Doing astronomy with SDSS from your armchair

Željko Ivezić, University of Washington & University of Zagreb

"Partners in Learning" webinar, Zagreb, 15. XII 2010

Supported by: Microsoft Croatia and the
Croatian National Science Foundation

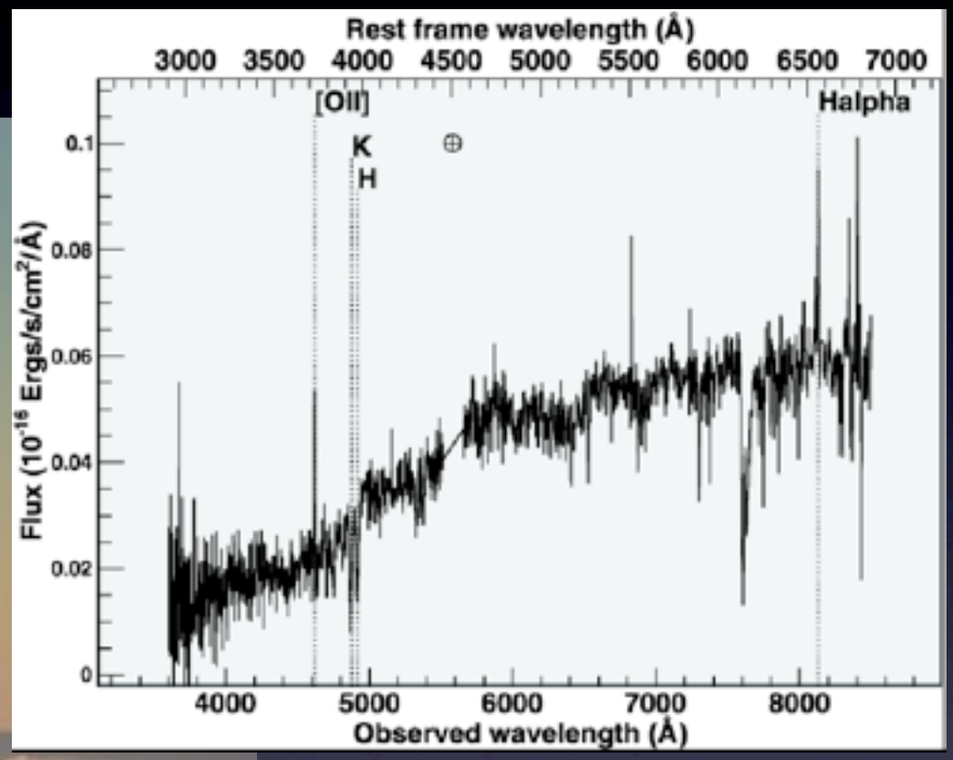
Apache Point Observatory, New Mexico

Topics:

- **Sky Maps:**
  from Hipparchos to digital sky surveys
- **The first large digital color map of the night sky:**
  Sloan Digital Sky Survey (SDSS)
- **Astronomy from your armchair:**
  How to use public SDSS databases?
  A peek into the future: LSST

Context: modern observational methods in astronomy and astrophysics:

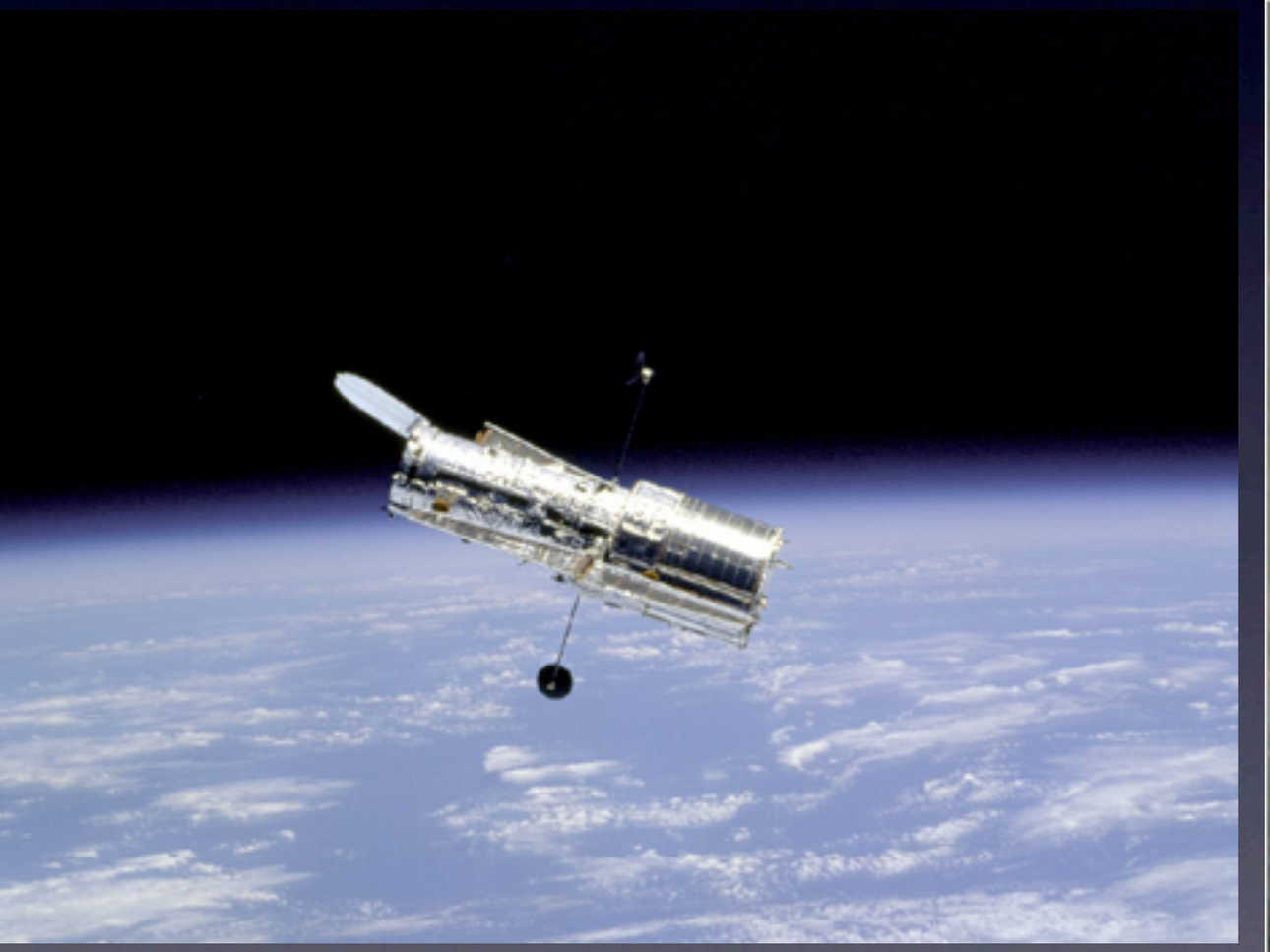
- **Large telescopes (~10m):** faint objects, especially spectroscopy



The Keck telescopes on Mauna Kea (Hawaii)

Context: modern observational methods in astronomy and astrophysics:

- **Telescopes above the atmosphere:** high angular resolution (e.g., the Hubble Space Telescope) and other wavelength regions (X-ray, radio, infrared)



The HST in orbit and an example of a galaxy image

Context: modern observational methods in astronomy and astrophysics:

- Large telescopes (~10m): faint objects, especially spectroscopy
- Telescopes above the atmosphere: high angular resolution (e.g., the Hubble Space Telescope) and other wavelength regions (X-ray, radio, infrared)
- Large sky surveys: digital sensor tehnology (CCD: charge-coupled device), information tehnology (data processing and data distribution)

Key point: modern sky surveys make all their data (images and catalogs) publicly available

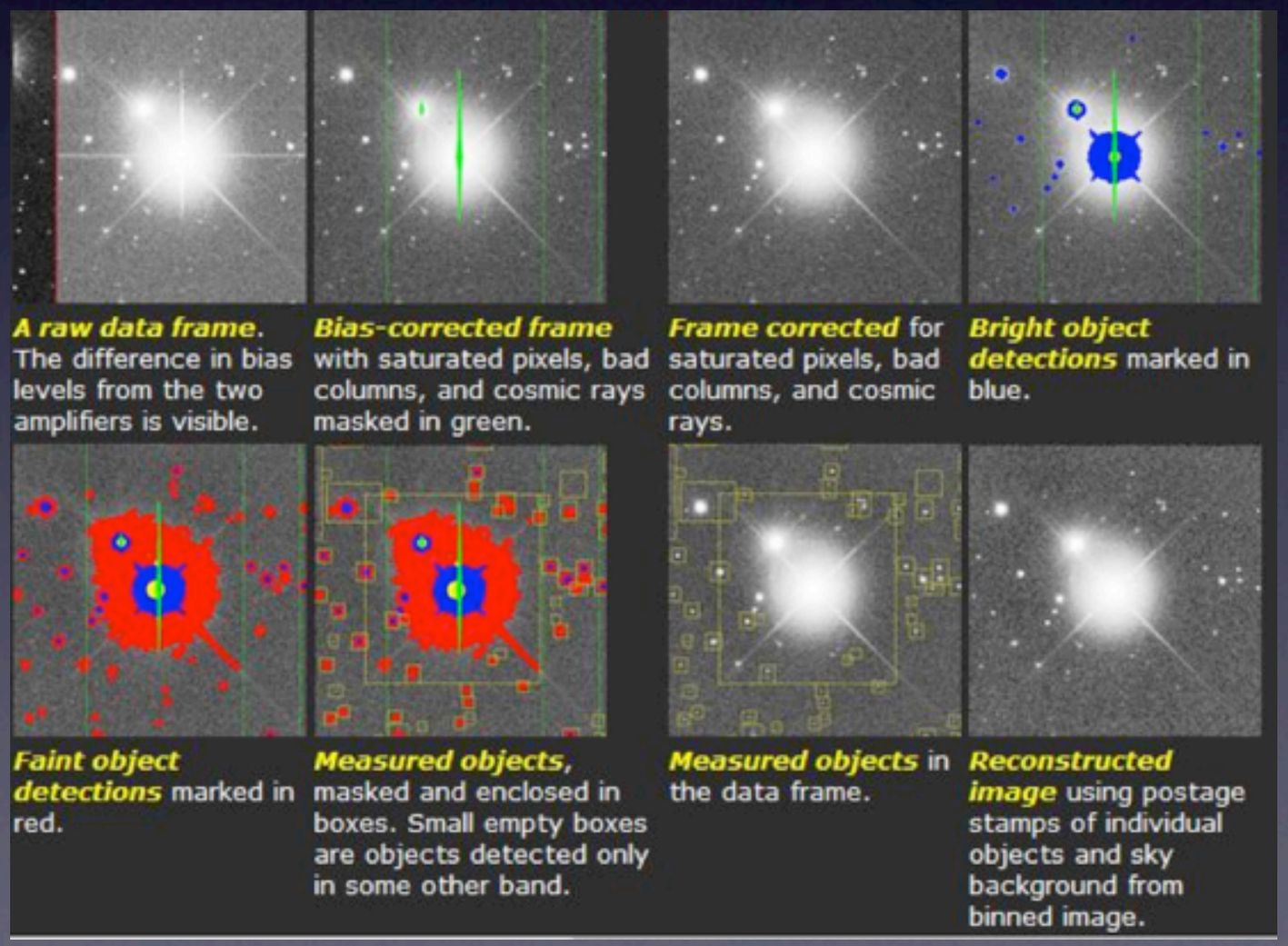
What is a sky map?
Why are sky maps useful?

- Sky map:
  - a list of all detected objects (stars, galaxies, ...)
  - measured parameters (size, color, brightness,...)

Basic steps in astronomical image processing (example: Sloan Digital Sky Survey):

All these (complicated) steps are already done:

"science-ready database"



What is a sky map? Why are sky maps useful?

- Sky map:
  – a list of all detected objects (stars, galaxies, ...)
  – measured parameters (size, color, brightness,...)

- The utility of sky maps:
  Discoveries of new objects: "Is this a new asteroid, or is it already cataloged?"
  Object classification: "What types of galaxies exist?"
  Statistical population studies: "Do quasars change their properties with time?"
  Search for unusual objects: "Is this star very weird?"
  Cosmological measurements: "How fast does the Universe expand?"

"Science-ready database": measurements can be (simply) analyzed without the need for (complex) image processing

Short history of sky mapping

- Hipparchos
  - about 3,000 years ago
  - all stars visible from Greece: about 3,000
  - the main source of astronomical measurements for the next 2,500 years!

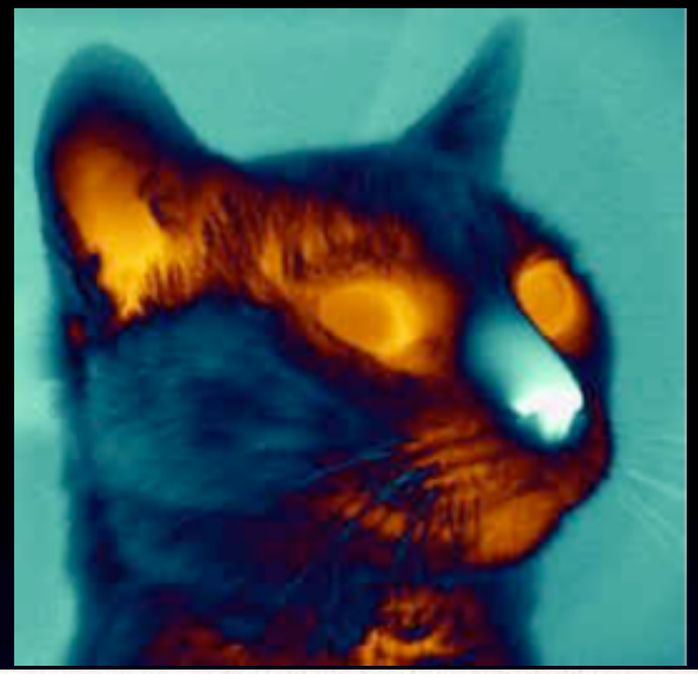
- Tycho Brahe
  - XVI century, much more accurate measurements than Hipparchos
  - still without a telescope: about 3,000 stars
  - the main results: Kepler's Laws of planetary motions, Newton's theory of gravity

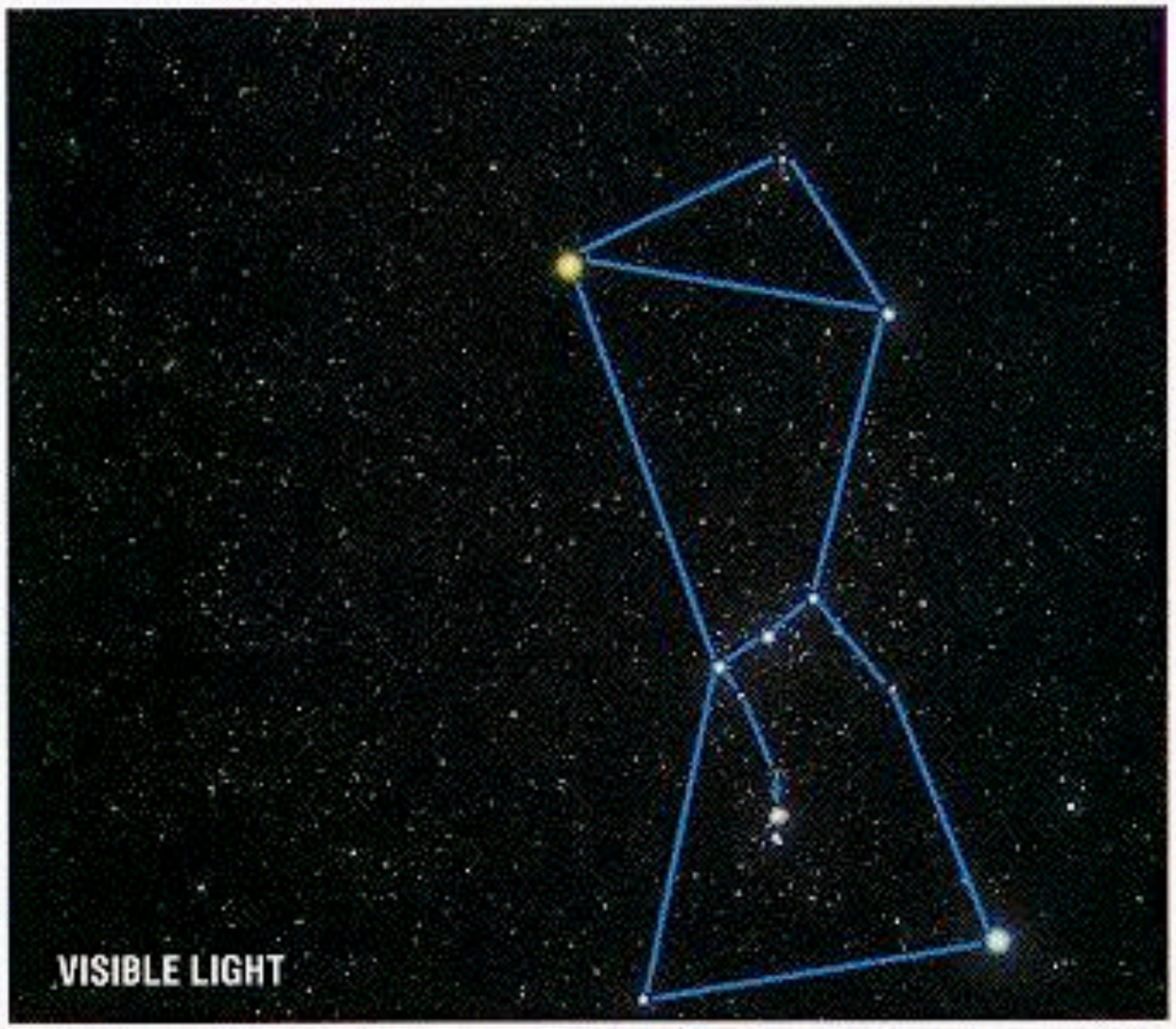
Modern sky mapping

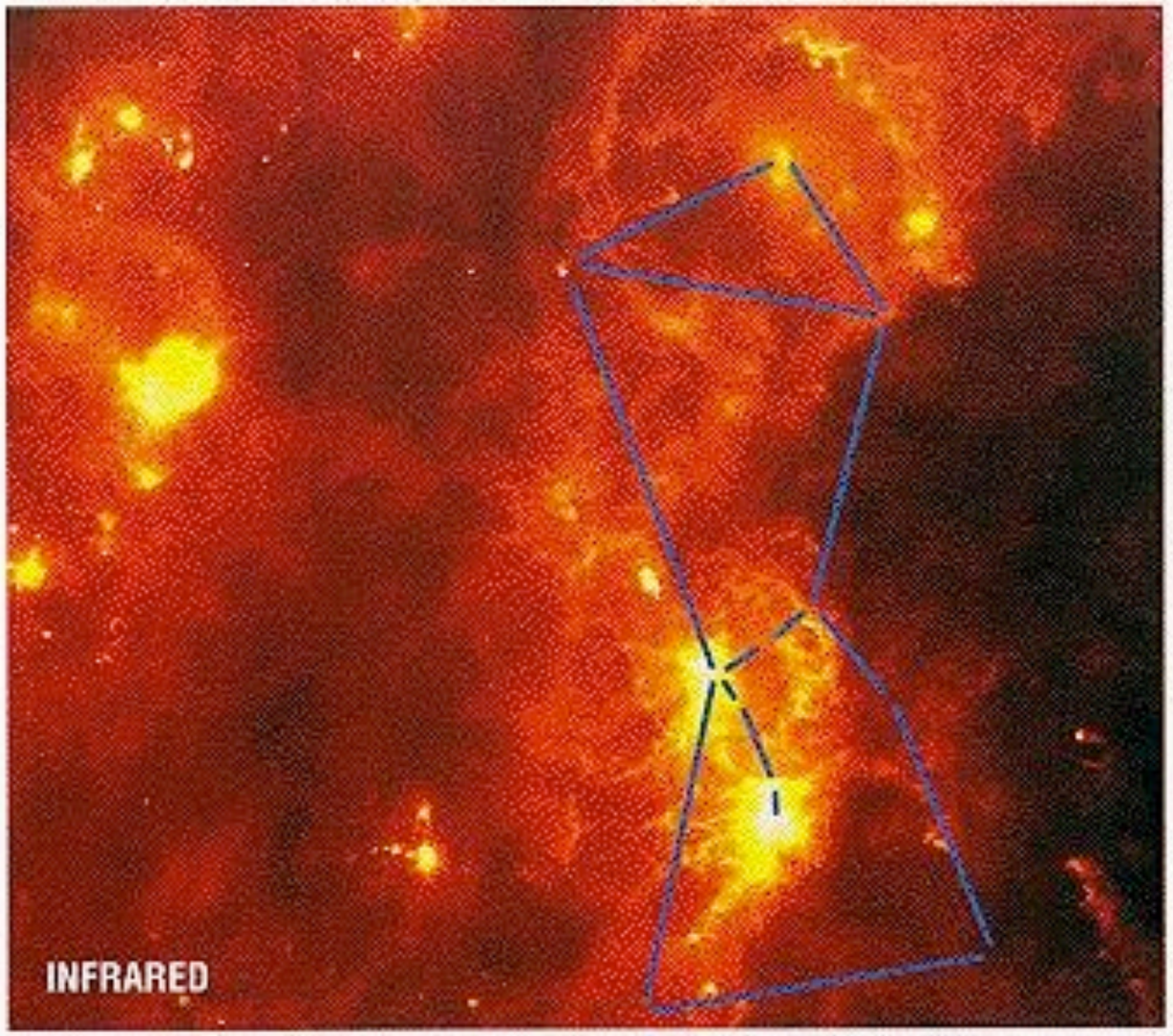
- Palomar Observatory Sky Survey
  (National Geographic Sky Survey):
  – optical wavelengths, two bandpasses
  – 1950-1955 (second phase in 80's)
  – about 1,000 photographs (whole sky)

- Other wavelengths:
  – X rays (Chandra, XMM-Newton)
  – ultraviolet (GALEX)
  – infrared (2MASS, Spitzer)
  – radio (FIRST, NVSS)

Optical wavelengths reveal only a bit of reality...





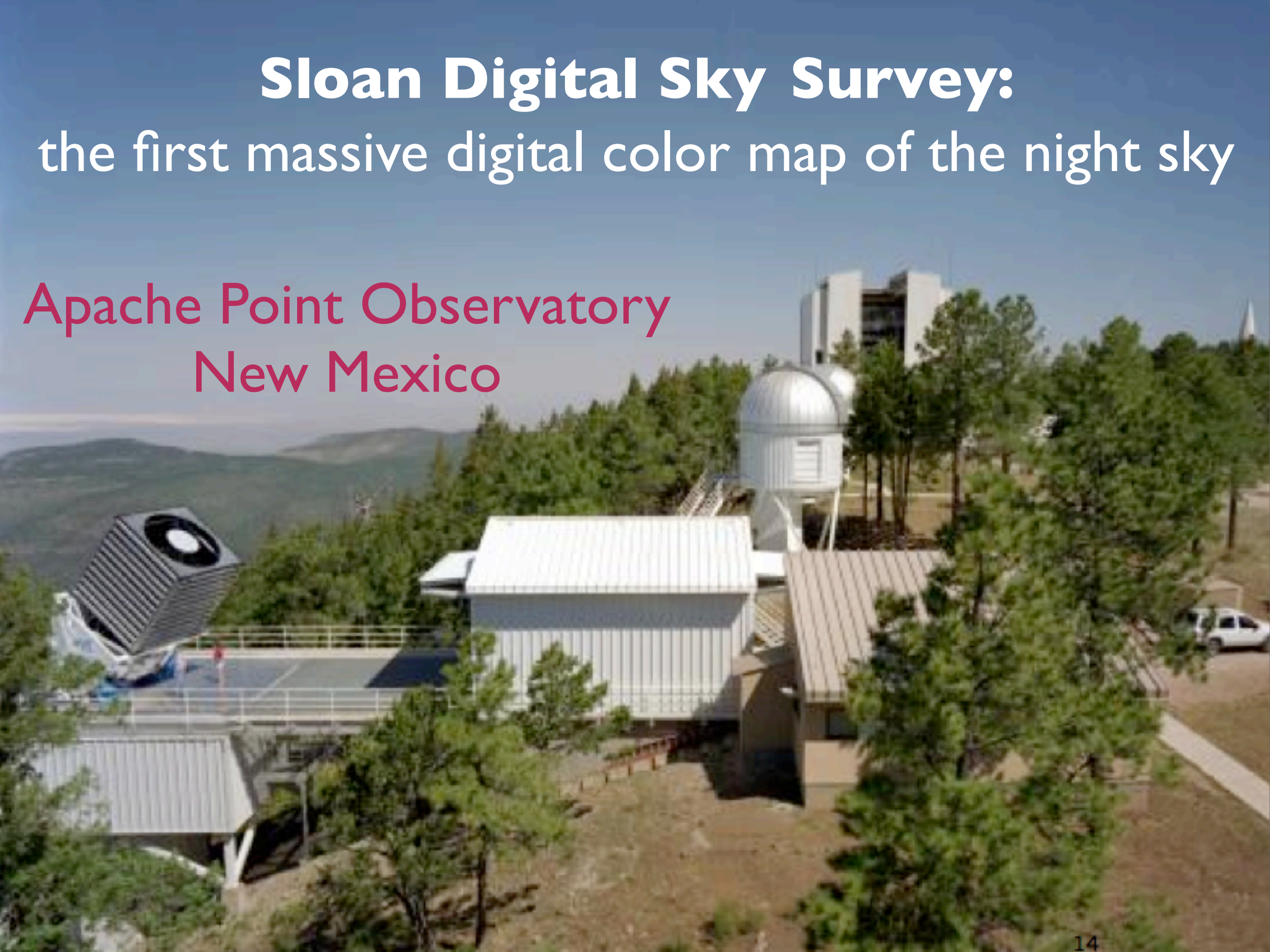


Orion: visible light infrared light

Sloan Digital Sky Survey:

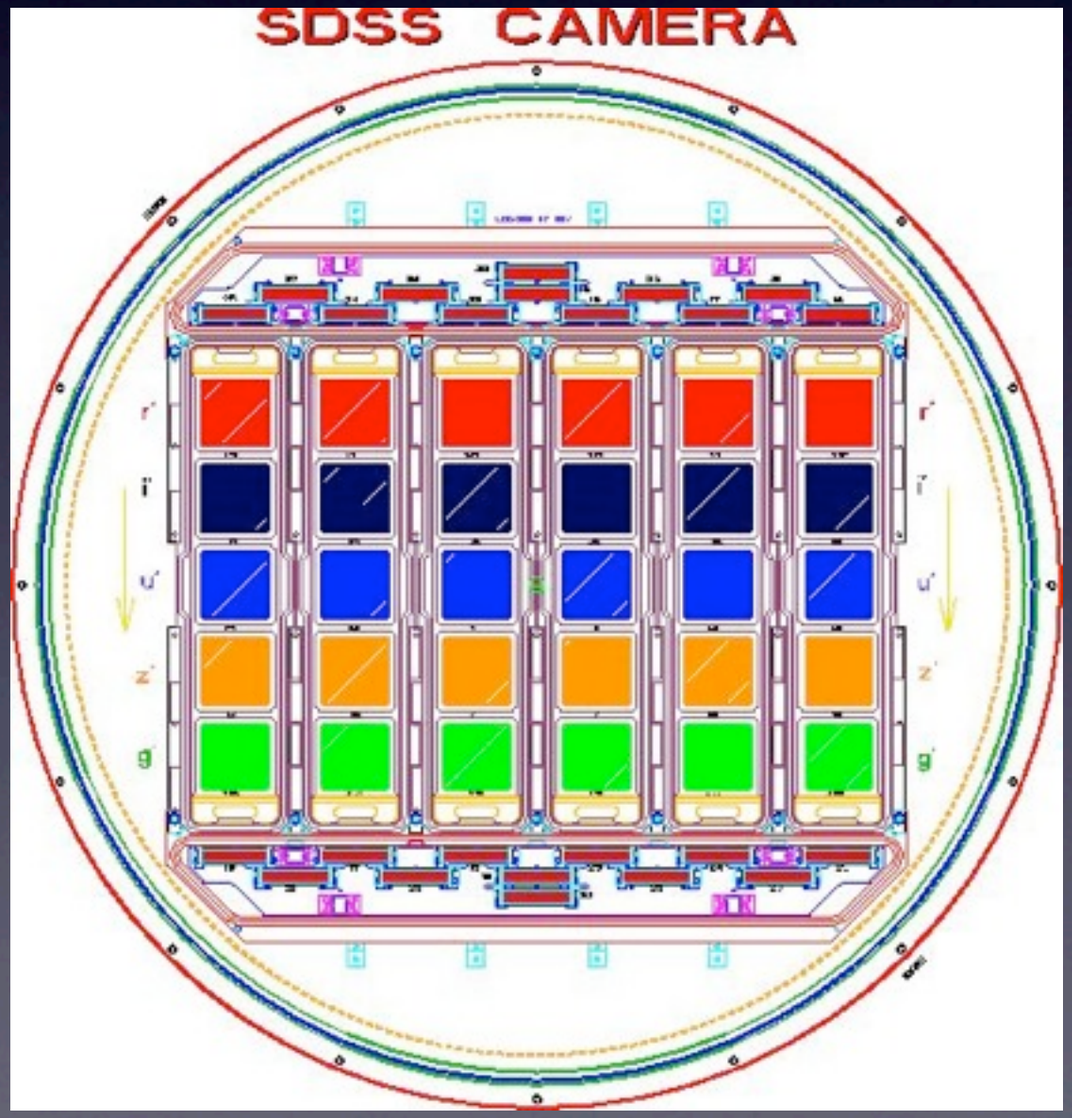
the first massive digital color map of the night sky

Apache Point Observatory
New Mexico



The last decade: Sloan Digital Sky Survey

- Digital sky survey with a 120 Megapix CCD camera
- Precise measurements for 400,000,000 objects
- Revolution in astronomy: public databases



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Prof. James E. Gunn accepts a National Medal of Science

Surveys are made by real people :-)

The 2010 SDSS-III collaboration meeting in Paris

SDSS sky mapping: "drift scanning"

Examples of SDSS images

Run 745 Col 4 Field 498

Comet

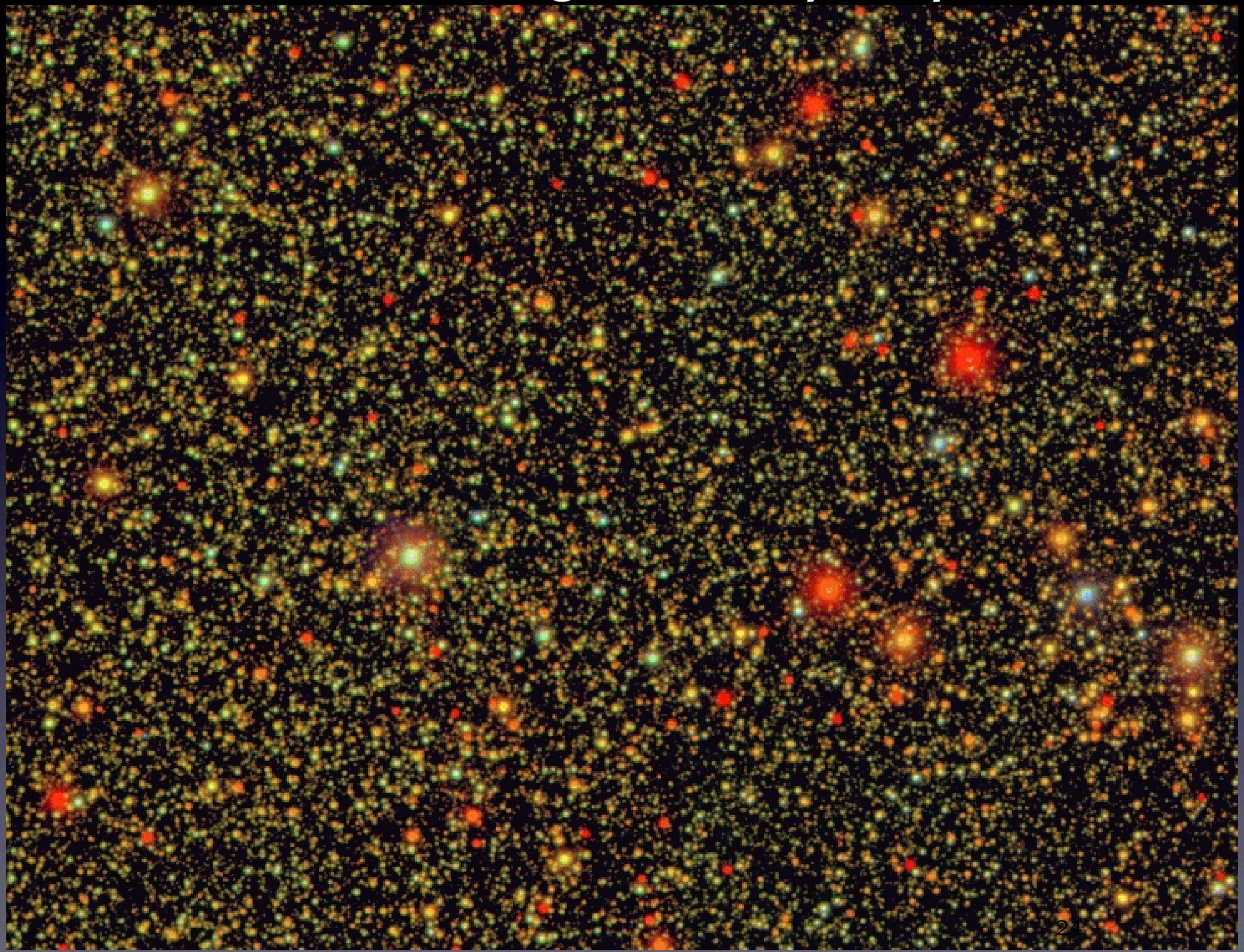
Dwarf galaxy

Spiral galaxy

Nebula

Spiral galaxies

SDSS view along the Milky Way Disk



Astronomy "from your armchair"

http://cas.sdss.org/dr7/en/

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Sloan Digital Sky Survey / SkyServer

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Welcome to the DR7 site!!!

This website presents data from the Sloan Digital Sky Survey, a project to make a map of a large part of the universe. We would like to show you the beauty of the universe, and share with you our excitement as we build the largest map in the history of the world.

News

The site hosts data from **Data Release 7 (DR7)**. **What's new in DR7**, **what's new on this site**, and **known problems**. **More...**

For Astronomers

A separate branch of this website for professional astronomers (English)

More...

SDSS is supported by

SkyServer Tools

- Famous places
- Get images
- Visual Tools
- Explore
- Search
- Object Cross-ID
- CasJobs

Science Projects

- Basic
- Advanced
- Challenges
- For Kids
- Games and Contests
- Teachers
- Links to other projects

Info Links

- About Astronomy
- About the SDSS
- About the SkyServer
- SDSS Data Release 7
- SDSS Project Website
- Open SkyQuery
- Images of RC3 Galaxies

Help

- Getting Started
- FAQ
- How To
- Glossary
- Schema Browser
- Sample SQL Queries
- Details of SDSS Data

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For teachers!




SDSS (and other) tools: why are they useful?

- Designed for works with students
  - step-by-step instructions
  - solutions to all problems and excercises

- Work with real astronomical data
  - developing familiarity with faint night sky
  - meeting digital technology
  - introduction to astrophysics (colors, ...)

- Technical knowledge is not astro-specific
  - work with large databases
  - data visualization (graphs, etc.)
  - statistics

Astronomy offers one of the most efficient methods for attracting students to STEM professions!

Welcome Teachers!

We are happy to present a variety of lesson plans that use data from the Sloan Digital Sky Survey. Our materials will show your students everything from asteroids in our own Solar System to the most distant quasars ever observed! Students can explore the sky using all using the same high-quality data that professional astronomers use.

Go to teacher guides

Design specialized for use in classroom!

What does SkyServer offer?

With SkyServer, you and your students will have access to:

- Full color images of almost 14 million objects
- Complete photometric (imaging) data for every object
- Spectra of almost 50,000 objects
- Access to data on almost every type of astronomical object
- Excel workbooks that allow students to save data easily

What types of lessons are available?

SkyServer lessons are written at a variety of levels, for students from grade school through introductory college courses. Lessons are designed to give teachers flexibility to implement them in ways that will fit the time constraints of the class and the abilities of the students.

Lessons are available on a wide variety of topics including:

Lessons are available on a wide variety of topics including:

- The Hubble Diagram
- Colors in Astronomy
- Spectral Types of Stars
- Image Processing
- Asteroids
- The H-R Diagram
- Galaxies
- Sky Surveys
- Quasars

More lesson plans are being added on a regular basis, so check back soon!

What materials are available for teachers?

Teacher's pages are available for all lessons. The teacher's pages include:

- Notes and teaching tips on all lessons
- Sample solutions and scoring rubrics for all questions and exercises
- Strategies to help you fit the lessons into your available time
- Correlations to national Math and Science Standards

How much does this cost?

Nothing!

All materials on SkyServer are available free of charge, including all lesson plans, access to the teacher's pages, and access to all data.

So, how do I access all this material?

All the student lessons can be accessed from the **Projects** main page. All the teacher's pages can be accessed from the **teacher's site**.

To view sample solutions or to use our evaluation forms, please fill out a simple **registration form** (opens in a new window). We will not give your information to any other organization. For details, see our privacy policy.

http://cas.sdss.org/dr7/en/proj/default.asp

Reader

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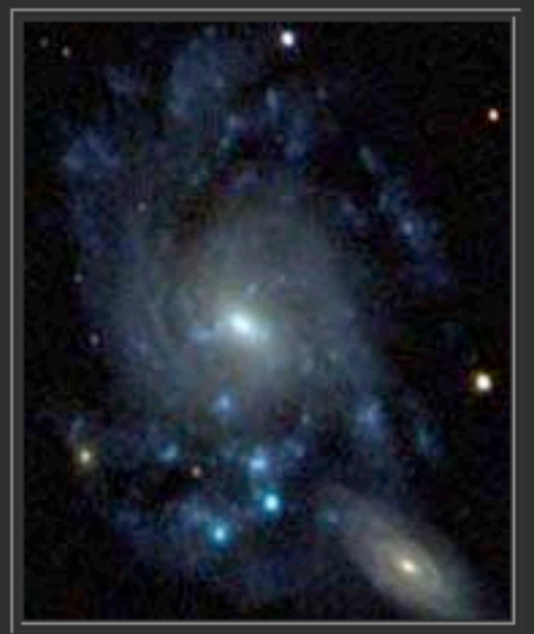
DR7 Projects

- Basic
- Advanced
- Research Challenges
- For Kids
- User Activities
- Games and Contests
- Links to Others

Projects

In our SkyServer Projects, you will learn science by studying the 14 million stars and galaxies of the Sloan Digital Sky Survey (SDSS) - the same objects that professional astronomers study. Most of these objects have never been seen before by human eyes.



STUDENTS:

- **Register** as a SkyServer student user
- **Request answers** to SkyServer projects
- **View answers** you have requested
- **Evaluate** a project you have finished

TEACHERS:

- **Learn** how you can use SkyServer in your classroom
- **See the teacher guides** for SkyServer projects
- **Register** as a SkyServer teacher
- **Communicate** with other teachers on the **SkyServer Yahoo group** (links open in new window)

Work through these projects at your own pace. Each consists of several questions and exercises. If you get stuck, try reading our **About Astronomy** or **About SDSS** pages. The projects include downloadable Excel spreadsheets to help you keep track of your data.

Each project ends with a Research Challenge, which lets you do real astronomy research, just like thousands of professional astronomers around the world. When you finish the Research Challenge for each project, E-mail it to us. We'll look over all the results we get, and we'll put the best up on these pages!

Click on one of the following project categories to get started:

Basic projects	For middle school, high school, and Astronomy 101 students, and for people who want a basic understanding of astronomy

- **Evaluate** a project you have finished

TEACHERS:

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Projects for different ages and levels of background knowledge

Click on one of the following project categories to get started:

Basic projects	For middle school, high school, and Astronomy 101 students, and for people who want a basic understanding of astronomy
Advanced projects	Appropriate for advanced high school and college students, and for people who want a detailed understanding of astronomy
Research Challenges	Independent research in astronomy - you pick a problem and choose how to solve it! The Research Challenges are great for Science Fair projects or guided inquiry activities.
For Kids	Projects designed for kids
Games and Contests	Games for fun, and contests with prizes
Links	A few of the best astronomy education sites on the Internet

Want to hear when we add new projects? Join the **SkyServer mailing list**!

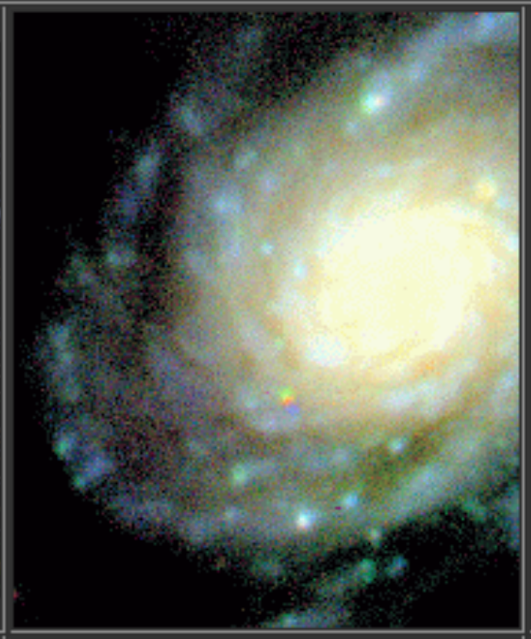
Types of Objects

Asteroids

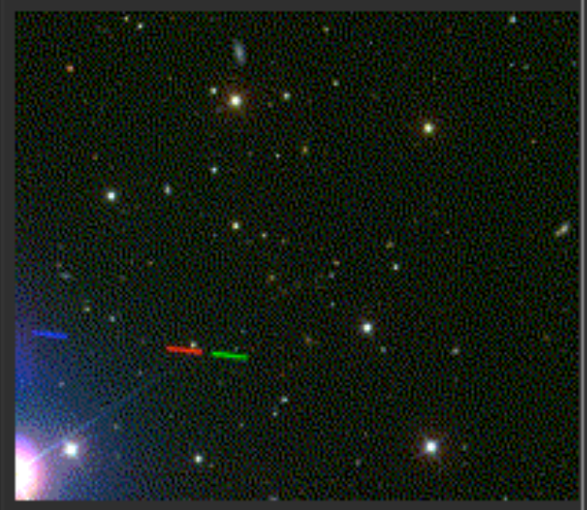
... from simple to...

Asteroids are small pieces of rock that orbit the Sun, mostly between Mars and Jupiter. Asteroids move quickly across the sky, so they can be seen in SDSS images (see the **Asteroids** project to learn more). If an asteroid moves slowly, it will show up in images as a blue dot next to a yellow dot. Fast moving asteroids show up as a red, green and blue dot in succession. Very fast moving asteroids may appear as colored streaks. Examples of each type are shown below. Asteroids that appear as blue-yellow dots trick the computer program that classifies objects, so their types are listed as stars.

A slow-moving asteroid



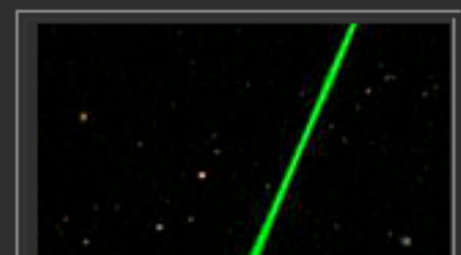
A slightly faster asteroid in front of a galaxy



A very fast-moving asteroid

Meteors

Sometimes, tiny particles of rock or dust fall toward the Earth. As they enter the Earth's atmosphere, they heat up and start to glow. From the ground, we see a long, glowing trail of light that passes quickly through the sky. These trails of light are called ***meteors***. They are also known as shooting stars.



http://cas.sdss.org/dr7/en/tools/search/sql.asp

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DR7 Tools

- Getting Started
- Famous places
- Get images
- Scrolling sky
- Visual Tools
- Search
  - - Radial
  - - Rectangular
  - - Search Form
  - - Query Builder
  - - SQL
- Object Crossid
- CasJobs

SQL Search

... advanced

This page allows you to directly submit a SQL (Structured Query Language) query to the SDSS database server. You can modify the default query as you wish, or cut and paste a query from the SDSS Sample Queries page.

Please note: To be fair to other users, queries run from SkyServer search tools are restricted in how long they can run and how much output they return, by **timeouts** and **row limits**. Please see the Query Limits help page. To run a query that is not restricted by a timeout or number of rows returned, please use the CasJobs batch query service.

Clear Query

```
-- This query does a table JOIN between the imaging (PhotoObj) and spectra
-- (SpecObj) tables and includes the necessary columns in the SELECT to upload
-- the results to the DAS (Data Archive Server) for FITS file retrieval.
SELECT TOP 10
  p.objid,p.ra,p.dec,p.u,p.g,p.r,p.i,p.z,
  p.run, p.rerun, p.camcol, p.field,
  s.specobjid, s.specClass, s.z,
  s.plate, s.mjd, s.fiberid
FROM PhotoObj AS p
  JOIN SpecObj AS s ON s.bestobjid = p.objid
WHERE
  p.u BETWEEN 0 AND 19.6
  AND g BETWEEN 0 AND 20
```

Submit | Check Syntax Only? | **Output Format** HTML XML CSV | Reset

To find out more about the database schema use the Schema Browser.

For an introduction to the Structured Query Language (SQL), please see the Searching for Data How-To tutorial. In particular, please read the Optimizing Queries section.

The inclusion of the imaging and spectro columns for DAS upload in your query (as in the default query on this page) will ensure that when you press **Submit**, the appropriate button(s) are displayed on the query results page to allow you to upload the necessary information to the DAS to retrieve the FITS file data corresponding to your CAS query. The imaging columns needed for upload to the DAS are *run*, *rerun*, *camcol*, and *field*. The spectroscopic columns needed are *plate*, *mjd*, *fiberid*, and optionally *sprerun* (the latter requires a join with the PlateX table).

"Navigation" around the sky...

http://cas.sdss.org/dr7/en/tools/chart/navi.asp

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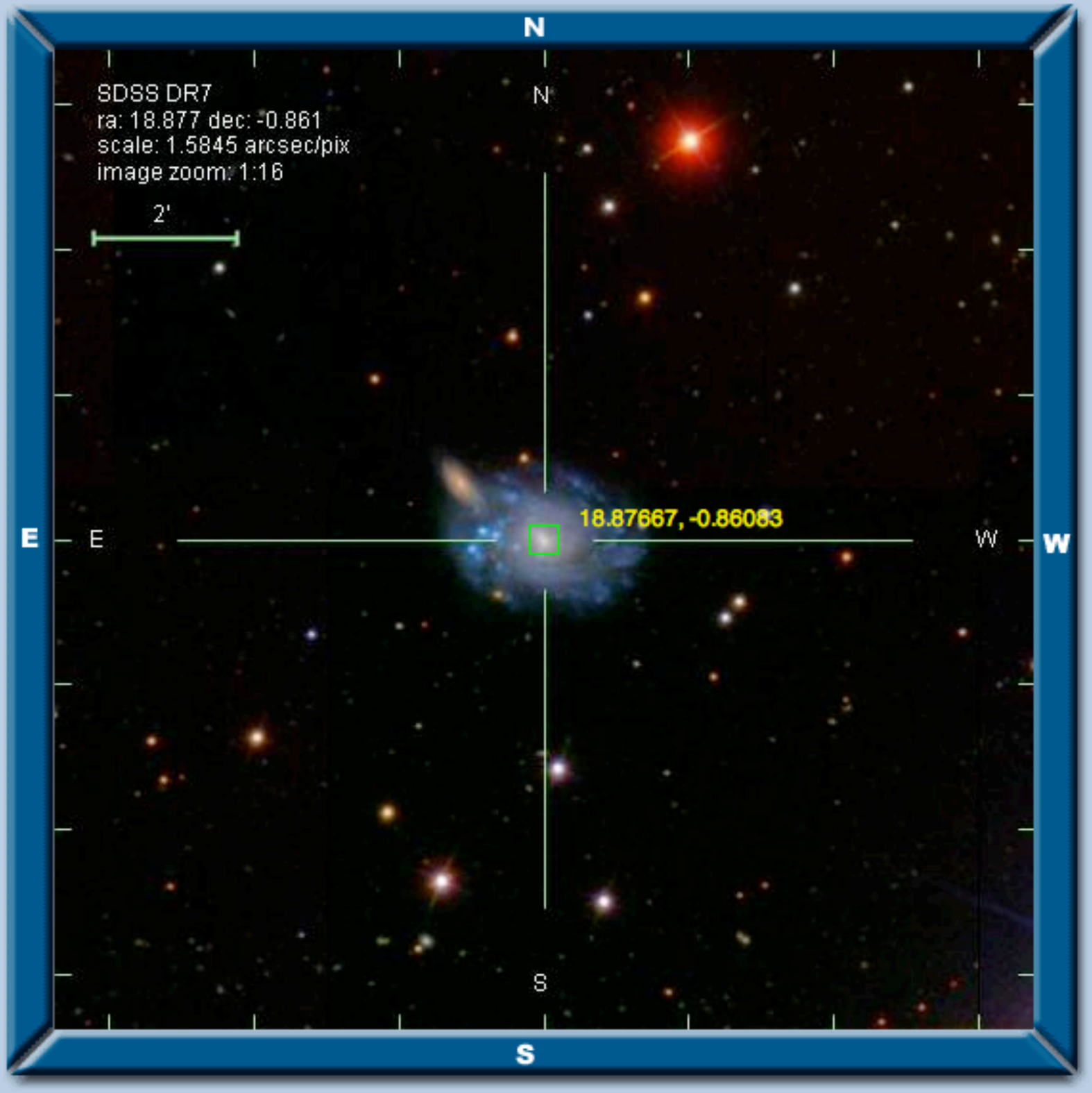
|Home |Help |Tutorial |
Chart | List | Explore |

Parameters		
ra	18.87667	deg
dec	-0.86083	deg
opt	GL	

Get Image

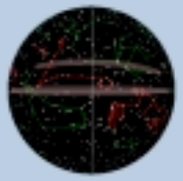
Drawing options	
☑	Grid
☑	Label
☐	Photometric objects
☐	Objects with spectra
☐	Invert Image
Advanced options	
☐	Spectroscopic Targets
☐	Outlines
☐	Bounding Boxes
☐	Fields
☐	Masks
☐	Plates



Selected object

ra	18.87684
dec	-0.86098
type	GALAXY
u	14.82
g	13.74
r	13.19
i	12.91
z	12.93

- Quick Look
- Explore
- Recenter
- Add to notes
- Show notes



Click to open Sky Maps ?

To see Sky Maps, install the latest Flash and Shockwave players.

"Navigation" around the sky: zoom in, zoom out...

http://cas.sdss.org/dr7/en/tools/chart/navi.asp

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Parameters		
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Get Image

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☑	Grid
☑	Label
☐	Photometric objects
☐	Objects with spectra
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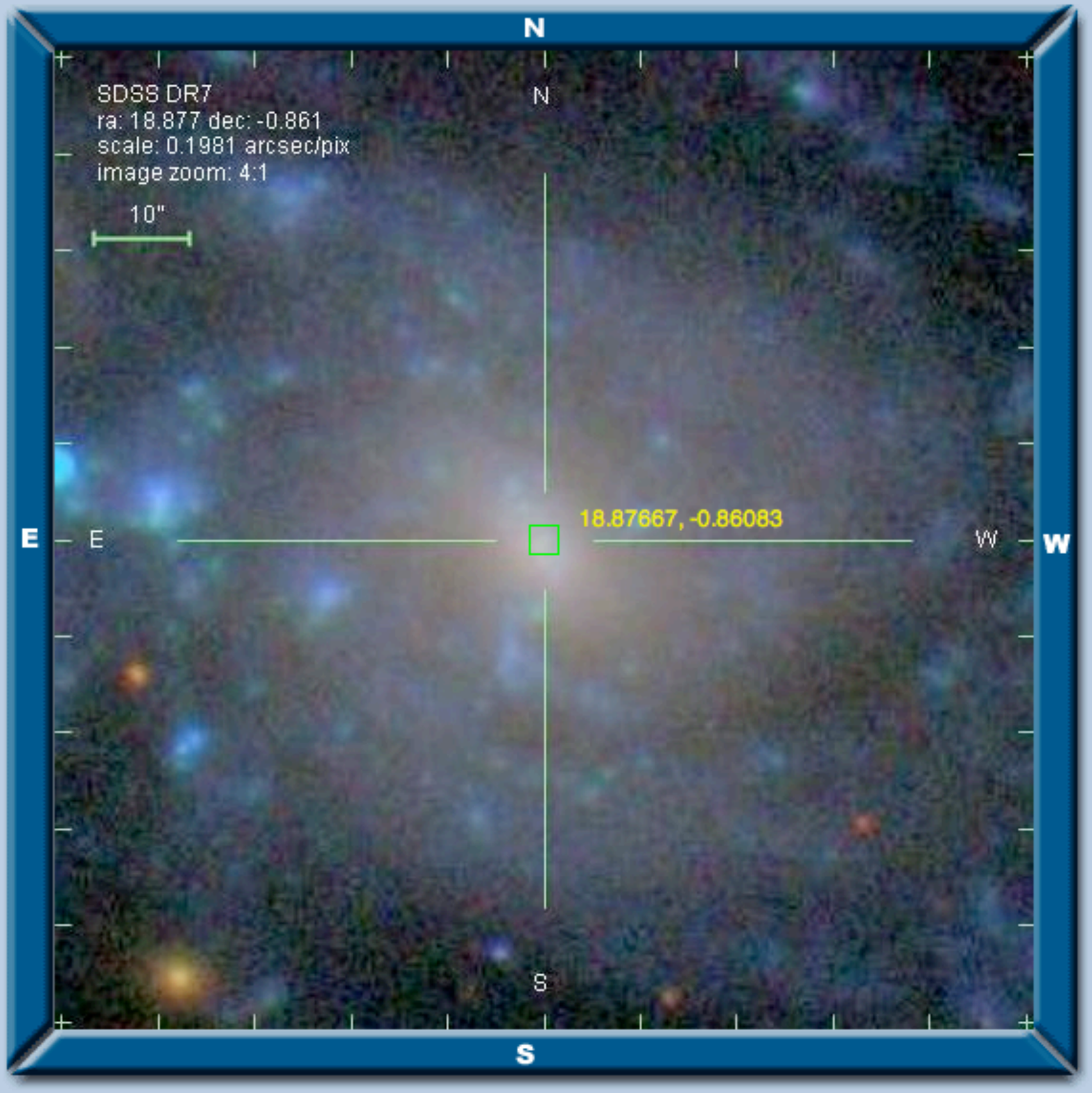
Advanced options	
☐	Spectroscopic Targets
☐	Outlines
☐	Bounding Boxes
☐	Fields
☐	Masks
☐	Plates



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- Quick Look
- Explore
- Recenter
- Add to notes
- Show notes

Click to open Sky Maps ?

To see Sky Maps, install the latest Flash and Shockwave players.
Sky Maps does not work in

Additional, more detailed, information...

http://cas.sdss.org/dr7/en/tools/explore/obj.asp?ra=18.87667&dec=-0.86083

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Explore Home

Search by
ObjId
Ra,dec
5-part SDSS
Plate-MJD-Fiber
SpecObjId

Summary

PhotoObj
PhotoTag
More Observations
Field
Frame
PhotoZ
Neighbors
Finding chart
Navigate
FITS

SpecObj
All Spectra
SpecLine
SpecLineIndex
XCredShift
ELredShift
Spectrum
Plate
FITS

NED search
SIMBAD search
AKARI FIS
AKARI IRC
ADS search

Notes
Save in Notes
Show Notes

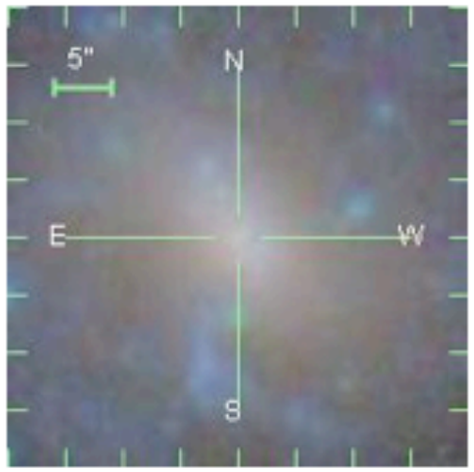
Print

SDSS J011530.44-005139.5

GALAXY ra=18.87683906, dec=-0.86097998, ObjId = 587731511532060697

Column names link to glossary entries. Move mouse over a column name to get its units.

mode	PRIMARY
status	TARGET PRIMARY OK_STRIPE OK_SCANLINE PSEGMENT RESOLVED OK_RUN GOOD SET
flags	DEBLEND_DEGENERATE BAD_MOVING_FIT BINNED1 INTERP COSMIC_RAY NOPETRO CHILD
PrimTarget	TARGET_GALAXY TARGET_GALAXY_RED TARGET_QSO_CAP
SecTarget	



u	g	r	i	z
14.82	13.74	13.19	12.91	12.93

err_u	err_g	err_r	err_i	err_z
0.01	0.00	0.00	0.00	0.00

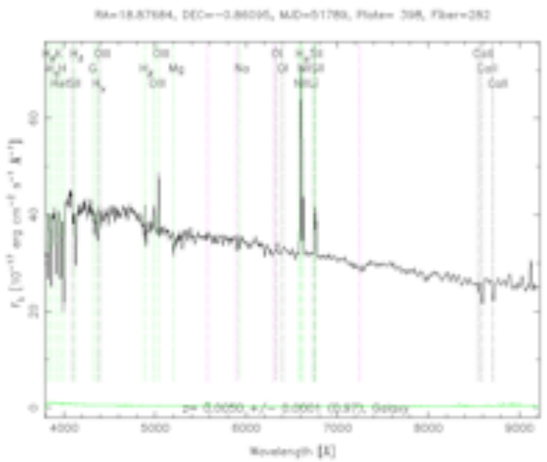
run	rerun	camcol	field	obj	rowc	colc
2738	40	1	44	25	972.5	1786.6

fiberMag_r	petroMag_r	devMag_r	expMag_r	psfMag_r	modelMag_r
17.56	12.97	13.14	13.19	18.16	13.19

extinction_r	petroRad_r	parentId	nChild
0.11	106.724	587731511532060693	0

SpecObjID = 112249473974927360

plate	mjd	fiberId	z	zErr	zConf	specClass	ra	dec	fiberMag_r	objId
398	51789	282	0.005	0.00006	0.969081	GALAXY	18.87684	-0.86095	17.53	587731511532060697



zStatus	XCORR_EMLINE
zWarning	OK
PrimTarget	TARGET_GALAXY TARGET_GALAXY_RED
SecTarget	
eClass	0.095797
emZ	0.006
emConf	0.874995
xcZ	0.005
xcConf	0.969081

Cross-identifications

For example, spectra (here: a Seyfert [active] galaxy)

http://cas.sdss.org/dr7/en/tools/explore/obj.asp?ra=18.87667&dec=-0.86083

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Search by
ObjId
Ra,dec
5-part SDSS
Plate-MJD-Fiber
SpecObjId

Summary

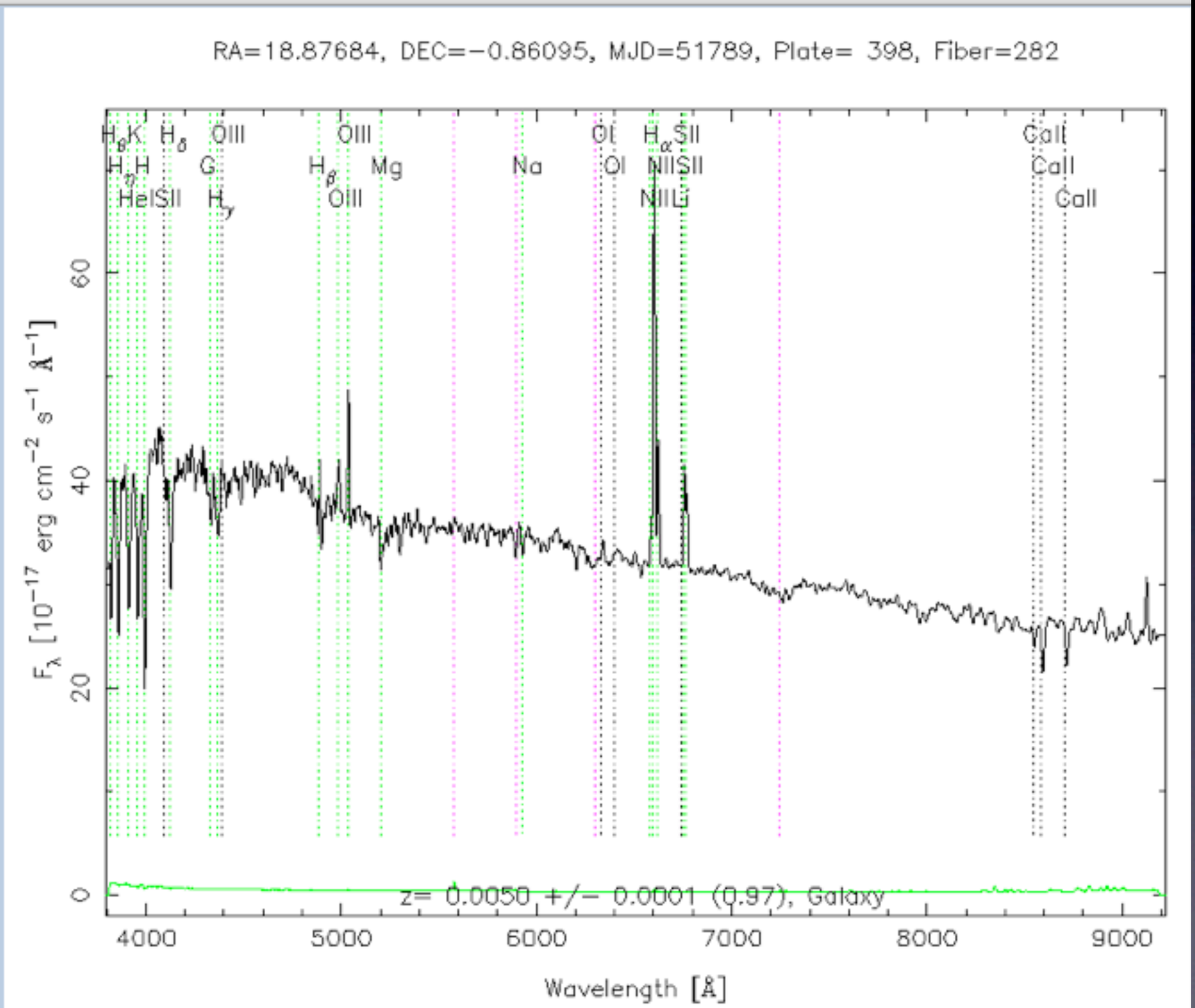
PhotoObj
PhotoTag
More Observations
Field
Frame
PhotoZ
Neighbors
Finding chart
Navigate
FITS

SpecObj
All Spectra
SpecLine
SpecLineIndex
XCredShift
ELredShift
Spectrum
Plate
FITS

NED search
SIMBAD search
AKARI FIS
AKARI IRC
ADS search

Notes
Save in Notes
Show Notes

Print



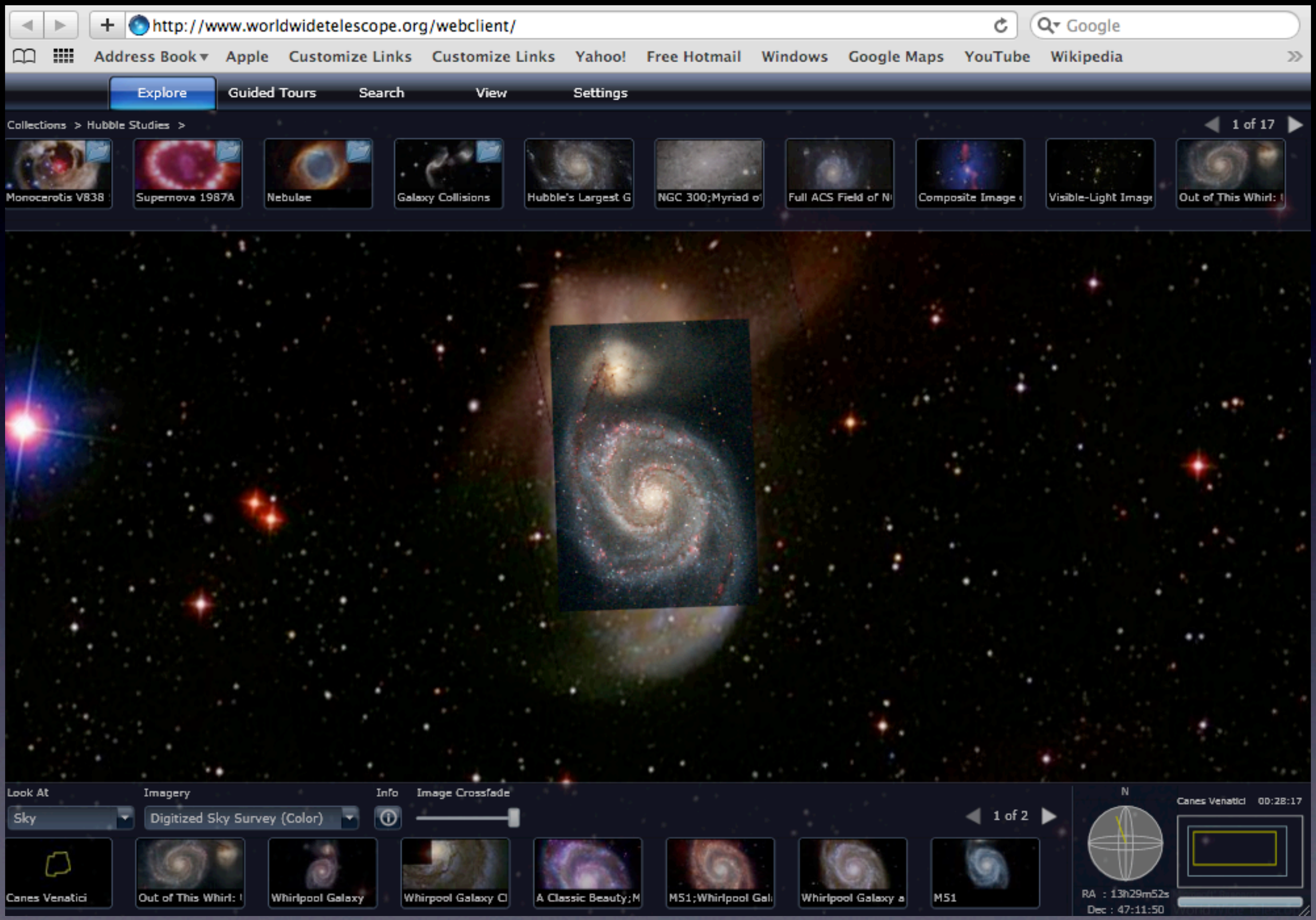
Methods for accessing SDSS data

- SDSS site: www.sdss.org
- World Wide Telescope
  - Microsoft (code download & Web client)
  - not only SDSS data
- Google Sky
  - Google (code download & Web client)
  - not only SDSS data

The functionality of these sites is fantastic, and the data quality is sufficient even for scientific work.

Astronomy offers one of the most efficient methods for attracting students to STEM professions!

World Wide Telescope



Google Sky

http://www.google.com/sky/ — Google Sky

Address Book ▾ | Apple | Customize Links | Customize Links | Yahoo! | Free Hotmail | Windows | Google Maps | YouTube | Wikipedia

Sky | Moon | Mars — See sky in Google Earth | Help | About Google Sky

Google Sky — Search — English (US)

e.g.: Galaxy, M31, NGC3628, Mars

Link to this page — Print

Infrared | Microwave | Historical

POWERED BY Google — 9h 56m 16.0s — 69° 5' 10.4"

Image Credit: DSS Consortium, SDSS, NASA/ESA - Terms of Use

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SDSS: from science to astronomy in every home!

www.sdss.org

Apache Point Observatory
New Mexico

A peek into the future: the Large Synoptic Survey Telescope

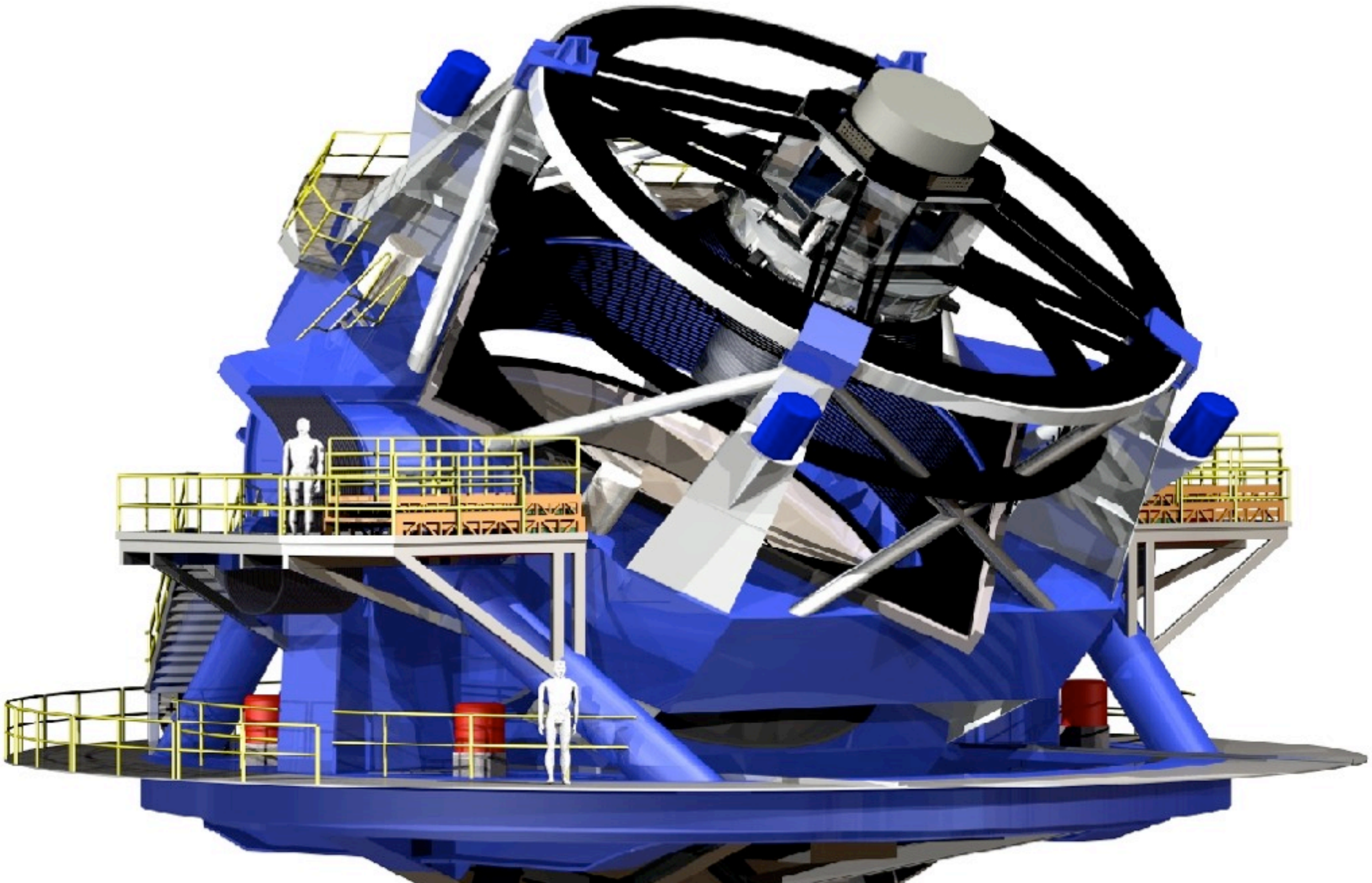
SDSS:

a digital color map of the night sky

LSST:

a digital color movie of the sky

LSST Telescope: 8.4m mirror (6.7m effective)

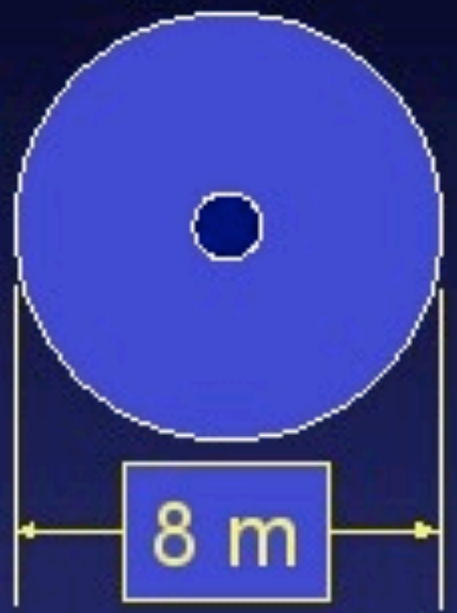


Gemini vs. LSST field-of-view comparison

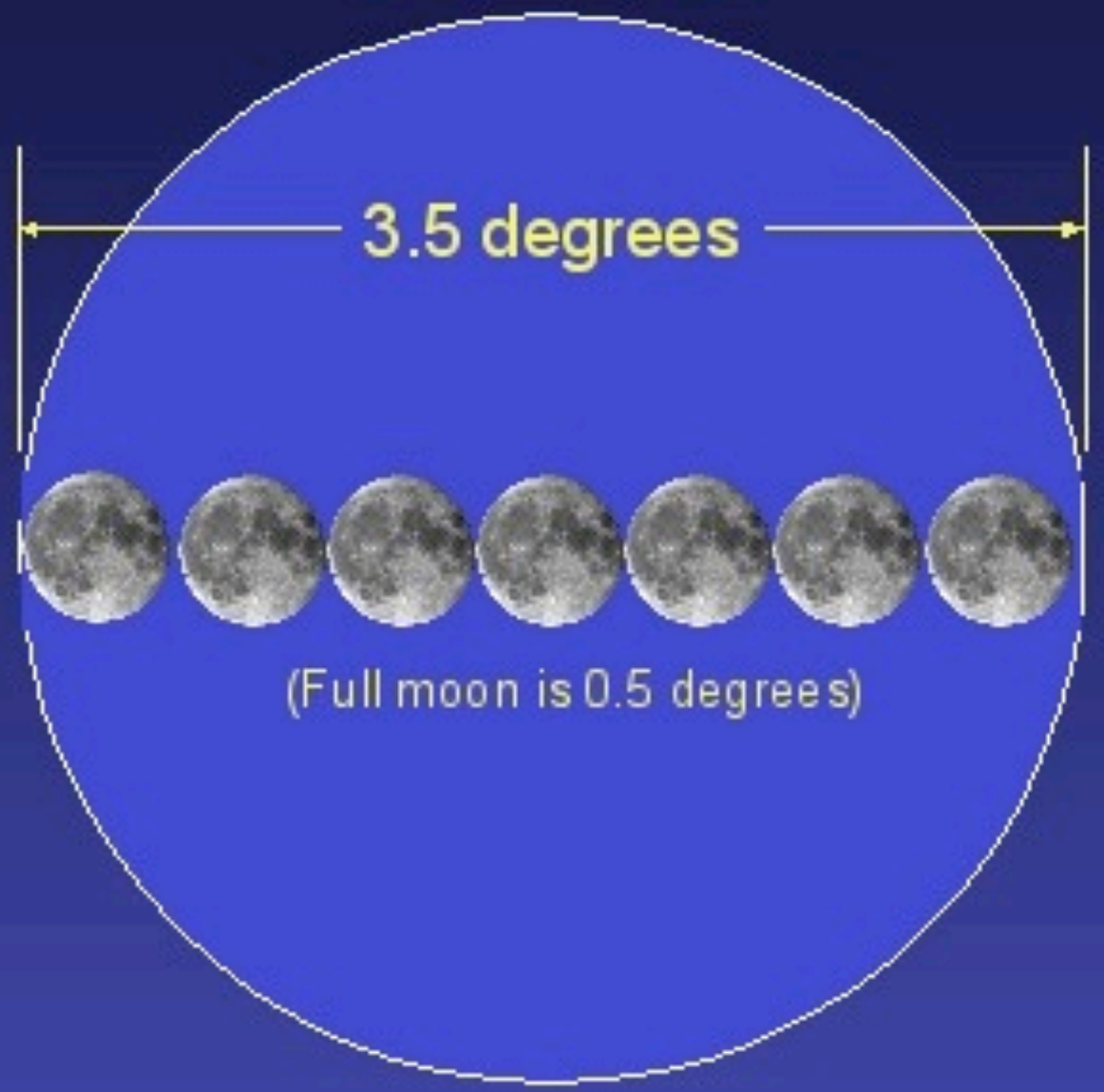
Gemini South Telescope

LSST

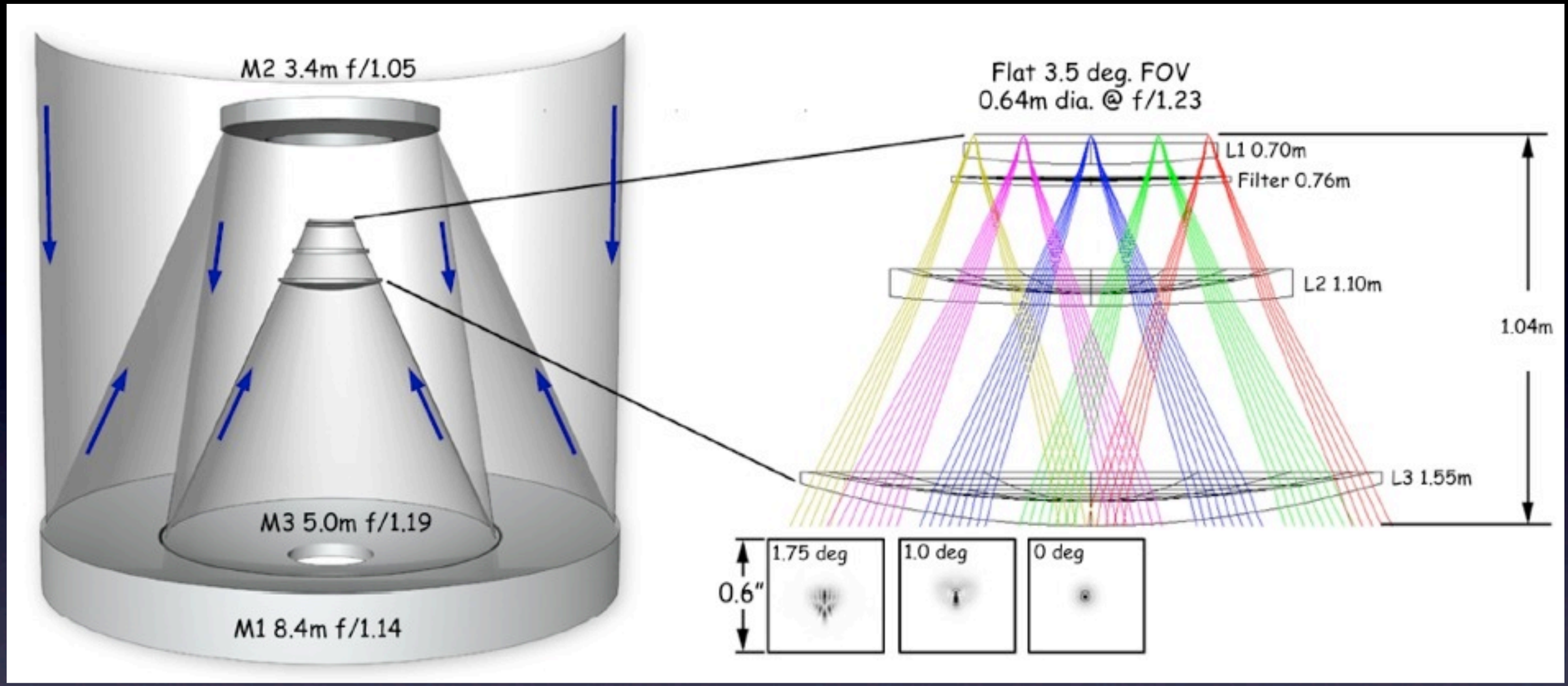
Primary Mirror Diameter



Field of View



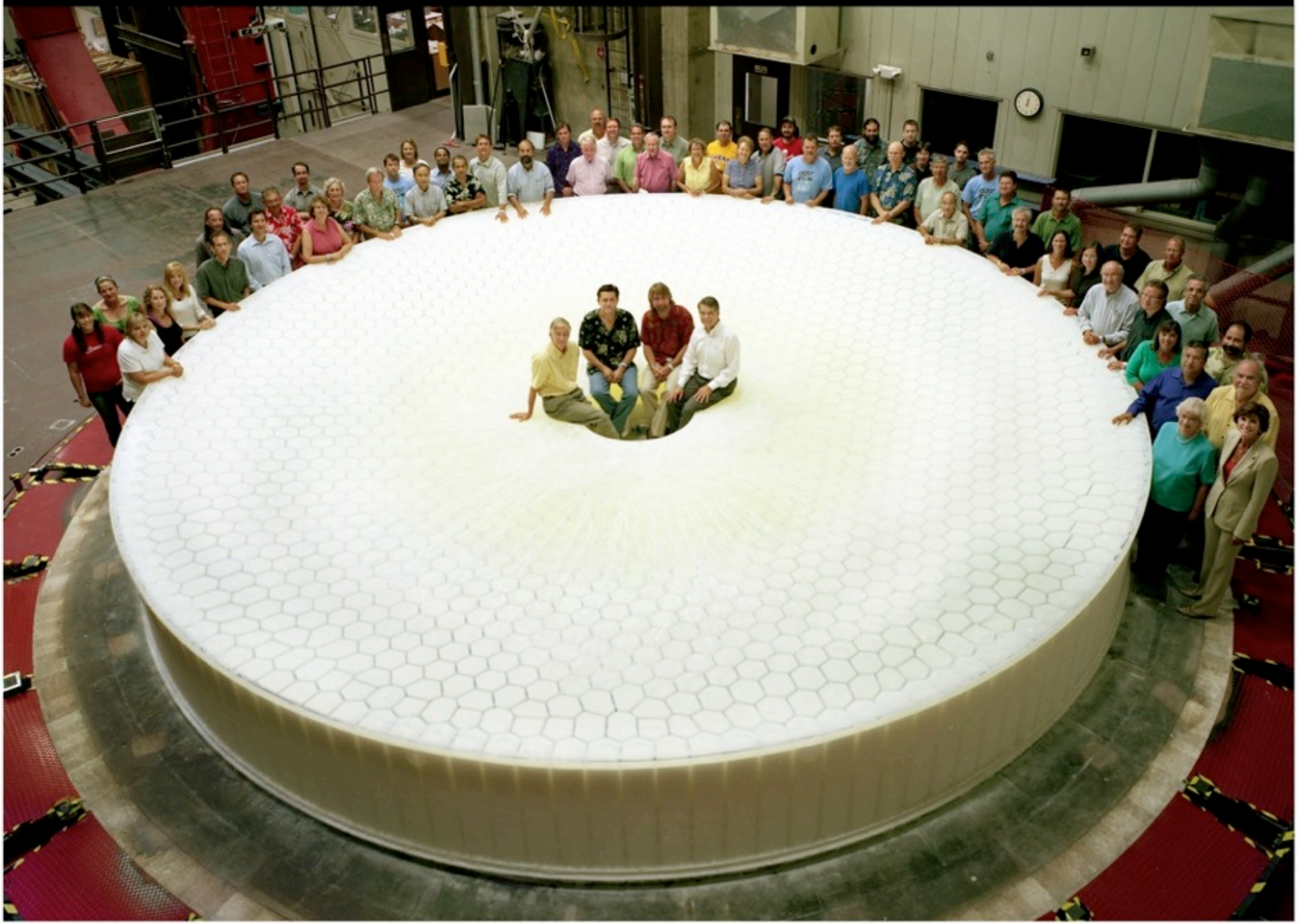
Optical design for the LSST telescope



"Classical" telescopes: two mirrors, hard to simultaneously get both a large field of view and small image distortions

LSST: three-mirror design that enables a large field of view with small image distortions (Paul-Baker system)

Large Synoptic Survey Telescope



The University of Arizona. Tucson Arizona

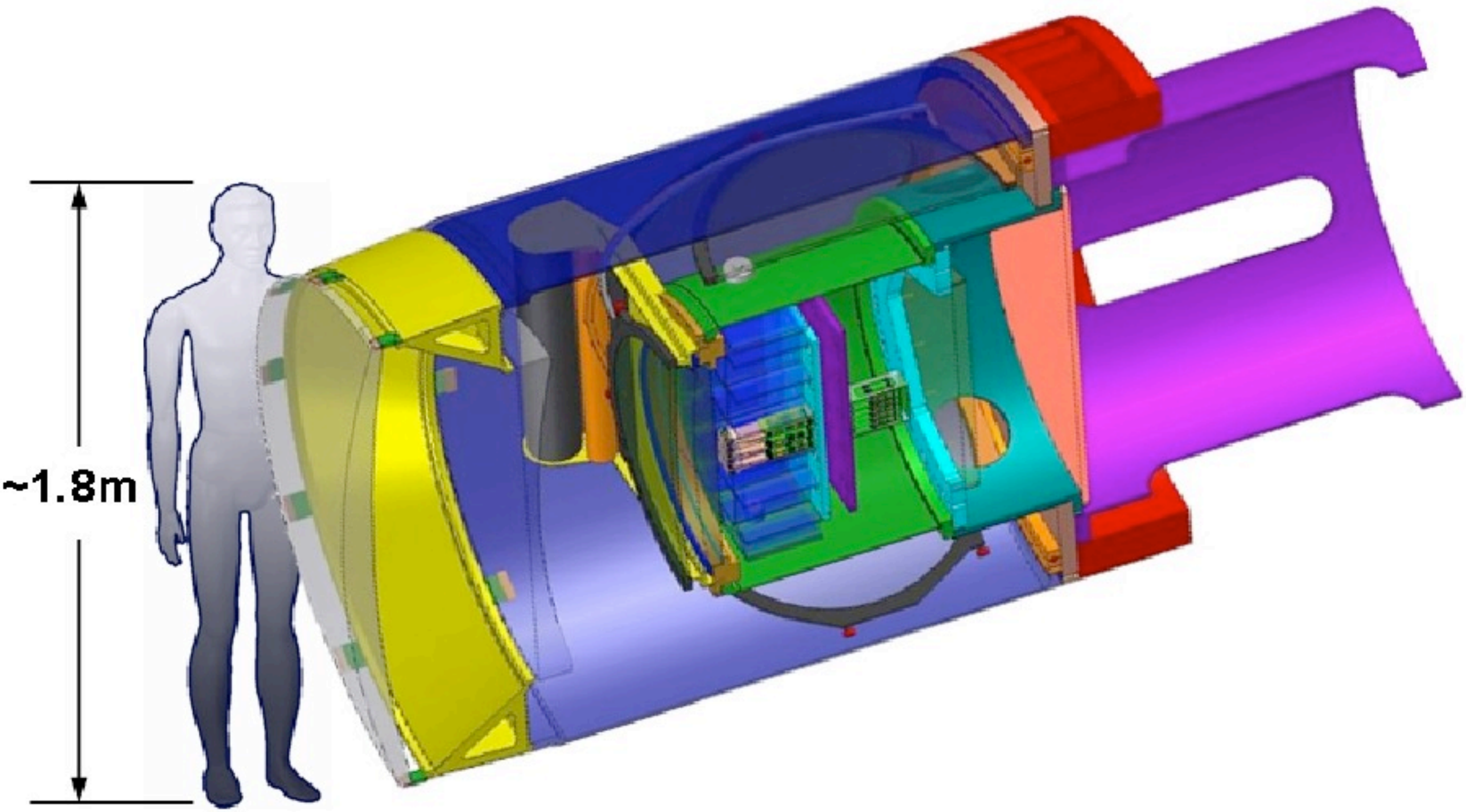
SOML

LSST Primary/Tertiary Mirror Blank

August 11, 2008, Steward Observatory Mirror Lab, Tucson, Arizona

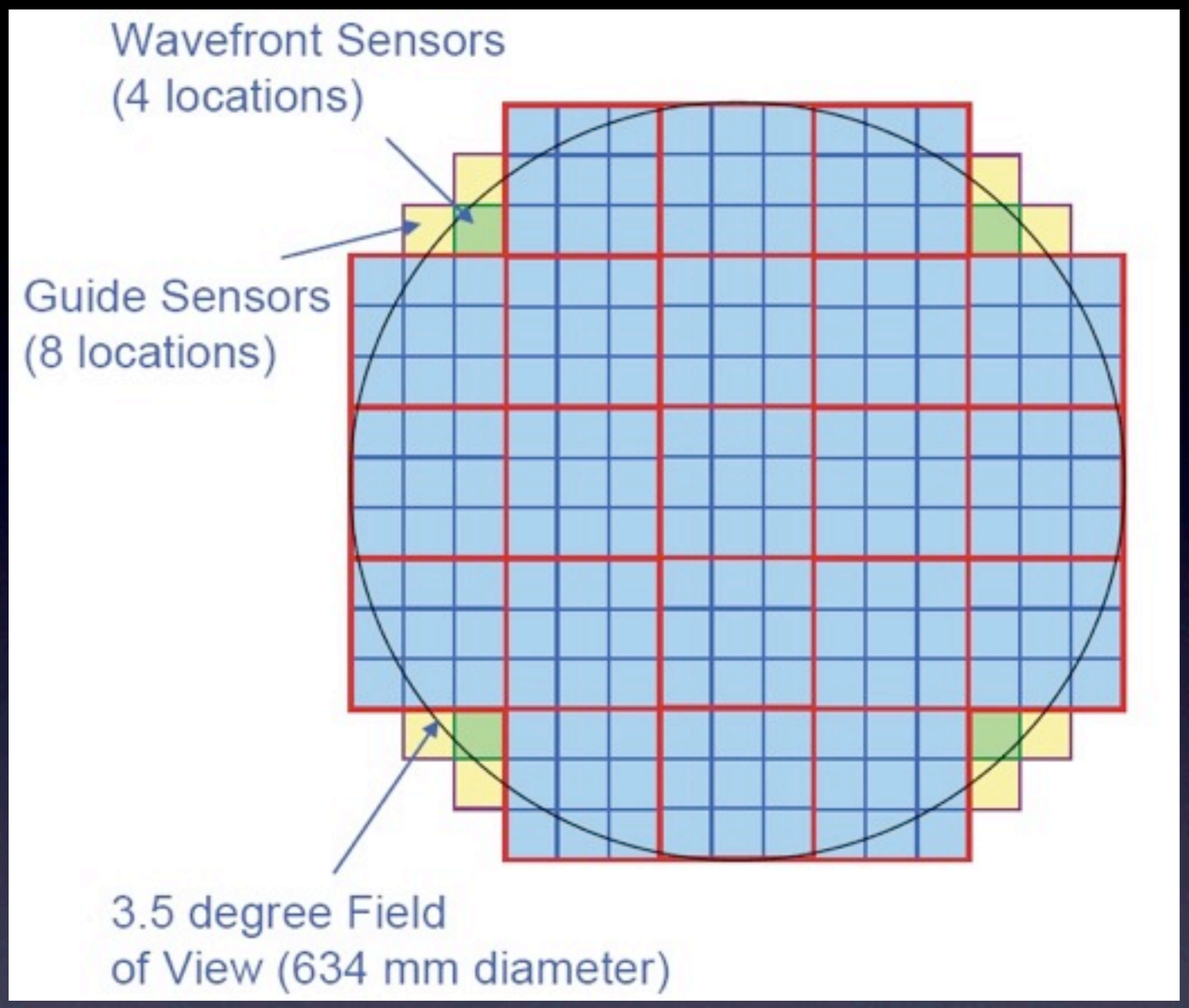
LSST
Large Synoptic Survey Telescope

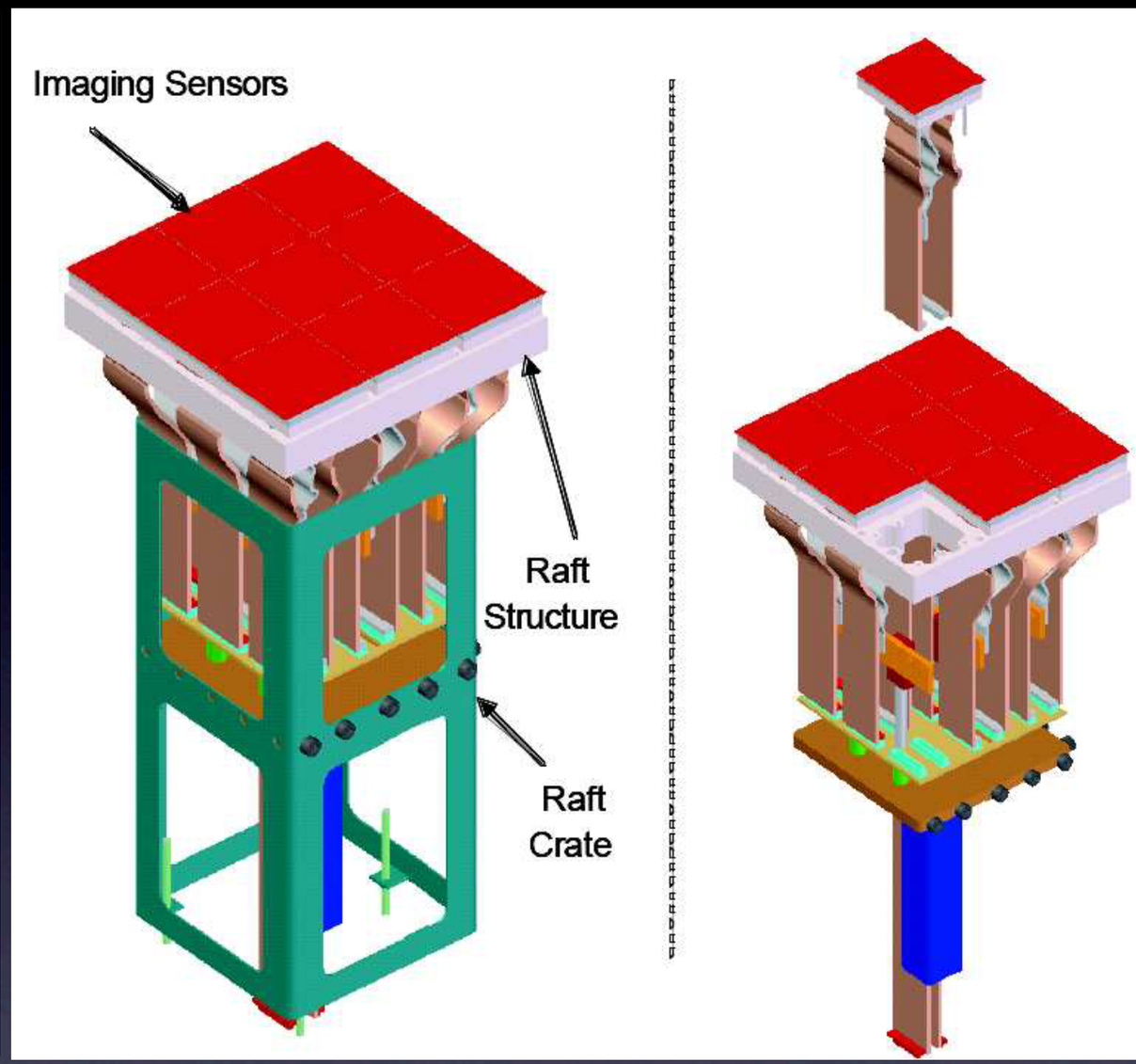
LSST camera



The largest astronomical camera: 2800 kg, 3200 Megapixels

LSST camera





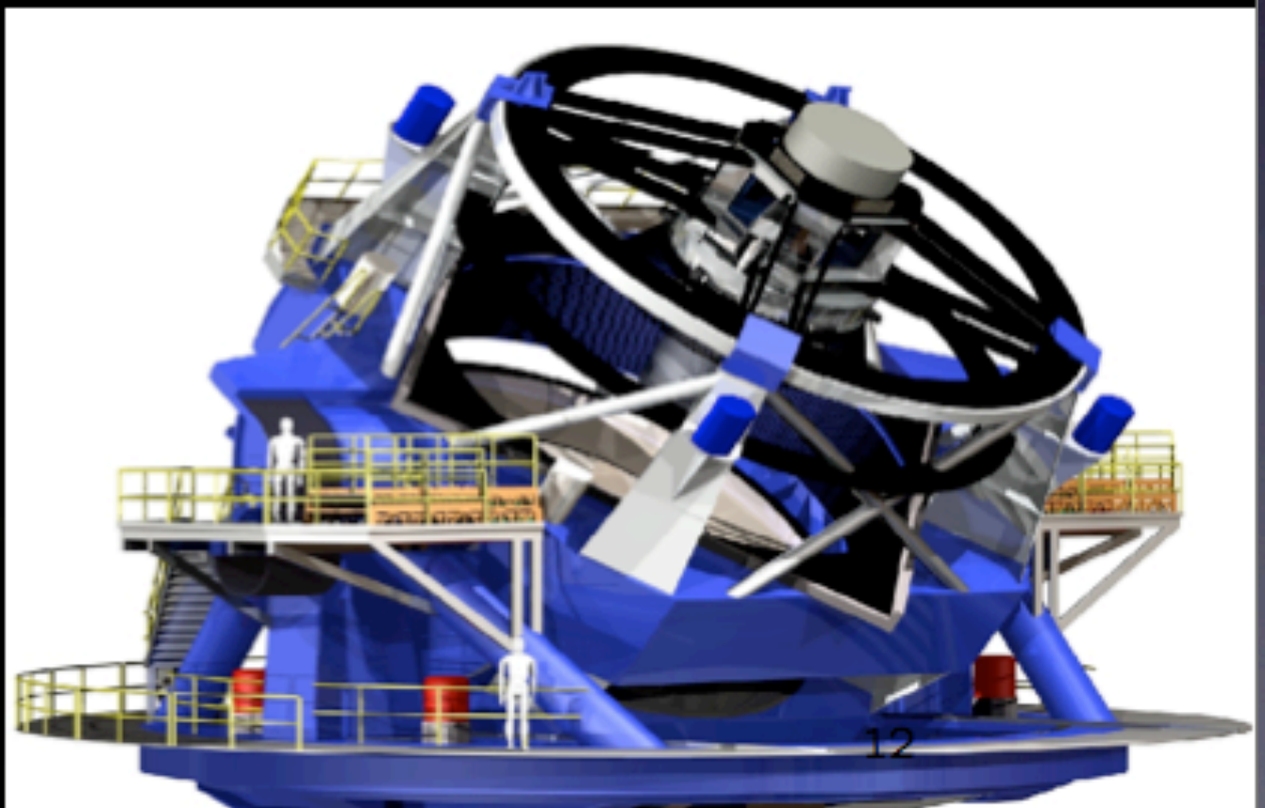
Modular design: 3200 Megapix = 189 x16 Megapix CCD

9 CCDs in a raft = effectively a stand-alone camera

Raft with problems can be replaced with a spare one

SDSS: one US Library of Congress worth of data

LSST: one SDSS per night, or all the words ever printed!



The Data Challenge

- ~3 Terabytes per hour that must be mined in real time.
- 20 billion objects will be monitored for important variations in real time.

The LSST data, all >100,000 TB, will be available to everyone in 2020s, just like 20 TB of SDSS data are today