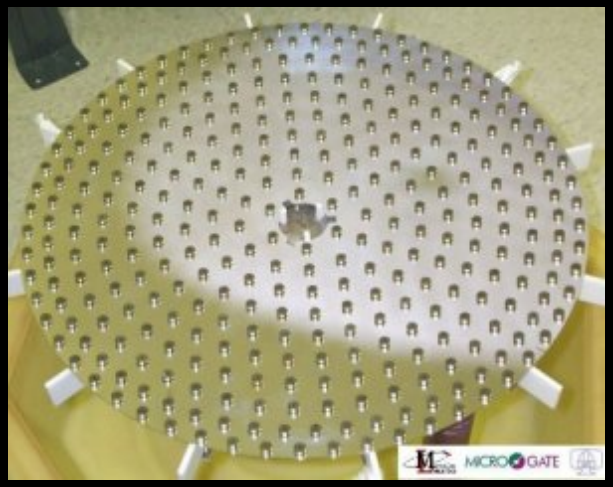


MMT Consorptium f/5 Instruments available to go to SPMT

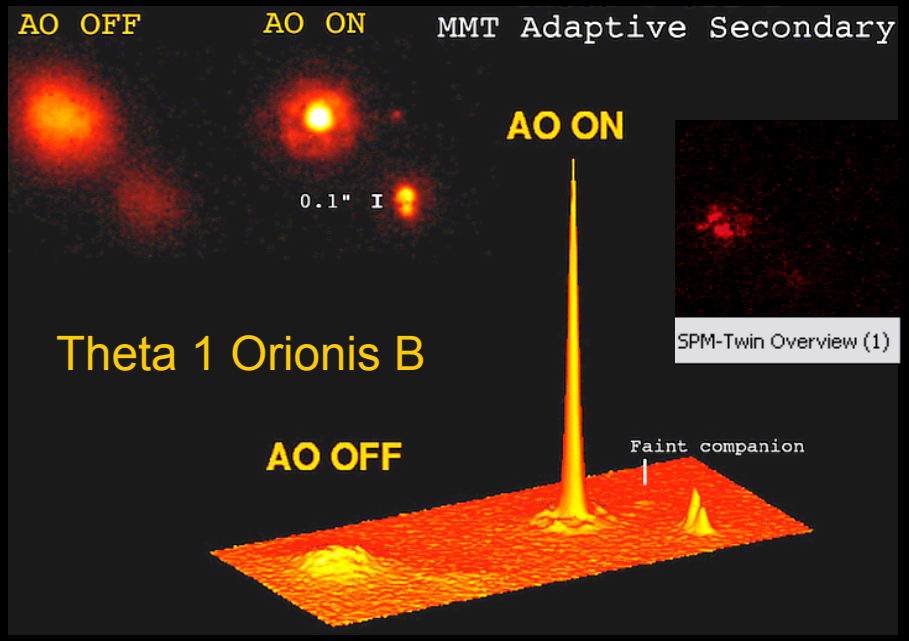
Instrument	Type	Spectral Range	Resolution/ Scale	Field	Considered for SPMT ?
Hectochelle	Optical fibre-fed multi-object echelle spectrograph	3800 - 9200Å	R = 32,000 - 40,000	1 deg 240 fibers	Yes
Hectospec	Optical fibre-fed multi-object spectrograph	3650 - 9200Å	R = 1000 - 2500	1 deg 300 fibers	Yes
Binospec http://www.mmto.org/node/60	MOS/Long-Slit/Imager 2-arms, 4 gratings	3900- 10000Å g, r, i,z	R = 1200 - 10000 0.24”/px	8’x15’ (MOS)	Yes (2014)
Megacam	Wide-field optical imager	3200 - 8300Å	0.08"/pix	24' x 24'	Maybe (PI inst) (está en Magallanes)
SWIRC	Wide-field IR imager	0.84 - 1.8um	YJH 0.15"/pix	5.12' x 5.12'	No (PI instrument) Interest dep
MAESTRO	Single-slit echelle spectrograph	3185 - 9850Å	R = 28,000 - 93,000 0.154”/px	4” Single object Single & dual slit	No (PI instrument)
MMIRS	IR multi-object spectrograph & imager	0.9 - 2.5um	R = 1200 – 3000 0.2"/pix	7' x 7'	No (PI instrument)

More datailed information on MMT instrumenst (also f/9 y f/15)
http://www.mmto.org/
Magallan Instrument Suite (f/5, f/11)
http://obs.carnegiescience.edu/astronomers

MMT & SPMT can then be optimal for different applications (e.g. MMT NIR & AO)



64 cm diameter
1.9 mm thick
336 actuators



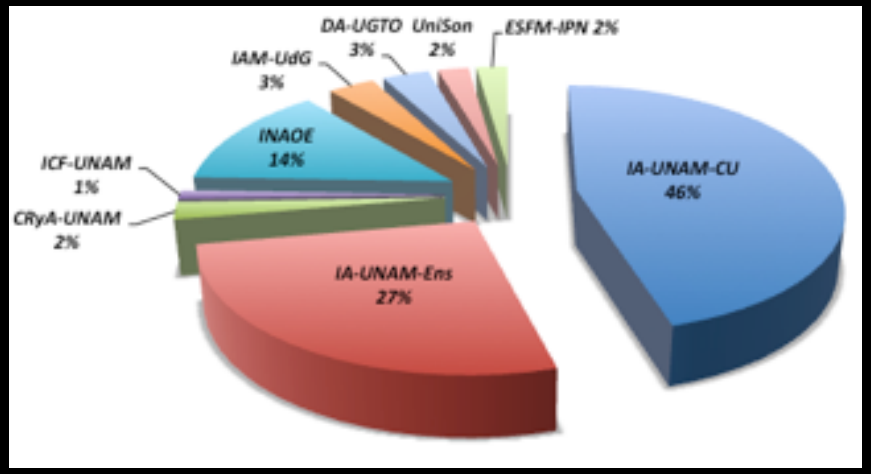
Broad interest in the Mexican Community

Ad-hoc commission named at UNAM/INAOE to survey Mexican community for interest (summer/fall 2012)

Interaction between UNAM, INAOE, U Guanajuato, U de Guadalajara, U de Sonora, Instituto Politécnico Nacional

Over 90 members participated, including faculty, engineers, students & postdocs

1. Instituto de Astronomía UNAM (IA-UNAM, México D.F. y Ensenada, Baja California)
2. Instituto Nacional de Astrofísica Óptica y Electrónica (INAOE, Tonantzintla, Puebla)
3. Universidad de Guadalajara (UdG, Guadalajara, Jalisco)
4. Universidad de Guanajuato (UGTO, Guanajuato, Guanajuato)
5. Universidad de Sonora (UniSon, Hermosillo, Sonora)
6. Escuela Superior de Física y Matemáticas del Instituto Politécnico Nacional (ESFM-IPN, México, D.F.)
7. Centro de Radioastronomía y Astrofísica UNAM (CRyA-UNAM, Morelia, Michoacán)
8. Instituto de Ciencias Físicas UNAM (ICF-UNAM, Cuernavaca, Morelos)



2012 Survey

1. Community-wide interest in a new OIR telescope at SPM.

2. Certainty on the quality of the site, deserving at least one telescope of greater breadth than those existing.

3. Consideration that an international collaboration is key to make this happen.

4. Support for the proposal to bring optics and instrumentation from MMT at SPMT, minimizing costs and lead times, and allowing the beginning of science operations as soon as possible.

5. Personal and institutional interest to participate in all aspects of the project: planning, design, construction and operation. Importance of maximizing in-house developments.

6. Great disposition to collaborate in the development and use of the MMT as part of the package to build the SPMT.

7. There is a desire to make the SPMT design as flexible as possible in order to accommodate future instrumentation and uses (other focal lengths and stations).

8. Time and participation would be made available to the entire Mexican community.

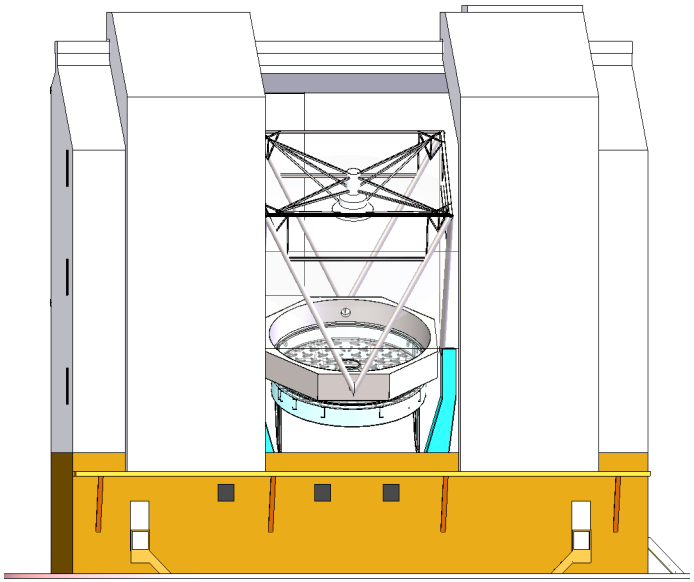
$SPMT_6$

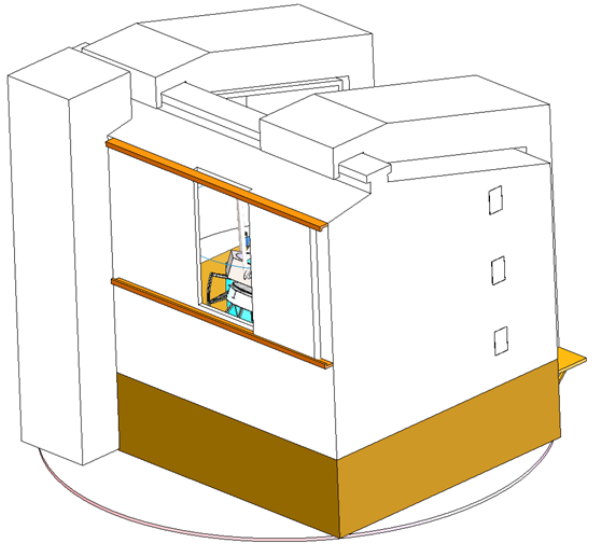
- Counts with:
  - Tested site at SPM
  - Primary mirror: casted and starting fine figuring this fall (INAOE & UA)
  - F/5 secondary from the MMT
  - 1^o Wide-Field Corrector (WFC) & Atmospheric-dispersion corrector (ADC)
  - MMT (UA & SAO) F/5 instrumentation suite
    - 300+ fiber possitioner
    - Hectospec
    - Hectoschelle
    - Binospec
    - Potentially others (Megacam, ?)
- Still Need the Telescope Structure, Enclosure & Auxiliary Services
- Mexico-UA+SAO consortium will operate SPMT & MMT jointly
  - MMT concentrating on longer foci, IR and AO
  - SPMT on wide-field, better seeing and darker site astronomy
  - Second phase instrumentation yet to be decided

Telescope Structure & Building

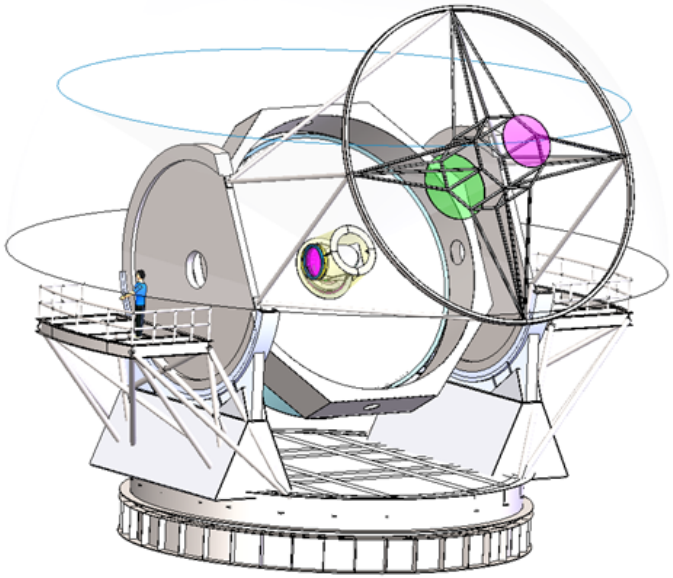
- Feasibility Study: Compare three systems
  - Adapt Magellan to SPM
  - Adapt MMT to SPM
  - An Improved Solution (3+ focal stations)
- Followed by a conceptual design by the end of the year

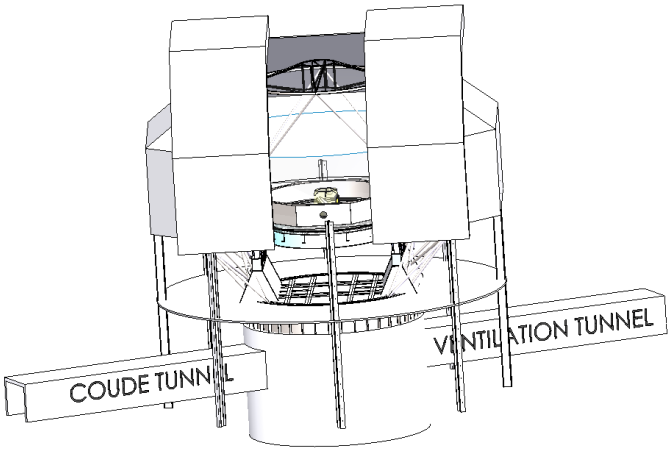
Modelación y estudio del MMT



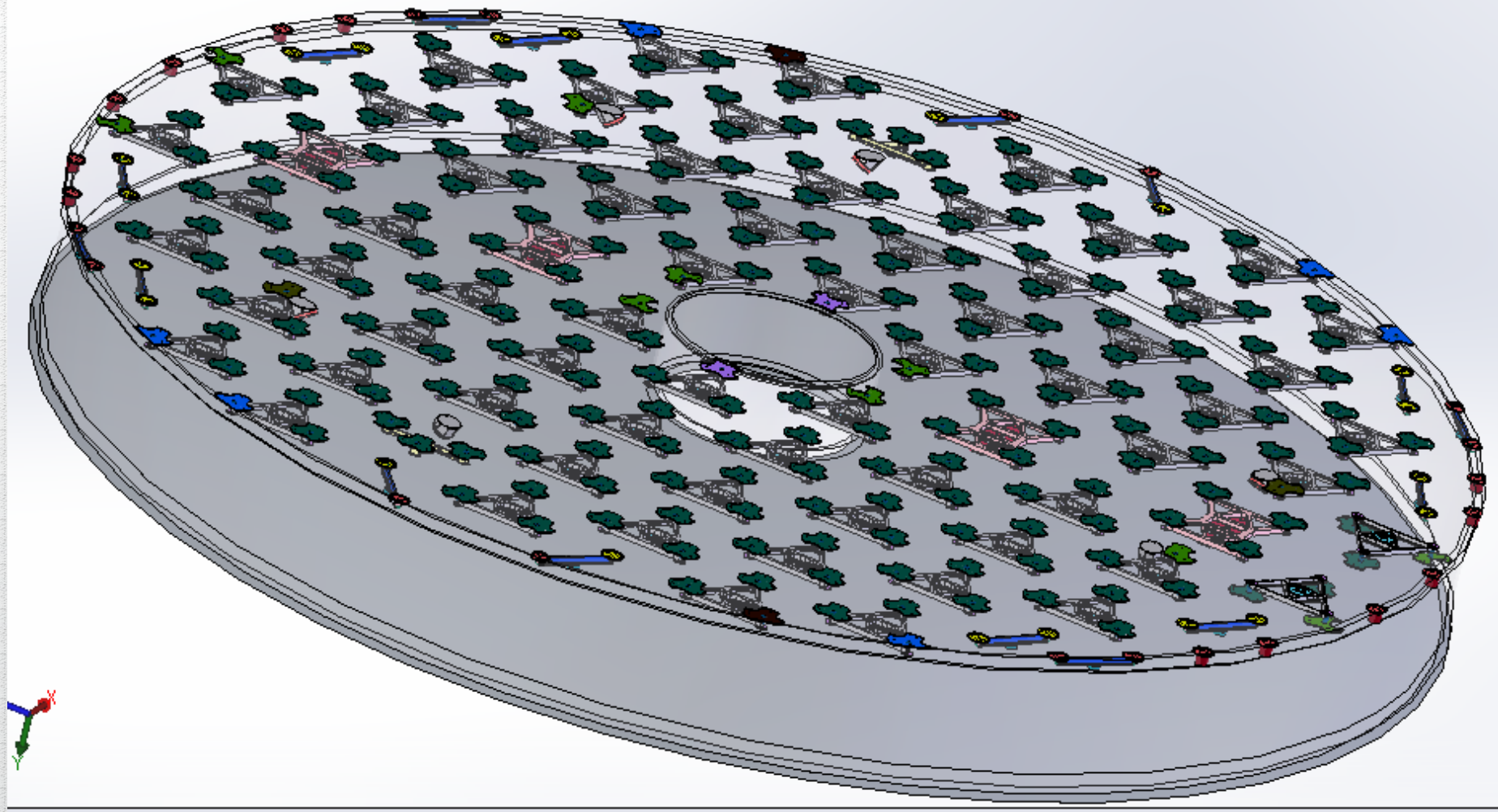


Modelación y estudio del Magellan

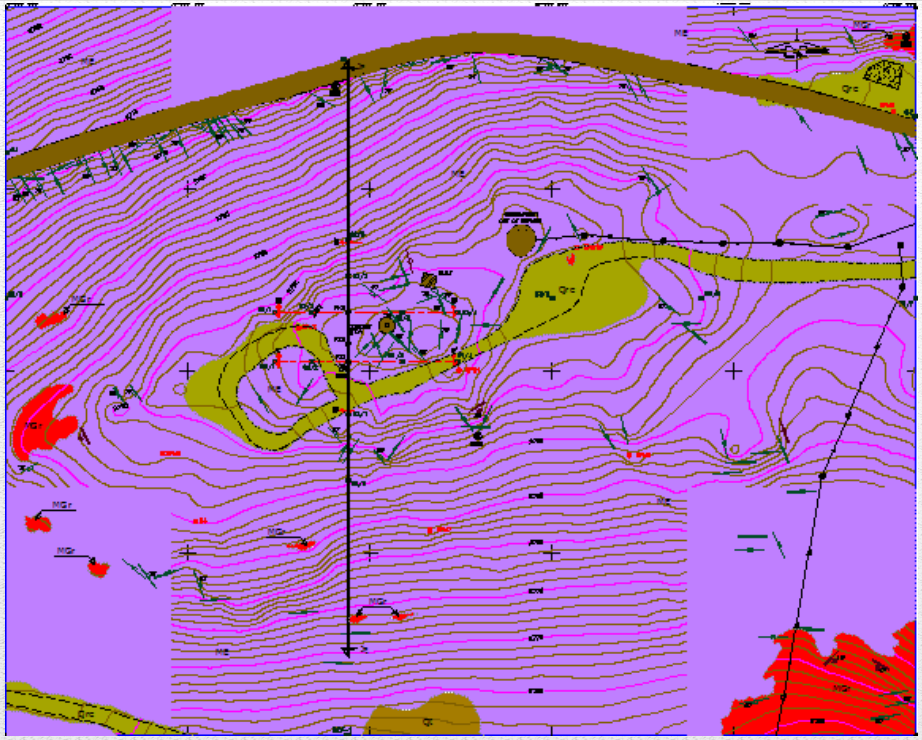


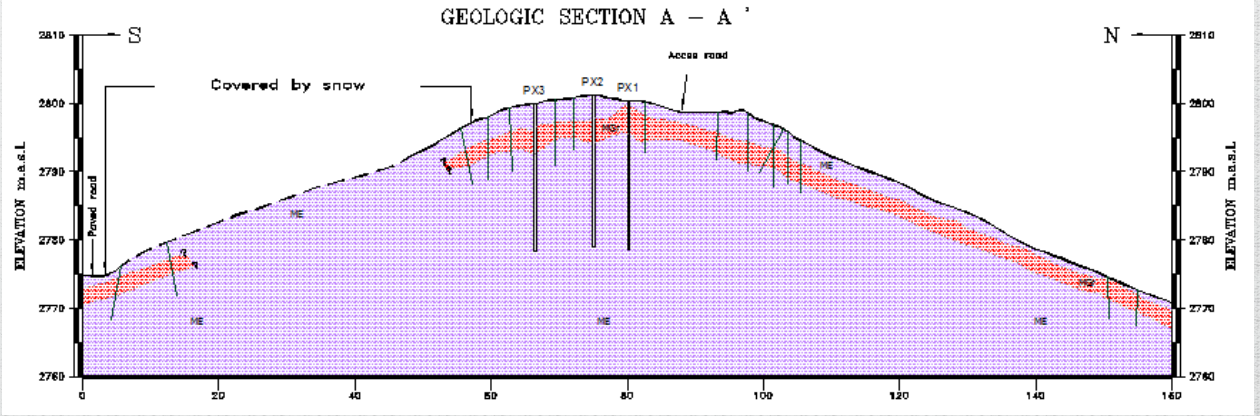


Espejo definitivo del SPMT

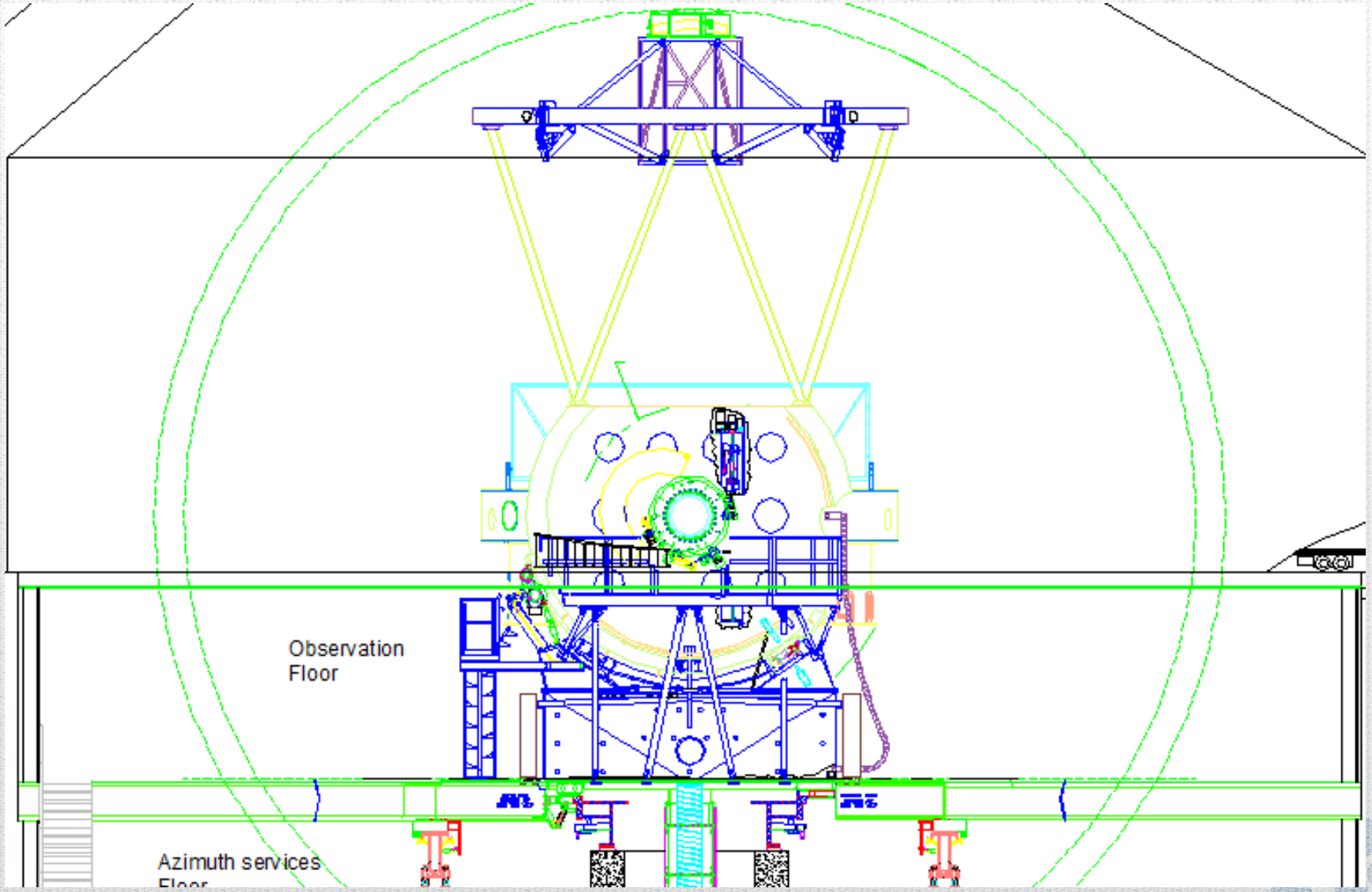


Localización y Estudio Getoécnico SPMT

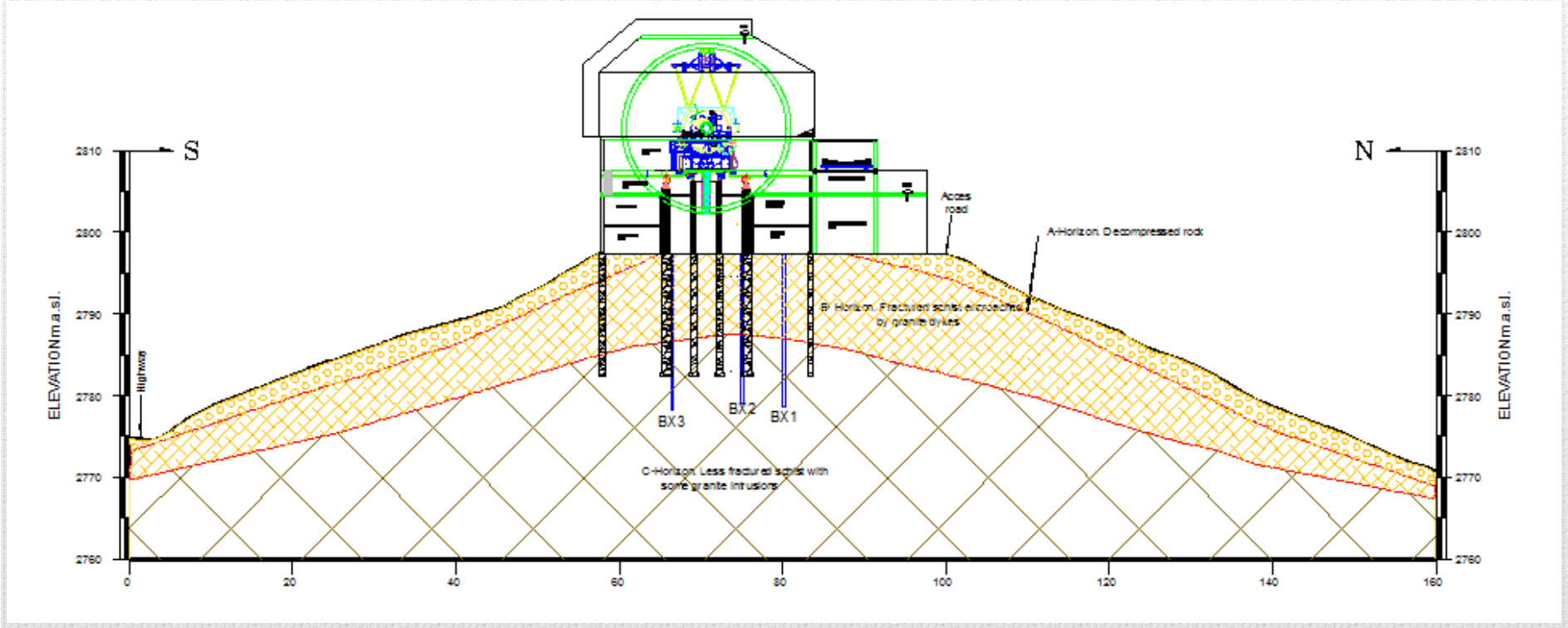




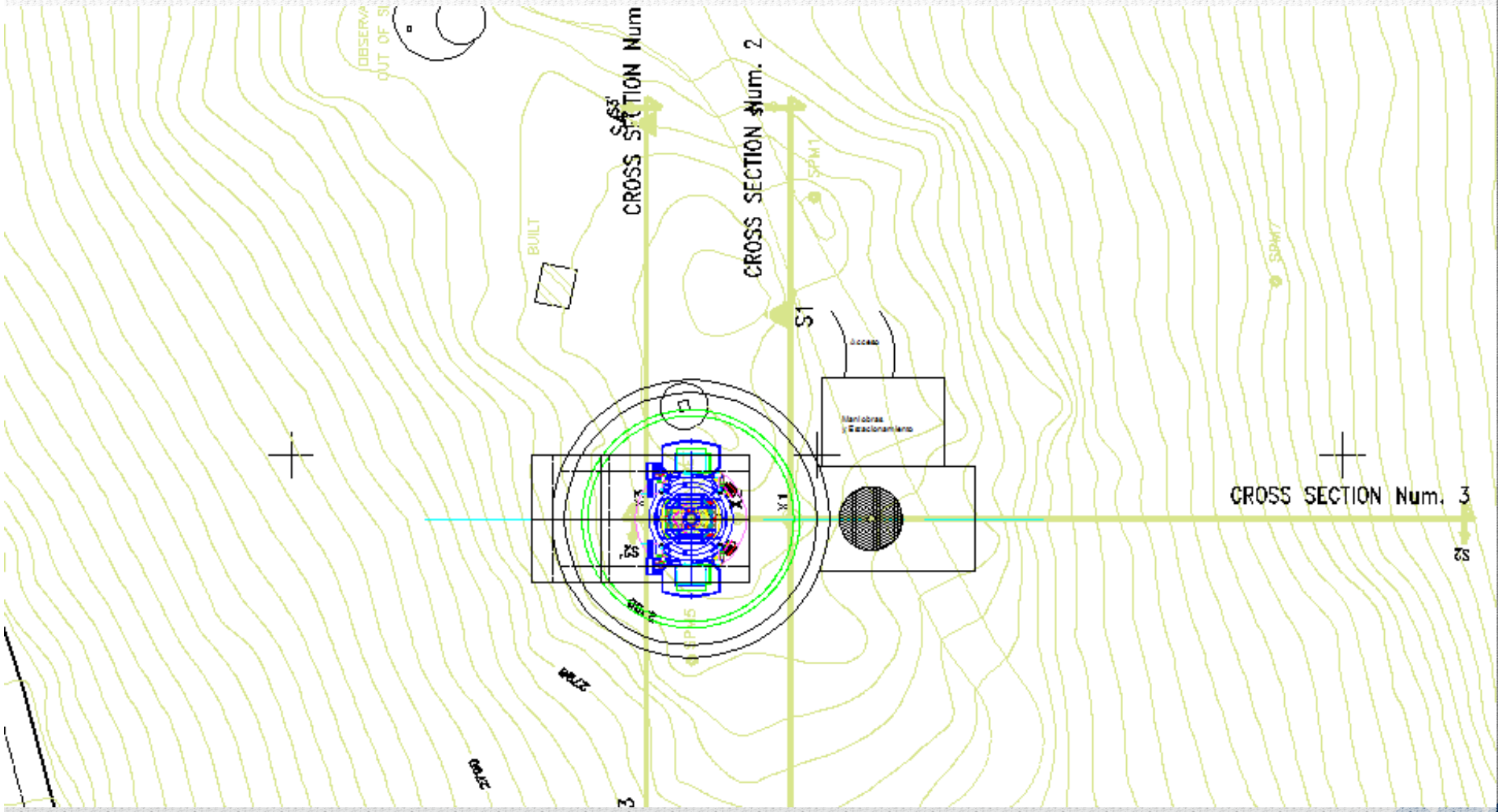
Segunda aproximación concepto SPMT



Localización y cimentación SPMT



Localización y cimentación SPMT



$SPMT_6$ Outlook

Contracted with CIDESI in January 2013 the pre-conceptual design study.

Seek funding for full design in 2013, explicitly stating the total cost and schedule: ~45MUSD in <6 yrs.

New government signals & policies:

- Administration has explicitly stated they will raise the % of GDP devoted to S&T,
- New Office for Science & Technology coordination from the President,
- CONACyT sounding out for projects, particularly those that can link academia with the technological & productive sector.

The simplest solution in technical terms can multiply our capacity significantly in a minimum time scale with the lowest possible risk.

Insert the SPMT in the global context of the development of scientific infrastructure in Mexico that will push technological synergies with the public and private sector.

Make the project a complement to other facilities and projects: HAWC, LMT, GTC, SDSSIV, as a part of a coherent whole.

Couple proposal to a growth in the community nationwide.

Should we seek for IFUs in SPM with and/or before $SPMT_6$?

- Extremely appealing on its own giving its multiplex efficiency-gains

- But must be scientifically driven:
  - Continuation of general astronomical projects
  - Special, more focused, larger-scale programs
  - Killing science case
  - Fully or partially specialized or dedicated facility

IFU Science niches

Extragalactic Astronomy (this conference)

- After Califa, Manga and alike Surveys, what is there left to do in the next few years?
- Adding more local universe galaxies and case-by-case follow ups sound interesting, but not that attractive for a large-scale development
- Higher spatial (smaller spaxels) resolution in local and mid-z galaxies; circumnuclear regions of AGNs
- More detailed kinematics of resolved galaxies (Mid-R spectrograph)
- Interacting Systems
- NIR extension (up to the H band) for stellar populations; obscure regions; ISM features; redshifted O&Uv
- M31 Bulge/Halo
- Local dwarf galaxies (and the Milky Way Halo)
- Distance indicators (stellar populations for SB fluctuation techniques)

Galactic Astronomy (large community in México)

- Planetary Nebulae
- Open Clusters
- HII & SF regions
- Globular clusters

Unexplored Territories:

- Ultra-Low Surface Brightness Spectroscopy
  - Faint halos
  - Novel Sky-subtraction techniques
  - Device new concepts:
    - Interferometric spectrometer for dispersion & rotation velocities

Brain Storm discussion session here

IFU Technical Considerations

- Wavelength range (optical or/and NIR)
- Spatial resolution, sampling and filling factor
- Need for an ADC
- Concept: Lenslets, Fibers, Image-slicers
- Pre & post optics (F/# matching, scale factors and spectral resolution needs)
- Spectral Resolutions wanted
- Stability, calibration, guiding requirements
- AO-aided IFU? (ground layer/diffraction limited)

IFU Short-time deployment

- Difficult or very limiting with present SPM telescopes
- Decommissioned but usable units/spectrograph elsewhere

Mid-Term alternatives

- Can we built a strong science case to attract partners for a new 2-4 m telescope? Potentially dedicated to IFS (hardly unique these days)
- Wait 5-6 yrs for $SPMT_6$.
  - Contemplate 1st epoch operations with the Hectos & Binospec? Or already propose a new optical or NIR IFS instrument
  - Or wait even longer for 2nd-generation instrumentation and programs? Potentially dedicated programs

IFU & Present SPM Telescopes

- 0.84-m Tel (F/15): too small, but has an spectrograph

- 1.5-m Tel (F/13.5):
  - Dedicated now, up to a few years, for Robotic multi-band Vis-NIR imaging (RATIR)
  - May still be too small, but if dedicated can be interesting (best image quality ~0.8")

- 2.1m Tel (F/7.5, F/13.5 & F/30):
  - Present observatory's workhorse telescope
  - Can't be upgraded or transformed into a dedicated facility yet (an optimal use can be found in conjunction with the similar GH 2-m Telescope at Cananea)
  - 4 Spectrographs (all F/7.5 optical):
    - Low-Res B&Ch
    - Riosc-Echelle: R~20,000 visible X-disp Echelle spectrograph
    - Mezcal: Single order long-slit Echelle (has imaging & MOS modes)
    - ESOPO: 2-arm R~5000 spectrograph (panchromatic design for potential imaging & MOS)

    All four can in principle be feed with fibers, with moderately low powered optics to minimize Focal-ratio degradation

- All are pre sub-arcsec telescope designs and do not exploit fully the SPM skies

IFU Unit for the 2.1 m SPM Telescope

- Potentially very appealing to bust the performance of the present spectrographs, and to sit them on the floor (fiber fed)
  - B&Ch: 2' slit-length up to R~1,500 (UV blind)
  - Esopo: 10' slit ; full Wv-coverage at R=4000
  - Reosc-Echelle: 2.67' slit (13.3" to separate most orders) R~18,000
  - Mezcal: up to 5´ slit R~100,000 (single order)

- Can start development now, without adding pressure to the telescope operations and with limited resources

- Coupled to the development of the ADC (designed by ESOPO) as a single, fixed unit
- Does not seem hard to find a PI and form a local Instrument Team
- Will need a guiding system and a calibration unit
- Need to consider
  - F/7.5 –F/5ish pre-optics? 13"/mm scale
  - Spectrograph-matching or live with collimator underfilling
  - Potentially different fiber-coupler for the different spectrographs
  - ...

General Discussion

- How appealing looks the proposed IFS capabilities of $SPMT_6$?
- Science cases brain storm
- Technical Requirements
- IFU unit for the 2.1-m Telescope
- New dedicated facility?