Hello!

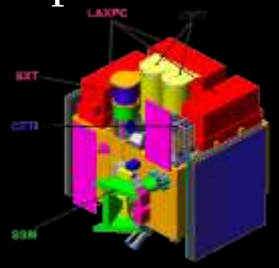
Large Projects in Astronomy

Opportunities and Challenges

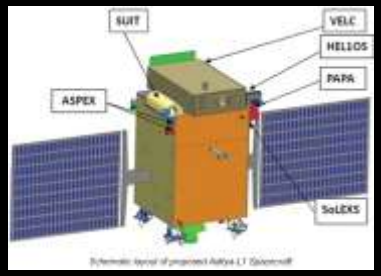
Ajit Kembhavi

Current & Future Facilities for India

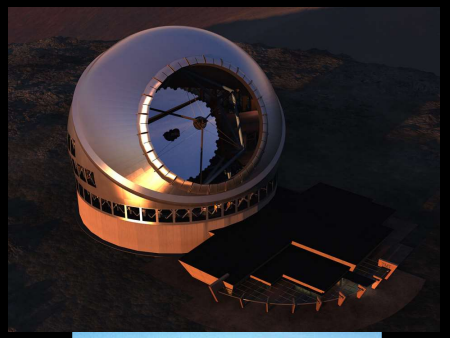
ASTROSAT
Launched by PSLV-C30
September 28, 2015

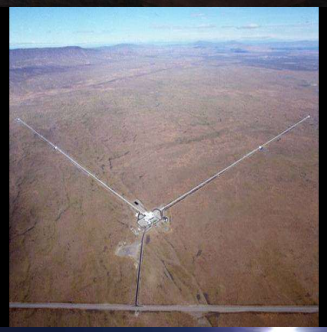


Next 5 years
ADITYA L1



Next Decade
TMT
LIGO-India
SKA





Funding Agencies

MHRD

DST **DAE** **ISRO** **UGC**

IIA, ARIES, RR… Research Projec…

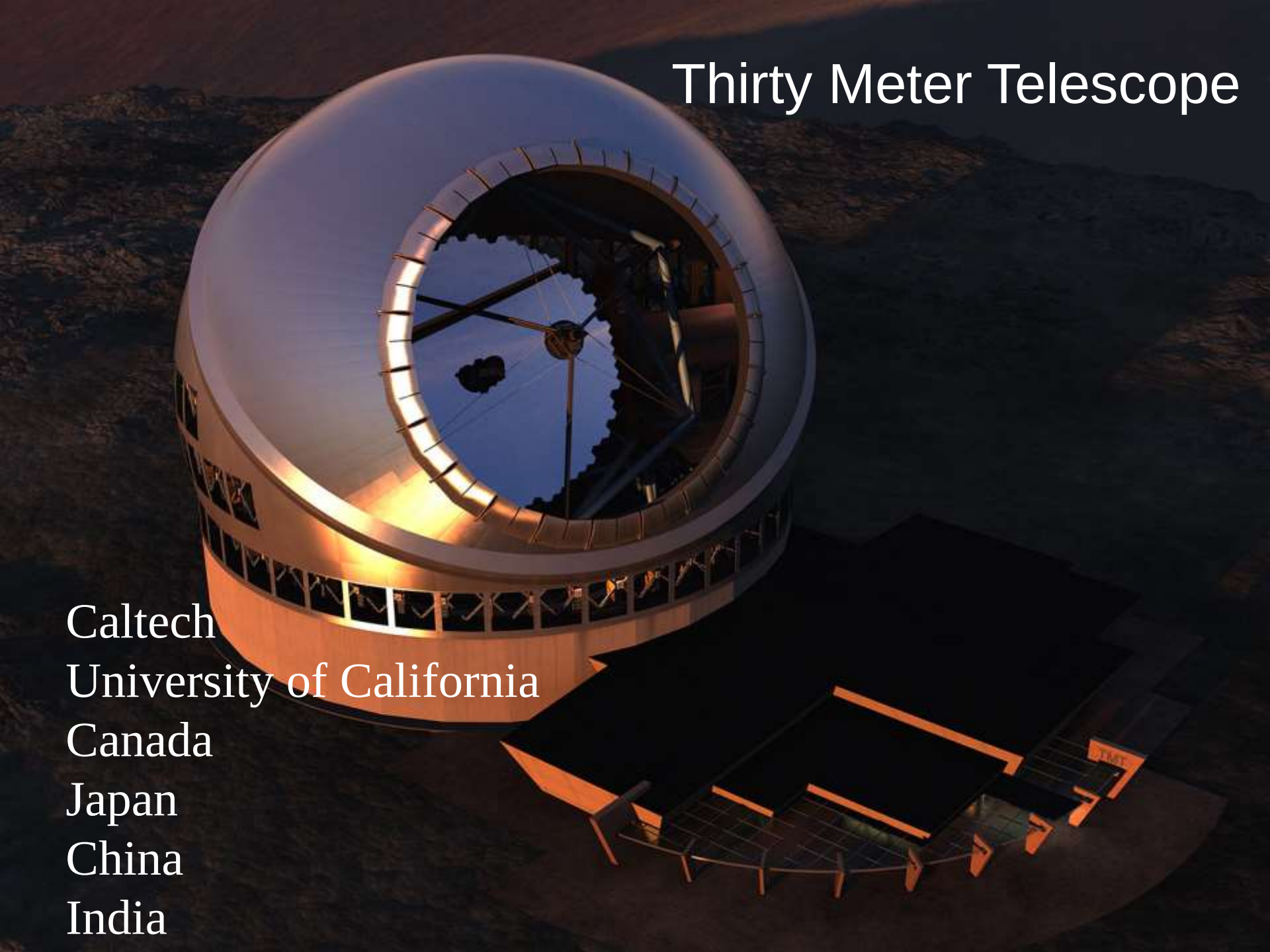
Large Projects are funded jointly by DST and DAE

…S, …RO

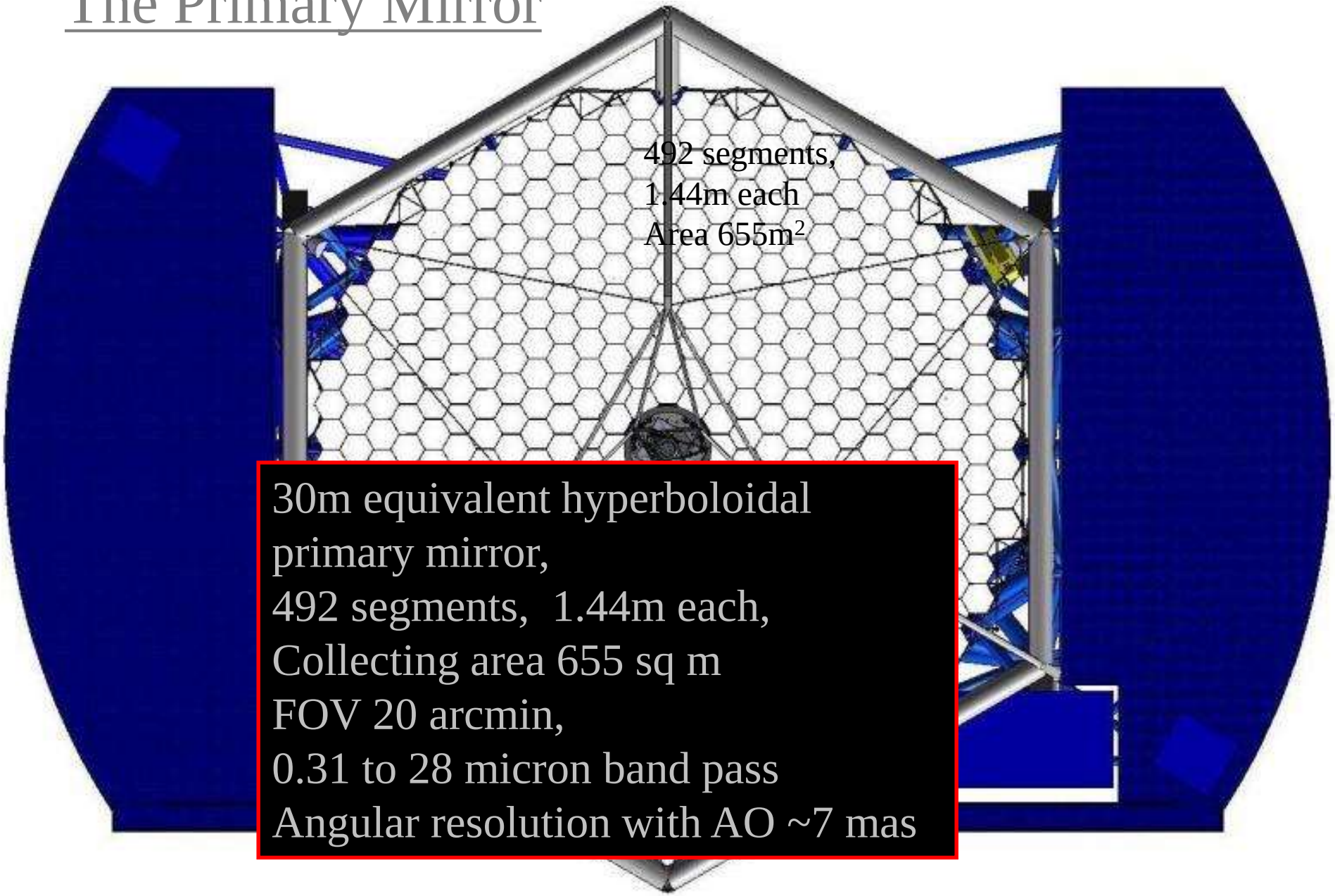
…Centres, IRE…

TIFR, NCRA, IOP…
Research Projects
Nuclear Programme

Universities,
Inter-University
Centres

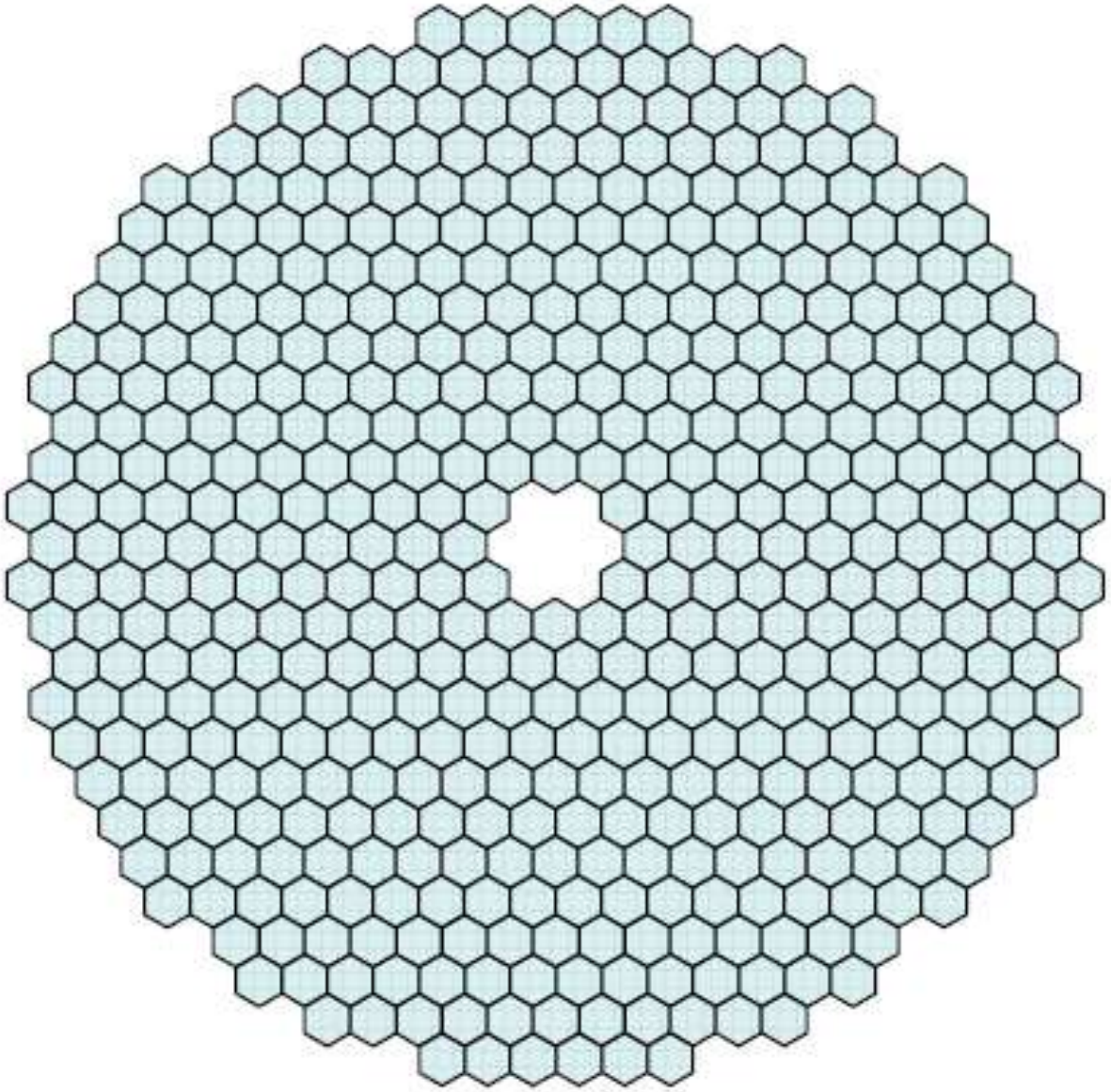

Thirty Meter Telescope
Caltech
University of California
Canada
Japan
China
India

The Primary Mirror



30m equivalent hyperboloidal primary mirror,
492 segments, 1.44m each,
Collecting area 655 sq m
FOV 20 arcmin,
0.31 to 28 micron band pass
Angular resolution with AO ~7 mas

TMT

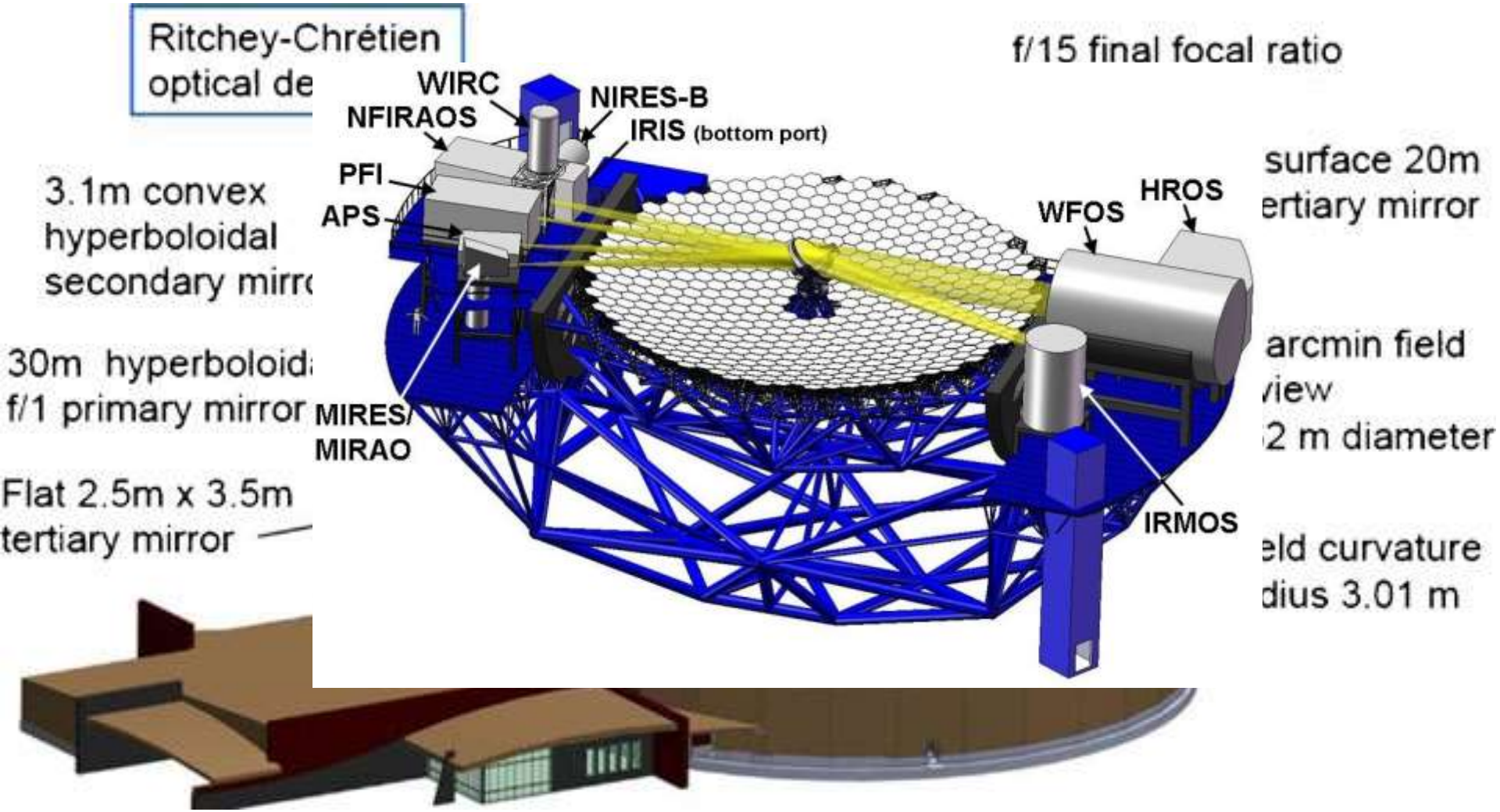


492 Segments

Keck

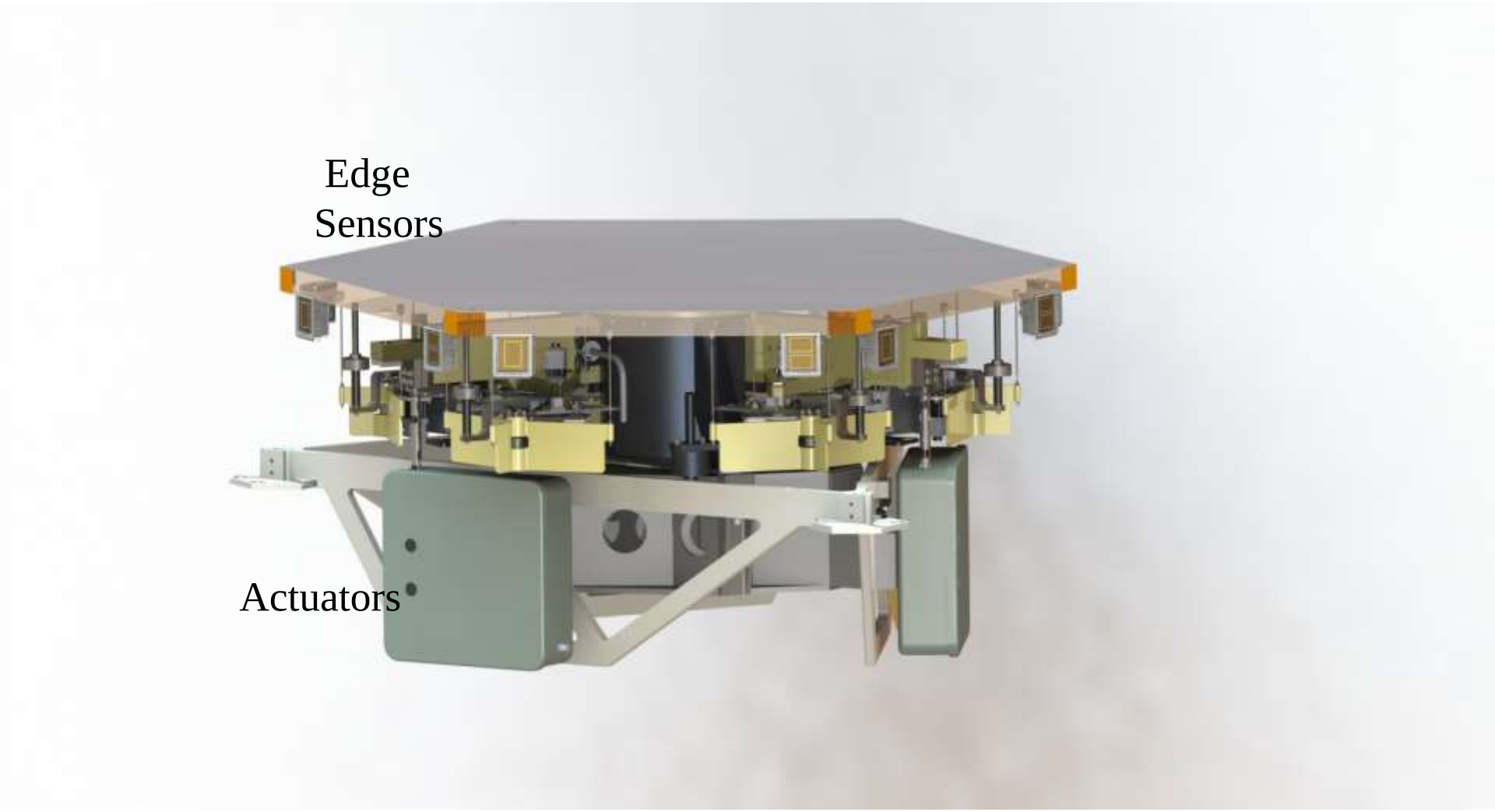
36 Segments

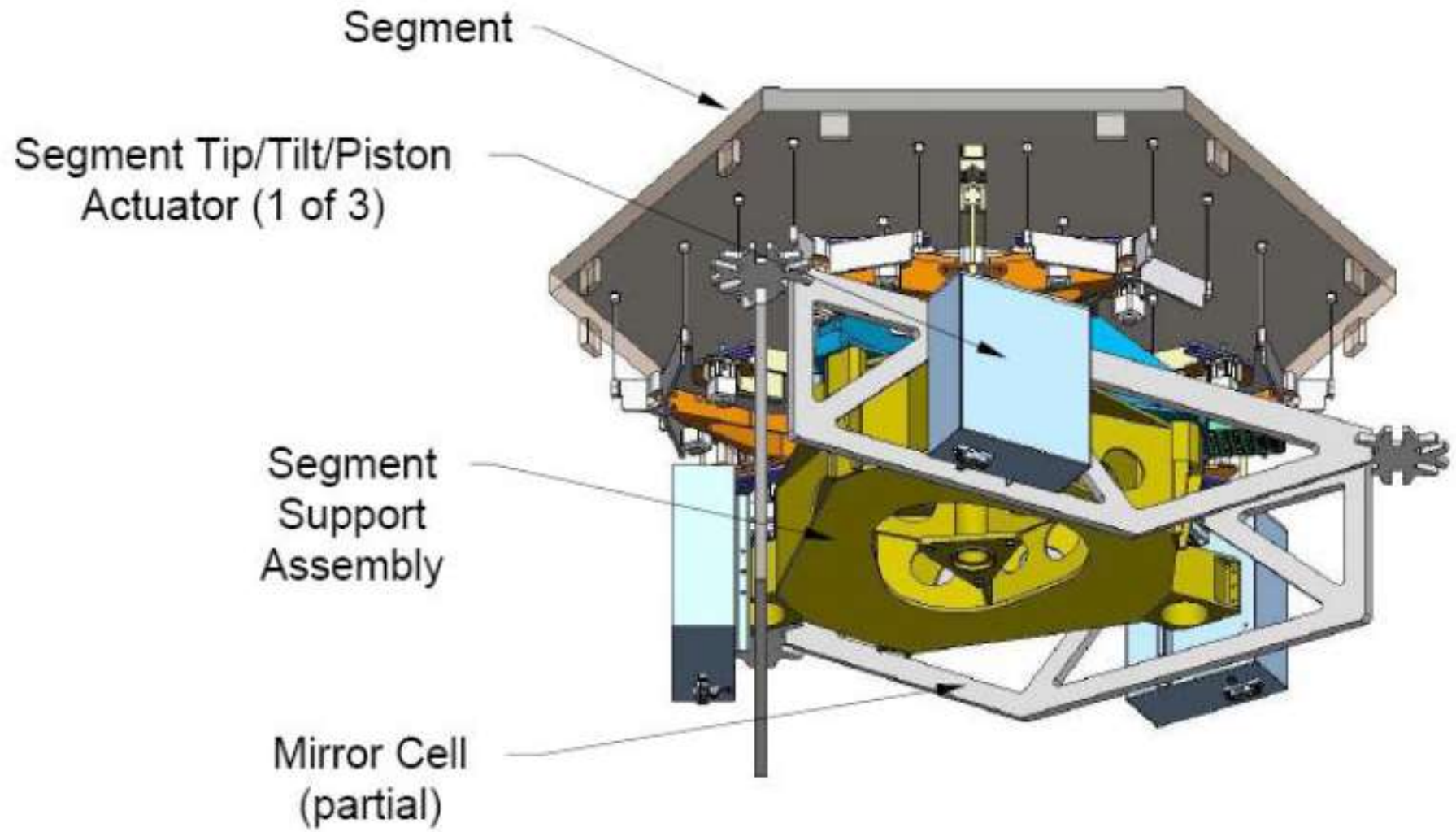
TMT

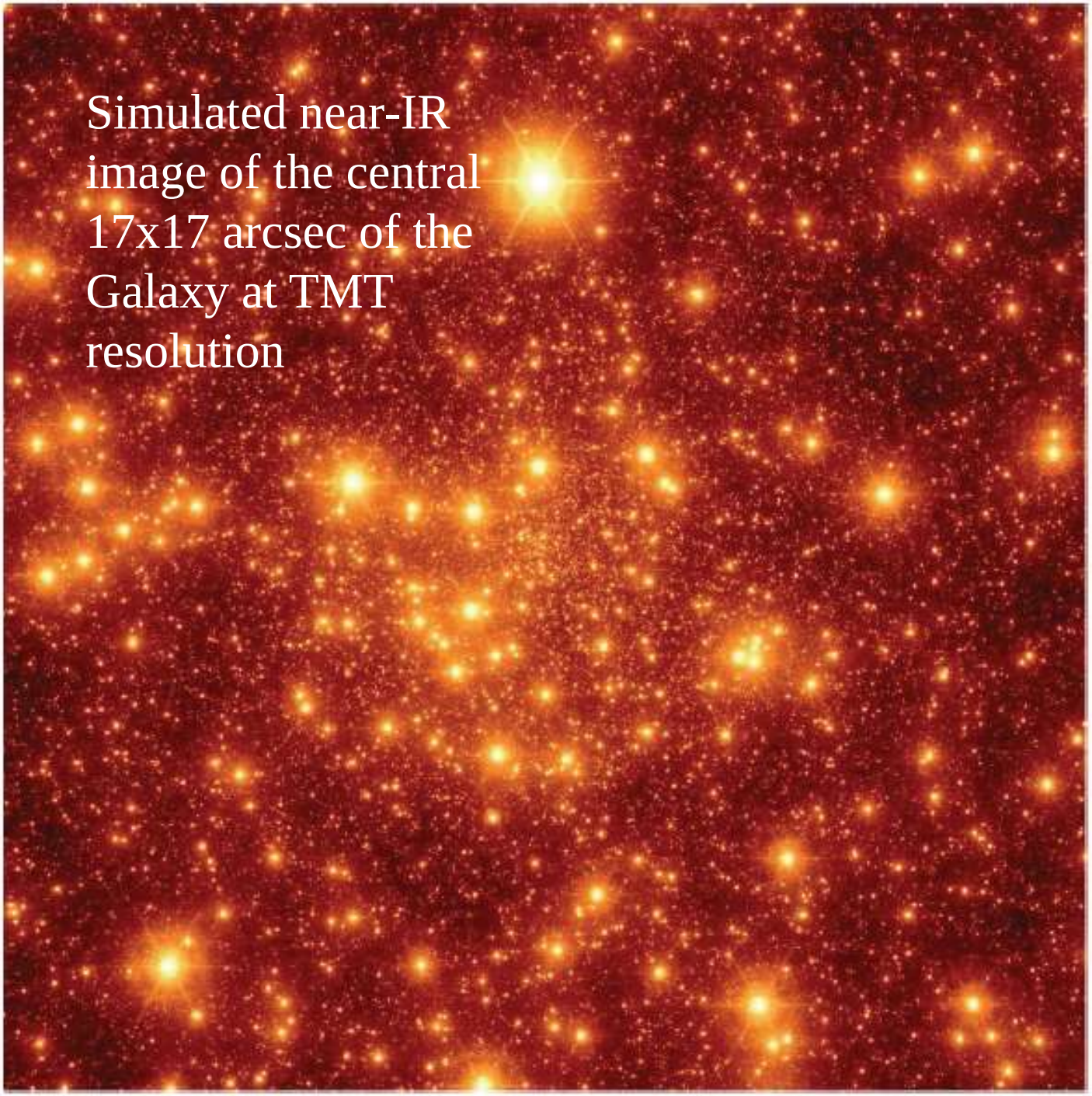


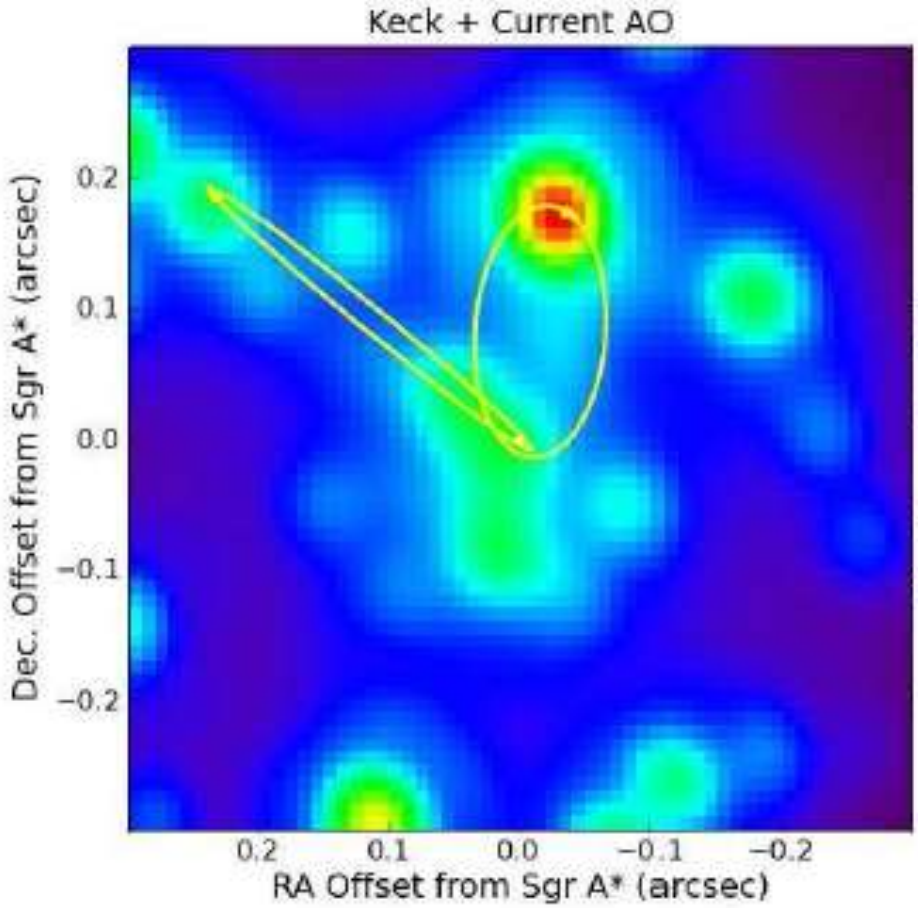
50m tall, 56m wide, 1430 tonnes moving mass of telescope, optics and instruments.

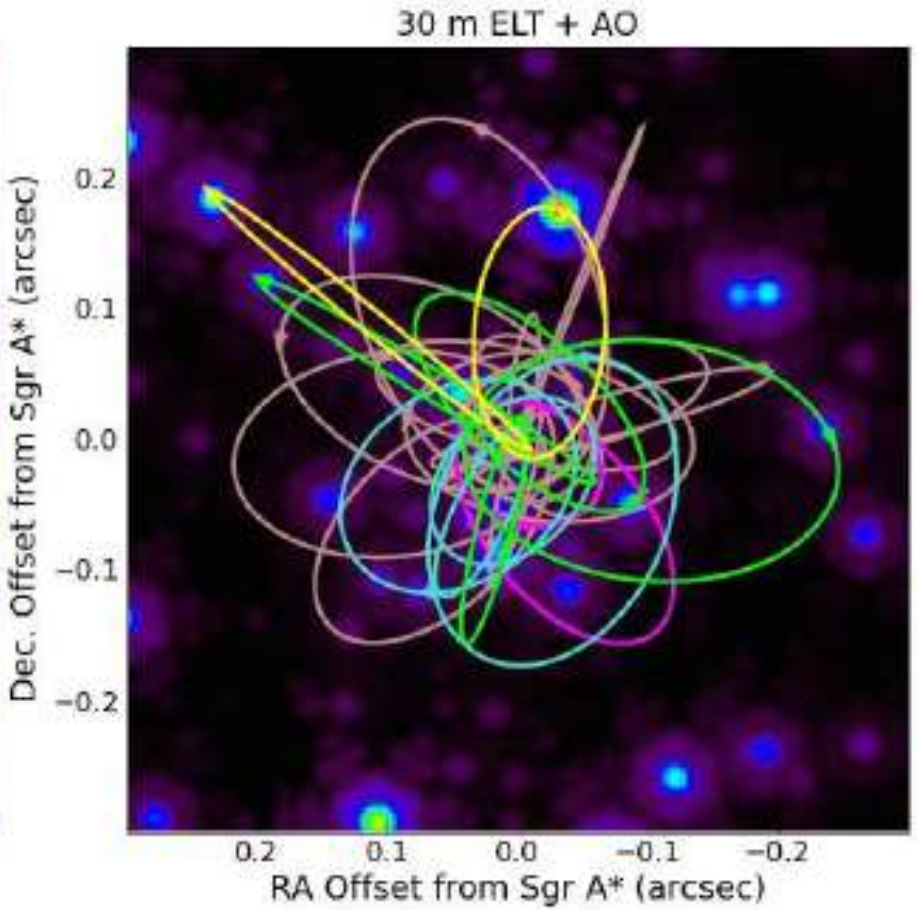
TMT Segment Support Assembly




Segment
Segment Tip/Tilt/Piston Actuator (1 of 3)
Segment Support Assembly
Mirror Cell (partial)


Simulated near-IR
image of the central
17x17 arcsec of the
Galaxy at TMT
resolution


Keck + Current AO
Dec. Offset from Sgr A* (arcsec)
0.2
0.1
0.0
−0.1
−0.2
0.2
0.1
0.0
−0.1
−0.2
RA Offset from Sgr A* (arcsec)


30 m ELT + AO
Dec. Offset from Sgr A* (arcsec)
0.2
0.1
0.0
−0.1
−0.2
0.2
0.1
0.0
−0.1
−0.2
RA Offset from Sgr A* (arcsec)

The TMT-India Partnership

Indian Institute of Astrophysics

Lead Institute, TMT-India Centre

Inter-University Centre for Astronomy and Astrophysics

Aryabhata Research Institute of Observational Sciences

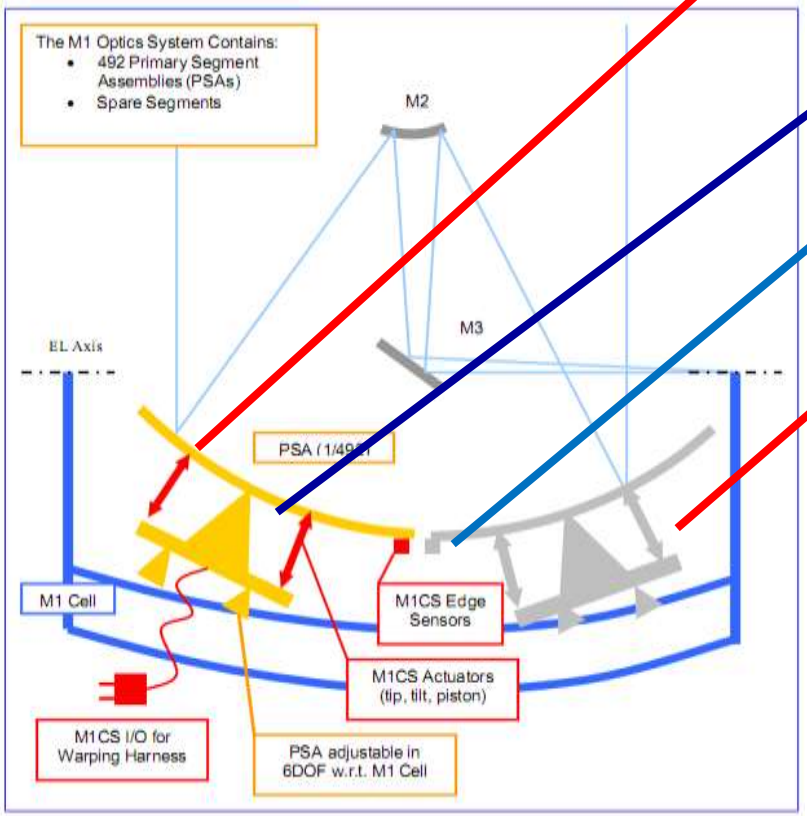
Other Research Institutes

University Departments

India-TMT role in the project

Eswar Reddy

➢ **Emphasis was given to WPs whose knowhow could directly help to take-up projects such as 10-12-m within the country.**



✓**M1 polishing**

✓**M1 Control system**

- **Actuators**
- **Edge Sensors**
- **Electronics**

✓**Segment Support Assembly (SSAs)**

✓ **Mirror Coating:**

✓ **Control Software**

✓**Instrument Development – IRMS**

✓**TMT science Center-under proposal**

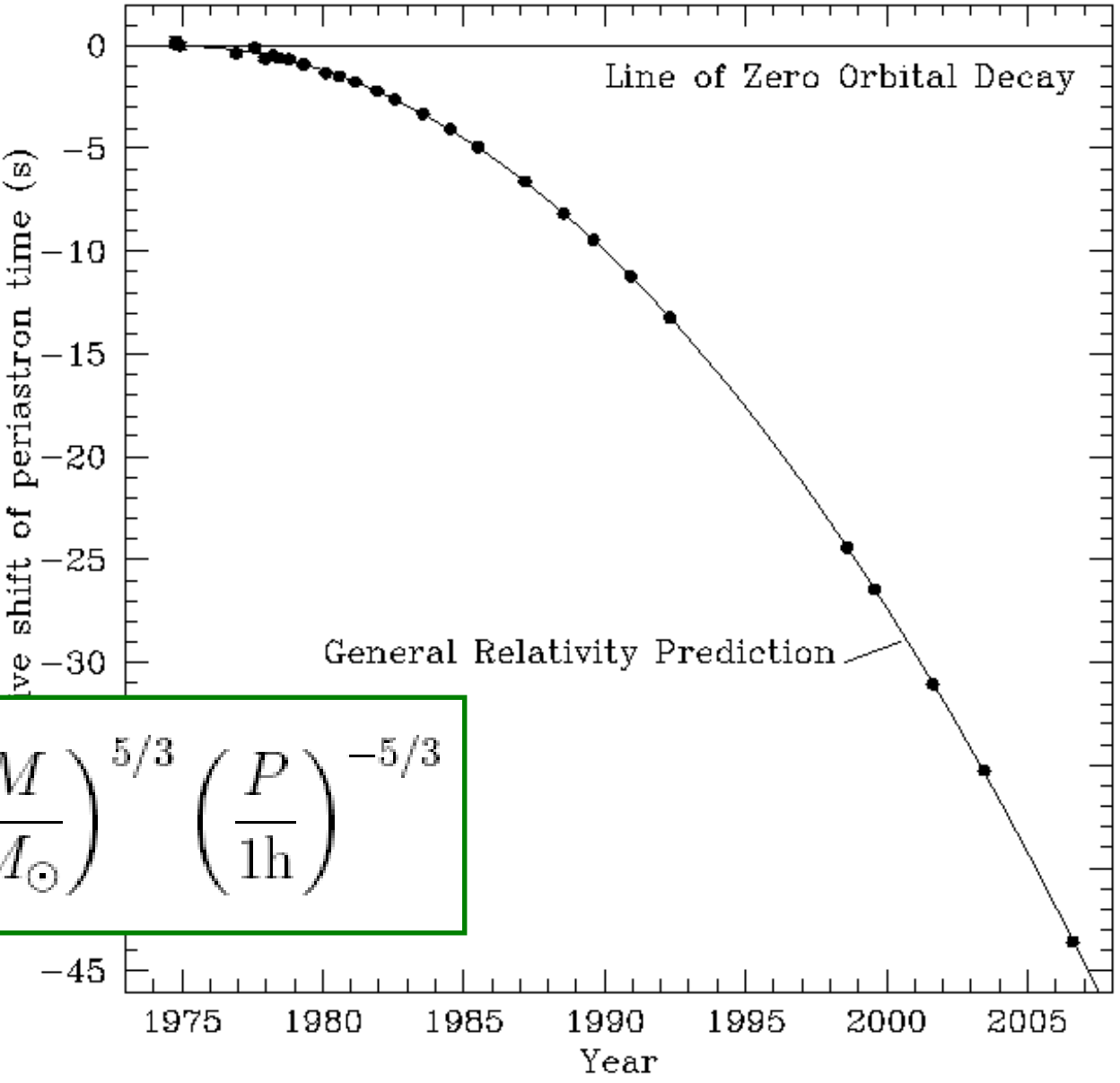
LIGO India

Direct Detection of
Gravitational Waves

The Binary Pulsar 1913+16

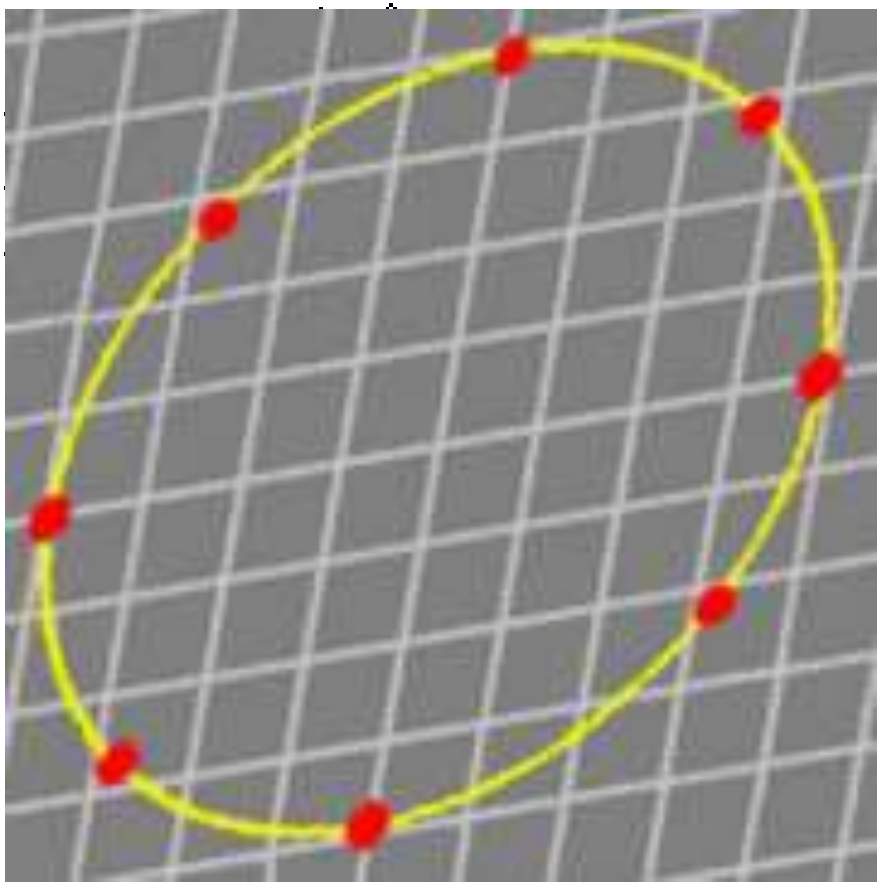
Hulse & Taylor 1974

Orbital decay due to the emission of gravitational waves



$$\dot{P} = -3.4\times10^{-12}\left(\frac{M}{M_\odot}\right)^{5/3}\left(\frac{P}{1\mathrm{h}}\right)^{-5/3}$$

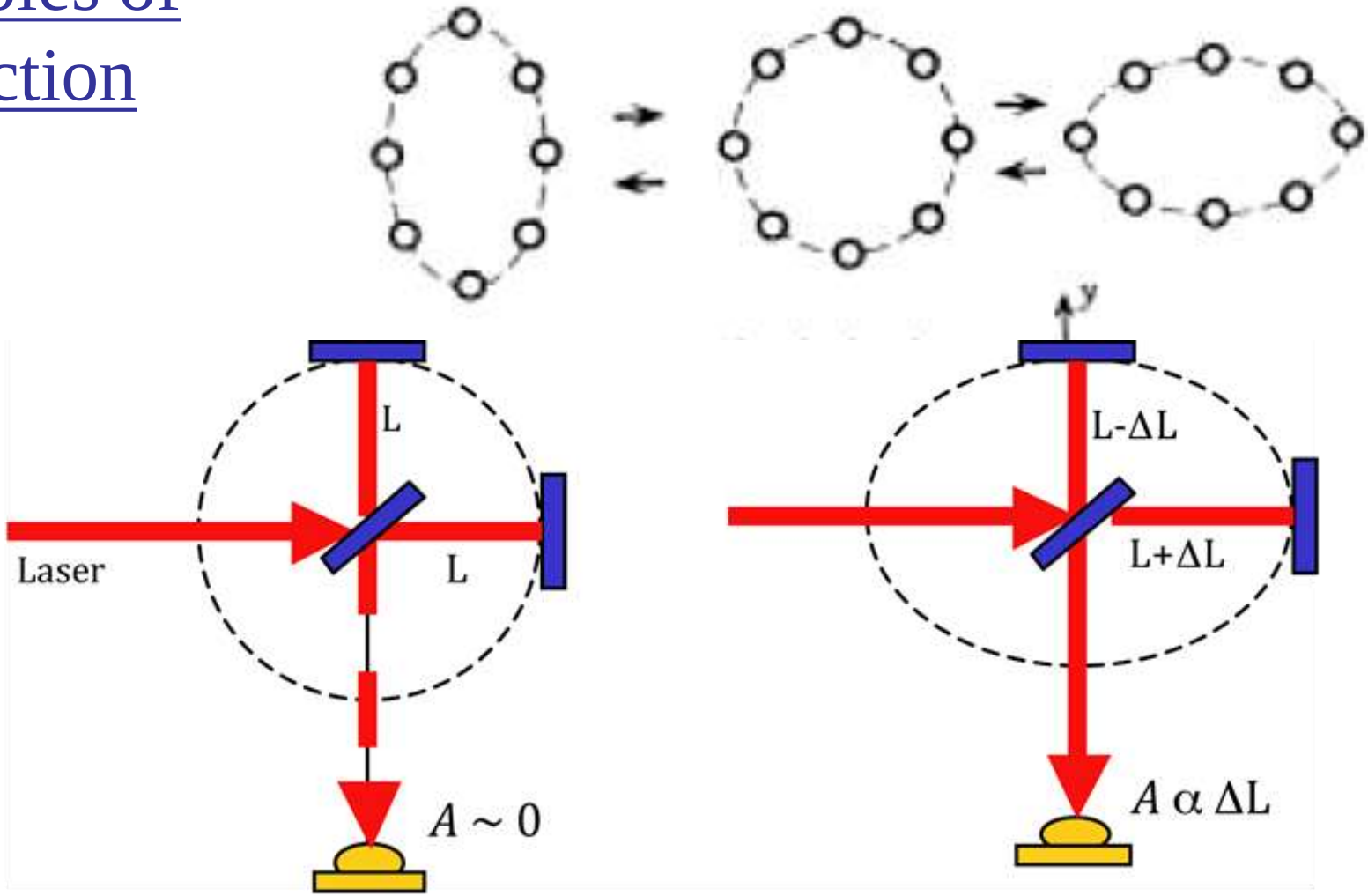
Principles of Detection



$\Delta L \sim 10^{-20} m/\sqrt{Hz}$

T. Sourdeep

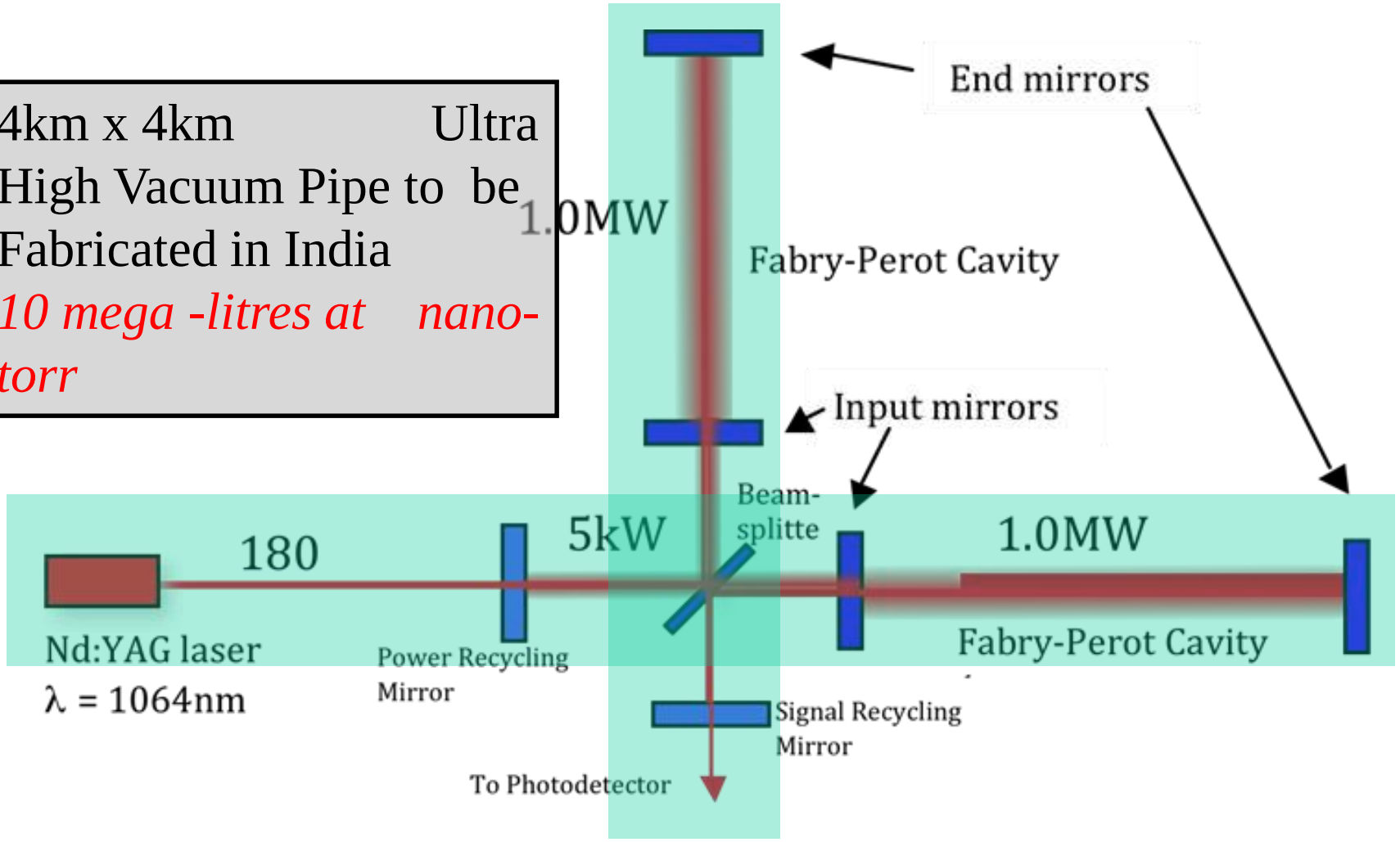
Principles of Detection



Schematic of the Advanced LIGO Detector

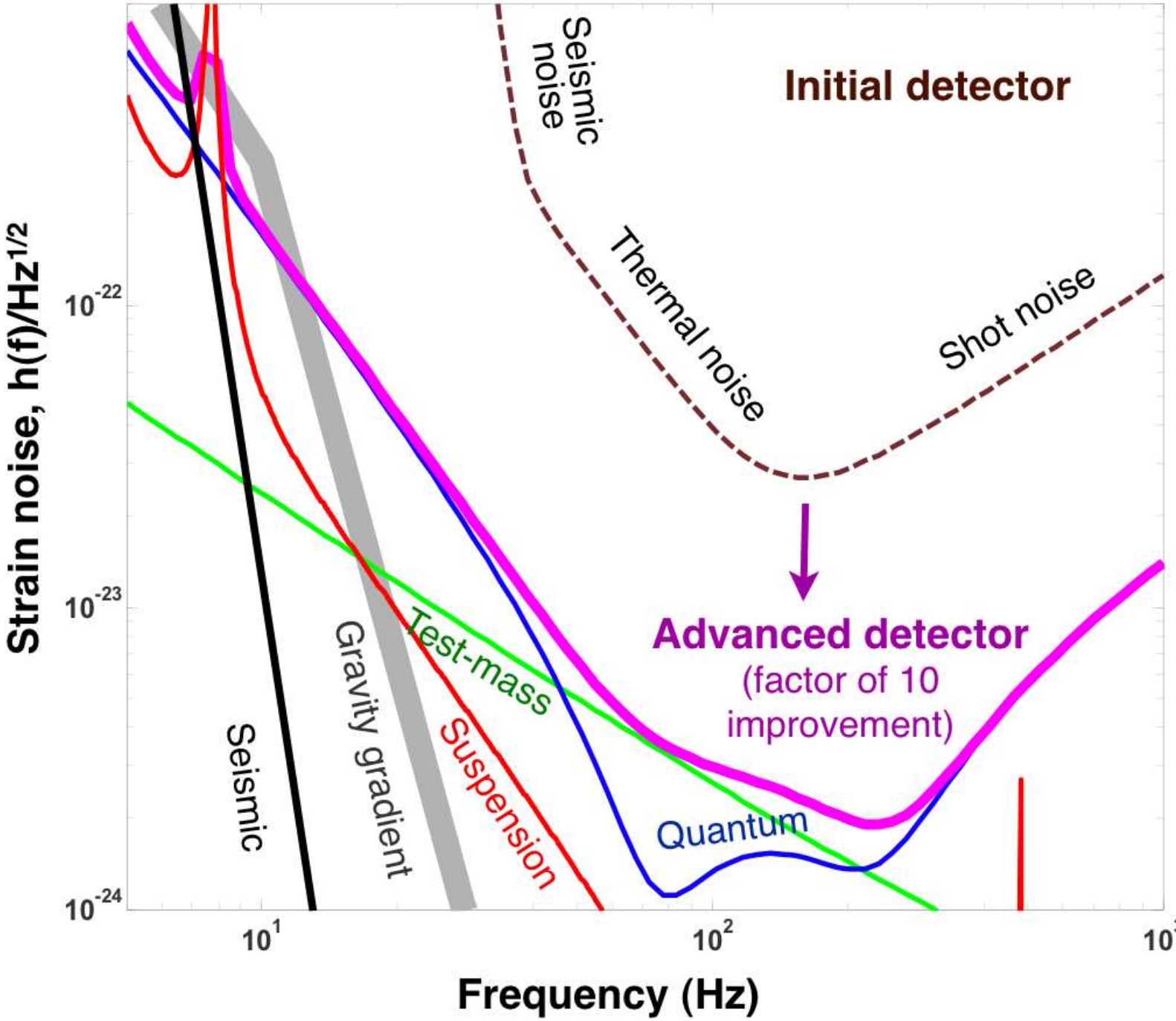
4km x 4km Ultra High Vacuum Pipe to be Fabricated in India

10 mega -litres at nano-torr

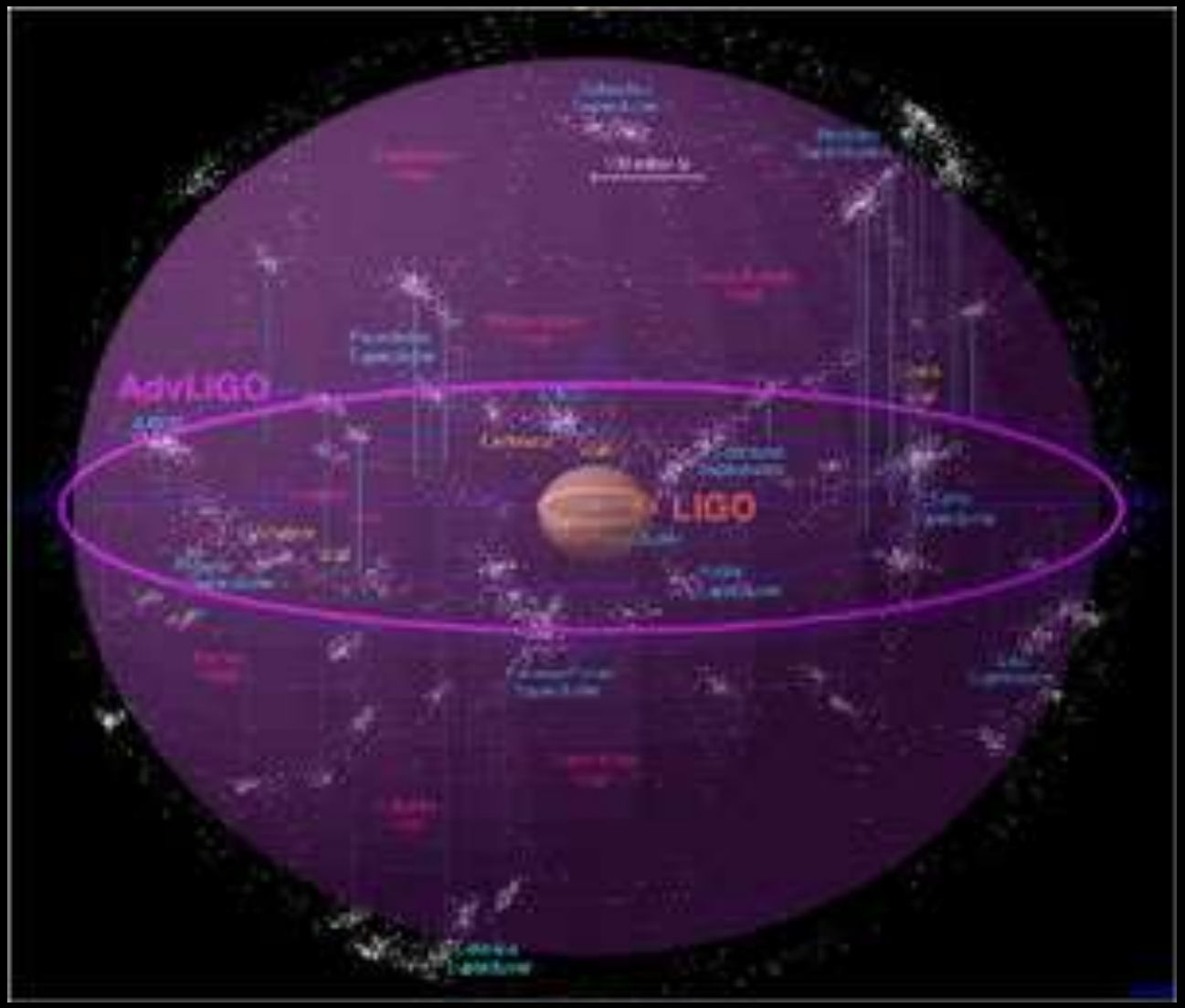


LIGO Hanford

Northern Arm


Initial detector
Seismic noise
Thermal noise
Shot noise
Advanced detector
(factor of 10 improvement)
Seismic
Gravity gradient
Test-mass
Suspension
Quantum
Strain noise, h(f)/Hz^1/2
Frequency (Hz)
10^-22
10^-23
10^-24
10^1
10^2
10^3

The Reach of Advanced LIGO



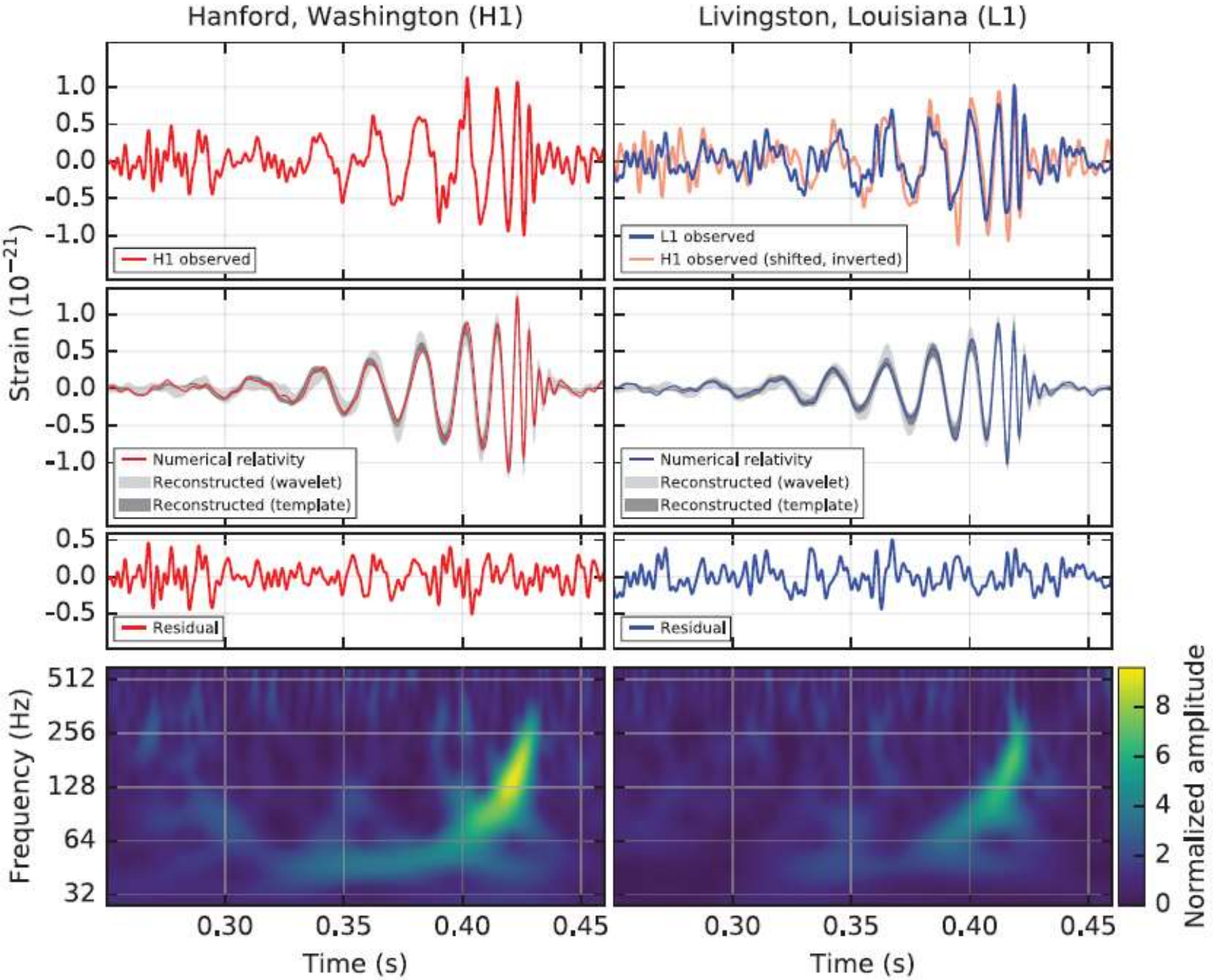
Sensitivity
10 x LIGO

Volume 1000
x LIGO

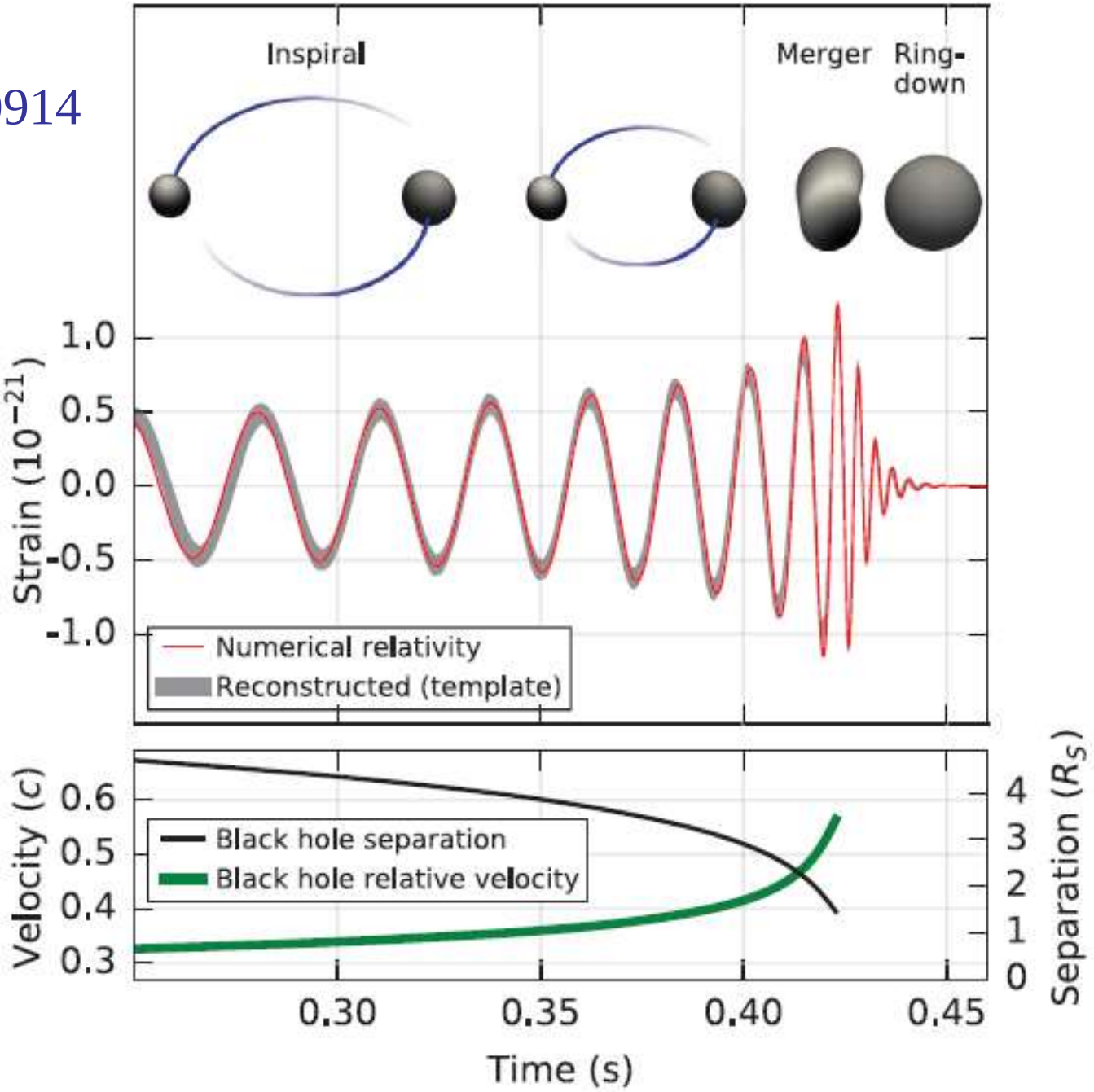
Event Rate
>>1000 x LIGO

A day in the life of A-LIGO ~
A year in the life of LIGO

First Detection
GW 150914


Hanford, Washington (H1)
Livingston, Louisiana (L1)
Strain (10^{-21})
H1 observed
L1 observed
H1 observed (shifted, inverted)
Numerical relativity
Reconstructed (wavelet)
Reconstructed (template)
Residual
Frequency (Hz)
512
256
128
64
32
0.30
0.35
0.40
0.45
Time (s)
Normalized amplitude
0
2
4
6
8

GW 150914


Inspiral
Merger
Ring-down
Strain (10^{-21})
1.0
0.5
0.0
-0.5
-1.0
Numerical relativity
Reconstructed (template)
Velocity (c)
0.6
0.5
0.4
0.3
Black hole separation
Black hole relative velocity
Separation (R_S)
4
3
2
1
0
0.30
0.35
0.40
0.45
Time (s)

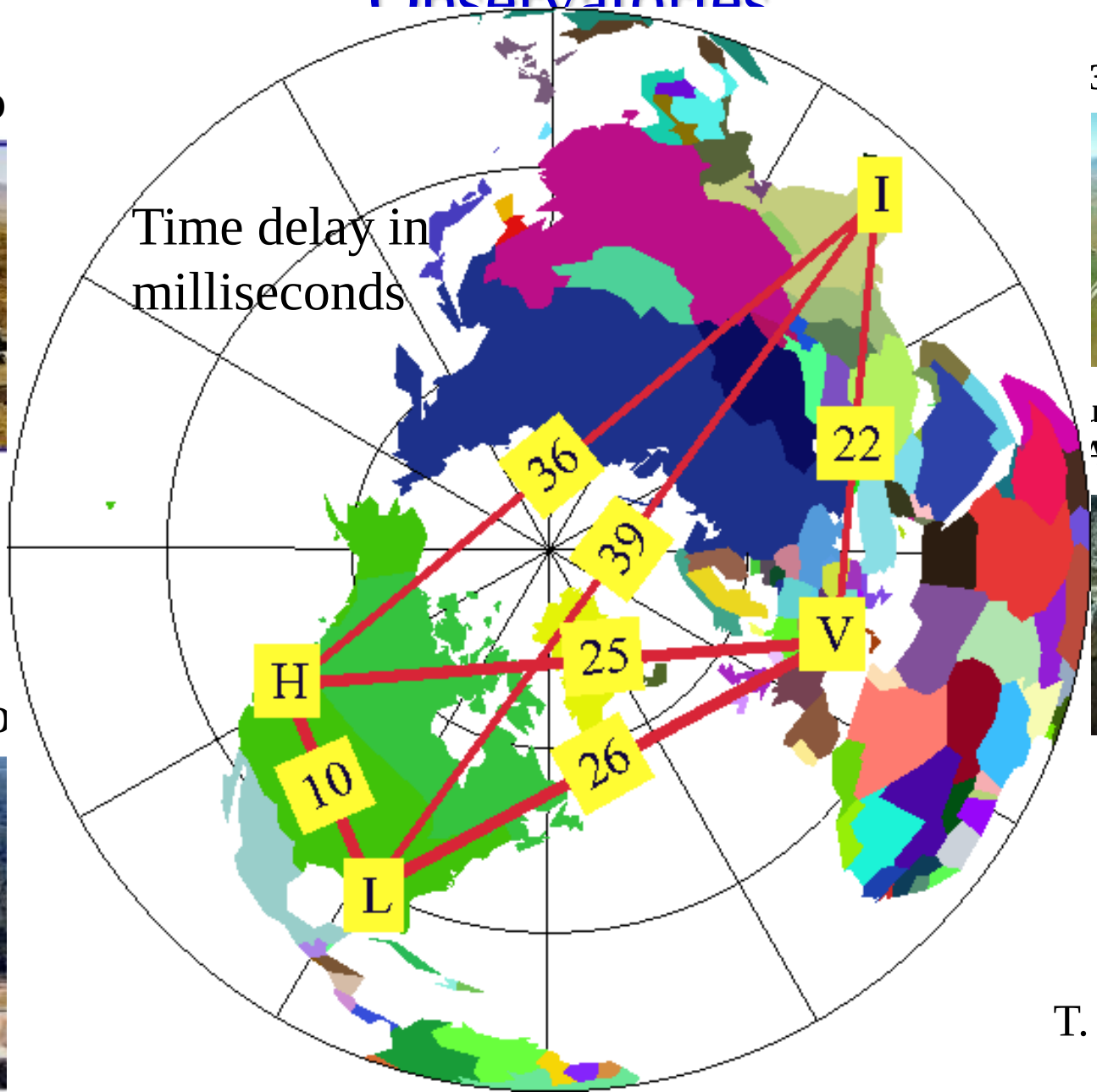
GW 150914

Primary black hole mass	$36^{+5}_{-4} M_{\odot}$
Secondary black hole mass	$29^{+4}_{-4} M_{\odot}$
Final black hole mass	$62^{+4}_{-4} M_{\odot}$
Final black hole spin	$0.67^{+0.05}_{-0.07}$
Luminosity distance	410^{+160}_{-180} Mpc
Source redshift z	$0.09^{+0.03}_{-0.04}$

Global Network of Gravitational Wave Observatories

LIGO-LHO

Time delay in milliseconds



3km

ıture: LCGT 3 k
AMA/CLIO

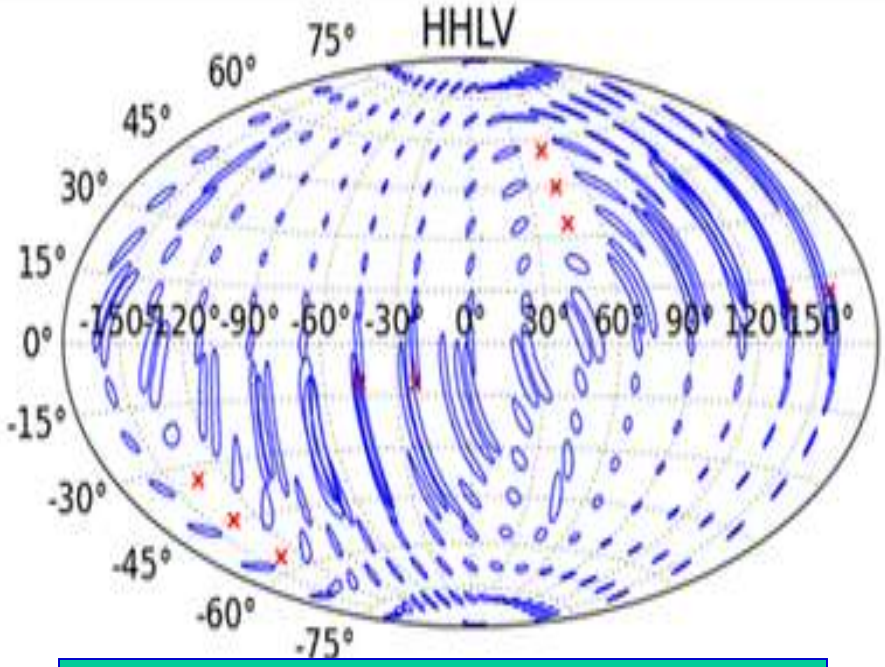
LIGO-LLO

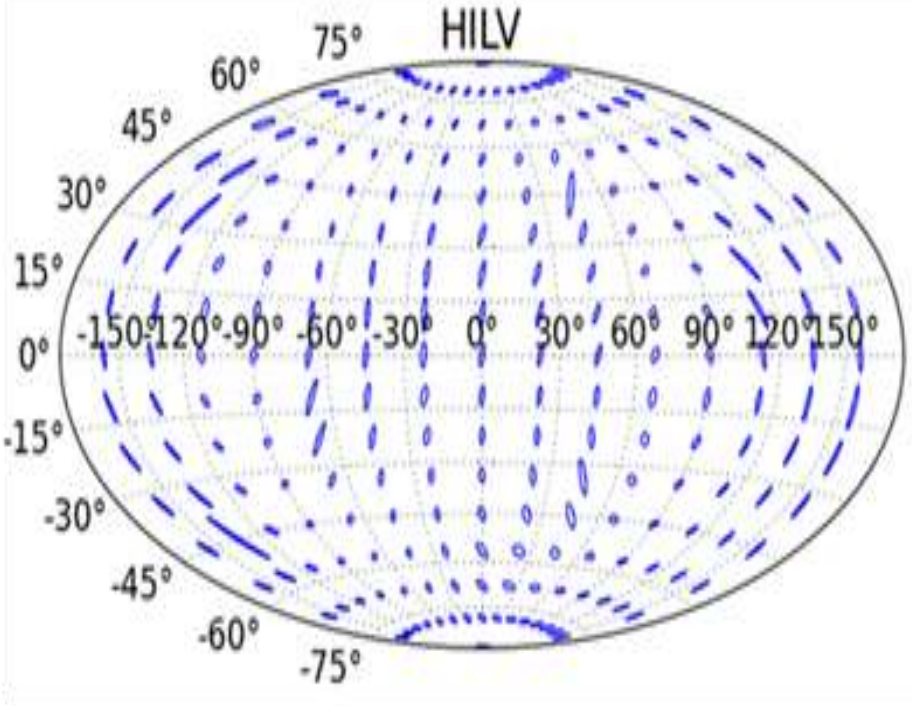
T. Sourdeep

Science Gain from Strategic Geographical Relocation

Courtesy:
S. Fairhurst

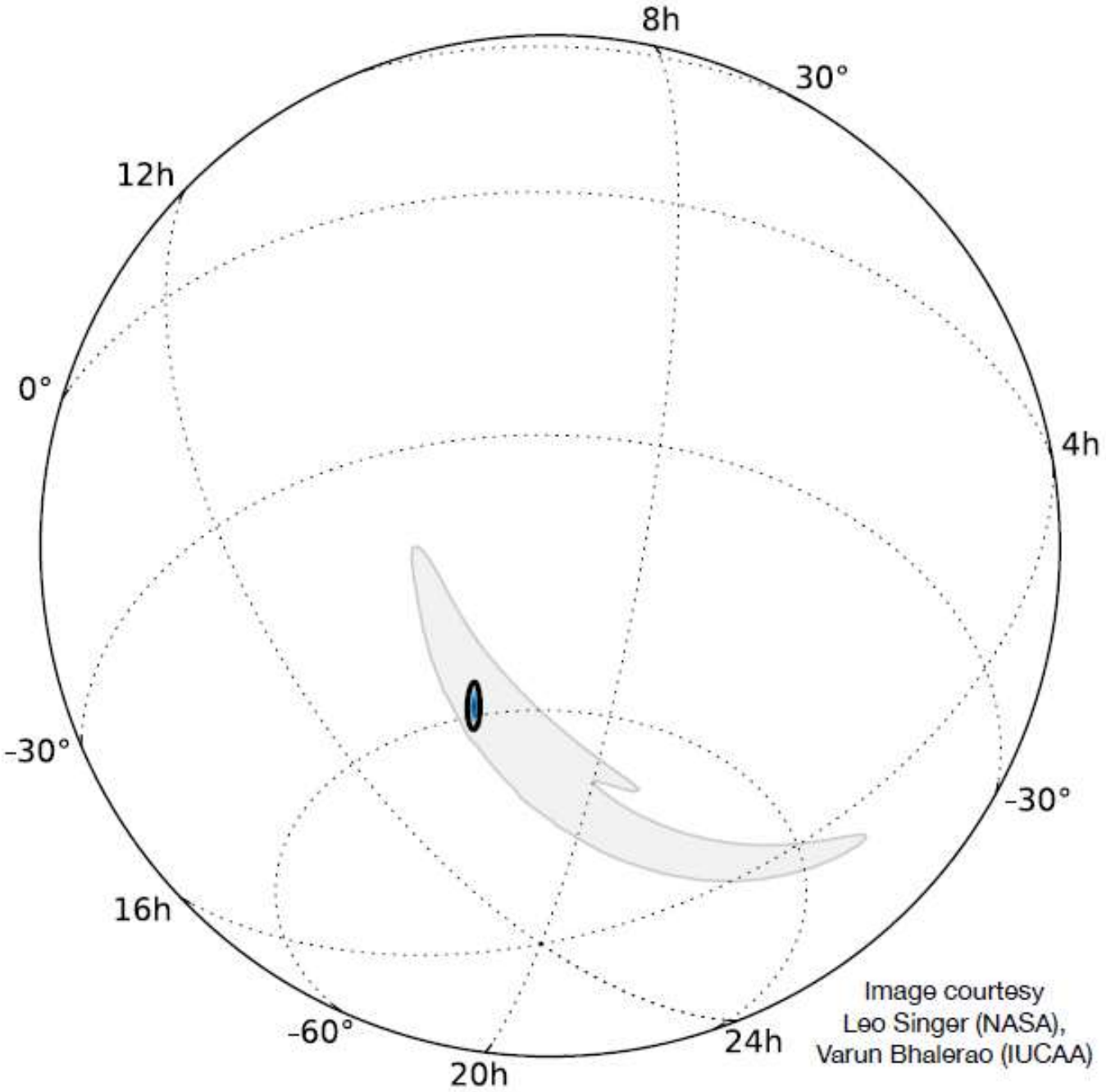
Source localization error

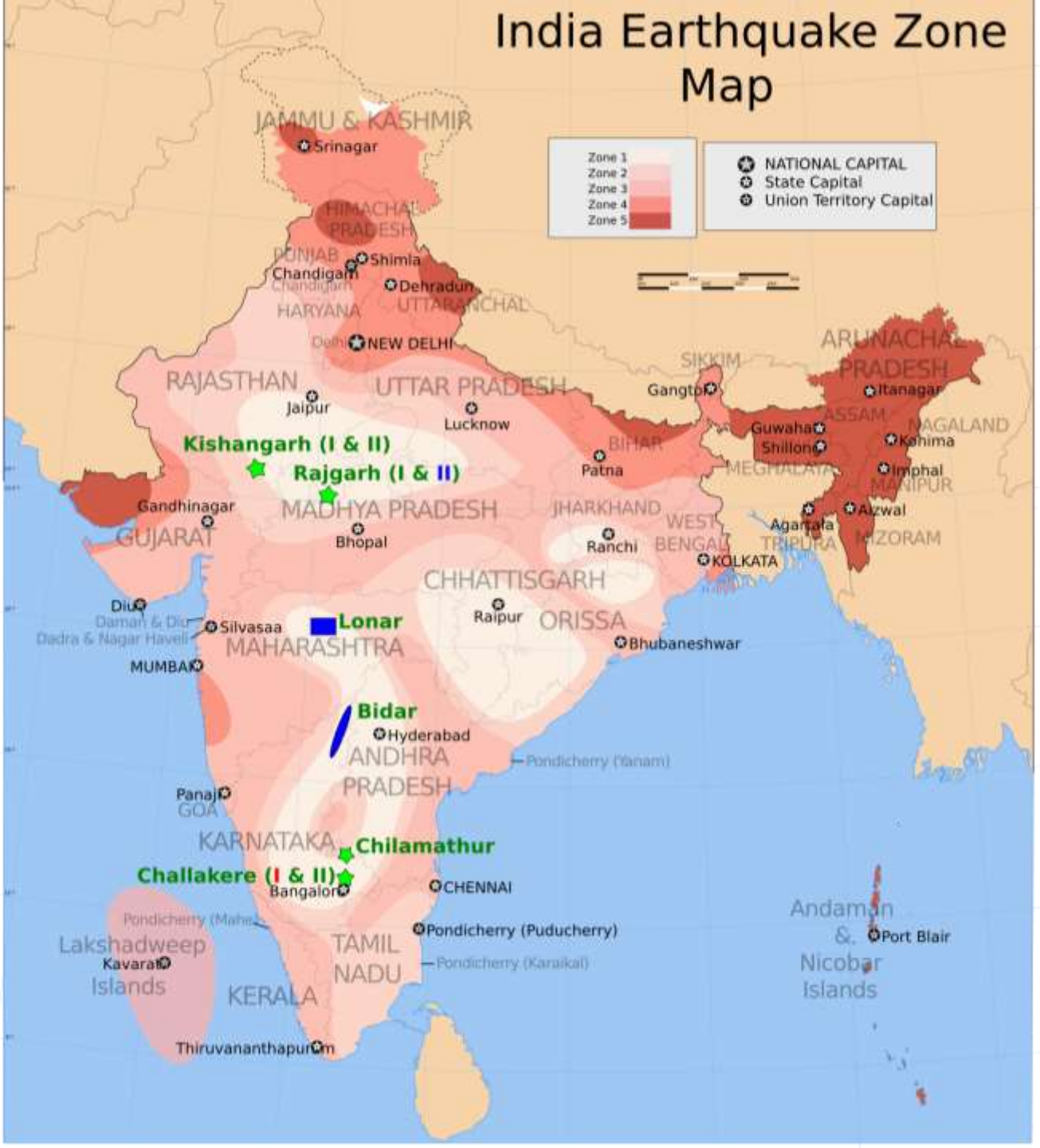




Detection confidence
Duty cycle
Source localization
Polarization information

LIGO-India plan
1+1 LIGO USA+ Virgo+ LIGO India


8h
30°
12h
0°
4h
-30°
-30°
16h
-60°
20h
24h
Image courtesy
Leo Singer (NASA),
Varun Bhalerao (IUCAA)


India Earthquake Zone Map
Zone 1
Zone 2
Zone 3
Zone 4
Zone 5
NATIONAL CAPITAL
State Capital
Union Territory Capital
JAMMU & KASHMIR
Srinagar
HIMACHAL PRADESH
PUNJAB
Shimla
Chandigarh
Dehradun
UTTARANCHAL
HARYANA
NEW DELHI
RAJASTHAN
Jaipur
UTTAR PRADESH
Lucknow
Kishangarh (I & II)
Rajgarh (I & II)
BIHAR
Patna
SIKKIM
Gangtok
ARUNACHAL PRADESH
Itanagar
ASSAM
NAGALAND
Guwahati
Shillong
Kohima
MEGHALAYA
Imphal
MANIPUR
Aizwal
MIZORAM
Agartala
TRIPURA
Gandhinagar
MADHYA PRADESH
JHARKHAND
Bhopal
Ranchi
WEST BENGAL
KOLKATA
GUJARAT
CHHATTISGARH
Diu
Daman & Diu
Dadra & Nagar Haveli
Silvasaa
Lonar
Raipur
ORISSA
Bhubaneshwar
MAHARASHTRA
MUMBAI
Bidar
Hyderabad
ANDHRA PRADESH
Pondicherry (Yanam)
Panaji
GOA
KARNATAKA
Chilamathur
Challakere (I & II)
Bangalore
CHENNAI
Pondicherry (Mahe)
Pondicherry (Puducherry)
Lakshadweep Islands
Kavaratti
TAMIL NADU
Pondicherry (Karaikal)
KERALA
Andaman & Nicobar Islands
Port Blair
Thiruvananthapuram

The LIGO-India Partnership

Inter-University Centre for Astronomy and Astrophysics

Site Survey, LIGO Science and Data Centre, HRD

Institute for Plasma Research

Vacuum, Controls

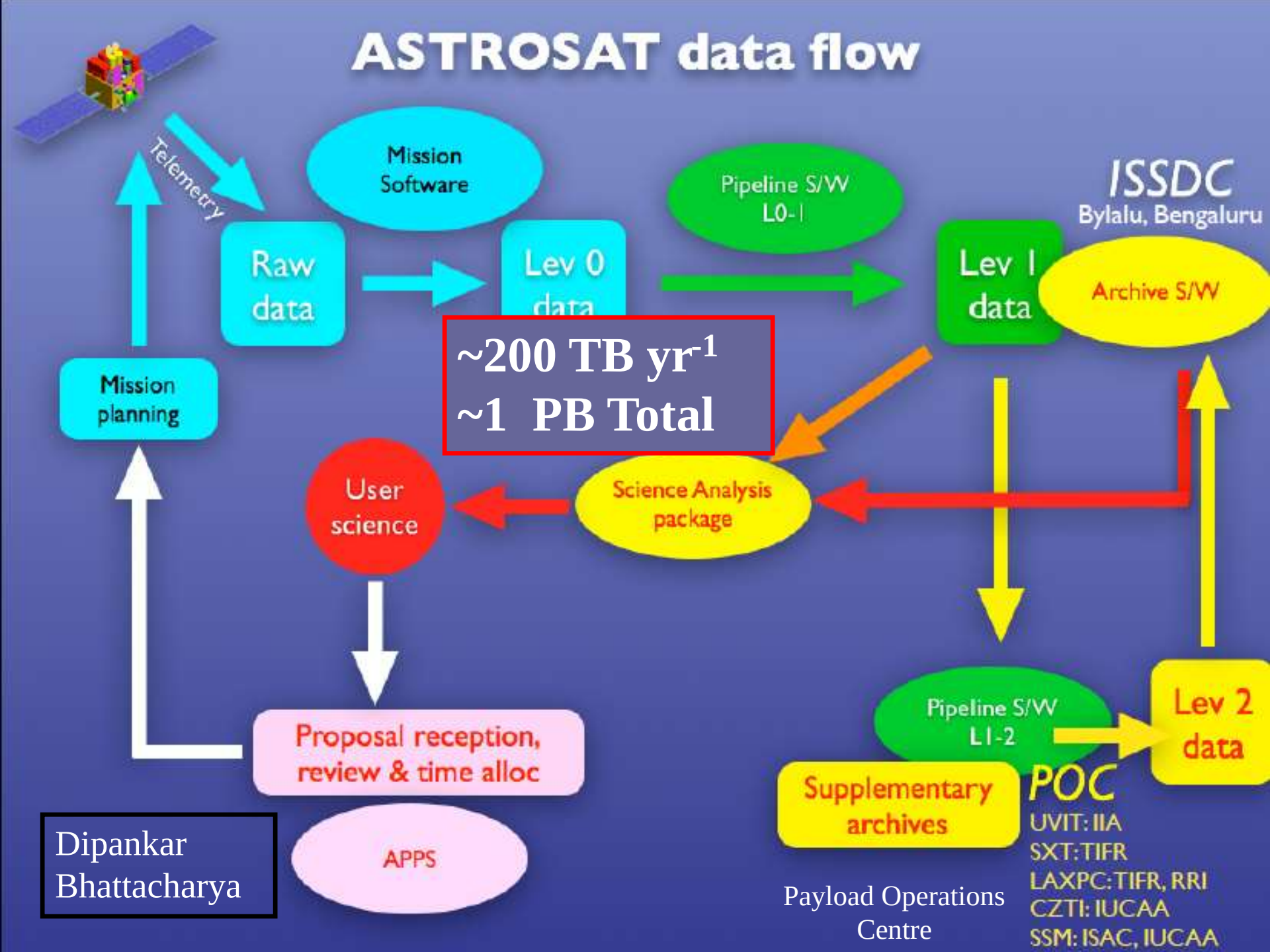
Raja Ramanna Centre for Advanced Technology

Laser, Detector, Controls, Next Generation Developments

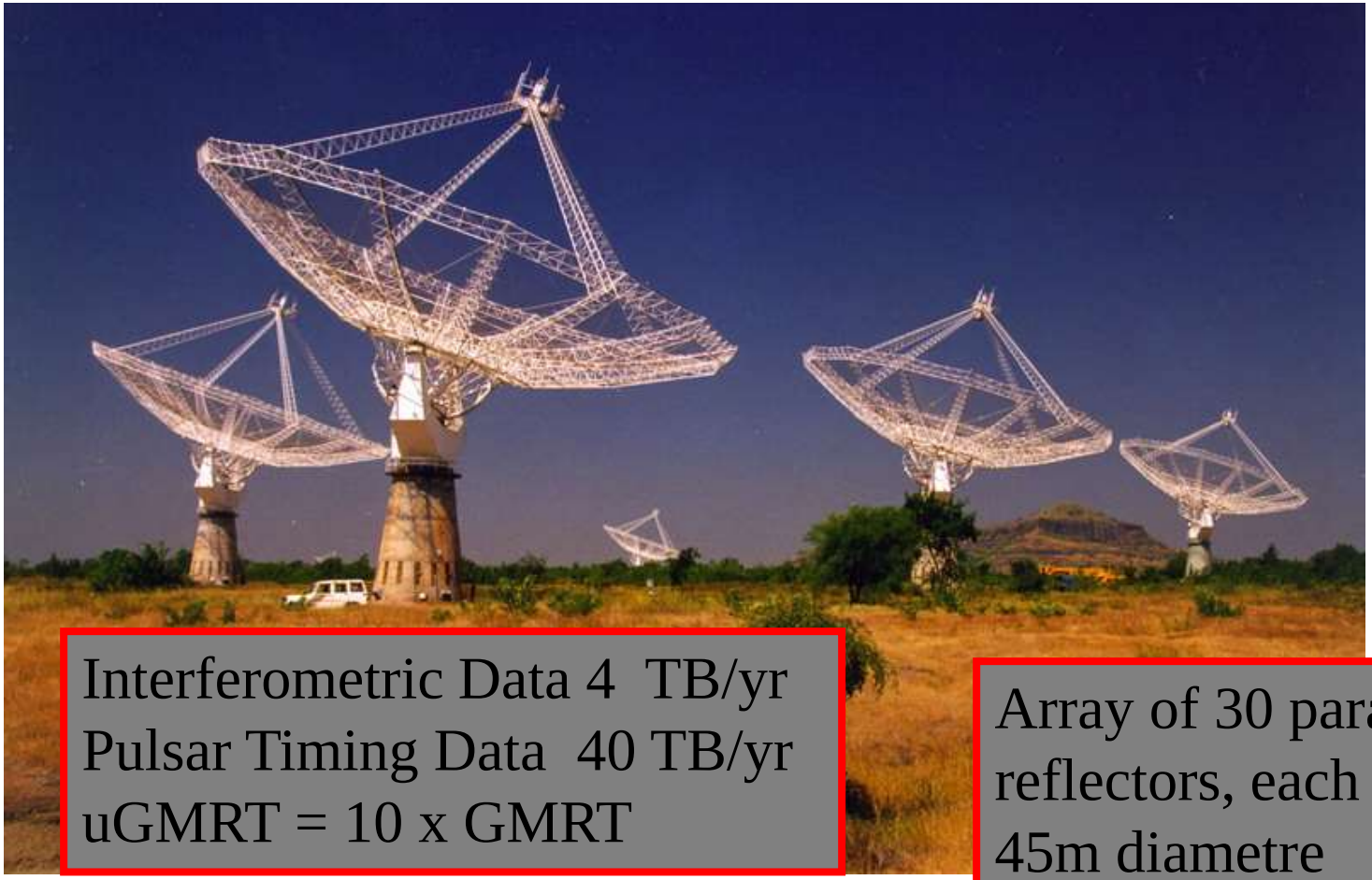
The IndIGO Consortium

IISER, IIT, IISc, Universities, Institutes…

Big Data in Astronomy


ASTROSAT data flow
Telemetry
Mission Software
Raw data
Lev 0 data
Pipeline S/W L0-1
Lev 1 data
ISSDC
Bylalu, Bengaluru
Archive S/W
~200 TB yr-1
~1 PB Total
Mission planning
User science
Science Analysis package
Proposal reception, review & time alloc
APPS
Pipeline S/W L1-2
Lev 2 data
Supplementary archives
POC
UVIT: IIA
SXT: TIFR
LAXPC: TIFR, RRI
CZTI: IUCAA
SSM: ISAC, IUCAA
Payload Operations Centre
Dipankar Bhattacharya

GMRT



Interferometric Data 4 TB/yr
Pulsar Timing Data 40 TB/yr
uGMRT = 10 x GMRT

Array of 30 parabolic reflectors, each of 45m diametre
Baseline ~25km
50-1500 MHz

National Centre for Radio Astrophysics – Tata Institute of Fundamental Research

SKA

South Africa – Australia
2020, 2024
~3000 dishes, 15m diameter
70MHz-10GHz, <0.1”

45 TB/sec
exits correlators
500 PB/yr
archival data
Hexaflop computing

High Performance Computing Facilities

Data Centres

Data Analytics:

Domain Knowledge
Mathematics
Statistics

Visualisation
Data Mining
Machine Learning
Deep learning

Headline in The Times of India and
The Economic Times, May 8, 2016

"Sexiest Job in the 21st Century: Data Analytics…"

Mega-Projects and Young Astronomers

Are these long term projects relevant to young astronomers?

Is developmental work possible while remaining astronomers?

Is there a place for theorists?

Are the projects preventing individuality?

What will trained people do after finishing with projects? Is there only jobless growth?

How does on keep up with cutting edge IT?

Thank You!

ASTROSAT

LAXPC
3-80 keV X-ray Timing

UVIT
1.8" UV imaging

CZTI
10-150 keV
hard X-ray
imager

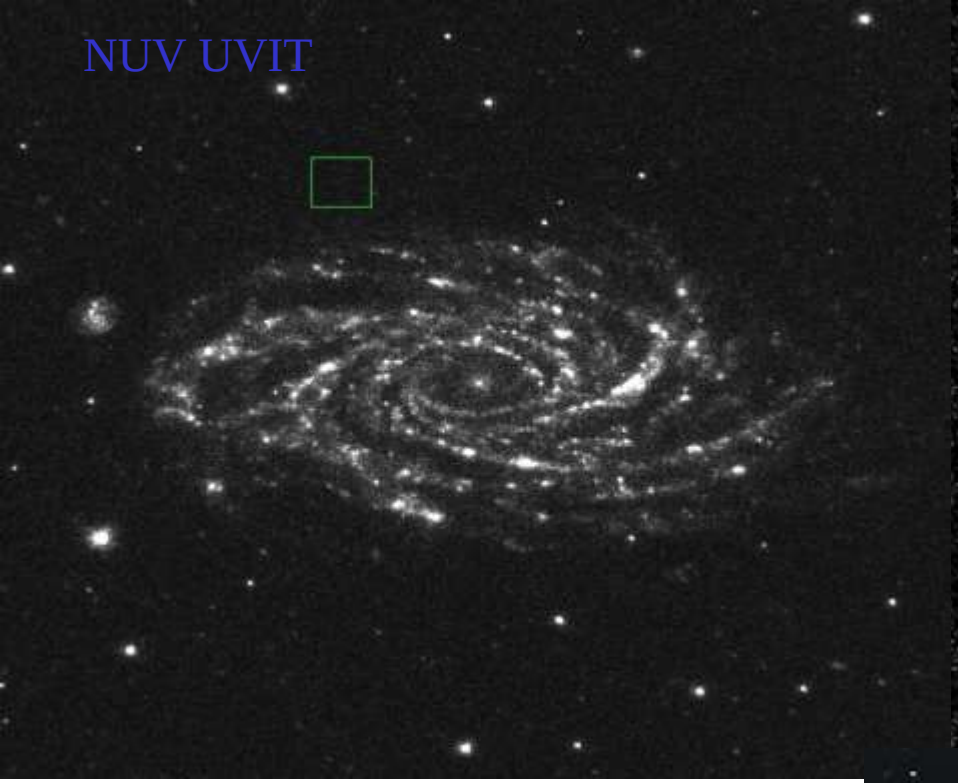
SXT
0.3-8 keV imaging

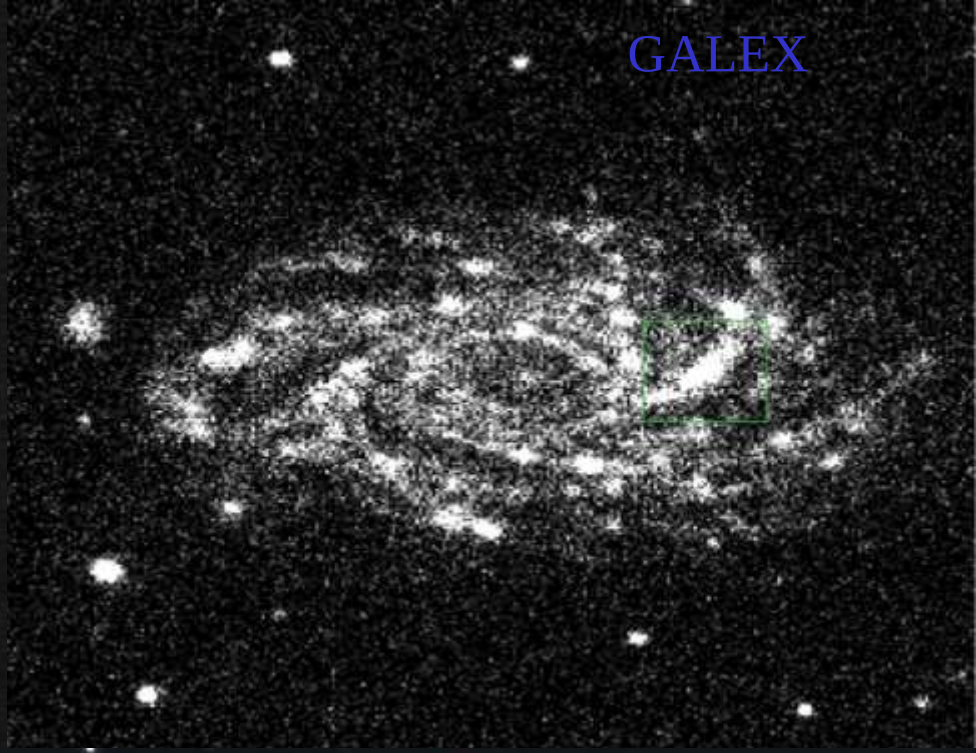
Star Sensors

SSM
rotating 2-10
keV monitor

Phased
Array
Antenna

http://astrosat.iucaa.in/


NUV UVIT


GALEX


Ground

Aditya-L1 Solar Space Mission

- First Indian space mission to study the Sun.
- The spacecraft will be in an halo orbit around the from an Halo orbit around the Sun-Earth Lagrangian Point L1, which is at a distance of ~1.5 million km from the Earth.
- The 1.5 ton satellite will carry seven payloads to observe the Solar photosphere, chromosphere and corona
- Launch by PSLV-XL is expected in 2019-20.

Visible Emission Line Coronagraph

Internally occulted Solar coronagraph capable of simultaneous imaging spectroscopy and spectro-polarimetry close to the Solar limb.

It is designed to image the Solar corona at 500 nm with angular resolution ~5 arcsec with FOV 1.05-3 R_{Sun}.

It will help study the coronal plasma, heating of the corona, origin and dynamics of coronal mass ejections and measurement of coronal magnetic fileds over active regions.

IIA, USO, ISRO Centres

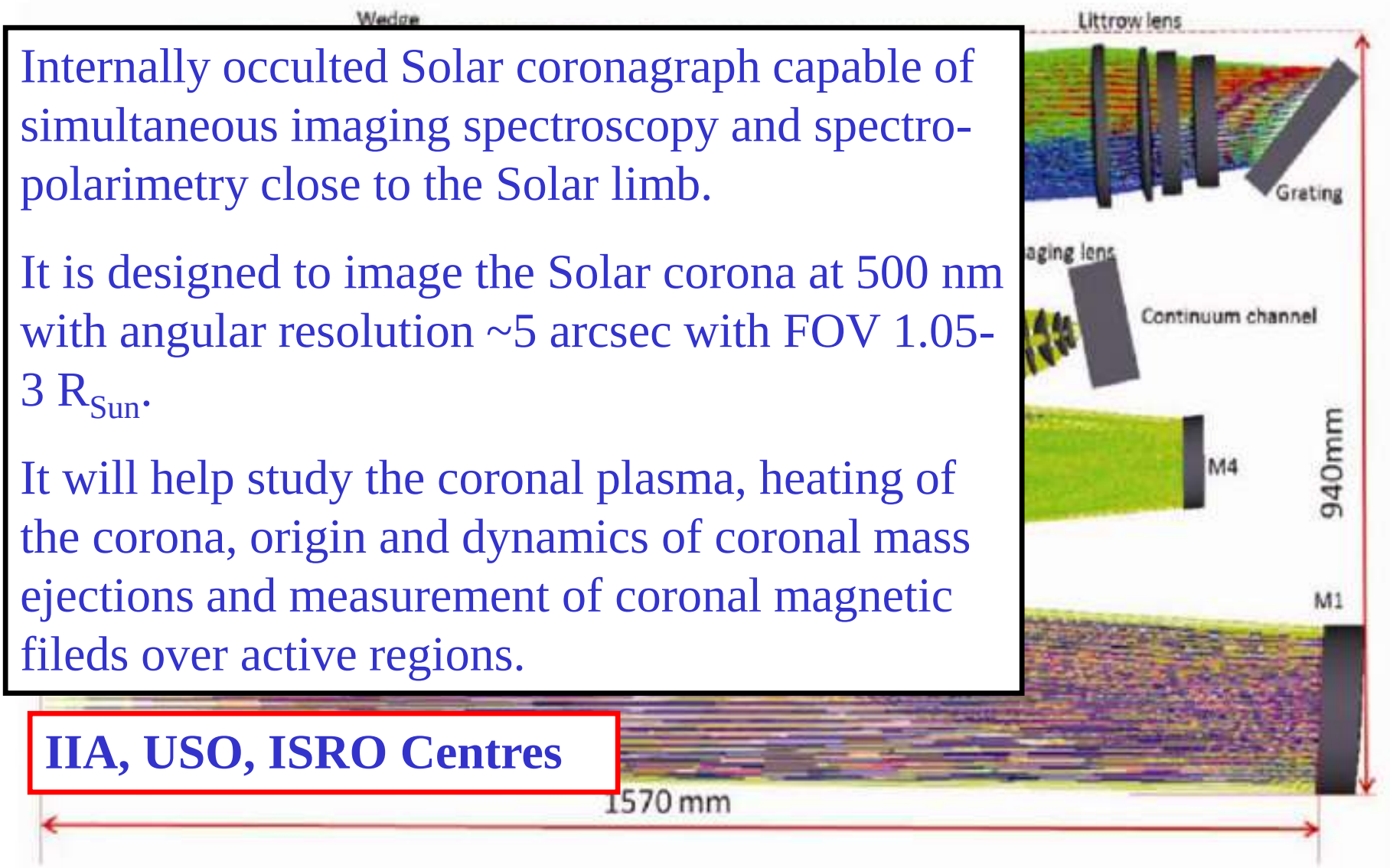


Figure 1. Optical layout of Visible Emission Line Coronagraph (VELC).

Solar Ultraviolet Imaging Telescope

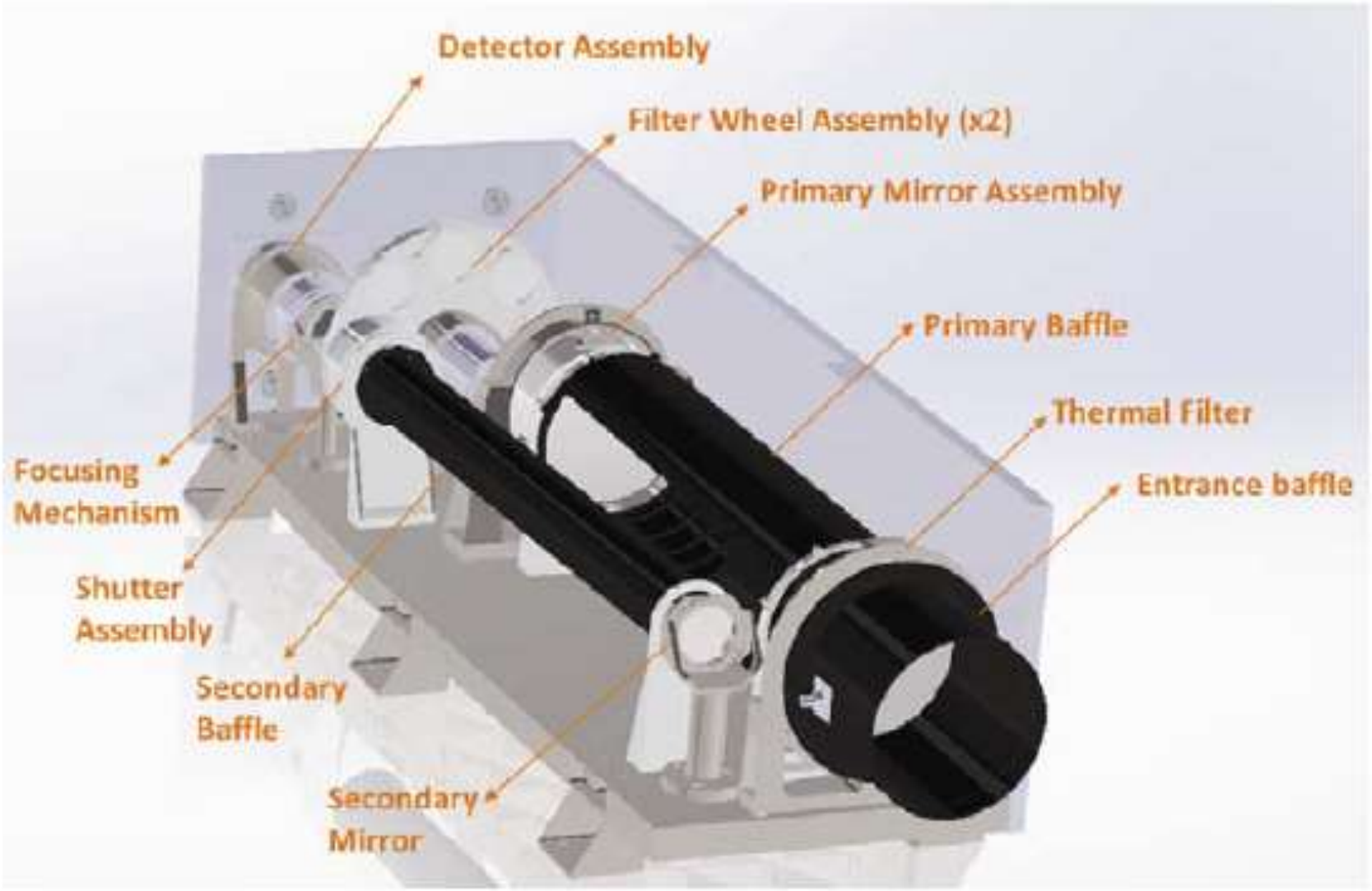


Figure 5. SUIT payload with all the subsystems.

Thermal filter transmits Angular resolution of 1.4

SUIT will for the first time provide full disk observations in the near-UV. It will

- Measure and monitor Solar radiation in NUV (200-400 nm)
- Simultaneously map the photosphere and chromosphere using 11 filters covering different heights in the Solar atmosphere.
- Measure and monitor spatially resolved Solar spectral irradiance that governs the chemistry of oxygen and ozone in the Earth's atmosphere.

IUCAA , IISER Kolkata,
IIA, ISRO Centres.

In Situ Experiments

- There are three *in situ* experiments: Aditya Solar wind Particle Experiment; Plasma Analyser Package for Aditya and a Magnetometer Package.
- The three payloads will sample heliospheric data at L1.
- A unique opportunity to get a better understanding of the inner heliosphere, and predict space weather more accurately.

  PRL, IISER-Pune, Udaipur Solar Observatory, Space Physics Laboratory, Laboratory or Electro-Optical Systems

X-ray Spectrometers on Aditya-L1

- The mission will have two high spectral resolution X-ray spectrometers to study Solar flares.
- A soft X-ray spectrometer will cover the range 1-30 keV, while a hard spectrometer will cover 10-150 keV.
- The instruments together will enable the study of Solar flare plasma parameters and accelaration mechanism of energetic particles.

Helios-1 Payload

Figure 4. Engineering model of the HEL1OS payload.