Astrophysics Missions

Big Ideas
Big Design
Big Dev
Big Ops
Big Data

T.H. Jarrett (UCT)
04 Oct 2017

SCIENCE

question

hypothesis

prediction

procedure

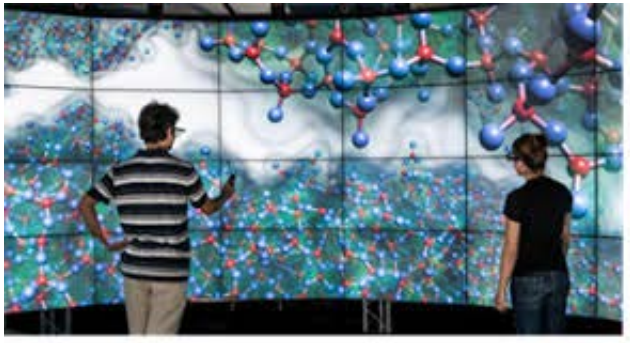
Instrumentation

Data

Analysis &
Visualization

experiment

theory



Mission Bottom line: DATA

Mission Chronology (and spending) order, the end of the line is

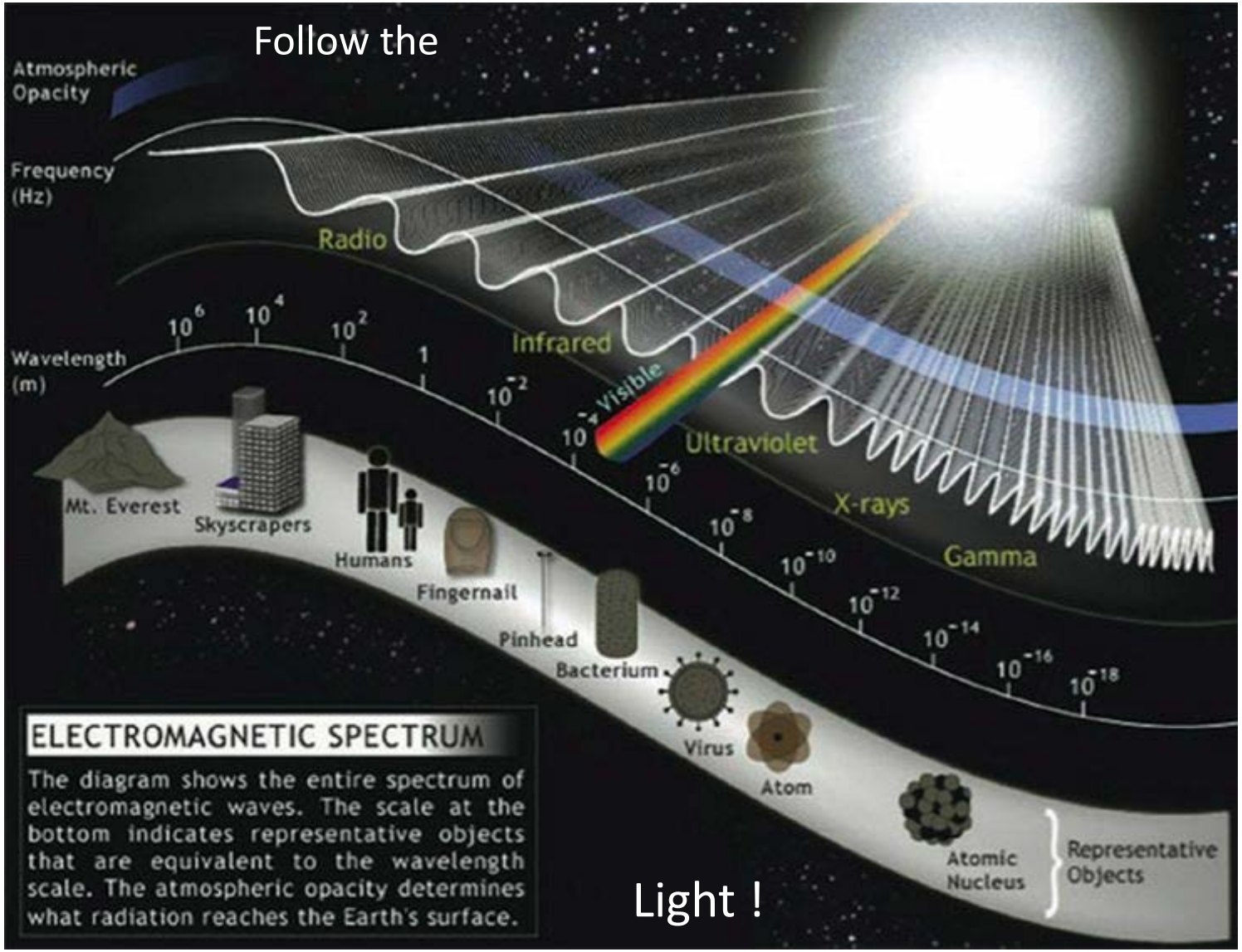
Data Archival,

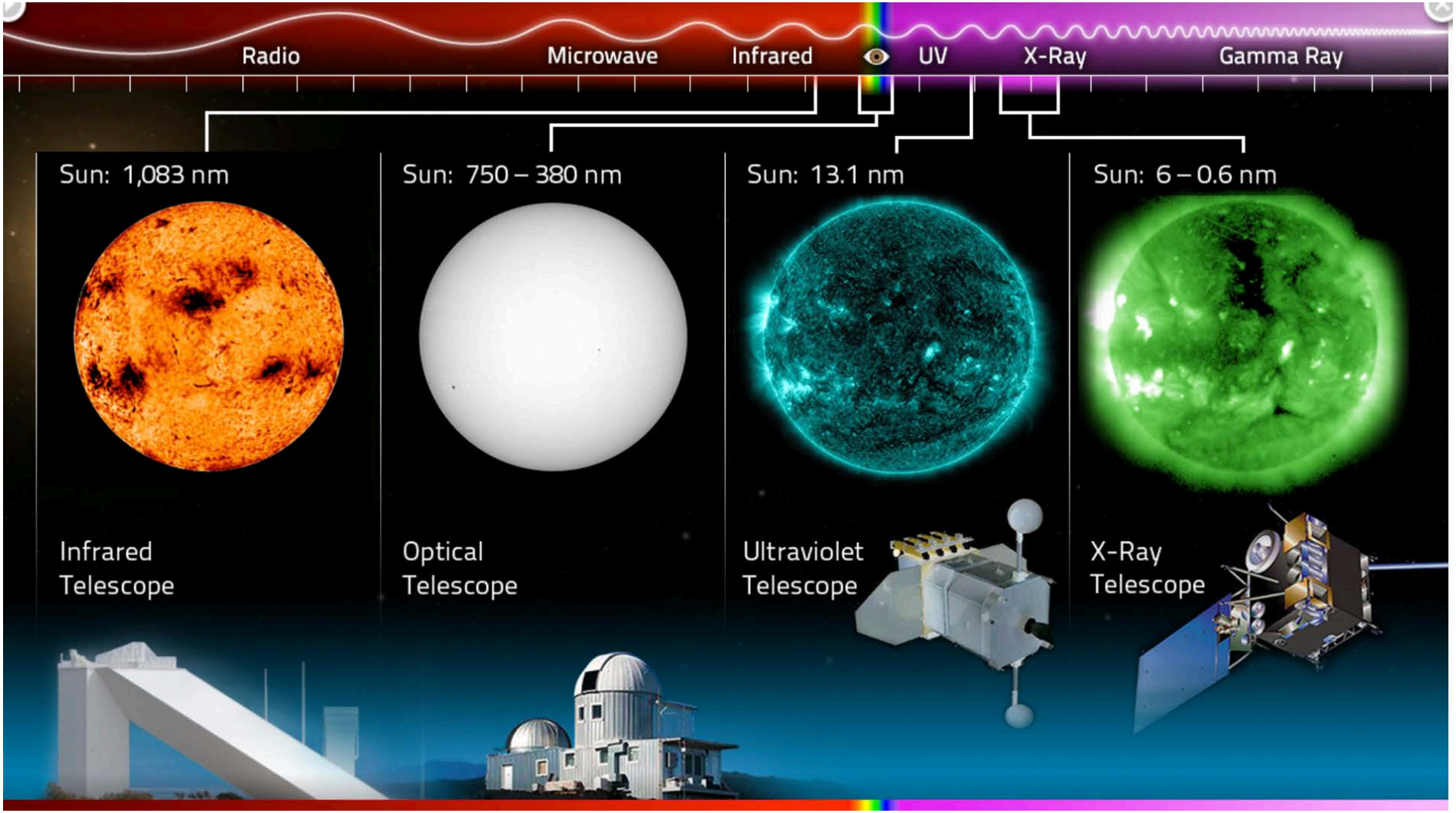
Curation & Mining tools (exploration)

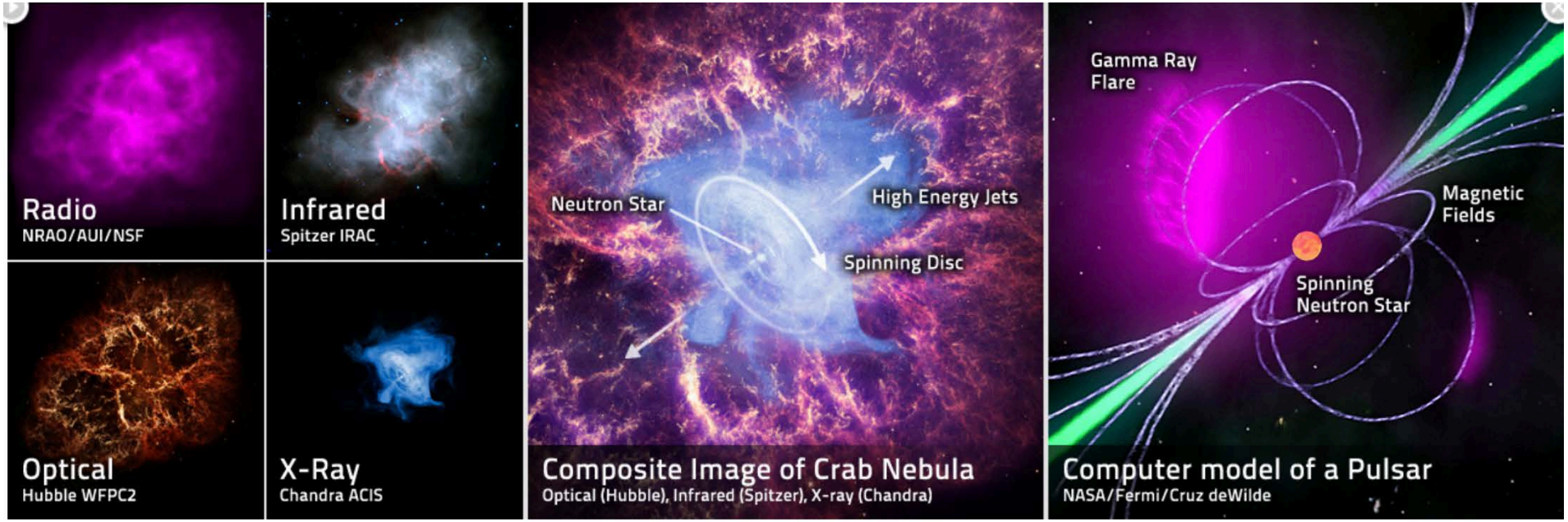
Focus on the data aspect, but first some context on modern astrophysics and the observational missions themselves …

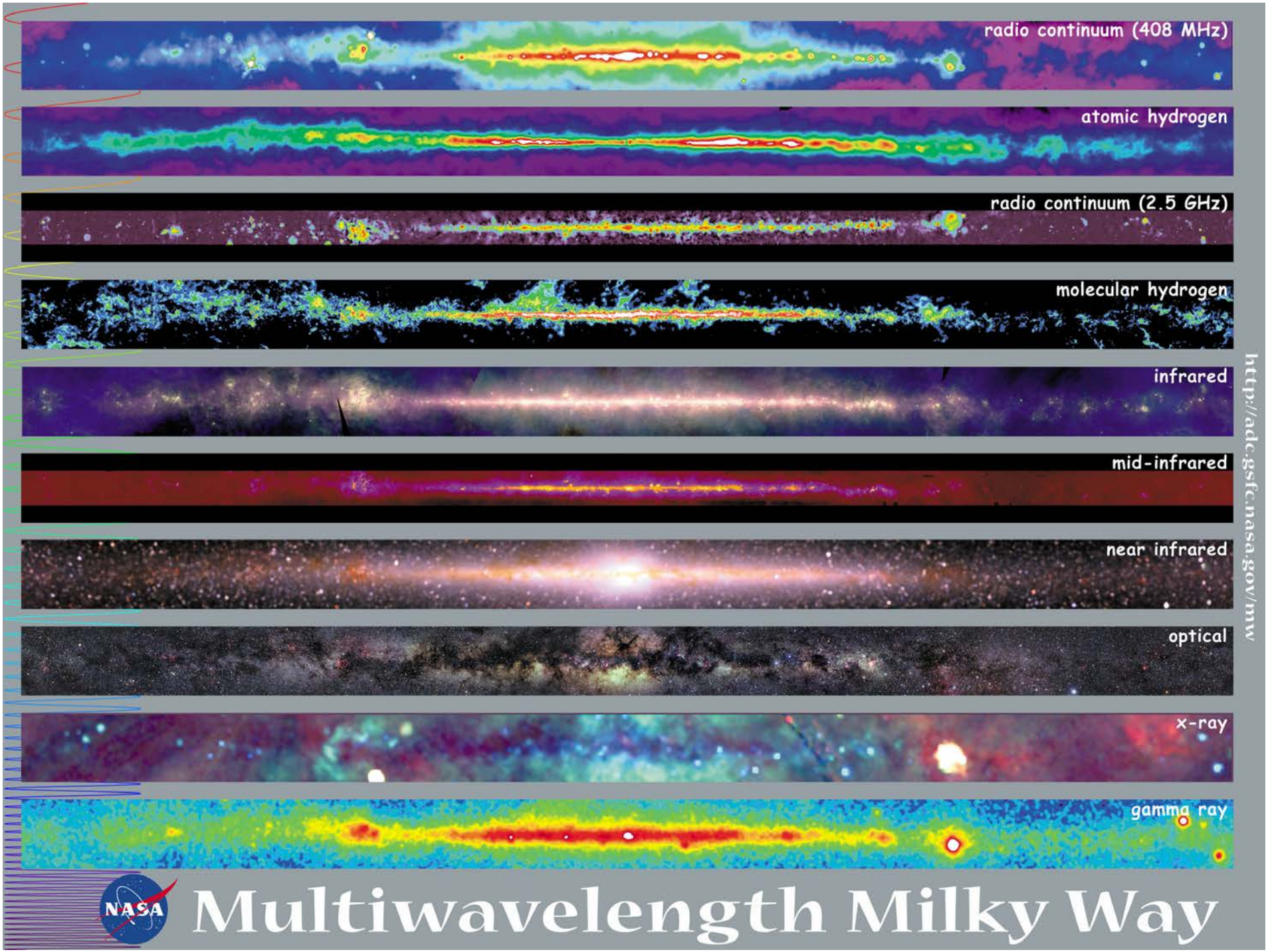
Multi-wavelength Astrophysics

The path to understanding the Cosmos

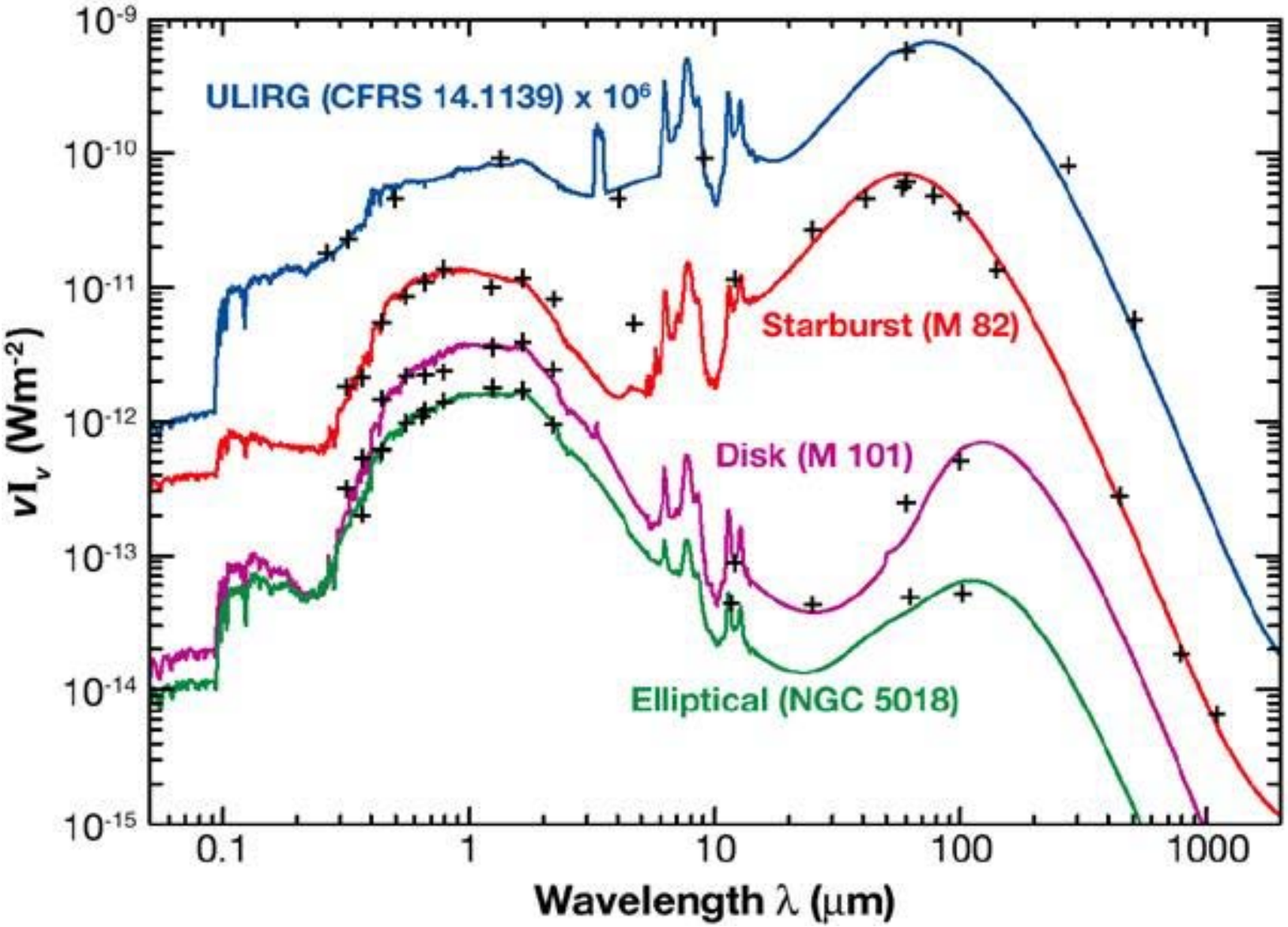



Radio
Microwave
Infrared
UV
X-Ray
Gamma Ray
Sun: 1,083 nm
Sun: 750 – 380 nm
Sun: 13.1 nm
Sun: 6 – 0.6 nm
Infrared Telescope
Optical Telescope
Ultraviolet Telescope
X-Ray Telescope

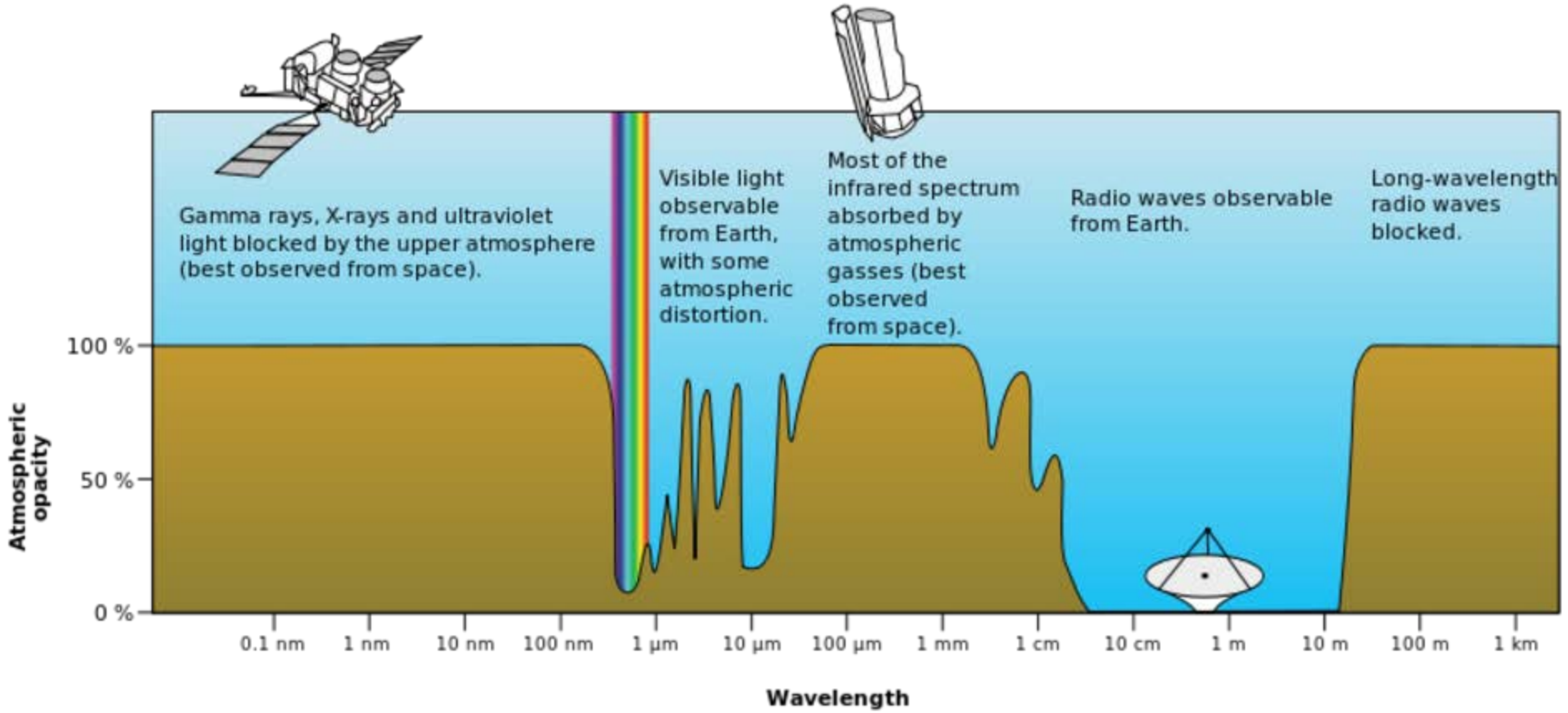

Radio
NRAO/AUI/NSF
Infrared
Spitzer IRAC
Optical
Hubble WFPC2
X-Ray
Chandra ACIS
Neutron Star
High Energy Jets
Spinning Disc
Composite Image of Crab Nebula
Optical (Hubble), Infrared (Spitzer), X-ray (Chandra)
Gamma Ray
Flare
Magnetic
Fields
Spinning
Neutron Star
Computer model of a Pulsar
NASA/Fermi/Cruz deWilde


radio continuum (408 MHz)
atomic hydrogen
radio continuum (2.5 GHz)
molecular hydrogen
infrared
mid-infrared
near infrared
optical
x-ray
gamma ray
http://adc.gsfc.nasa.gov/mw
NASA
Multiwavelength Milky Way

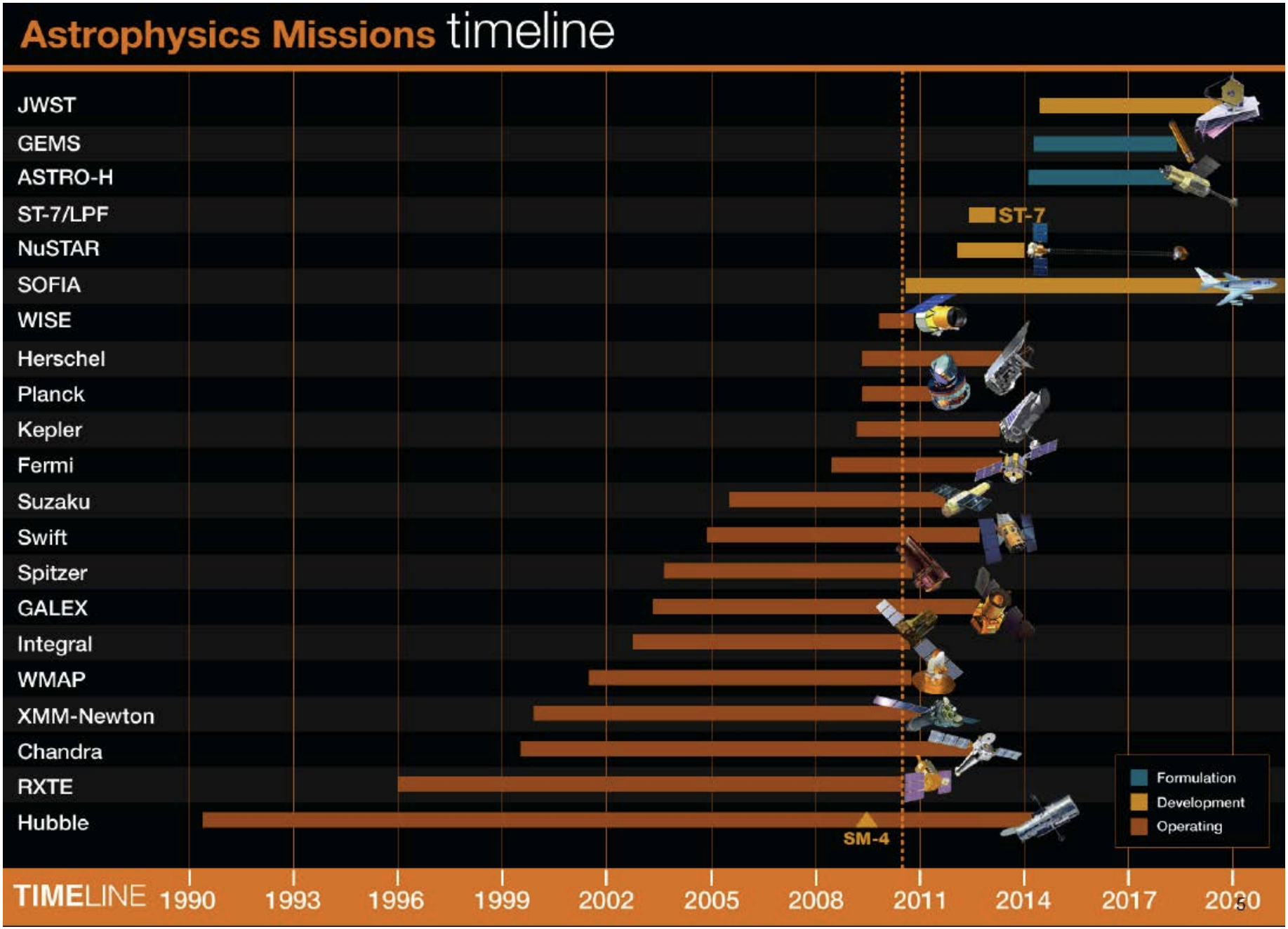

Radio
Microwave
Infrared
UV
X-Ray
Gamma Ray
Radio
60,000 nm
600 K
Infrared
1200-800 nm (10-3.6 um)
4,500 K
Optical
450-750 nm
6,000 K
Ultraviolet
400-200 nm
10,000 K
X-ray
100-10 nm
10,000,000 K
Multiwavelength Whirlpool Galaxy
COLD GAS: Radio waves reveal regions of gas cool enough for CO_2 molecules to exist.
COOL STARS: Infrared shows smaller cool red stars that make up most of the galaxy.
SOLAR STARS: Optical light comes from stars around the size of the Sun.
HOT STARS: Ultraviolet shows the larger hot blue stars that are less frequent in galaxies.
HOT GAS: X-rays are emitted from the hottest regions of gas where atoms are ionized.
COOL LOW ENERGY RADIATION
VISIBLE LIGHT
HOT HIGH ENERGY RADIATION


ULIRG (CFRS 14.1139) x 10⁶
Starburst (M 82)
Disk (M 101)
Elliptical (NGC 5018)
νI_ν (Wm⁻²)
Wavelength λ (μm)
10⁻⁹
10⁻¹⁰
10⁻¹¹
10⁻¹²
10⁻¹³
10⁻¹⁴
10⁻¹⁵
0.1
1
10
100
1000

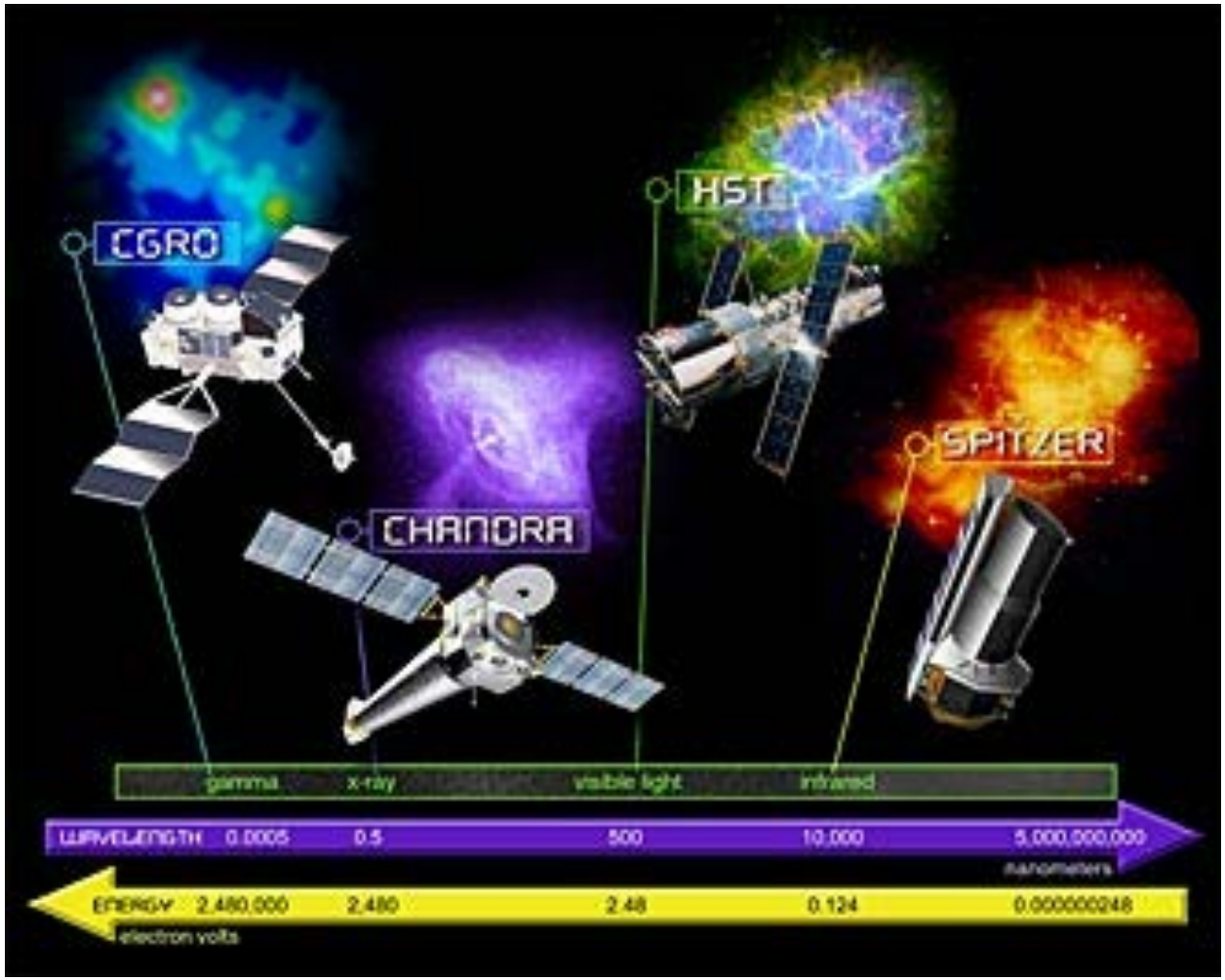
Why Space?


Gamma rays, X-rays and ultraviolet light blocked by the upper atmosphere (best observed from space).
Visible light observable from Earth, with some atmospheric distortion.
Most of the infrared spectrum absorbed by atmospheric gasses (best observed from space).
Radio waves observable from Earth.
Long-wavelength radio waves blocked.
100 %
50 %
0 %
Atmospheric opacity
0.1 nm
1 nm
10 nm
100 nm
1 µm
10 µm
100 µm
1 mm
1 cm
10 cm
1 m
10 m
100 m
1 km
Wavelength

And so we spend the big bucks on the Big Missions

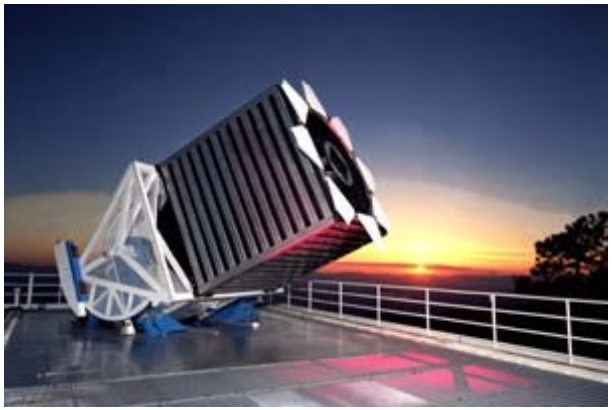

Astrophysics Missions timeline
JWST
GEMS
ASTRO-H
ST-7/LPF
NuSTAR
SOFIA
WISE
Herschel
Planck
Kepler
Fermi
Suzaku
Swift
Spitzer
GALEX
Integral
WMAP
XMM-Newton
Chandra
RXTE
Hubble
ST-7
SM-4
Formulation
Development
Operating
TIMELINE
1990
1993
1996
1999
2002
2005
2008
2011
2014
2017
2020

Observatories vs Surveys

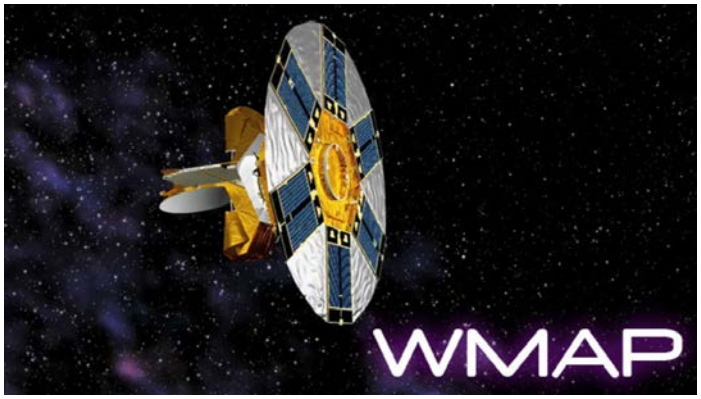


Observatories vs Surveys

SDSS



IRAS



Consider the WISE Mission

WISE is a NASA-funded Explorer mission that will provide a vast storehouse of knowledge about the solar system, the Milky Way, and the Universe. Among the objects WISE will study are asteroids, the coolest and dimmest stars, and the most luminous galaxies.

Science Objectives

WISE will provide an all-sky survey from 3 to 25 μm with 500,000 times the sensitivity of COBE/DIRBE and hundreds of times that of IRAS. The survey will help search for the origins of planets, stars, and galaxies and create an infrared atlas whose legacy will endure for decades.

ALLWISE (data) Overview

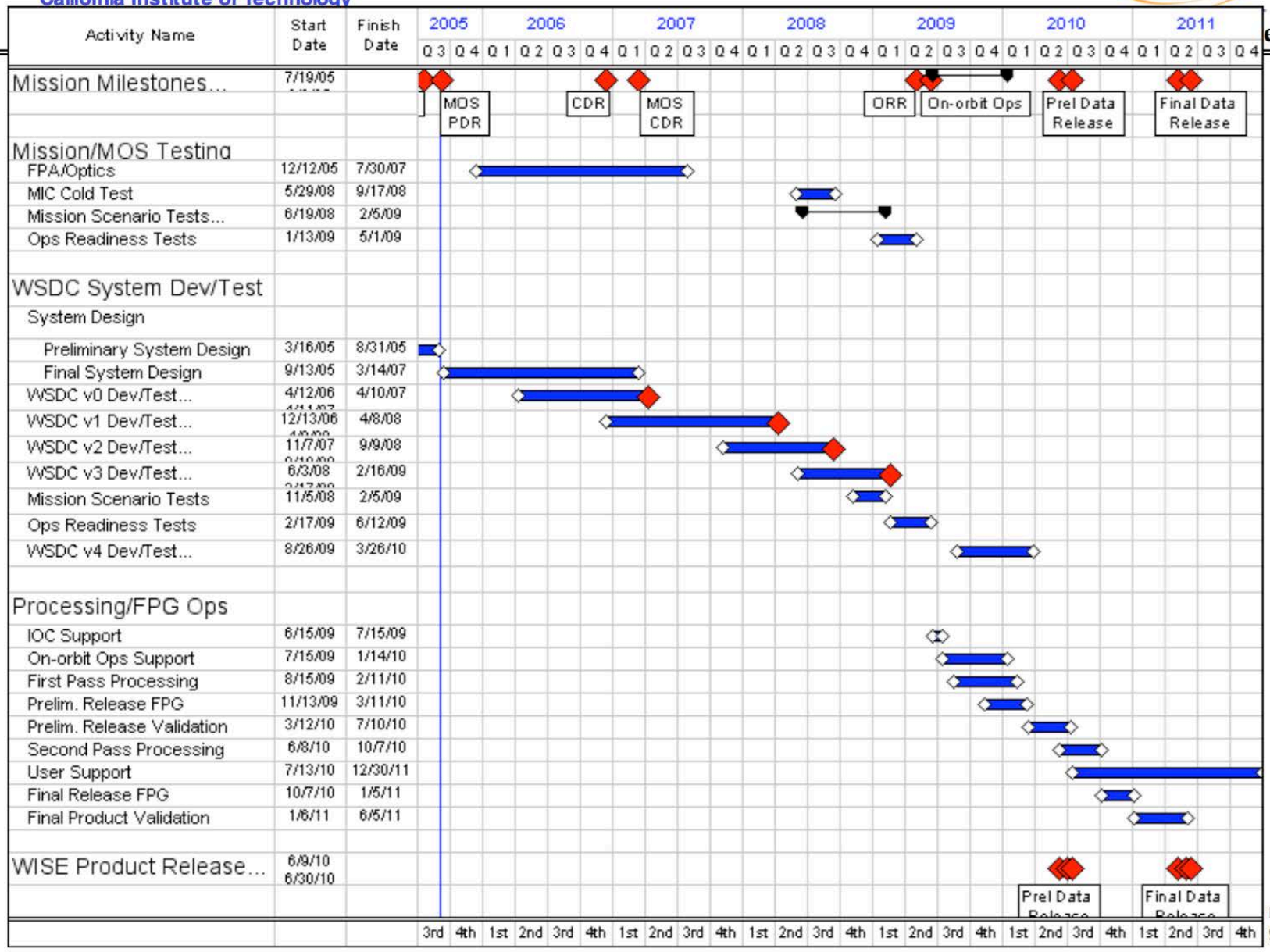
http://wise2.ipac.caltech.edu/docs/release/allwise/expsup/sec1_1.html

Mission design …

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

Wide-field Infrared Survey Explorer (WISE)

Top Level Schedule



Mission design …

Partnership with IRSA - 1

- The Infrared Science Archive, at IPAC, is NASA's designated archive for infrared and sub-millimeter astronomy mission (http://irsa/ipac/caltech.edu)
- WISE extracted source and metadata databases will be developed within the IRSA infrastructure, so data products are implicitly delivered to the archive
  - Successfully implemented for 2MASS
- IRSA infrastructure is optimized for handling and serving massive datasets
  - Currently holds ~20TB in images, 2 billion rows of catalogs
  - From Jan. 2001 to April 2004, processed over 9,000,000 data requests and delivered 1.2 TB of data to users

Mission design …

Partnership with IRSA - 2

- Archive-related development for WISE minimized
  - Use existing and augmented IRSA middleware
  - New development limited to "thin-layer" interfaces customized for WISE services
  - WISE project supplies bulk storage for IRSA storage system (included in WSDC hardware cost estimate)
- IRSA web-based image and database access tools will be primary project and public interfaces into WISE data
  - Proven tools will enable prompt, easy access to processed image and source data by Science Team to facilitate analysis, validation and research
  - Project will utilize additional custom analysis and QA tools for internal analysis
  - Password control for pre-release and internal data sets
  - Public interfaces will be a subset of project interfaces, allowing thorough testing prior to release
- Interoperability
  - All IRSA services support program access (e.g. to be used by multi-orbit pipeline)
  - Automatic incorporation into existing IRSA inter-op tools such as OASIS (Image/Catalog interaction) and RADAR (cross-IRSA inventory tool)
  - All IRSA services are registered with the Virtual Observatory (VO) so that can be exploited by VO-compliant interfaces

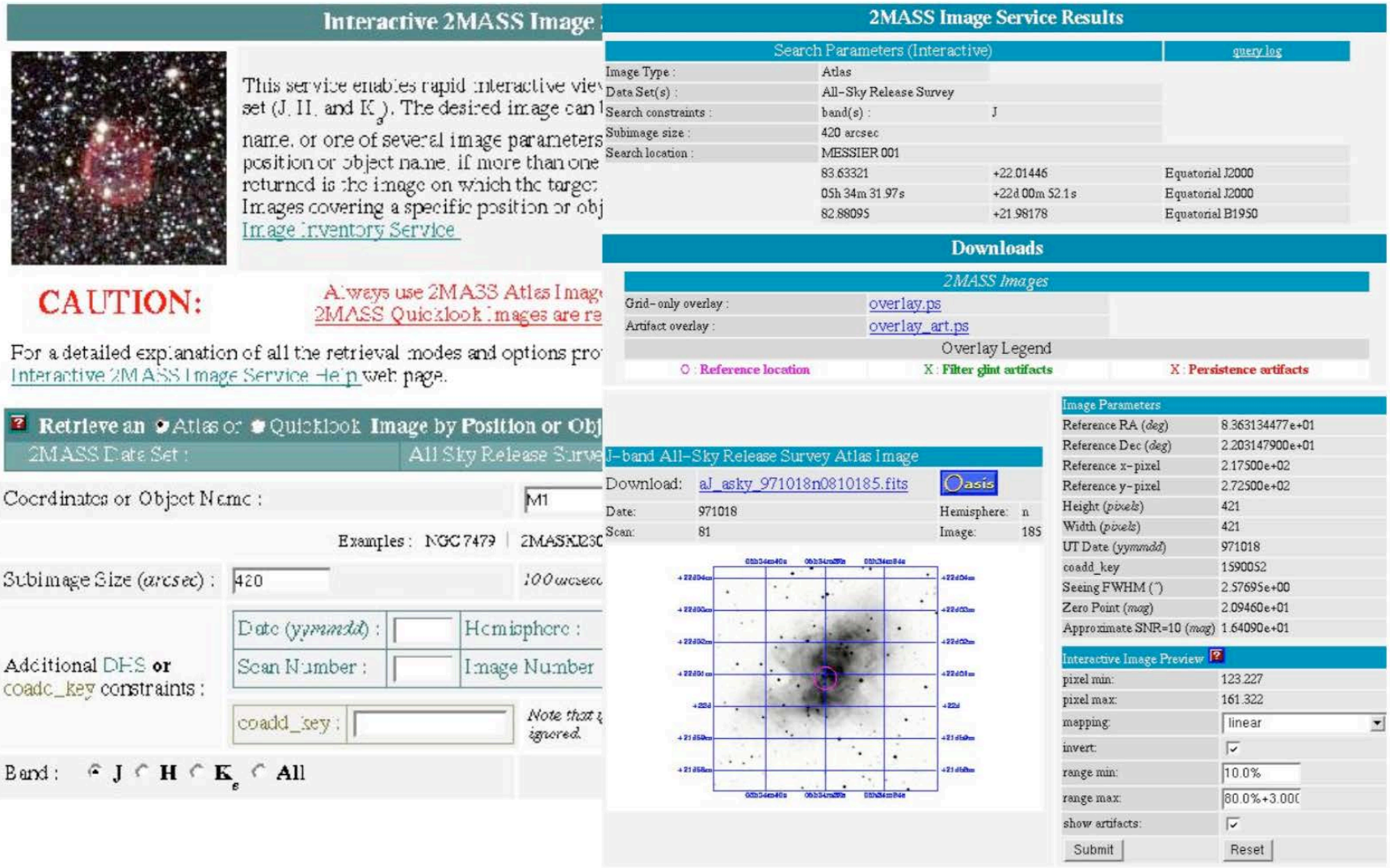
Mission design …

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

Wide-field Infrared Survey Explorer (WISE)

IRSA Image Services

WISE Science Data Center



Mission design …

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

Wide-field Infrared Survey Explorer (WISE)

IRSA Catalog Queries

WISE Science Data Center

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\RowsRetreived =                 183
\QueryTime      =   00:00:26.68448
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\DATETIME= '2005-08-15 10:10:05'
\DATABASE= 'GLIMPSE Spring '05 Catalog (<a href=/applications/Gator/src/html/GLIMPSE_columns.html>reliable</a>)  (glimpse_s05)'
\EQUINOX = 'J2000'
\SKYAREA = 'within 240 arcsec radius of ra=221.91009 dec=-59.36011 Eq J2000 '
\SQL      = 'WHERE (f3_6 is not NULL and f4_5 is not NULL and f5_8 is not NULL and f8_0 is not NULL)'
\SQL      = 'SELECT (23 column names follow in next row.)'
|                designation|                  l|                  b|             mag3_6|              d3_6m|             mag4_5|
|                        char|             double|             double|             double|              double|             double|
|                           |                deg|                deg|                mag|                 mag|                mag|
|                        null|               null|               null|               null|                null|               null|
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    SSTGLMC G317.2708+00.2804          317.270813          0.280447           11.430000           0.061000          11.533000
    SSTGLMC G317.2869+00.2975          317.286865          0.297452            9.326000           0.033000           9.374000
    SSTGLMC G317.2878+00.2720          317.287811          0.271995           10.629000           0.048000          10.676000
    SSTGLMC G317.2885+00.2837          317.288513          0.283738            9.323000           0.035000           9.540000
    SSTGLMC G317.3159+00.2744          317.315887          0.274398            9.565000           0.036000           9.792000
    SSTGLMC G317.2706+00.2815          317.270630          0.281525           11.644000           0.057000          11.700000
    SSTGLMC G317.2796+00.2830          317.279602          0.283010            9.912000           0.041000          10.061000
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    SSTGLMC G317.3122+00.2572          317.312225          0.257205           10.580000           0.056000          10.687000
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    SSTGLMC G317.2129+00.2814          317.212891          0.281420           11.240000           0.061000          11.208000
    SSTGLMC G317.2147+00.2525          317.214722          0.252487            9.176000           0.043000           9.291000
    SSTGLMC G317.2164+00.2501          317.216431          0.250082            7.306000           0.044000           7.373000
    SSTGLMC G317.2168+00.2680          317.216766          0.268047           11.897000           0.055000          11.848000
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Name	Description	Sel	Low Limit (include >,=,=)	Up Limit (include <,<=,=)	Units	Indx	DBType
designation	source name	☑					character(28)
l	Galactic longitude	☑			deg		float

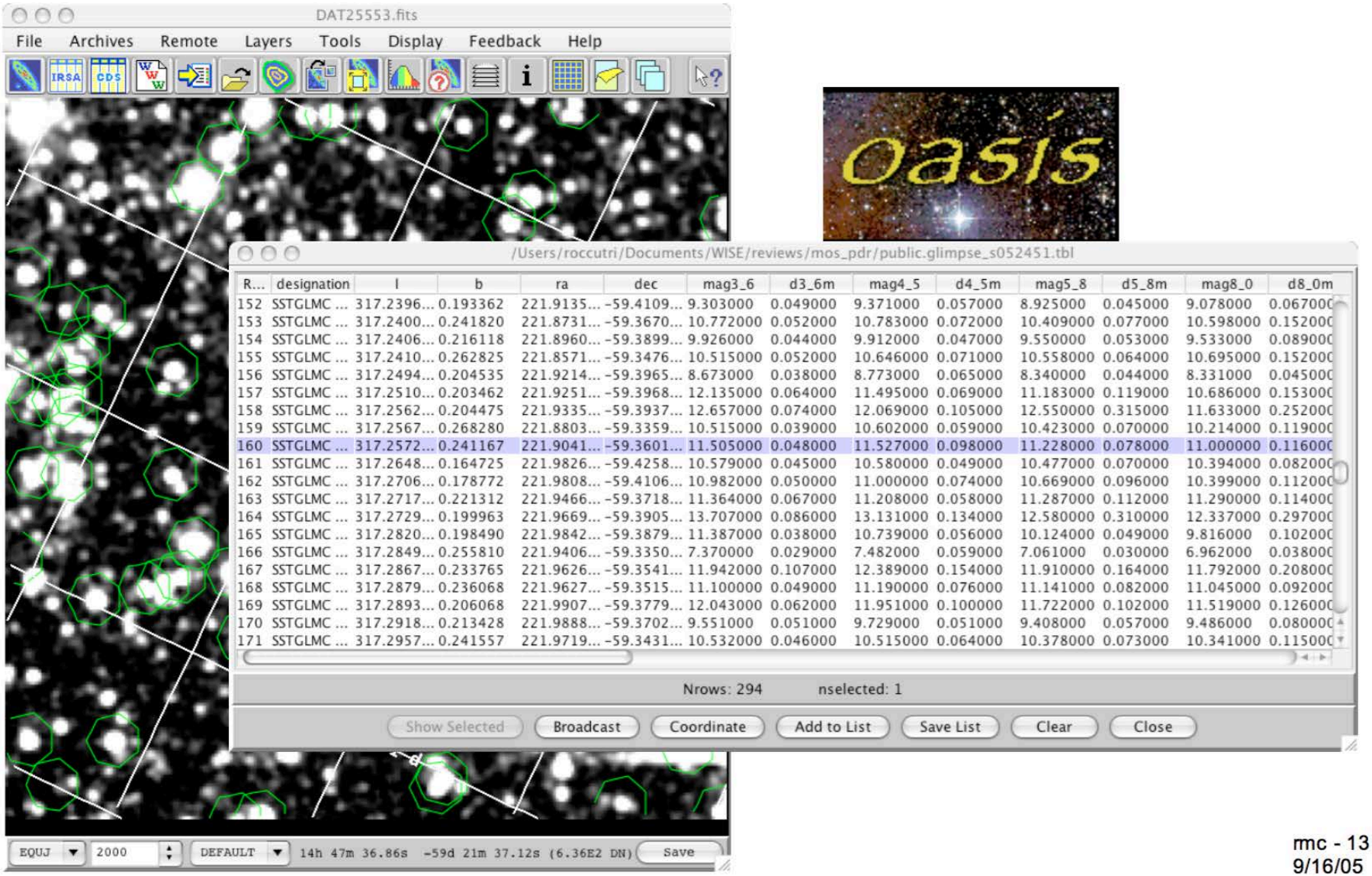
Mission design …

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

Wide-field Infrared Survey Explorer (WISE)

IRSA Interoperability

WISE Science Data Center



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153	SSTGLMC ...	317.2400...	0.241820	221.8731...	-59.3670...	10.772000	0.052000	10.783000	0.072000	10.409000	0.077000	10.598000	0.152000
154	SSTGLMC ...	317.2406...	0.216118	221.8960...	-59.3899...	9.926000	0.044000	9.912000	0.047000	9.550000	0.053000	9.533000	0.089000
155	SSTGLMC ...	317.2410...	0.262825	221.8571...	-59.3476...	10.515000	0.052000	10.646000	0.071000	10.558000	0.064000	10.695000	0.152000
156	SSTGLMC ...	317.2494...	0.204535	221.9214...	-59.3965...	8.673000	0.038000	8.773000	0.065000	8.340000	0.044000	8.331000	0.045000
157	SSTGLMC ...	317.2510...	0.203462	221.9251...	-59.3968...	12.135000	0.064000	11.495000	0.069000	11.183000	0.119000	10.686000	0.153000
158	SSTGLMC ...	317.2562...	0.204475	221.9335...	-59.3937...	12.657000	0.074000	12.069000	0.105000	12.550000	0.315000	11.633000	0.252000
159	SSTGLMC ...	317.2567...	0.268280	221.8803...	-59.3359...	10.515000	0.039000	10.602000	0.059000	10.423000	0.070000	10.214000	0.119000
160	SSTGLMC ...	317.2572...	0.241167	221.9041...	-59.3601...	11.505000	0.048000	11.527000	0.098000	11.228000	0.078000	11.000000	0.116000
161	SSTGLMC ...	317.2648...	0.164725	221.9826...	-59.4258...	10.579000	0.045000	10.580000	0.049000	10.477000	0.070000	10.394000	0.082000
162	SSTGLMC ...	317.2706...	0.178772	221.9808...	-59.4106...	10.982000	0.050000	11.000000	0.074000	10.669000	0.096000	10.399000	0.112000
163	SSTGLMC ...	317.2717...	0.221312	221.9466...	-59.3718...	11.364000	0.067000	11.208000	0.058000	11.287000	0.112000	11.290000	0.114000
164	SSTGLMC ...	317.2729...	0.199963	221.9669...	-59.3905...	13.707000	0.086000	13.131000	0.134000	12.580000	0.310000	12.337000	0.297000
165	SSTGLMC ...	317.2820...	0.198490	221.9842...	-59.3879...	11.387000	0.038000	10.739000	0.056000	10.124000	0.049000	9.816000	0.102000
166	SSTGLMC ...	317.2849...	0.255810	221.9406...	-59.3350...	7.370000	0.029000	7.482000	0.059000	7.061000	0.030000	6.962000	0.038000
167	SSTGLMC ...	317.2867...	0.233765	221.9626...	-59.3541...	11.942000	0.107000	12.389000	0.154000	11.910000	0.164000	11.792000	0.208000
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Mission design …

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

Wide-field Infrared Survey Explorer (WISE)

IRSA Interoperability

WISE Science Data Center

Image Preview | Name Resolve

Object Name/Coordinate	Source	Type	Glon	Glat	Equatorial J2000	Mission
10h00m00s +02d15m00s	Coordinate		236.68078	+42.05026	10h 00m 00.00s +02d 15m 00.0s	All, 2MASS, IRAS, MSX, NED, SPITZER

Cone Search (0<Radius<=6.25 Deg.) 30.0 arcmin
Box Search (Deg) (0<Size<=12.5 Deg.) 1
Collection Name: default
No email

Target Name / Coordinate: 10h00m00s +02d

Examples:
289.3848 11.9674 eq | 4
19h17m32s 11d58m02s

Cone Search (0<Radius<=6.25 Deg.) 30.0
Box Search (0<Size<=12.5 Deg.) 0.00555556 de

Get Inventory
Save Inventory
Get Data
Clear All
Select All
Full Inventory

Optional Se
Mission Selection
All
2MASS
IRAS
MSX
NED
No email
Collection Nam

Catalog Availability

Source Description	Count	Select Data	Link to Service
2MASS All-Sky Point Source Catalog (PSC)	1416		GO
2MASS All-Sky Extended Source Catalog (XSC)	25		GO
IRAS Faint Source Catalog v2.0 (FSC)	1		GO
IRAS Faint Source Catalog Rejects	5		GO
IRAS Point Source Catalog Rejects	4		GO
NED Basic Search	275		GO

Image Availability

Source Description	Estimated Count	Select Data	Link to Service
The MAST Image Table/Spectra Scrapbook	282		GO
2MASS All-Sky Image Service	165		GO
2MASS All-Sky Extended Source Image Server	25		GO
The IRAS Sky Survey Atlas (ISSA)	4		GO
NASA/IPAC Extragalactic Database Image Data Atlas (NED)	NED Images may be found.		GO
Cosmic Evolution Survey with HST	894		GO

NASA/IPAC Infrared Science Archive

IRSA | Data sets | Search | Tools | Help

Search for Source

Name or Coordinates

Search

Radius 10 arcsec

Guide for Solar System Observers

Search Catalog:

WISE

Search

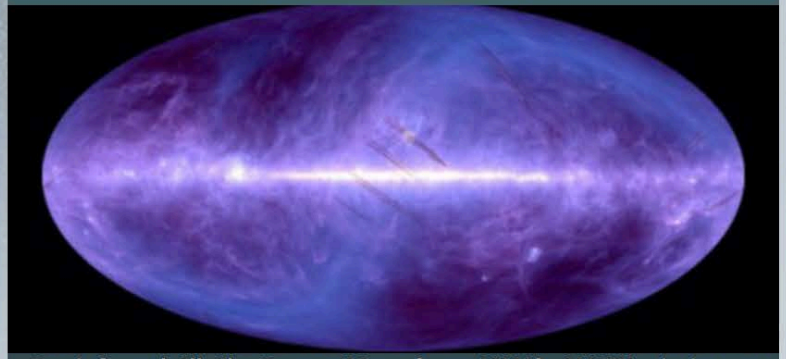
Catalogs

Images

Finder Chart

{http://} VO/API

AKARI Far-infrared All-Sky Survey Maps



Far-infrared All-Sky Survey Maps from JAXA's AKARI mission are now additionally available at IRSA. These maps cover the entire sky in the N60, WIDE-S, WIDE-L, and N160 bands (65, 90, 140, 160 microns).

Past News

Featured Images

Spitzer

WISE

Herschel

Planck

2MASS

IRAS

COSMOS

More

IRSA Services - AllWISE, All-Sky, 3-Band Cryo, NEOWISE Post-Cryo, and NEOWISE Reactivation 2015, 2016, and 2017 Releases

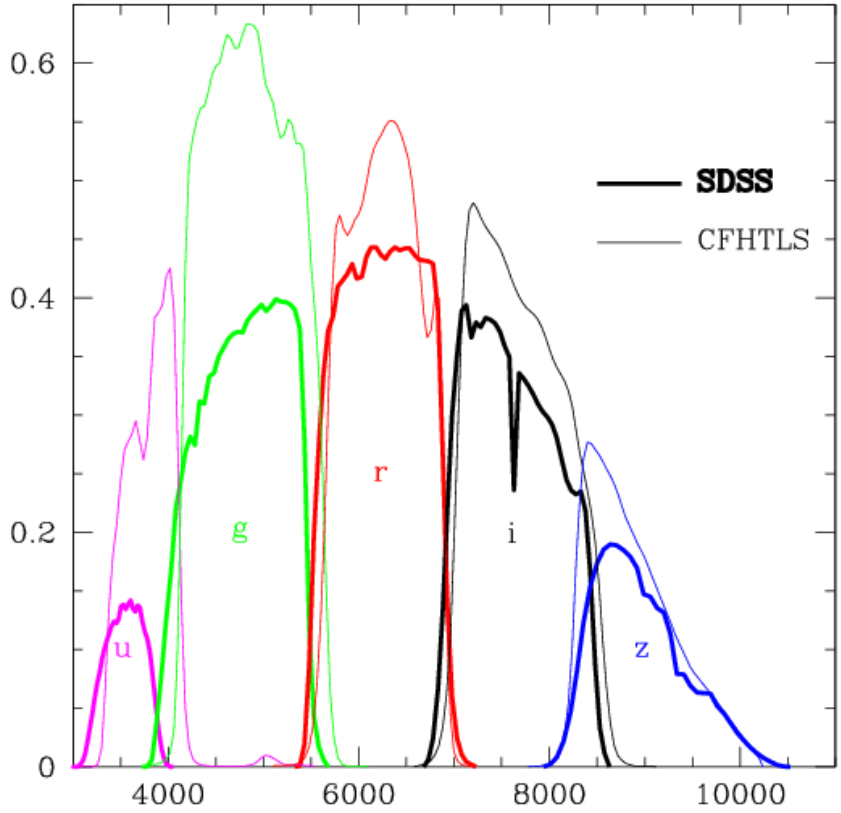
WISE Catalog Search	Access WISE catalog and other tabular data products
WISE Image Service	Access WISE image data
WISE/NEOWISE Coadder	Create science-quality image mosaics from all phases of the WISE and NEOWISE missions
Time Series Tool	Plot time series data, view associated images, find period, and phase fold.
WISE Release Coverage Service	Preview coverage in the WISE data releases
Montage Image Mosaic Service	Create science-quality image mosaics
Catalog Bulk Download	Bulk Download of WISE Catalog and 3-Band Cryo Source Working Database

SDSS

Astronomical Databases: SDSS

"Sloan Digital Sky Survey maps one-quarter of the entire sky in detail, determining the positions and absolute brightnesses of hundreds of millions of celestial objects. It also measures distances to more than a million galaxies and quasars."

SDSS



95% completeness in typical seeing to magnitudes of 22.0, 22.2, 22.2, 21.3, and 20.5, for u, g, r, i, z, respectively.

AB Mags

This magnitude system is defined such that, when monochromatic flux f is measured in erg sec^-1 cm^-2 Hz^-1,

```
m(AB) = -2.5 log(f) - 48.60
```

where the value of the constant is selected to define m(AB)=V for a flat-spectrum source. In this system, an object with constant flux per unit *frequency* interval has zero color.

References:

- Oke, J.B. 1974, ApJS, 27, 21

$$m(AB) = -2.5 \log (f_\nu / f_0)$$

$$F_0 = 3631 \text{ Jy}$$

SDSS had AB-system magnitudes, and most new surveys (notably optical) follow this system.

Vega Mags

Defined such that the bright AOV star α-Lyrae (Vega) has a magnitude of 0 (zero) at all wavelengths.

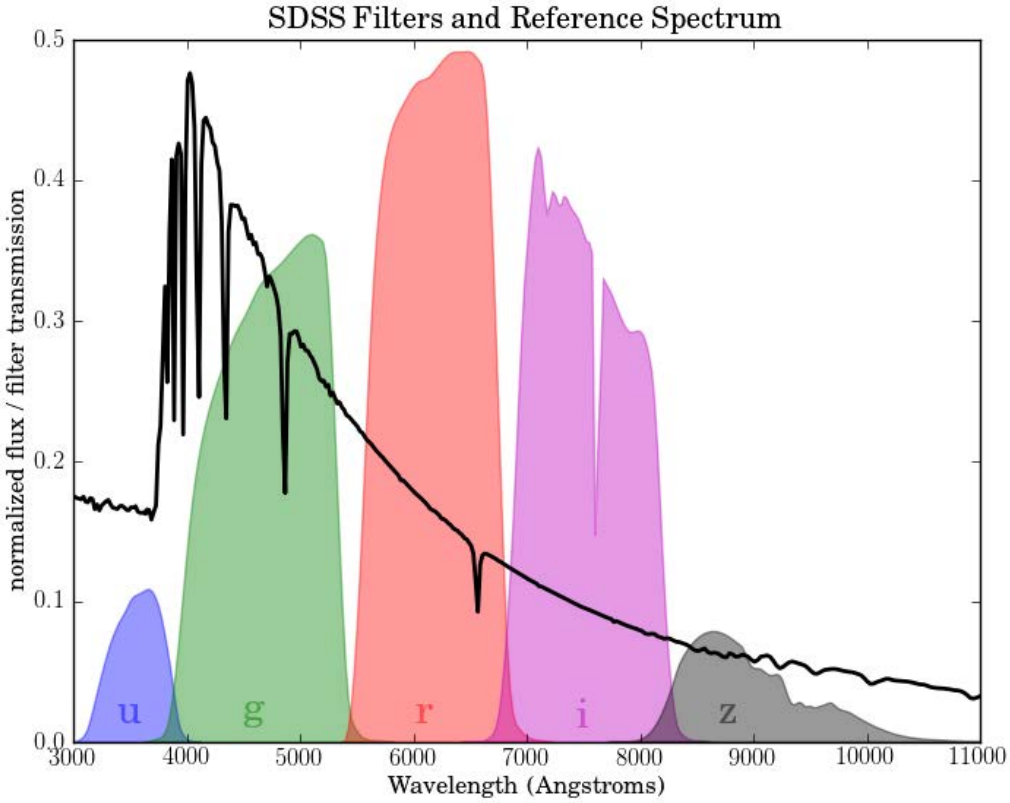
** A0 stars have a color of Zero **

$$m(vega) = -2.5 \log (f_\nu / f_0)$$

F_0 depends on the band

2MASS, Spitzer and WISE have Vega-system magnitudes, as do most other (historical) optical photometry publlications

SDSS

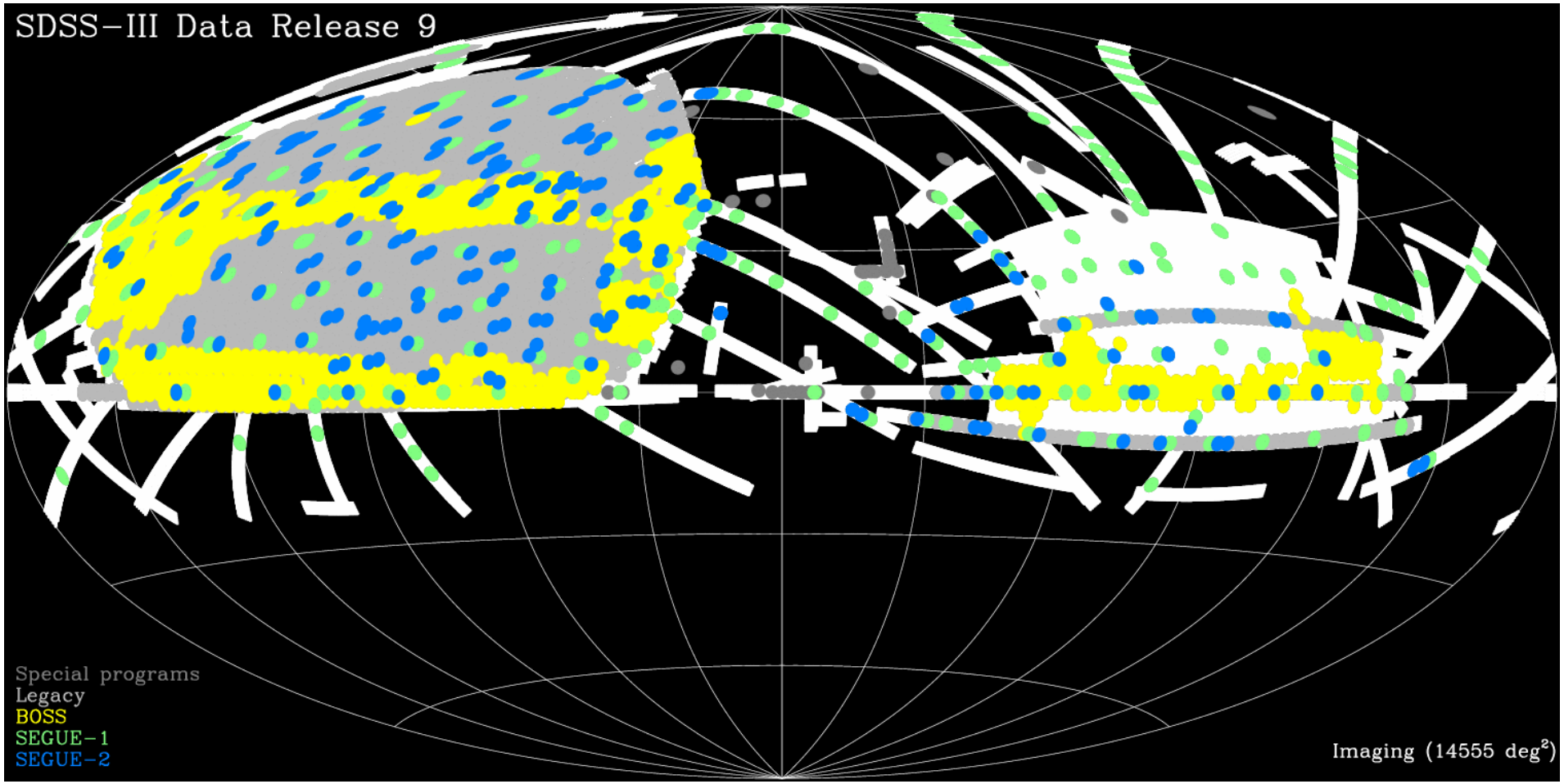


Flux limited to r ~ 17.8 mag

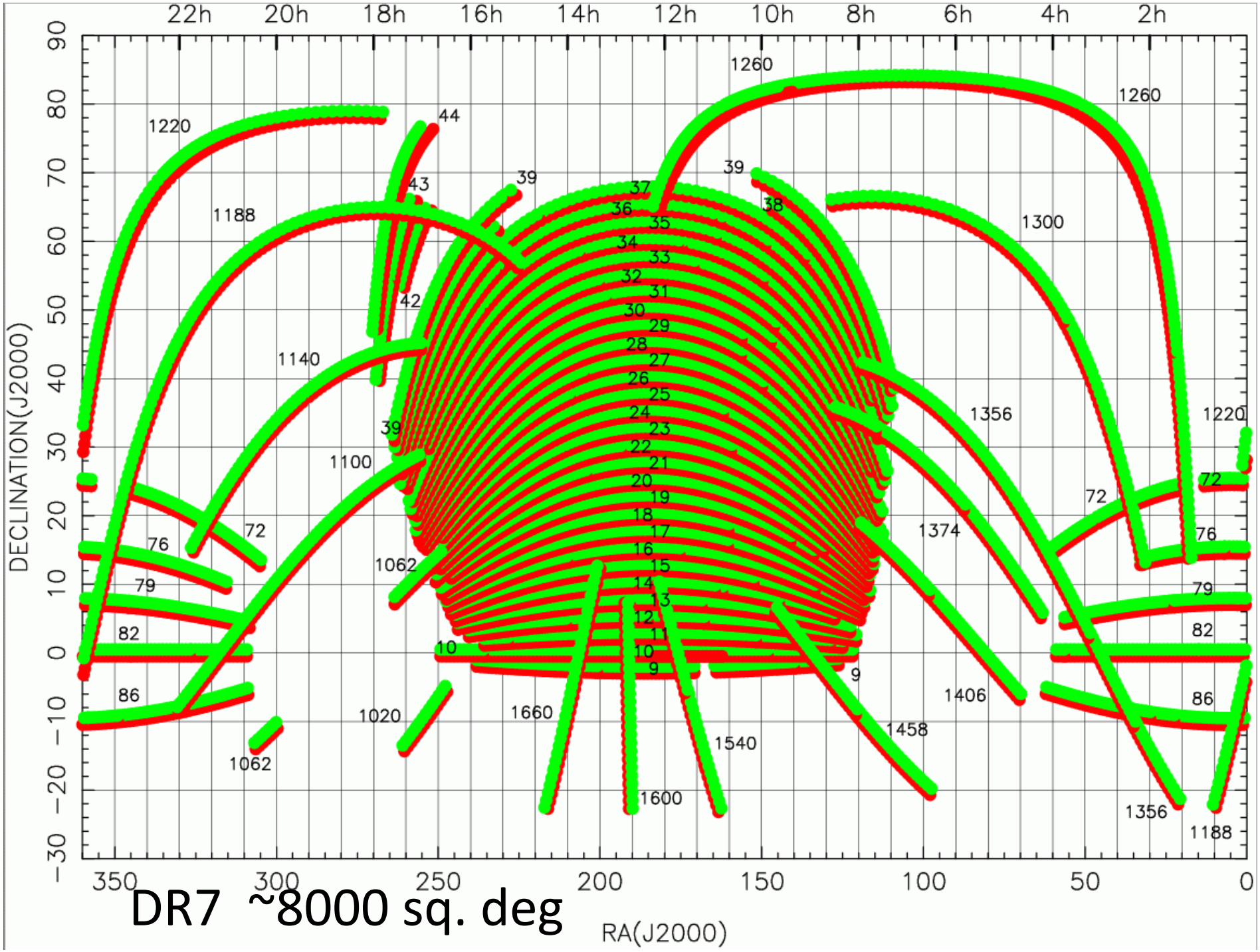
SDSS DR9

http://skyserver.sdss3.org/dr9/

SDSS

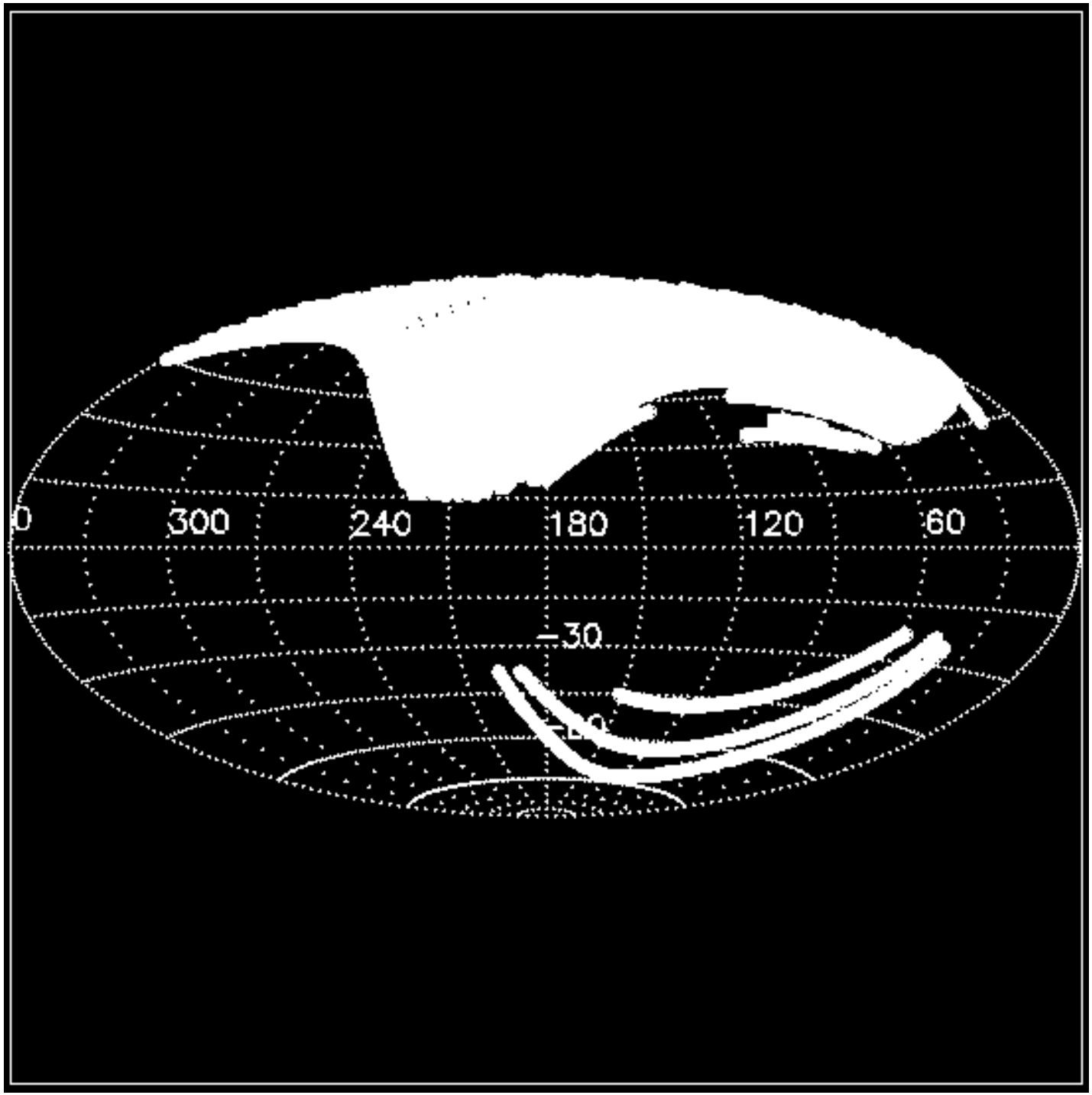


14,555 square degrees

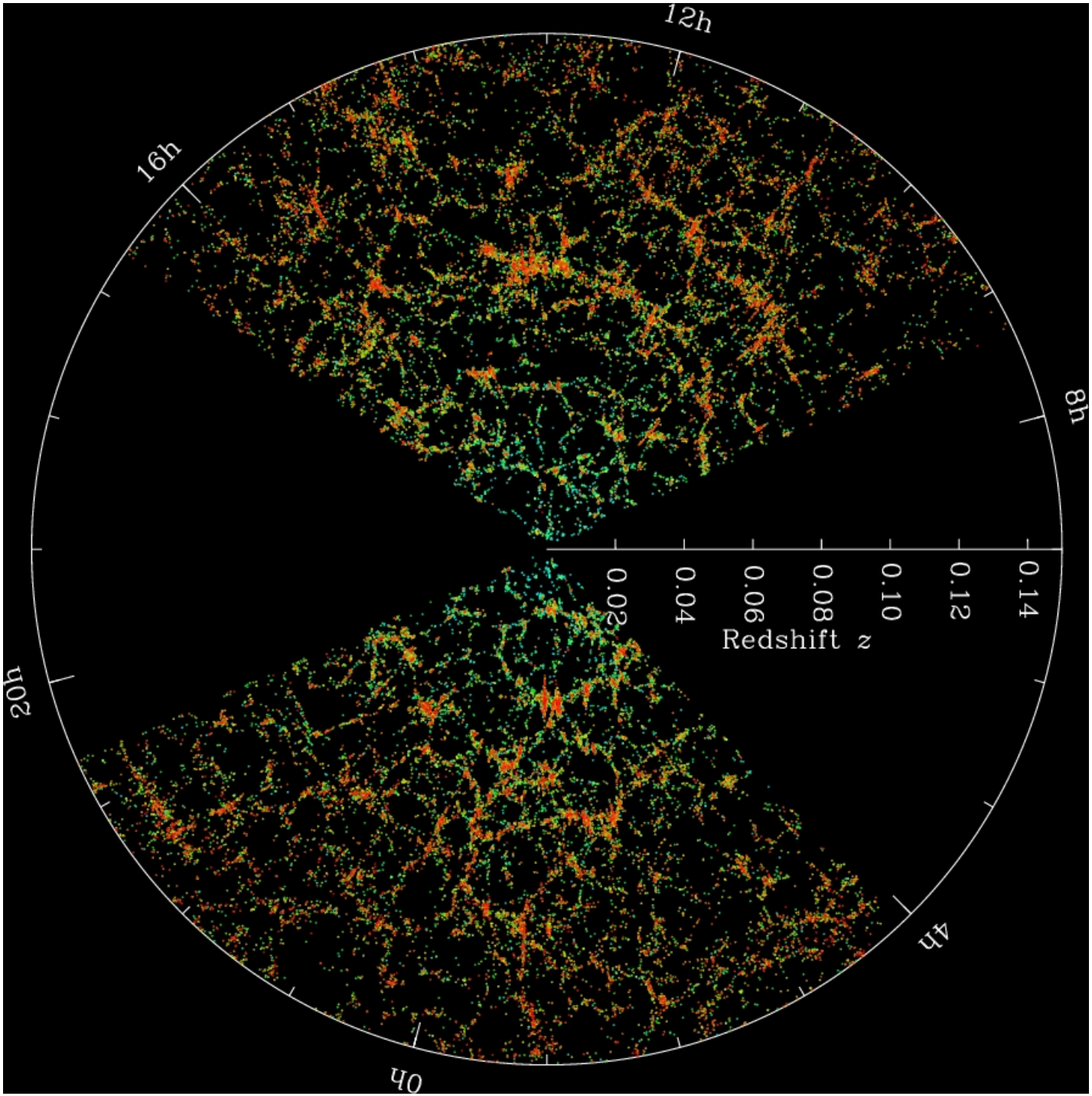


DR7 ~8000 sq. deg

DR7
galactic



DR7 hockey puck



SDSS

http://skyserver.sdss3.org/dr9/

http://skyserver.sdss3.org/dr9/en/tools/

SDSS

Schema Browser

Tables

name	description
AtlasOutline	Contains a record describing each AtlasOutline object
DataConstants	The table stores the values of various enumerated and bitmask columnns.
DBColumns	Every column of every table has a description in this table
DBObjects	Every SkyServer database object has a one line description in this table
DBViewCols	The columns of each view are stored for the auto-documentation
Dependency	Contains the detailed inventory of database objects
detectionIndex	Full list of all detections, with associated 'thing' assignment.
emissionLinesPort	Emission line kinematics results for BOSS galaxies using GANDALF
Field	All the measured parameters and calibrations of a photometric field
FieldProfile	The mean PSF profile for the field as determined from bright stars.

Schema Browser

- **PhotoObj**: all primary and secondary objects; essentially this is the view you should use unless you want a specific type of object.

psfMag_u	real	4	mag		PSF magnitude
psfMag_g	real	4	mag		PSF magnitude
psfMag_r	real	4	mag		PSF magnitude
psfMag_i	real	4	mag		PSF magnitude
psfMag_z	real	4	mag		PSF magnitude
psfMagErr_u	real	4	mag		PSF magnitude error
psfMagErr_g	real	4	mag		PSF magnitude error
psfMagErr_r	real	4	mag		PSF magnitude error
psfMagErr_i	real	4	mag		PSF magnitude error
psfMagErr_z	real	4	mag		PSF magnitude error

Schema Browser

TABLE SpecObjAll

Contains the measured parameters for a spectrum.

					Angstrom focal plan)
z	real	4			Final Redshift
zErr	real	4			Redshift error
zWarning	int	4			Bitmask of warning values; 0 means all is well
class	varchar	32			Spectroscopic class (GALAXY, QSO, or STAR)
subClass	varchar	32			Spectroscopic subclass
rChi2	real	4			Reduced chi-squared of best fit

Structured Query Language (SQL)

Search

You can search the SDSS database with a ***query***. A query is a request for information. You specify what data you want, and what conditions you want the data to satisfy. For example, you might ask the database to return the positions of all stars brighter than a certain magnitude in a certain filter.

To search the database, select one of the following tools

- **Radial**: Search the sky around a given point (**EASY**)
- **Rectangular**: Search the sky in a rectangular region (**EASY**)
- **SQL**: Type in a SQL query directly (**HARDEST**)

Search Tools for scientists

- **Imaging Query** : Form-based query on imaging data
- **Spectro Query** : Form-based query on spectroscopic data

SDSS SQL

NOTE: Please read the **query hints** below before you try any queries, especially if you are new to S
or the SkyServer.

Basic SQL:
Basic SELECT-FROM-WHERE
Basic position search
Using PhotoTag
Search for a Range of Values
Rectangular position search
More than one table: JOIN...ON
Photometry & spectroscopy
Counting by type or category
Using flags

SQL Jujitsu:
Data subsample
Objects in close pairs
Selected neighbors in run
Object counts and logic
Repeated high-z objects
Splitting 64-bit values
Using LEFT OUTER JOIN
Using Nested Queries

General Astronomy:
Only stars or galaxies
Clean photometry
Using Field MJD
Objects by spectral lines
Spectra by classification
Moving asteroids
Plates with repeat spectra
Galaxies blended with stars
Counts by type and program
Checking SDSS footprint

Stars:
Clean photometry - Stars
CVs using colors
Binary stars colors
Using sppLines table
Using sppParams table
Stars multiply measured
Proper motions

Galaxies:
Clean photometry - Galaxies
Galaxies with blue centers
Diameter limited sample
LRG sample selection
Galaxy counts on HTM grid
Classifications from Galaxy Zoo
BOSS target selection
BOSS Stellar Masses
BOSS Stellar Vel. Disps.

Miscellaneous:
QSOs by spectroscopy
QSOs by colors
FIRST matches for quasars
Photometric Redshifts
Spectra in Other Programs - I
Spectra in Other Programs - II

SDSS SQL

QSOs using colors Return to Top | Load Query | Run Query

```
-- Low-z QSO candidates using the color cuts from Gordon Richards.
-- Also a simple query with a long WHERE clause.

SELECT TOP 100
       g,
       run,
       rerun,
       camcol,
       field,
       objID
FROM Galaxy
WHERE ( (g <= 22)
       and (u - g >= -0.27)
       and (u - g < 0.71)
       and (g - r >= -0.24)
       and (g - r < 0.35)
       and (r - i >= -0.27)
       and (r - i < 0.57)
       and (i - z >= -0.35)
       and (i - z < 0.70) )
```

SDSS SQL

```
select
p.objID,p.ra,p.dec,p.psfMag_u, p.psfMagErr_u, p.psfMag_g, p.psfMagErr_g,
p.psfMag_r, p.psfMagErr_r,p.psfMag_i, p.psfMagErr_i ,
p.psfMag_z, p.psfMagErr_z, s.z as redshift, s.zErr
from
SpecObj s, PhotoObj p
where
p.ObjID=s.bestObjID and p.ra > 110. and p.ra < 115.
and p.dec > 20. and p.dec < 21. and s.z > 0.001
```

SDSS SQL

Your SQL command was:

```
select
SpecObjID,ra,dec, psfMag_u, psfMagErr_u, psfMag_g, psfMagErr_g,
psfMag_r, psfMagErr_r, psfMag_i, psfMagErr_i ,
psfMag_z, psfMagErr_z, z as redshift, zErr
from
SpecPhotoAll
where
ra > 110. and ra < 115.
and dec > 20. and dec < 21. and z > 0.001
```

SDSS SQL

SpecObjID	ra	dec	psfMag_u	psfMagErr_u	psfMag_g	psfMagErr_g	psfMag_r	psfMagErr_r	psfMag_i	psfMagErr_i	psfMag_z	psfMagErr_z	redshift	zErr
5044094073741702144	114.99803	20.936505	24.332054	0.74308	23.496904	0.291467	21.742285	0.081975	20.750193	0.048306	19.776255	0.077478	0.52843	2.214048E-4
5044098471788213248	114.85089	20.014359	23.890757	0.724105	23.583328	0.277011	21.823154	0.093212	20.628485	0.046307	20.298388	0.129022	0.574065	2.567671E-4
5044098746666120192	114.83078	20.186541	23.043238	0.422868	22.162731	0.096105	20.468784	0.03328	19.740719	0.029777	19.221035	0.063338	0.445227	7.320023E-5
5044099571299841024	114.86929	20.289205	24.121391	0.758139	22.550819	0.120731	21.218075	0.059011	20.347929	0.040834	19.982975	0.118068	0.509633	1.38407E-4
5044100121055654912	114.76663	20.005156	25.60051	0.63475	22.841244	0.165013	21.227135	0.052069	20.104929	0.032977	19.545832	0.081696	0.551272	1.099625E-4
5044100945689375744	114.79116	20.62758	23.78994	0.598725	21.985117	0.082877	21.320583	0.058167	20.58182	0.048823	20.714485	0.150459	1.529398	1.588623E-3
5044101770323096576	114.77984	20.51925	24.470268	0.775921	23.887304	0.39001	21.93117	0.098127	20.773411	0.050033	20.1675	0.098605	0.671958	1.992439E-4
5044102869834724352	114.87092	20.328083	23.142315	0.460188	22.594437	0.162566	20.945623	0.242555	20.160448	0.080798	19.602818	0.119827	0.448096	1.396089E-4
5044103419590538240	114.96565	20.881154	24.456522	0.7539	22.659986	0.144141	20.921589	0.041461	20.100491	0.02892	19.521383	0.061672	0.482514	1.019289E-4
5044103969346352128	114.89492	20.992202	24.929514	0.774246	23.486383	0.324161	21.850681	0.095658	20.870407	0.068797	20.21439	0.141279	0.565527	1.260042E-4
5044104244224259072	114.96157	20.80842	22.125528	0.167997	20.208614	0.023276	19.085337	0.017798	18.614647	0.015299	18.127436	0.027216	0.190653	2.898437E-5
5044104519102166016	114.95236	20.934098	24.73387	0.916342	23.482483	0.284798	21.790457	0.127836	20.63764	0.06207	20.242289	0.158925	0.566564	1.645693E-4
5044105068857979904	114.99394	20.908387	24.124647	0.696501	22.692434	0.148403	21.95858	0.097486	20.791246	0.050048	20.125483	0.103319	0.566611	1.612547E-4
5044105343735886848	114.82615	20.770699	23.177296	0.399578	22.780279	0.179459	21.365143	0.070513	20.427608	0.043445	19.867693	0.076051	0.543099	9.893598E-5
5044105893491700736	114.92101	20.838342	0	0	0	0	0	0	0	0	0	0	6.766904	2.277492E-3
5044109192026584064	114.74706	20.000996	21.41081	0.105861	20.94047	0.034592	20.916048	0.040531	20.736971	0.055958	20.848244	0.258274	1.746354	9.525449E-4
5044109466904491008	114.66351	20.069122	26.061026	0.44841	23.184198	0.222643	21.77298	0.082075	20.819708	0.060087	20.005413	0.121327	0.553272	1.978014E-4
5044109741782397952	114.66006	20.347508	21.769739	0.124258	19.725391	0.019443	19.443941	0.018115	19.374708	0.020785	19.381771	0.057312	3.121602	2.881343E-4
5044110016660304896	114.67821	20.109552	23.257393	0.489129	22.853376	0.172252	21.726061	0.09682	20.532452	0.055191	20.086067	0.136833	0.550037	1.546167E-4

CSV file

```
specObjID,ra,dec,psfMag_u,psfMagErr_u,psfMag_g,psfMagErr_g,psfMag_r,psfMagErr_r,psfMag_i,psfMagErr_i,psfMag_z,psfMagErr_z,redshift,zErr
5044094073741702144,114.99803,20.936505,24.332054,0.74308,23.496904,0.291467,21.742285,0.081975,20.750193,0.048306,19.776255,0.077478,0.52843,2.214048E-4
5044098471788213248,114.85089,20.014359,23.890757,0.724105,23.583328,0.277011,21.823154,0.093212,20.628485,0.046307,20.298388,0.129022,0.574065,2.567671E-4
5044098746666120192,114.83078,20.186541,23.043238,0.422868,22.162731,0.096105,20.468784,0.03328,19.740719,0.029777,19.221035,0.063338,0.445227,7.320023E-5
5044099571299841024,114.86929,20.289205,24.121391,0.758139,22.550819,0.120731,21.218075,0.059011,20.347929,0.040834,19.982975,0.118068,0.509633,1.38407E-4
5044100121055654912,114.76663,20.005156,25.60051,0.63475,22.841244,0.165013,21.227135,0.052069,20.104929,0.032977,19.545832,0.081696,0.551272,1.099625E-4
5044100945689375744,114.79116,20.62758,23.78994,0.598725,21.985117,0.082877,21.320583,0.058167,20.58182,0.048823,20.714485,0.150459,1.529398,1.588623E-3
5044101770323096576,114.77984,20.51925,24.470268,0.775921,23.887304,0.39001,21.93117,0.098127,20.773411,0.050033,20.1675,0.098605,0.671958,1.992439E-4
5044102869834724352,114.87092,20.328083,23.142315,0.460188,22.594437,0.162566,20.945623,0.242555,20.160448,0.080798,19.602818,0.119827,0.448096,1.396089E-4
5044103419590538240,114.96565,20.881154,24.456522,0.7539,22.659986,0.144141,20.921589,0.041461,20.100491,0.02892,19.521383,0.061672,0.482514,1.019289E-4
5044103969346352128,114.89492,20.992202,24.929514,0.774246,23.486383,0.324161,21.850681,0.095658,20.870407,0.068797,20.21439,0.141279,0.565527,1.260042E-4
5044104244224259072,114.96157,20.80842,22.125528,0.167997,20.208614,0.023276,19.085337,0.017798,18.614647,0.015299,18.127436,0.027216,0.190653,2.898437E-5
5044104519102166016,114.95236,20.934098,24.73387,0.916342,23.482483,0.284798,21.790457,0.127836,20.63764,0.06207,20.242289,0.158925,0.566564,1.645693E-4
5044105068857979904,114.99394,20.908387,24.124647,0.696501,22.692434,0.148403,21.95858,0.097486,20.791246,0.050048,20.125483,0.103319,0.566611,1.612547E-4
5044105343735886848,114.82615,20.770699,23.177296,0.399578,22.780279,0.179459,21.365143,0.070513,20.427608,0.043445,19.867693,0.076051,0.543099,9.893598E-5
5044105893491700736,114.92101,20.838342,0,0,0,0,0,0,0,0,0,0,6.766904,2.277492E-3
5044109192026584064,114.74706,20.000996,21.41081,0.105861,20.94047,0.034592,20.916048,0.040531,20.736971,0.055958,20.848244,0.258274,1.746354,9.525449E-4
5044109466904491008,114.66351,20.069122,26.061026,0.44841,23.184198,0.222643,21.77298,0.082075,20.819708,0.060087,20.005413,0.121327,0.553272,1.978014E-4
5044109741782397952,114.66006,20.347508,21.769739,0.124258,19.725391,0.019443,19.443941,0.018115,19.374708,0.020785,19.381771,0.057312,3.121602,2.881343E-4
5044110016660304896,114.67821,20.109552,23.257393,0.489129,22.853376,0.172252,21.726061,0.09682,20.532452,0.055191,20.086067,0.136833,0.550037,1.546167E-4
5044110841294025728,114.73201,20.1571,21.313406,0.099217,20.782177,0.031168,20.698639,0.035856,20.448721,0.060735,20.214041,0.147018,1.810802,2.163571E-3
5044111391049839616,114.69428,20.0199,0,0,0,0,0,0,0,0,0,0,2.747896,2.925828E-5
5044111940805653504,114.66838,20.222571,22.913235,0.393851,21.204927,0.039986,19.532249,0.017368,18.952444,0.016047,18.581778,0.034623,0.334502,5.104565E-5
5044112490561467392,114.70289,20.532422,0,0,0,0,0,0,0,0,0,0,0.20978,1.364594E-4
```

Write a python program to read the csv table, extract (parse) the information. Write a new table that has a set format, space – delimited table. The HEADER should follow an IPAC Table format.

IPAC Table

SpecObjID	ra	dec	u	uerr	g	gerr	r	rerr	i	ierr	zed	zederr	specz	zErr
char	d	d	d	d	d	d	d	d	d	d	d	d	d	d
5044094073741702144	114.998032	20.936504	24.332	0.743	23.497	0.291	21.742	0.082	20.750	0.048	19.776	0.077	0.52843E+00	0.22140E-03
5044098471788213248	114.850891	20.014359	23.891	0.724	23.583	0.277	21.823	0.093	20.628	0.046	20.298	0.129	0.57407E+00	0.25677E-03
5044098746666120192	114.830780	20.186541	23.043	0.423	22.163	0.096	20.469	0.033	19.741	0.030	19.221	0.063	0.44523E+00	0.73200E-04
5044099571299841024	114.869293	20.289206	24.121	0.758	22.551	0.121	21.218	0.059	20.348	0.041	19.983	0.118	0.50963E+00	0.13841E-03
5044100121055654912	114.766632	20.005156	25.601	0.635	22.841	0.165	21.227	0.052	20.105	0.033	19.546	0.082	0.55127E+00	0.10996E-03
5044100945689375744	114.791161	20.627581	23.790	0.599	21.985	0.083	21.321	0.058	20.582	0.049	20.714	0.150	0.15294E+01	0.15886E-02
5044101770323096576	114.779839	20.519251	24.470	0.776	23.887	0.390	21.931	0.098	20.773	0.050	20.167	0.099	0.67196E+00	0.19924E-03
5044102869834724352	114.870918	20.328083	23.142	0.460	22.594	0.163	20.946	0.243	20.160	0.081	19.603	0.120	0.44810E+00	0.13961E-03
5044103419590538240	114.965652	20.881153	24.457	0.754	22.660	0.144	20.922	0.041	20.100	0.029	19.521	0.062	0.48251E+00	0.10193E-03
5044103969346352128	114.894920	20.992203	24.930	0.774	23.486	0.324	21.851	0.096	20.870	0.069	20.214	0.141	0.56553E+00	0.12600E-03
5044104244224259072	114.961571	20.808420	22.126	0.168	20.209	0.023	19.085	0.018	18.615	0.015	18.127	0.027	0.19065E+00	0.28984E-04
5044104519102166016	114.952362	20.934097	24.734	0.916	23.482	0.285	21.790	0.128	20.638	0.062	20.242	0.159	0.56656E+00	0.16457E-03
5044105068857979904	114.993942	20.908386	24.125	0.697	22.692	0.148	21.959	0.097	20.791	0.050	20.125	0.103	0.56661E+00	0.16125E-03
5044105343735886848	114.826149	20.770699	23.177	0.400	22.780	0.179	21.365	0.071	20.428	0.043	19.868	0.076	0.54310E+00	0.98936E-04
5044105893491700736	114.921013	20.838343	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.67669E+01	0.22775E-02
5044109192026584064	114.747063	20.000996	21.411	0.106	20.940	0.035	20.916	0.041	20.737	0.056	20.848	0.258	0.17464E+01	0.95254E-03
5044109466904491008	114.663513	20.069122	26.061	0.448	23.184	0.223	21.773	0.082	20.820	0.060	20.005	0.121	0.55327E+00	0.19780E-03
5044109741782397952	114.660057	20.347507	21.770	0.124	19.725	0.019	19.444	0.018	19.375	0.021	19.382	0.057	0.31216E+01	0.28813E-03
5044110016660304896	114.678207	20.109552	23.257	0.489	22.853	0.172	21.726	0.097	20.532	0.055	20.086	0.137	0.55004E+00	0.15462E-03
5044110841294025728	114.732010	20.157101	21.313	0.099	20.782	0.031	20.699	0.036	20.449	0.061	20.214	0.147	0.18108E+01	0.21636E-02
5044111391049839616	114.694283	20.019899	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.27479E+01	0.29258E-04
5044111940805653504	114.668381	20.222570	22.913	0.394	21.205	0.040	19.532	0.017	18.952	0.016	18.582	0.035	0.33450E+00	0.51046E-04
5044112490561467392	114.702888	20.532421	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.20978E+00	0.13646E-03
5044112765439374336	114.691231	20.341961	25.041	0.815	22.860	0.135	20.960	0.059	20.292	0.040	19.817	0.103	0.50390E+00	0.55962E-04
5044113040317281280	114.661957	20.612154	22.938	0.322	21.045	0.038	20.938	0.052	20.704	0.051	20.428	0.117	0.14426E+00	0.10795E-04
5044113315195188224	114.700417	20.603626	23.163	0.386	21.907	0.075	21.180	0.051	20.350	0.035	19.934	0.078	0.67357E+00	0.10144E-03
5044113864951002112	114.631577	20.483753	20.700	0.056	19.977	0.021	20.038	0.023	19.878	0.028	19.890	0.085	0.23623E+01	0.59200E-03
5044114689584722944	114.606590	20.873718	24.683	0.780	22.938	0.161	21.829	0.097	20.846	0.069	20.297	0.153	0.47183E+00	0.13928E-03
5044114964462629888	114.785004	20.971880	25.132	0.711	23.037	0.176	21.100	0.051	20.280	0.041	19.737	0.093	0.45592E+00	0.15719E-03

WISE-SDSS x-Match

```
\fixlen = T
\primary    = 0
\RowsRetrieved =               109
\QueryTime     =  00:00:00.07761
\ORIGIN  = 'IPAC Infrared Science Archive (IRSA), Caltech/JPL'
\DATETIME= '2013-02-13 12:40:26'
\DATABASE= 'WISE All-Sky Source Catalog (wise_allsky_4band_p3as_psd)'
\EQUINOX = 'J2000'
\NOTE    = 'Column names with suffix _01 are from the input file Umy_table.tbl.'
\NOTE    = 'Column cntr_01 is a sequential counter added to ID each row in the user input file Umy_table.tbl.'
\NOTE    = 'dist_x is the distance in arcsec between each input source and its potential match in the WISE All-Sky Source Catalog.'
\NOTE    = 'pang_x is position angle, measured eastward from north, between the input source and potential match in the WISE All-Sky Source Catalog.
\NOTE    = 'Output rows are ordered by increasing cntr_01, and for each cntr_01 by increasing dist_x.'
\StatusFile = '/workspace/TMP_K5tln9_16375/Gator/irsa/1995/log.1995.html'
\SQL     = 'WHERE  A.cntr_01 = X.cntr1_x and B.cntr=X.cntr2_x '
\SQL     = 'SELECT (81 column names follow in next row.)'
\Upload   = 'file=Umy_table.tbl radius=3 unit=arcsec'
\
\
|             cntr_01|             dist_x|             pang_x|        specobjid_01|              ra_01|             dec_01|               u_01|            uerr_01|
|                long|             double|             double|                char|              double|              double|              double|              double|
|                    |                   |                   |                    |                    |                    |                    |                    |
|                null|               null|               null|                null|                null|                null|                null|                null|
                   1           0.455027           43.818293   5044094073741702144          114.998032          20.936504          24.332000          0.743000
                   2           0.458621           11.357334   5044098471788213248          114.850891          20.014359          23.891000          0.724000
                   3           0.687746          -37.284033   5044098746666120192          114.830780          20.186541          23.043000          0.423000
                   4           0.163778          116.782775   5044099571299841024          114.869293          20.289206          24.121000          0.758000
                   5           0.173212           44.359939   5044100121055654912          114.766632          20.005156          25.601000          0.635000
                   6           0.397785          105.807607   5044100945689375744          114.791161          20.627581          23.790000          0.599000
                   7           0.249365         -174.958067   5044101770323096576          114.779839          20.519251          24.470000          0.776000
                   8           0.457049           58.306780   5044102869834724352          114.870918          20.328083          23.142000          0.460000
                   9           0.380359           20.444685   5044103419590538240          114.965652          20.881153          24.457000          0.754000
                  11           0.468996           -5.393547   5044104244224259072          114.961571          20.808420          22.126000          0.168000
                  12           0.228081           58.926859   5044104519102166016          114.952362          20.934097          24.734000          0.916000
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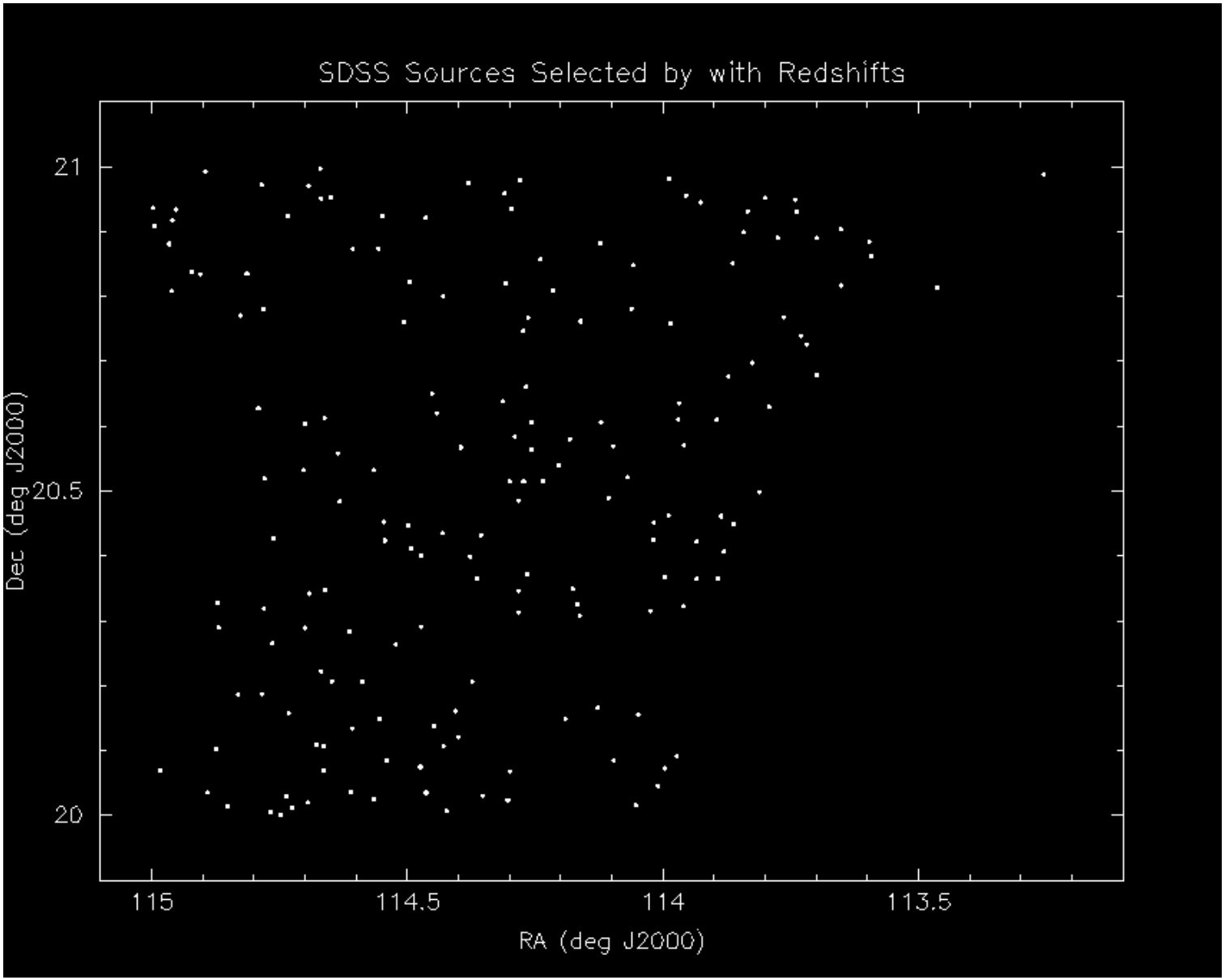
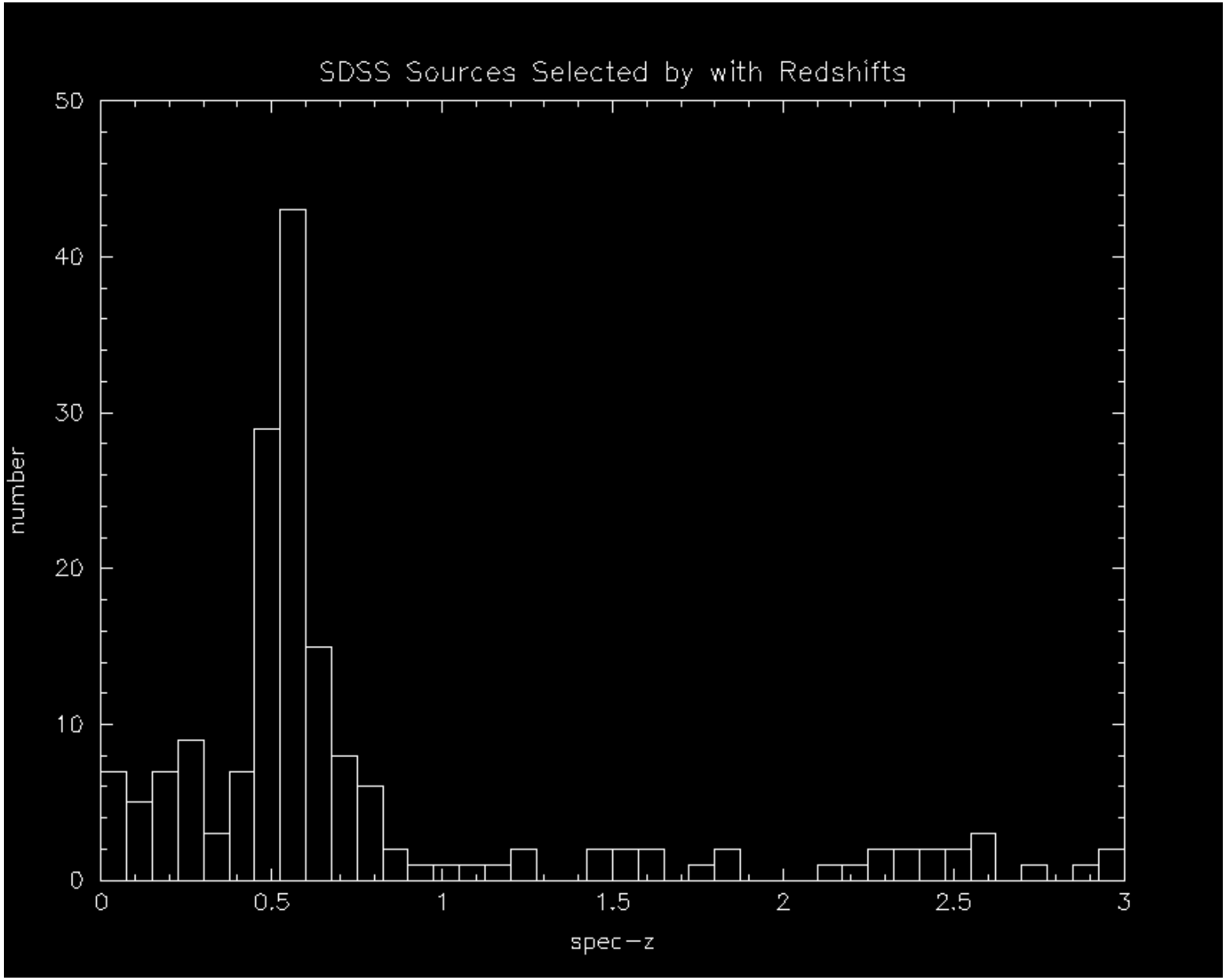
Area Distribution

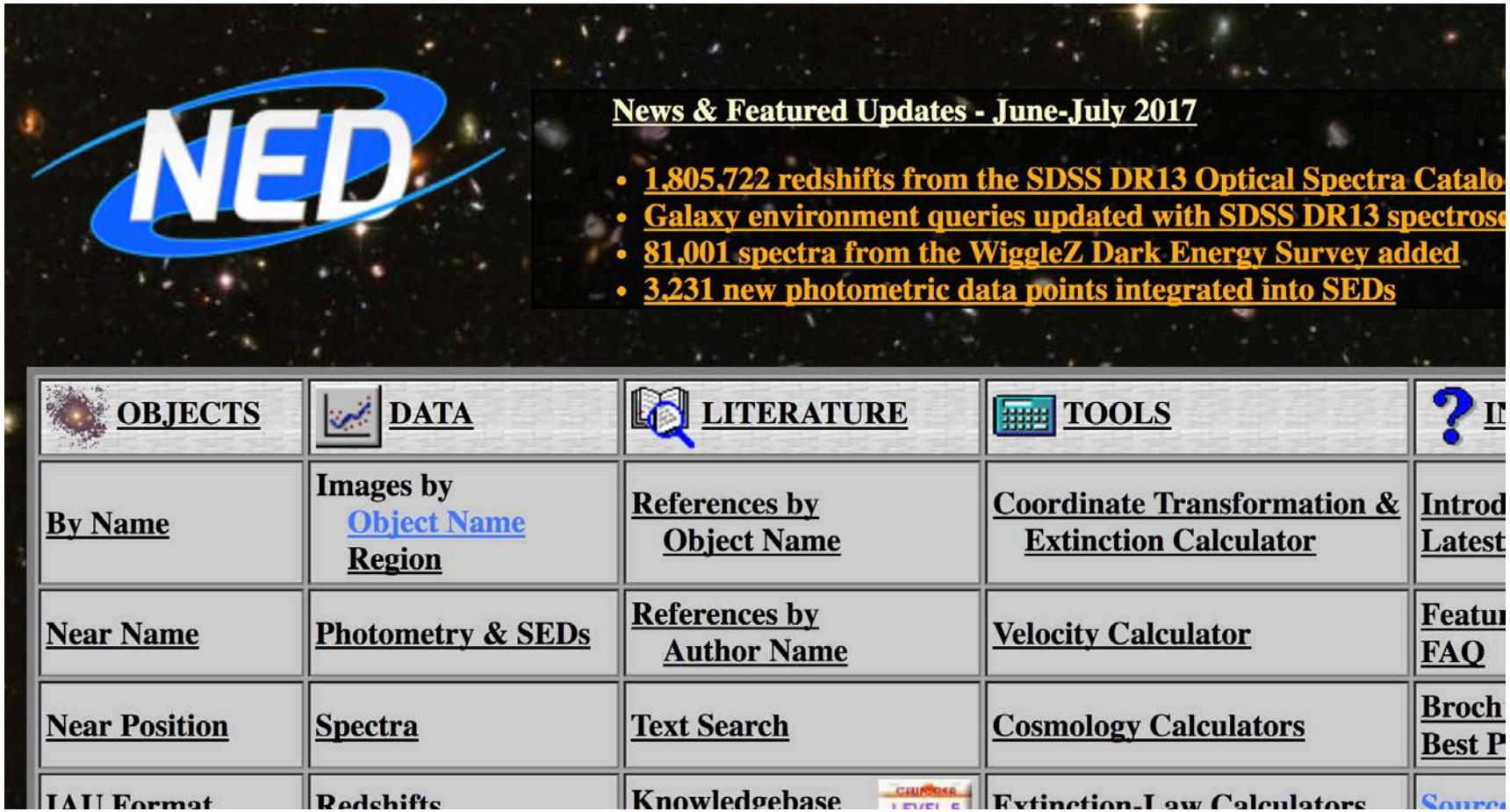


SDSS Redshift Distribution



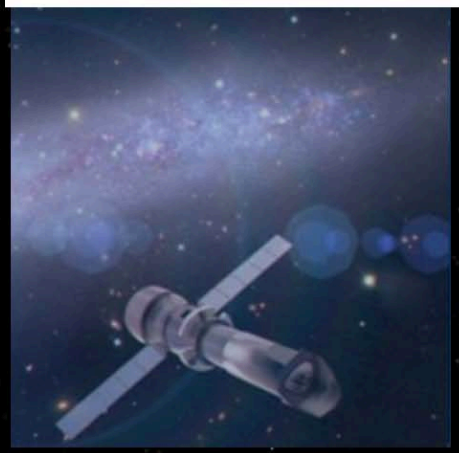
NED

- Meta and parametric information
- Carefully compiled data ("by hand")
- Non-flat tables, and diverse tools and info



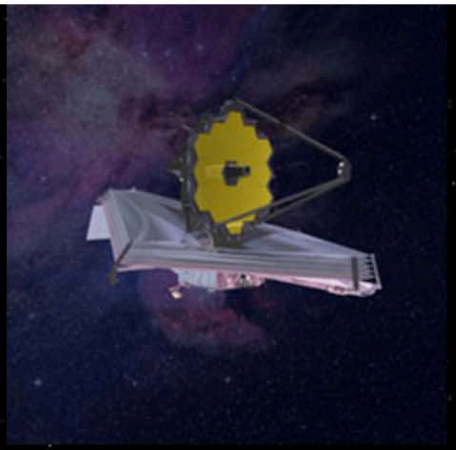
http://ned.ipac.caltech.edu/

Future Astrophysics Missions

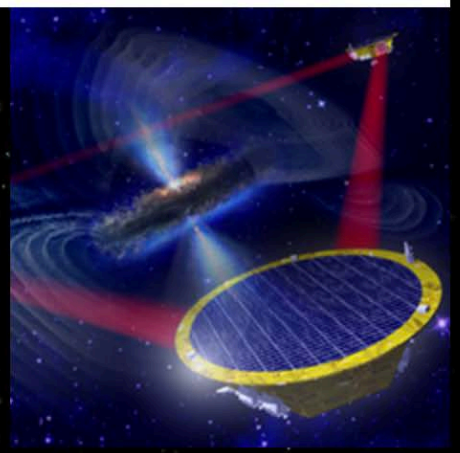


ATHENA
Future

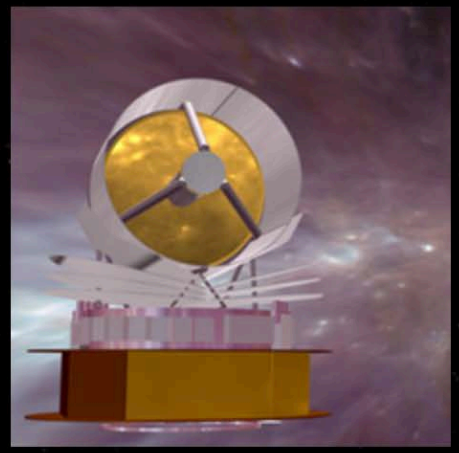
EUCLID
Future



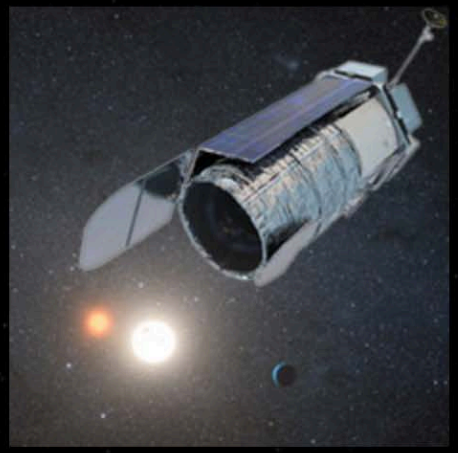
JWST
Future



LISA
Future

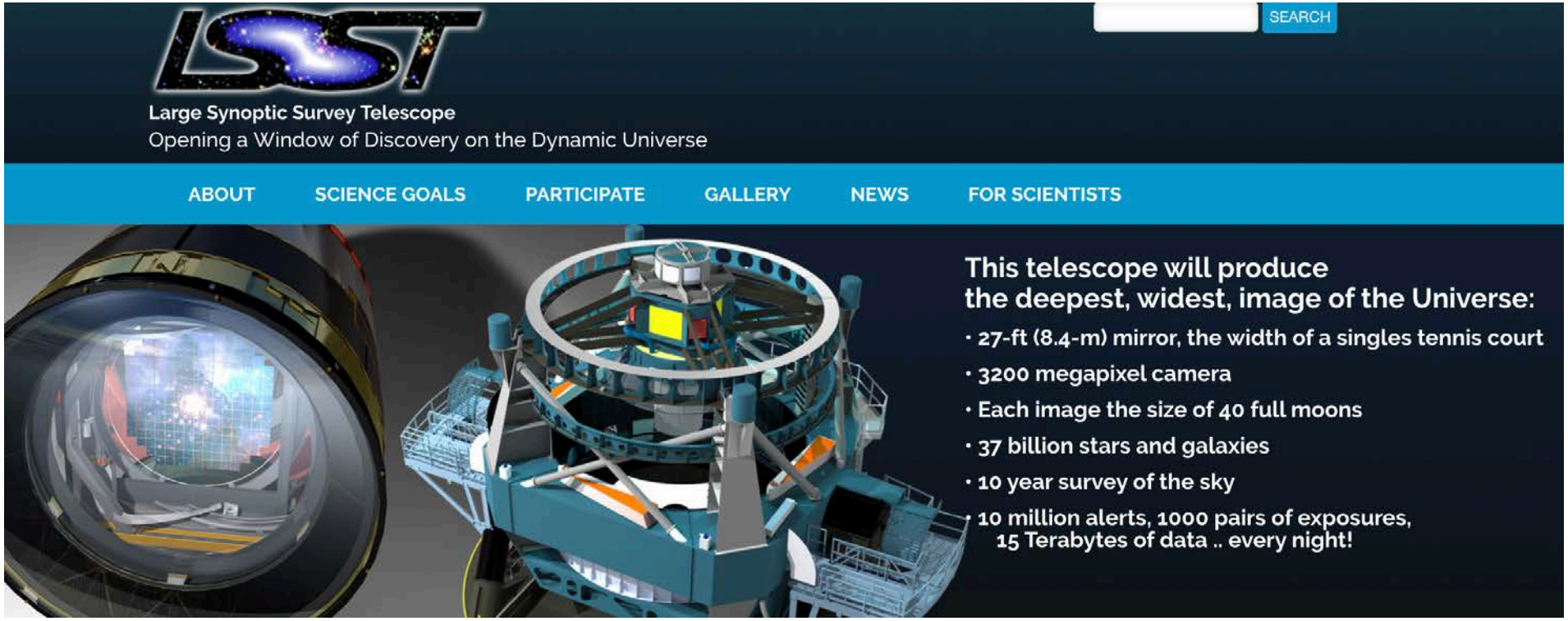


SPICA
Future



WFIRST
Future

LSST


SEARCH
Large Synoptic Survey Telescope
Opening a Window of Discovery on the Dynamic Universe
ABOUT
SCIENCE GOALS
PARTICIPATE
GALLERY
NEWS
FOR SCIENTISTS
This telescope will produce
the deepest, widest, image of the Universe:
· 27-ft (8.4-m) mirror, the width of a singles tennis court
· 3200 megapixel camera
· Each image the size of 40 full moons
· 37 billion stars and galaxies
· 10 year survey of the sky
· 10 million alerts, 1000 pairs of exposures,
15 Terabytes of data .. every night!

In a ten-year survey, the LSST will take more than five million exposures, collecting over 32 petabytes of raw image data to produce a deep, time-dependent, multi-color movie of 30,000 square degrees of sky. The sequence, or cadence, with which these exposures are made is essential to achieving multiple scientific goals from a single survey, an important feature of the LSST concept.

Data Releases:

Number of Data Releases = 11

Date of DR1 release = Date of Operations Start+ 12 months

Estimated numbers for DR-1 release

Objects = 18 billion

Sources = 350 billion (single epoch)

Forced Sources = 0.75 trillion

Estimated numbers for DR-11

Objects = 37 billion

Sources = 7 trillion (single epoch)

Forced Sources = 30 trillion

Visits observed = 2.75 million

Images collected = 5.5 million

Survey Area:

Fiducial main survey area = 18,000 deg2

Total covered area (est.) = 25,000 deg^2 (main survey + special programs)

Fiducial number of visits per pointing in the main survey = 825

Data and compute sizes:

Final image collection (DR11) = 0.5 Exabytes

Final database size (DR11) = 15 PB

Final disk storage = 0.4 Exabytes

Peak number of nodes = 1750 nodes

Peak compute power in LSST data centers = 1.8 PFLOPS

http://dm.lsst.org/

Entire website dedicated to data management !

Science Pipelines

The LSST Science Pipelines will implement the core image processing and data analysis algorithms needed to process optical survey imaging data at low latency and unprecedented scale and accuracy. We are writing pipelines for single-epoch image processing, coaddition, image differencing, optimal multi-epoch measurements, and (global) photometric and astrometric calibration, among others.

Scalable Database

To satisfy the need to efficiently store, query, and analyze catalogs running into trillions of rows and petabytes of data, we are developing Qserv, a distributed shared-nothing SQL database query system.

User Interface

One of the most important jobs of a large survey is to provide access. This includes access to catalogs, processed images, and raw images. Access in the next generation of surveys will extend to visualization and analysis. We are writing interfaces that will allow thousands of users to query, download, visualize, and analyze petabytes of LSST data.

Data Access Middleware

In order to build a scalable, portable processing system, we are creating extensible middleware to transparently access data irrespective of storage location or format.

Distributed Execution

The LSST data processing pipelines will need to efficiently scale from single core execution to tens of thousands of cores. To meet this requirement we are building an orchestration framework to launch and monitor jobs on many different systems at many different scales.