AURA Observatory in Chile:

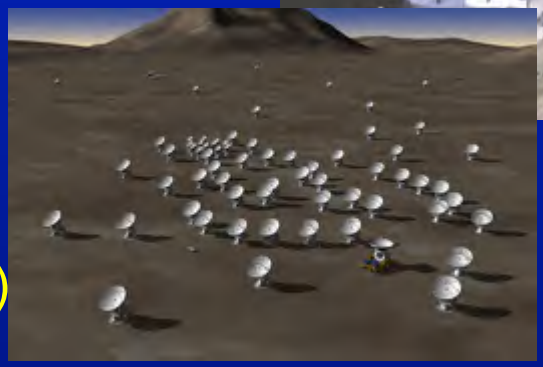
La Ciencia, Los Telescopios, y Los Cielos Oscuros

- Welcome to Chile!
  - Extremes: from glaciers to the driest desert
  - A modern country with stable government and solid infrastructure

CONTEXT: Astronomy Operations in Chile

- AURA-O
  - CTIO (4m + smaller telescopes)
  - SOAR (4.2-m)
  - Gemini (8m)
  - LSST (8.4m)
- European Southern Observatory
  - La Silla (3.6m + 3.5m + 2.2m + …)
  - Paranal (4 x 8m VLT + VISTA 4m + VST 2.4m
- Carnegie Observatories
  - Las Campanas Observatory (2.5m + 1m + …)
  - Magellan (2 x 6.5m)
- ALMA (= ESO + AUI + Japan)
  - ~64 12m radio telescopes
- GSMT
  - GMT (Las Campanas), E-ELT (Armazones?)





What is "AURA"

- AURA = Association of Universities for Research in Astronomy
  - A consortium of universities established in 1957 to manage public observatories
  - Membership currently includes 37 U.S. institutions and 7 international institutions (including 2 Chilean)

What is “AURA”?

- AURA currently manages many major public international astronomical facilities
  - National Optical Astronomy Observatory (NOAO)
    - Kitt Peak National Observatory
    - Cerro Tololo Inter-American Observatory
    - SOAR Telescope
  - National Solar Observatory (NSO)
  - Space Telescope Science Institute (STScI)
  - Gemini Observatory
    - Gemini-North & Gemini-South
  - Large Synoptic Survey Telescope (LSST)

AURA Observatory in Chile

- AURA came to Chile in 1960
  - Following up on an invitation from Prof. Federico Rutlant, Director of the Observatorio Nacional de Chile
  - In collaboration with the ON/UChile, AURA managed site survey work to establish the first large international observatory in Chile

Site Selection

AURA Observatory in Chile

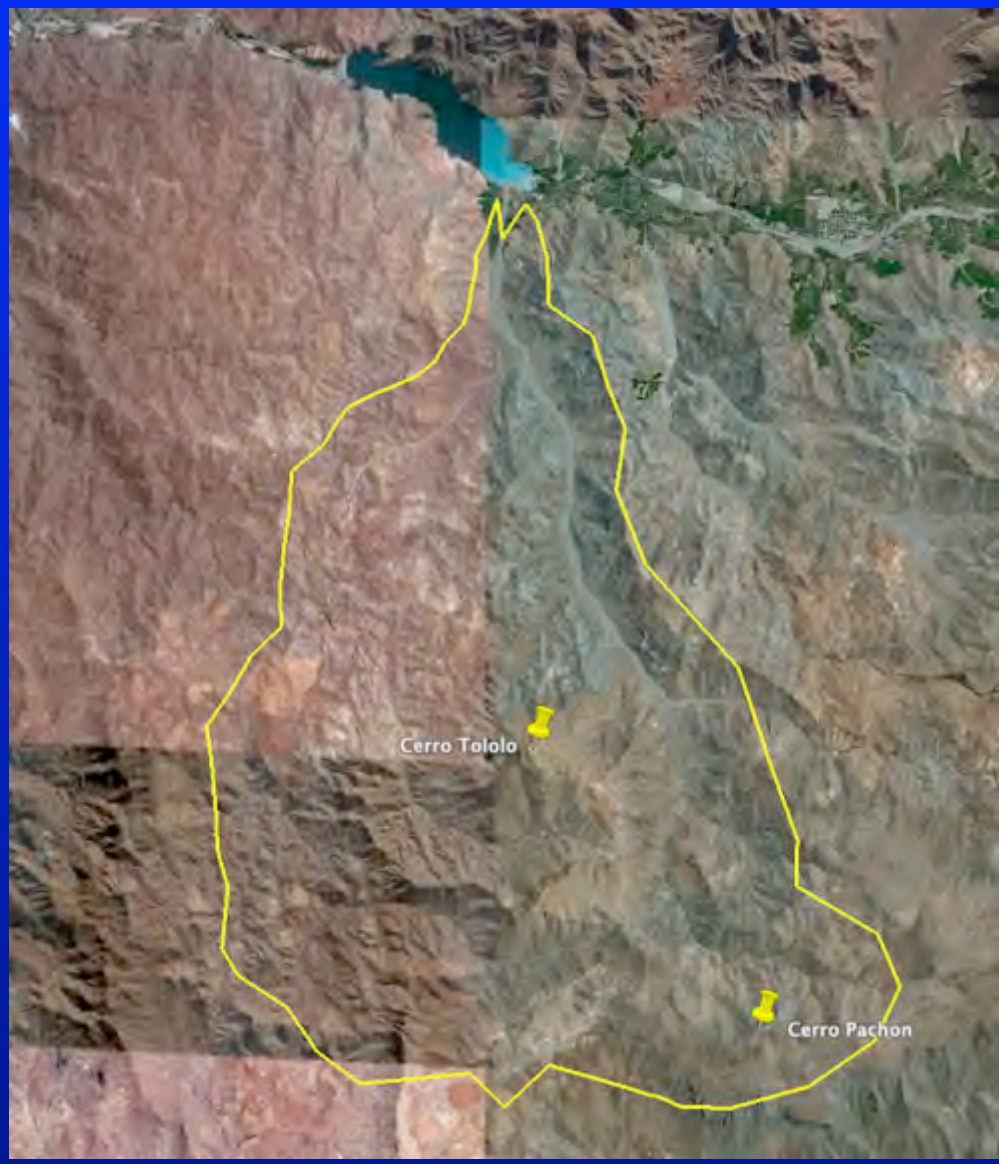
- In November 1962
  - Selected the site, Cerro Tololo

- Cerro Tololo Inter-American Observatory

Immediate Environment

AURA "Estancia"

- AURA-owned, purchased 1962
  - >90,000 acres
  - Access actively controlled at the gate house
  - Some native flora & fauna protected; no environ. issues
- Infrastructure
  - ~45km of well-maintained dirt road to mountaintops
    - With emergency phones & guardrails
  - A well in valley provides water, pumped up to Tololo, trucked over to Pachón
  - Power lines from paved road to mountaintops
  - Wholly owned & operated microwave link to La Serena



Cerro Tololo

- 17 telescopes
- 3 dormitories (+Dining Hall)
- 5 houses
- Warehouses
- Power station
- Water station
- Garage

- “Las Tacas”: Offices, Elec. Labs, Machine Shop
- The hub is the “Round Office Building” (ROB)
  - With admin offices, library, clinic, and meeting room

Cerro Tololo Aerial View (Year 2001)

Cerro Pachón

- 2 telescopes, Dining Hall, 2 Dormitories
  - Clinic in one of the dorm rooms
- Planned expansion of dorm
  - More dorm rooms, offices, & new kitchen/dining facility

May 2006: LSST Site Selected

El Peñon

Control Room & Support Bldg

Calibration Telescope

Immediate Environment

La Serena

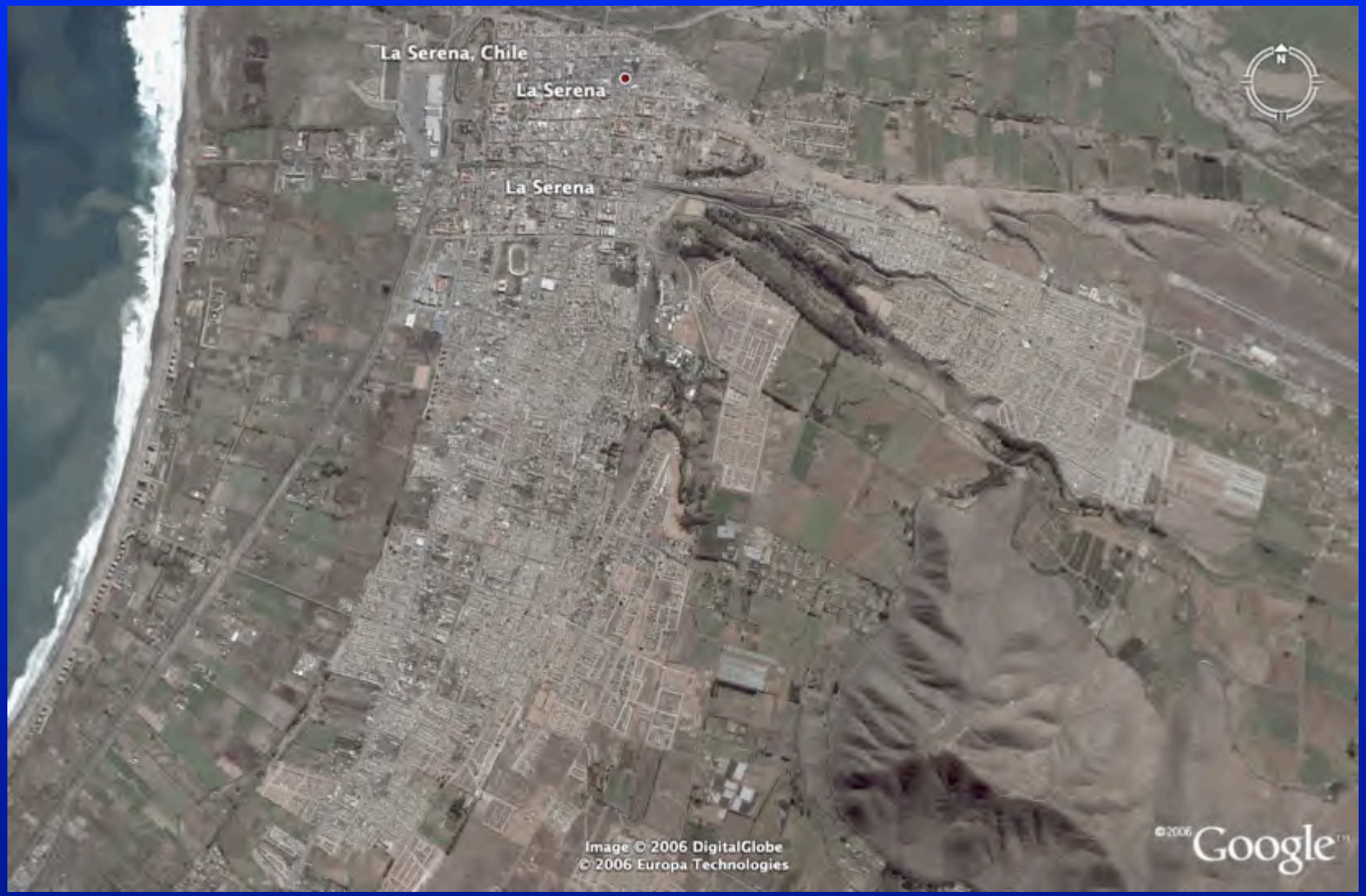

La Serena, Chile
La Serena
La Serena
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Image © 2006 DigitalGlobe
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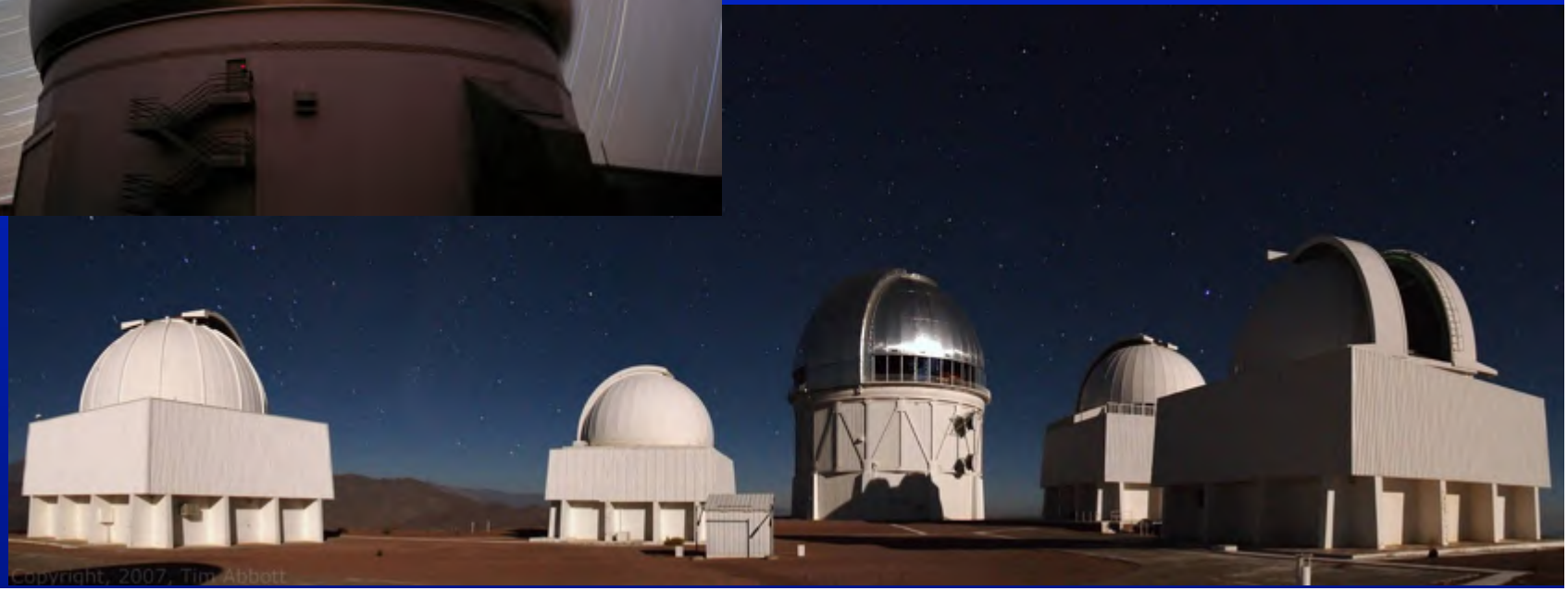
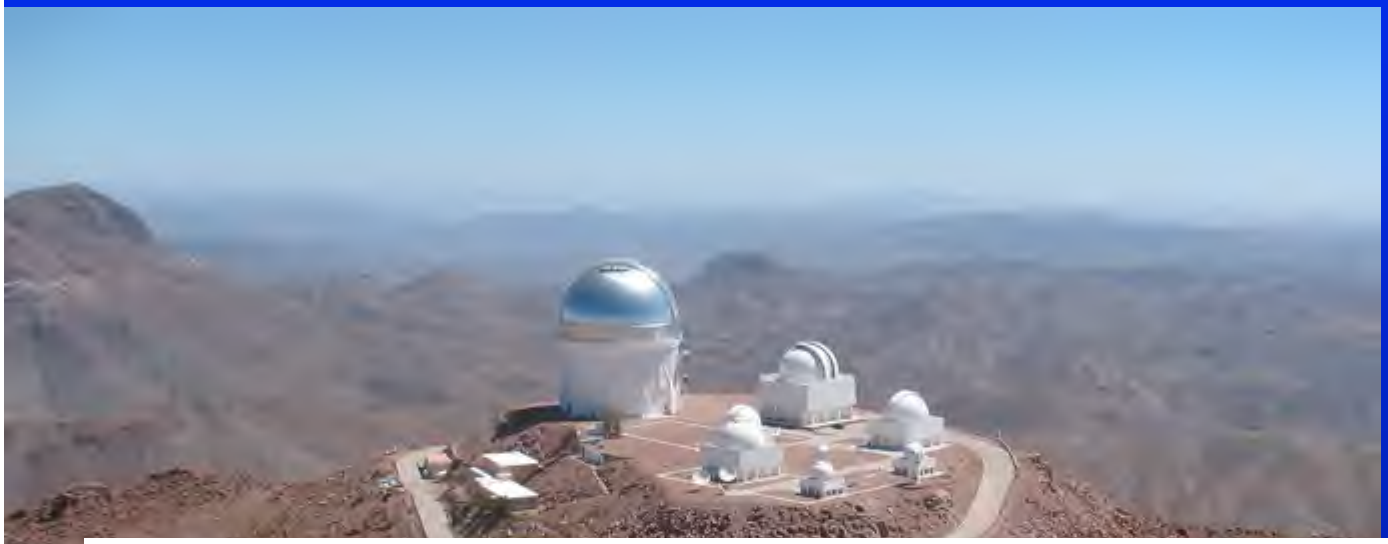
AURA Recinto

Telescopes of AURA Observatory



Cerro Tololo Inter-American Observatory



- Southern branch of the National Optical Astronomy Observatory (NOAO)
  - With CTIO+KPNO, since ~1965 we have provided access to the whole sky to astronomers from all over the world with a “open skies” policy

Gemini-South 8m

GEMINI

- **Among the largest telescopes in the world**
- Probing the most distant objects in the universe
- Probing nearby stars for planets with specialized instruments
- Most observing in QUEUE mode

SOAR 4.1m

- SOAR: SOuthern Astrophysical Research telescope
- Consortium with Brazil, UNC, MSU, & NOAO
- Large Instrument Payload
  - Up to 9 active instruments
  - Rapid switching between instruments
- Remote Observing

Cerro Tololo Small Telescopes

Other Activities

ATMOSPHERIC STUDIES

- DGAC (Chilean FAA)
  - Ozone monitoring, Weather Station
- Andes Lidar Observatory (ALO)
- SSI Airglow
- Univ. British Columbia Site testing

GEOLOGIC

- IRIS/Uchile Seismological station

Tools of the FUTURE

Selected Examples:

Coming soon to nearby mountaintops…

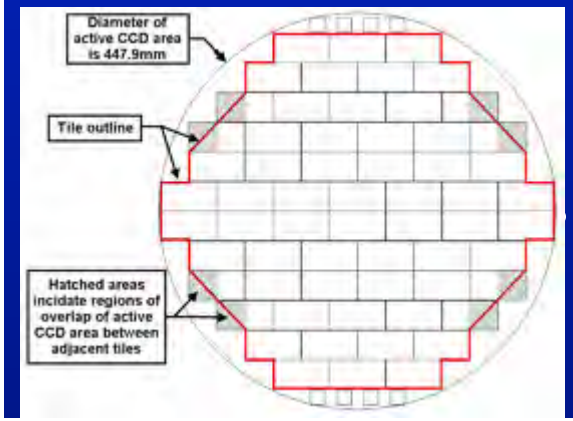
New Instruments (DECam)

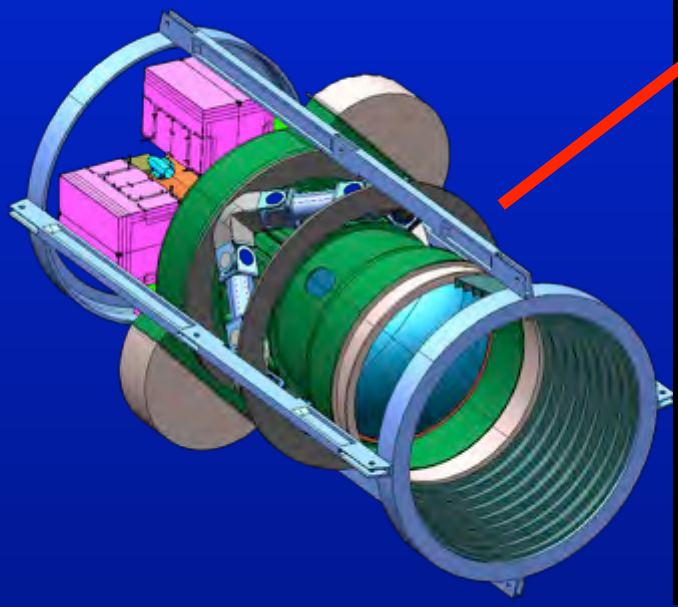
New Telescopes (LSST)

Dark Energy Camera

CAMERA:

- 62 2048 x 4096 pixel CCDs
- **570 Megapixel camera**
- The largest focal plane for astronomy in S. Hemisphere

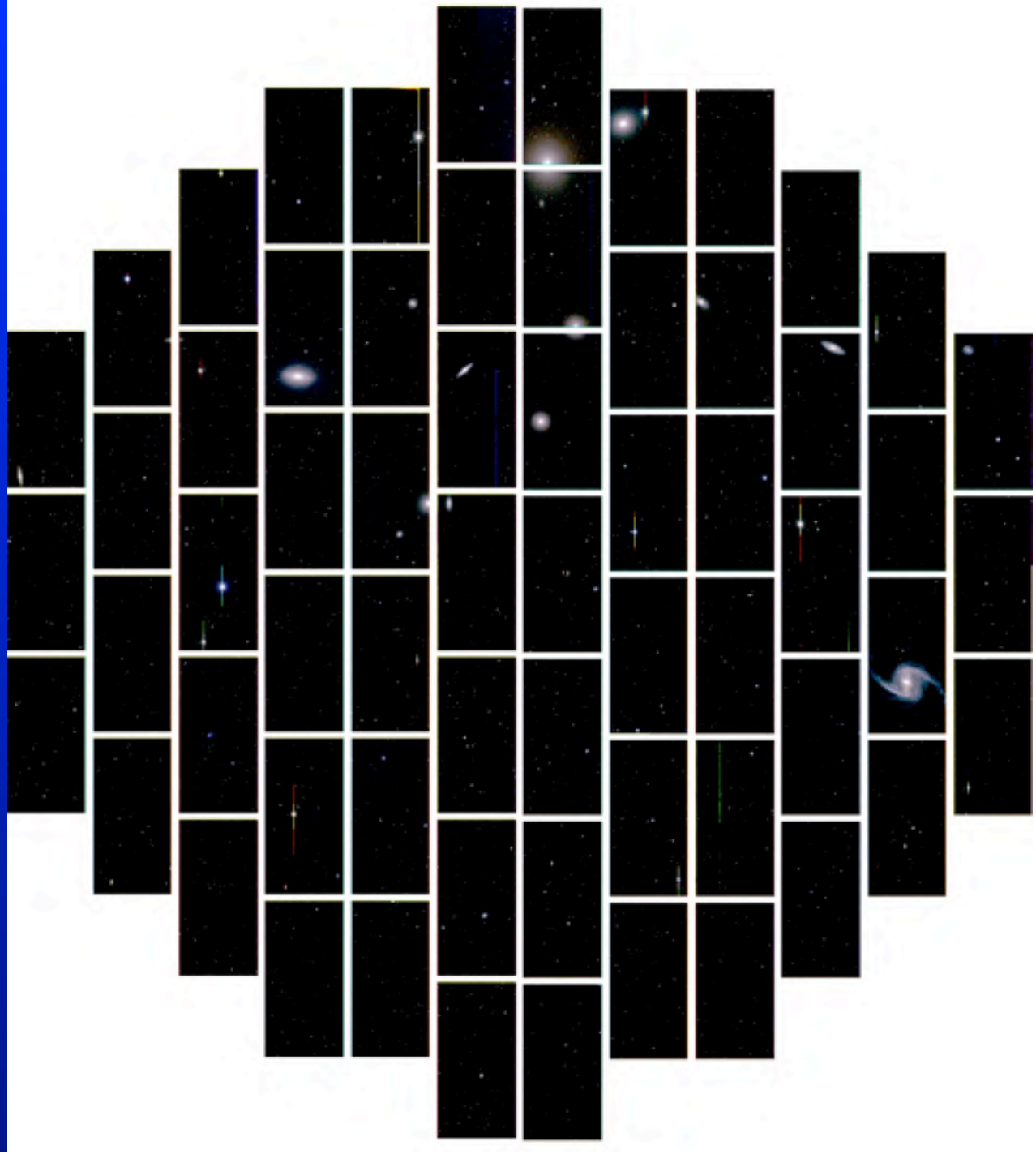




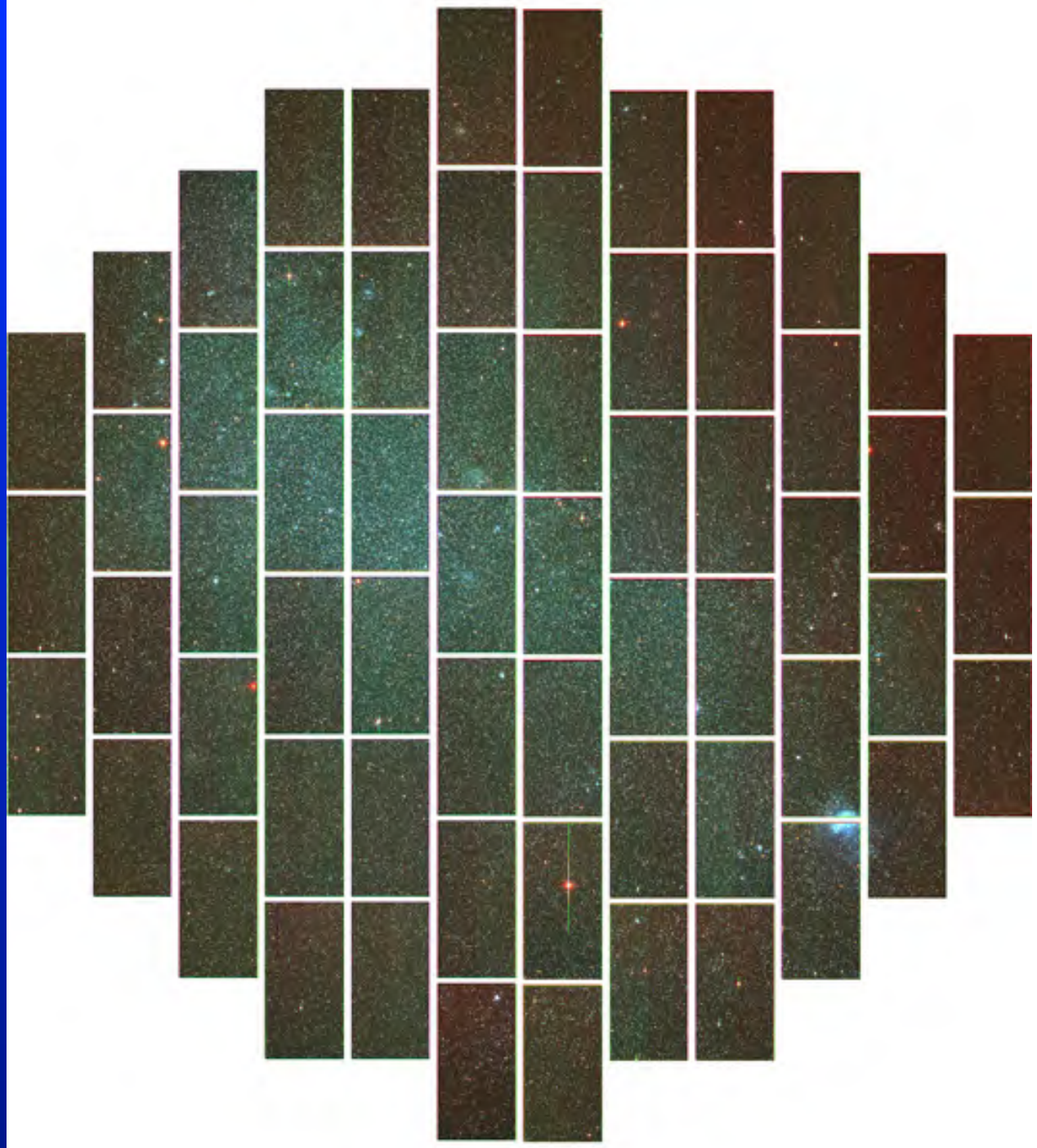
A “modest” data challenge

- Each image 1GB; 300–500 GB of raw data/night
  - Data must be moved from Chile to NCSA before next night begins (<18 hours), preferably in real time
  - Data must be processed within <24 hours to inform next night’s observing: using TERAGRID resources
- TOTAL Dataset 1 to 5 PB; w/ public access
  - Raw Images + Processed images + Catalogs

- First light images: September 12, 2012
- Fornax galaxy cluster



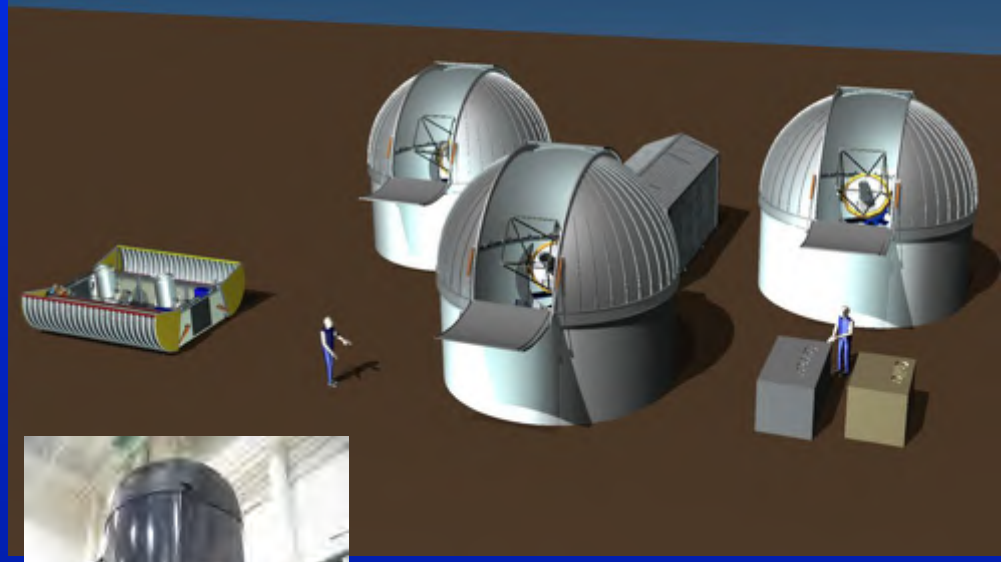
- **Small Magellanic Cloud**
- ~5 billion measurable stars in this single image!



New Techniques: Las Cumbres Observatory Global Telescope Network

- Privately funded network of nearly identical telescopes distributed worldwide (>6 sites)
- Mission: Mix of Science & Education
- Planned facilities:
  - 0.4m-s: mostly educational
  - 1m-s: mostly science, mostly photometry
  - 2m-s: mostly science, photometry+spectroscopy

Layout for LCOGTN at CTIO



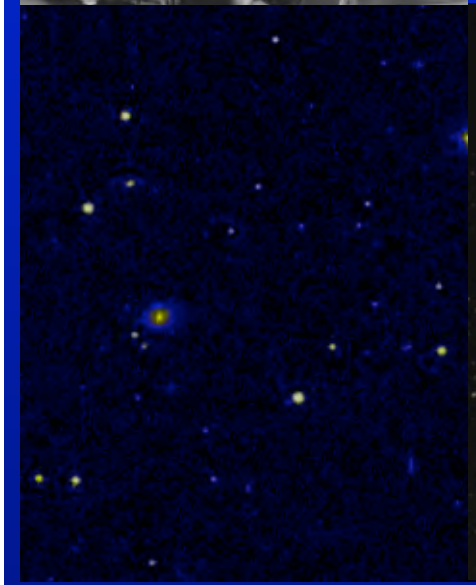
The next step…

ca. 1950 POSS
(Photographic)

ca. 2000 SDSS
(Digital)

ca. 2012 DES
(Digital + Depth)

ca. 2020 LSST
(Digital Sky
+Time Domain)



The Large Synoptic Survey Telescope – Massively Parallel Astrophysics

Survey the entire sky every 3-4 nights, to simultaneously detect and study:

- Dark Matter via Weak gravitational lensing
- Dark Energy via thousands of SNe per year
- Potentially hazardous near earth asteroids
- Tracers of the formation of the solar system
- Fireworks in the heavens – GRBs, quasars…
- Periodic and transient phenomena
- ……the unknown

LSST:
creating a "digital universe"

LSST is designed to image the whole sky every few nights for 10 years, giving us a movie-like window into our dynamic Universe.

- **8.4 M Telescope**
  - **3.5 Degree Field Of View**
  - **Telescope Located in Chile on Cerro Pachón**
- **3.2 Billion Pixel Camera**
- **~40 Second Cadence**
  - **Two 15 second exposures**
  - **Full sky coverage every few nights**
- **Advanced Data Management Systems**
- **Public Data**
  - **Alerts of new events**
  - **Catalogs of object**
  - **Archives of images**

May 2006: LSST Site Selected

El Peñon

Control Room & Support Bldg

Calibration Telescope

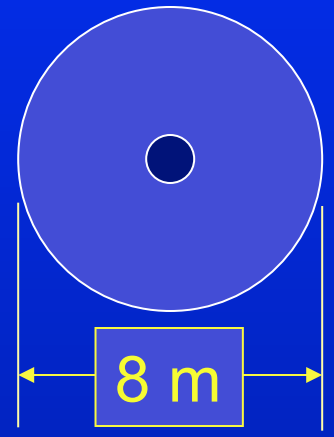
Why is the LSST so unique?

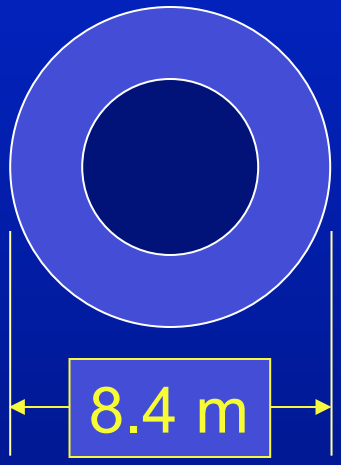
Primary Mirror Diameter

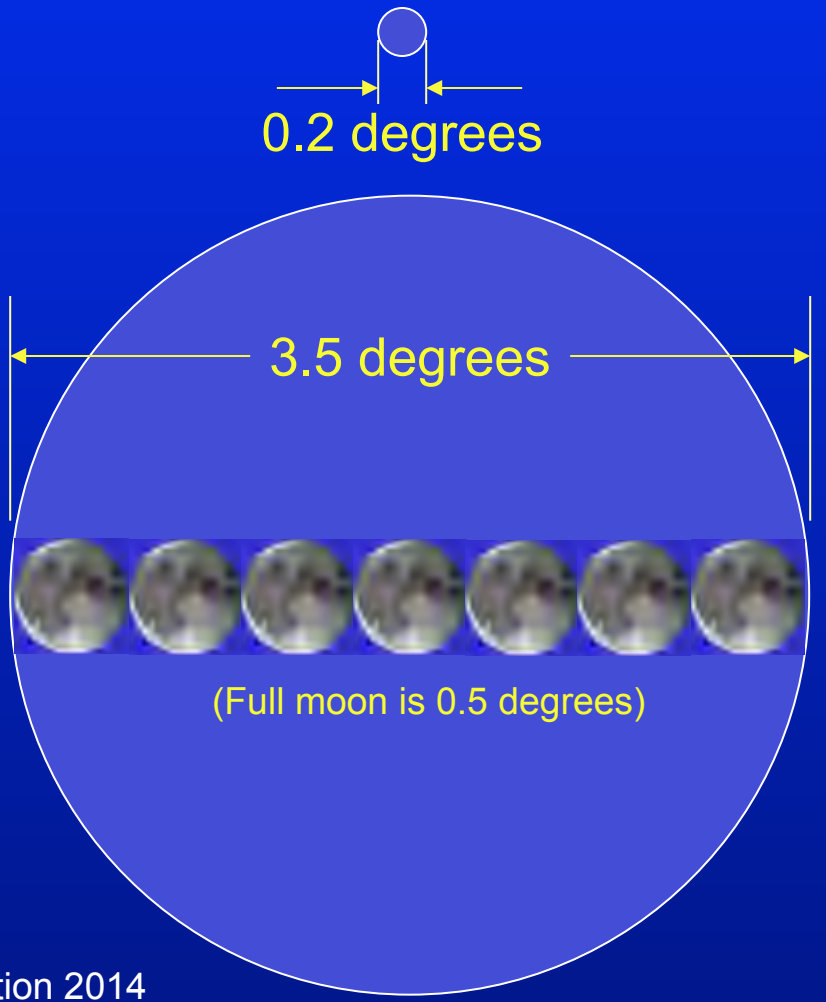
Field of View

Gemini South Telescope

LSST







Telescope and Site

30 m diameter dome

1.2 m diameter atmospheric telescope

Control room and heat producing equipment (lower level)

1,380 m^2 service and maintenance facility

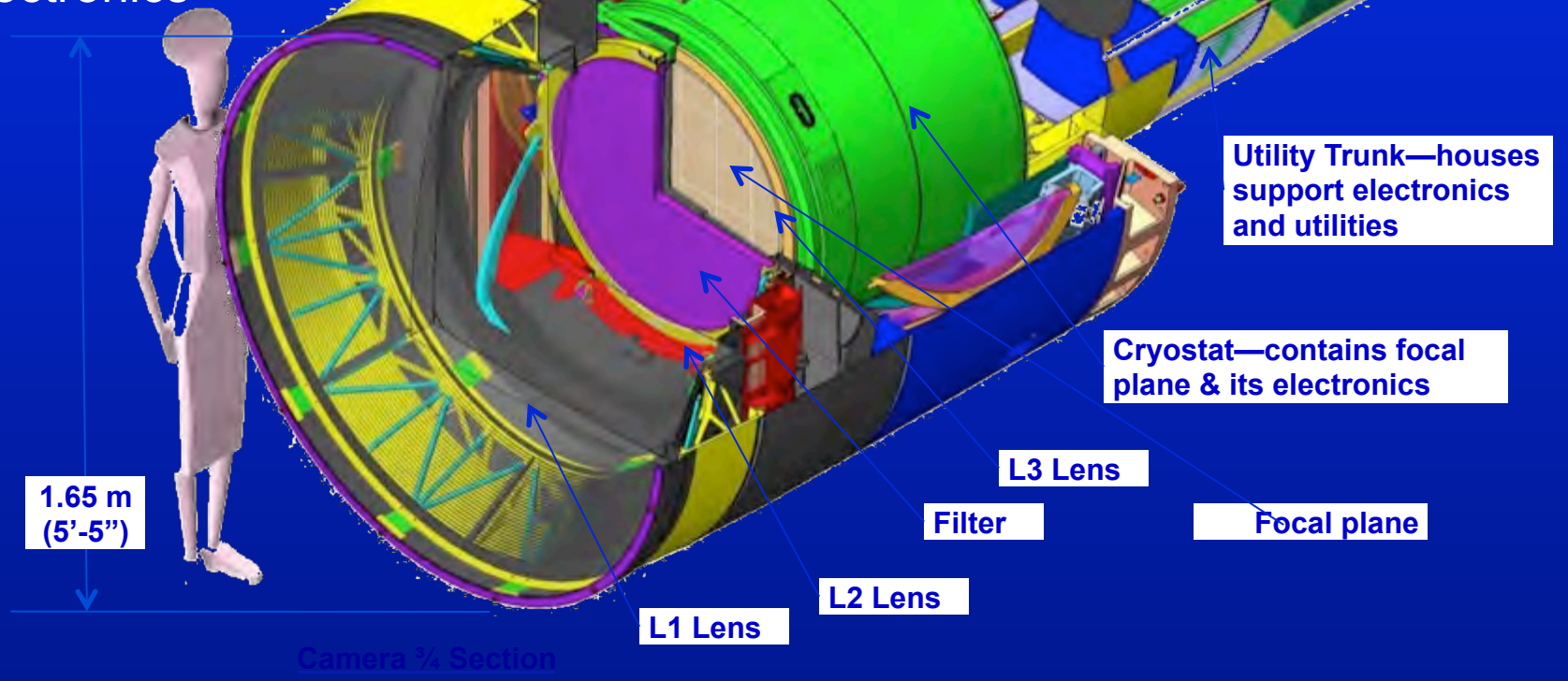
Base Facility

350 ton telescope

Project includes the facilities, and hardware to collect the light, control the survey, calibrate conditions, and support all LSST summit and base operations.

Camera

- 3.2 Gigapixel science array – 63 cm diameter
- Wavefront and guide sensors
- 2 second readout
- 5 filters in camera
- Electronics



Petascale Data Management

- Each image roughly 6 GB
- Cadence: ~1 image every 20s
- 15 to 18 TB per night, 30TB “reduced”!
  - ALL must be transferred to NCSA “archive center”
    - within image timescale (17s, hopefully <3s), >>10 Gbps
- REAL TIME processing, analysis, & alerts
  - Send out alerts of transient sources within 60s
    - ~2 million events per night every night for 10 years
  - Provide automatic data quality evaluation, alert to problems
  - Change survey observing strategy on the fly based on conditions, last field visited, etc.

LSST: Era of "Data Science"

TRANSIENT SCIENCE (Data Stream)

- >3 Terabytes per hour (reduced) that must be mined in real time for alerts.
- 20 billion objects will be monitored for important variations in real time.
- ~2 million events per night every night for 10 years

New approaches must be developed for knowledge extraction in real time

NON-TRANSIENT SCIENCE

- >10^{10} objects in a 20 PB final database catalog, backed by a 100 PB final image archive

New approaches to data mining needed to sift through data to identify samples, or individual objects, of interest

Data Management Sites and Centers

HQ Site
HQ Facility
Observatory Management
Science Operations
Education and Public Outreach

Archive Site
Archive Center
Alert Production
Data Release Production
Calibration Products Production
EPO Infrastructure
Long-term Storage (copy 2)
Data Access Center
Data Access and User Services

French Site
Processing Center
Data Release Production
(Proposed)

Summit Site
Summit Facility
Telescope and Camera
Data Acquisition
Crosstalk Correction

Base Site
Base Facility
Long-term storage (copy 1)
Data Access Center
Data Access and User Services

LSST Data Management: Baseline Solutions

- High-speed connectivity
  - Mountain to Base: >100 Gbps
  - Base to Archive: >10 Gbps (hopefully 100Gbps)
  - Archive to User: variable, UI challenge
- Supercomputer processing & storage
  - Based in La Serena & NCSA
  - 100 PB final image archive
  - Distributed (Grid) analysis facilities
    - Integrated into “Chilean Grid”: REUNA+NLHPC+
- Petascale DB (~100 PB final catalog)
  - Based on open source RDBMS (mysql)

Strategic Partnerships

- Connectivity
  - High-speed national bandwidth (**REUNA**)
  - and international bandwidth (AmLight/RNP/CLARA)
  - Others: South American Astronomy Coordination Cmte
- Distributed Computing Systems
  - Supercomputer center(s) to provide bulk storage, large scale processing (e.g., NCSA, **NLHPC** in Chile)
  - Grid processing, storage
- Scientific Analysis Challenges: Data Mining & Astro-Informatics or Astro-Statistics
  - Statistical analyses of large samples
  - Separating small signals from systematic effects
  - Automatically finding unique objects: one in billions

Second La Serena School for Data Science 2014

Applied Tools for Astronomy

August 2014

AURA Campus
La Serena - Chile

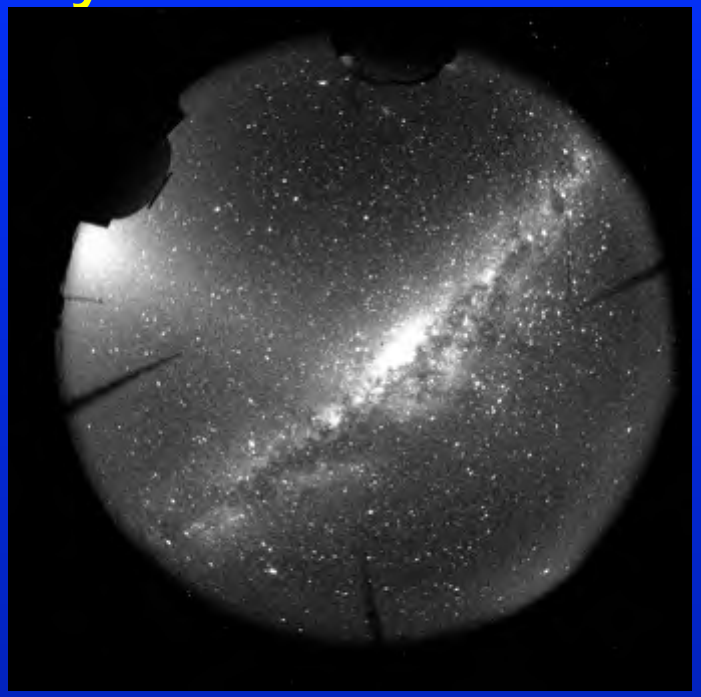


- Training the next generation of scientists (in fields of astronomy, mathematics, computer science, and others) in the tools and techniques of massive data
- International program: funding available for students from Chile and the U.S.A.; registration and applications for funding due in March
- Target students: senior undergraduates and beginning graduate students
- Program includes: Lectures, Hands-on activities, and Group Projects

For more information, visit:

http://www.aura-o.aura-astronomy.org/winter_school/

Site Quality Preservation



- Tololo & Pachon are extremely dark sites.
  - See www.ctio.noao.edu/site/pachon_sky
- But the population is growing
  - Particularly in La Serena-Coquimbo,
  - and extending up the valley
- Ongoing change to improved lighting
  - “Norma” regulates lighting fixtures
  - Mining activities need monitoring

- OPCC (Oficina de Protección de la Calidad de Cielo) of “CONAMA”
  - supported by the international observatories. Staff of 1(!)
  - Director: Pedro Sanhueza
  - Plus some scientific and technical assistance from CTIO & Gemini staff.
- “Sky preservation” is also an important part of our EPO message.
- Active at the national and international level (IDA, IAU, IYA etc).

1999 →

2007 →

- First efforts involved light fixture (limit upward directed light)
- Current efforts involve lights themselves (high-pressure sodium)
- Future efforts focus on light levels, and changing “norma” to “law”!
- Most recent measurements show
  - Still NO measurable effect near zenith
  - Significant effect toward La Serena/Coquimbo at 70-80 deg zenith angles; need to continue recently begun quantitative measurements

Chilean Commitment to Dark Skies

REPÚBLICA DE CHILE
MINISTERIO DEL MEDIO AMBIENTE

ESTABLECE NORMA DE EMISIÓN PARA LA REGULACIÓN DE LA CONTAMINACIÓN LUMÍNICA, ELABORADA A PARTIR DE LA REVISIÓN DEL DECRETO SUPREMO N°686, DE 1998, DEL MINISTERIO DE ECONOMÍA, FOMENTO Y RECONSTRUCCIÓN.

DECRETO N° 043

SANTIAGO, 17 DIC. 2012

'ESE, TÓMESE RAZÓN Y PUBLÍQUESE

SEBASTIÁN PIÑERA ECHENIQUE
Presidente de la República

PABLO LONGUEIRA MONTES
Ministro de Economía, Fomento y Turismo

MARIA IGNACIA BENÍTEZ PEREIRA
Ministra del Medio Ambiente

CONTRALORIA GENERAL
'OMA DE RAZON
28 MAY. 2013
EPCION
'ART.
IDIC
AMC
2013

- V1: 1998
- V2: published 2013 May 5,

With spectral restrictions (LEDs), quantitative limits, and also restrictions on luminous signs.

- Effective May 2014!
- Hard part: enforcement

AURA Observatory in Chile:
A platform for current and future U.S. and International astronomical facilities in Chile

The ~~End~~ *Beginning!*