E-Science and research in astronomy, astrophysics and cosmology

Utane Sawangwit

Outline

- Overview of the use of e-science in astronomy, astrophysics and cosmology
- Cosmology and structure evolutions and even larger facilities/surveys
- Review of NARIT facilities and need for e-science & Research and Education network

Astronomy Now

We are living during an age of very fast changes in the way to do Astronomy. Astronomy is one of the prime sciences of the human being

Astronomy goals through the centuries:

- Registering and recording of heaven events
- Developing of methodologies to keep and track such events
- SHARING the information and the knowledge
- Astronomy is one of the most internationally organized science endeavors (and of course, experimental particle physics)

Astronomy Now

- The technology (computers, communications, etc.) is changing the way to access to the information.
- Observational facilities based in astronomical satellites, "automated survey telescopes" and 48 meters class telescopes are available everywhere.
- Amazing facilities are planned in the coming decade
- The information gathered by these facilities (and their derived products) is organized in huge databases…
- and also, the services of such databases is being connected through computer grids **"Virtual Observatory"** is here now
- The observations are "there" in fact, we "don't need" telescopes to do high-quality observational astronomy

Astronomy Now

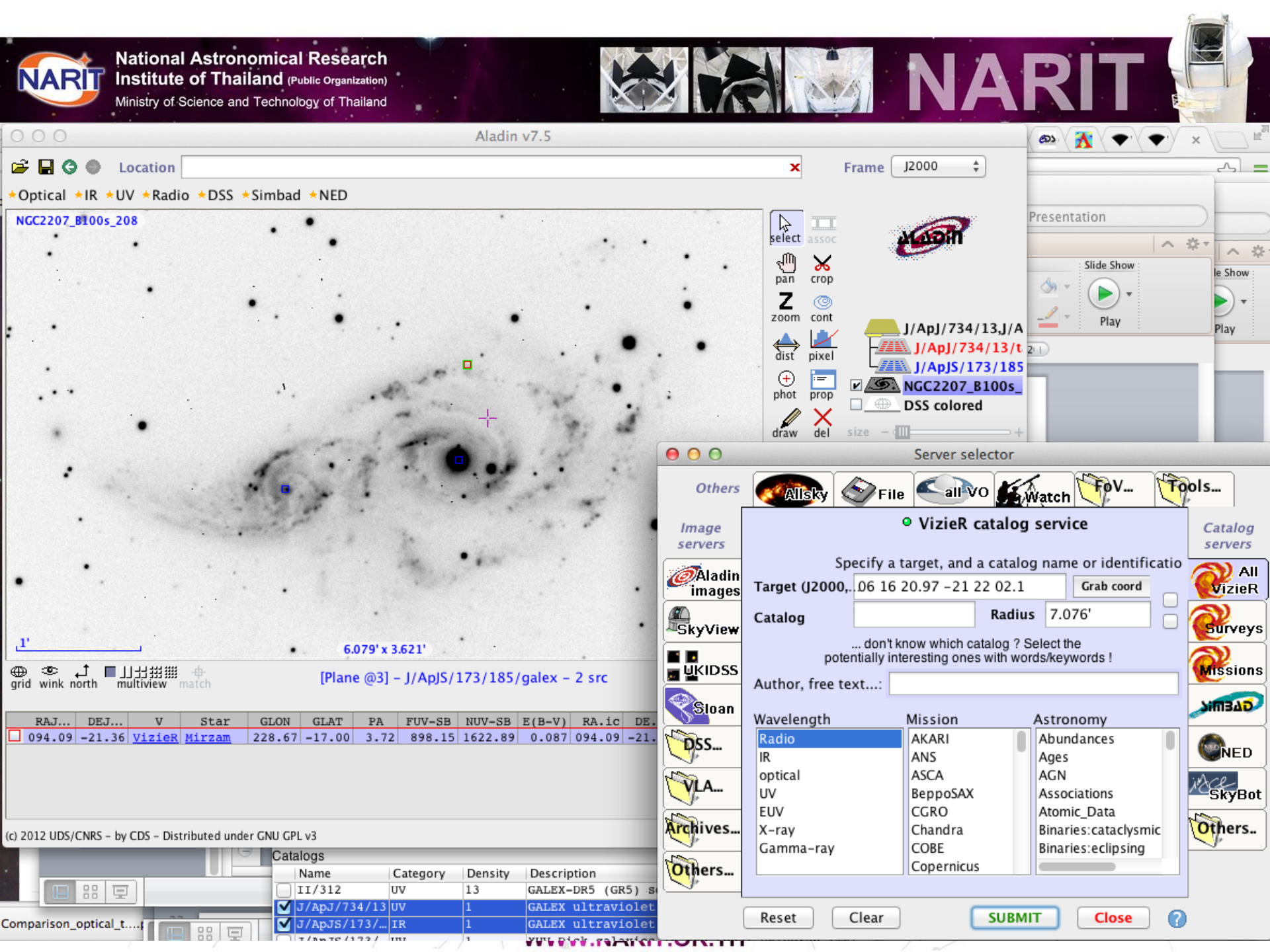
For our countries with scarce resources:

- Opportunity to access to high-quality material.
- We can do good "**observational astrophysics**" to relatively very low costs: free scientific software based on LINUX are available through Internet.
- Training young astronomer in the use of these observations as an "experimental observatory" to apply for observing time in international observatories (ground and space).
- Participating in the development of astronomical databases and grids and more...

International Virtual Observatory Alliance

Member Organizations

- Argentine Virtual Observatory
- Armenian Virtual Observatory
- AstroGrid, United Kingdom
- Australian Virtual Observatory
- Brazilian Virtual Observatory
- Chinese Virtual Observatory
- Canadian Virtual Observatory
- Chilean Virtual Observatory
- European Space Agency
- European Virtual Observatory
- German Astrophysical Virtual Observatory
- Hungarian Virtual Observatory
- Japanese Virtual Observatory
- Observatoire Virtuel France
- Russian Virtual Observatory
- South African Astroinformatics Alliance
- Spanish Virtual Observatory
- Italian Virtual Observatory
- Ukrainian Virtual Observatory
- Virtual Astronomical Observatory, USA
- Virtual Observatory India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Ministry of Science and Technology of Thailand
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Catalogs
Name Category Density Description
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J/ApJ/734/13 UV 1 GALEX ultraviolet
J/ApJS/173/... IR 1 GALEX ultraviolet
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Server selector
Others
Allsky
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Tools...
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Aladin images
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BeppoSAX
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Copernicus
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Atomic_Data
Binaries:cataclysmic
Binaries:eclipsing
Catalog servers
All VizieR
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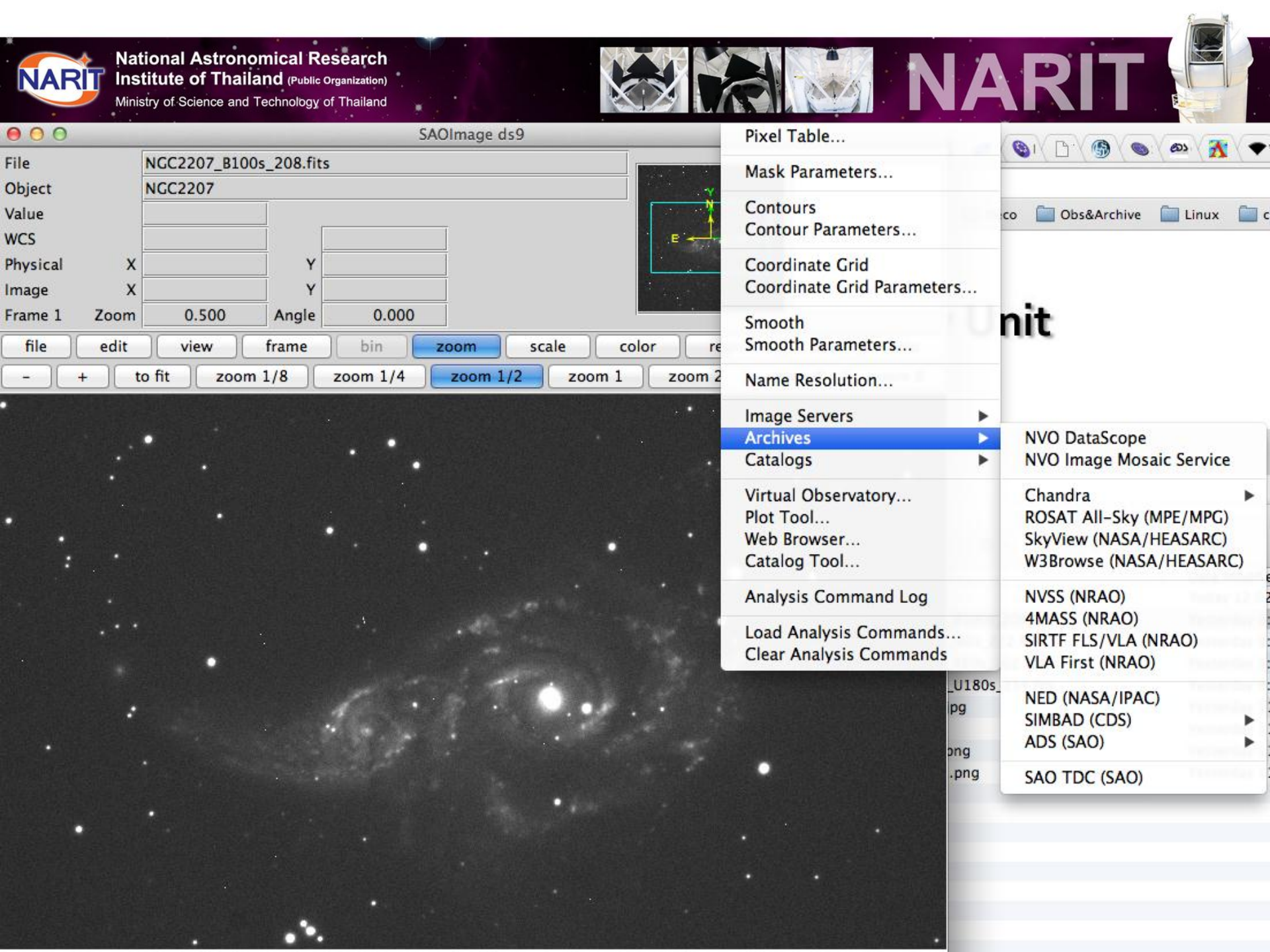
Slide Show
Play
www.narit.or.th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Institute of Thailand (Public Organization)
Ministry of Science and Technology of Thailand
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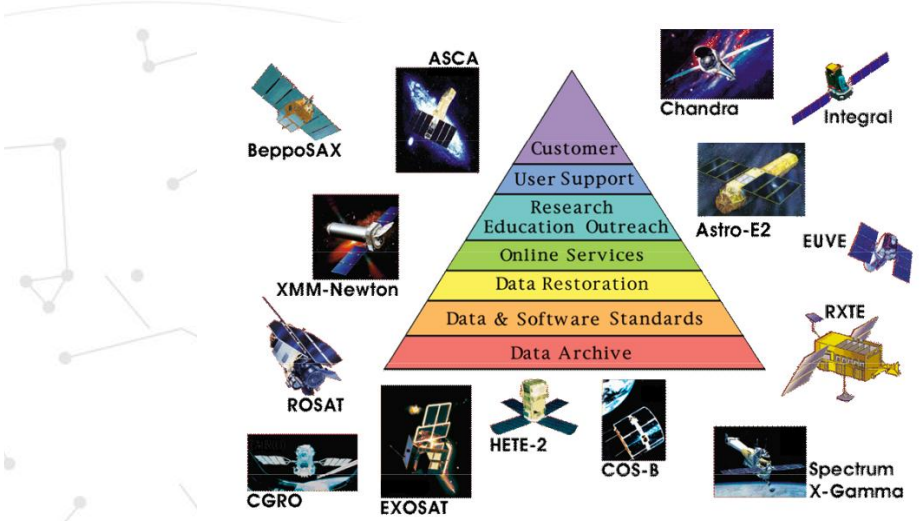
Name Resolution...
Image Servers
Archives
Catalogs
Virtual Observatory...
Plot Tool...
Web Browser...
Catalog Tool...
Analysis Command Log
Load Analysis Commands...
Clear Analysis Commands
NVO DataScope
NVO Image Mosaic Service
Chandra
ROSAT All-Sky (MPE/MPG)
SkyView (NASA/HEASARC)
W3Browse (NASA/HEASARC)
NVSS (NRAO)
4MASS (NRAO)
SIRTF FLS/VLA (NRAO)
VLA First (NRAO)
NED (NASA/IPAC)
SIMBAD (CDS)
ADS (SAO)
SAO TDC (SAO)
Obs&Archive
Linux

Web-based data archives

- **Infrared missions** (IRAS, ISO, Spitzer, Herschel, Planck, WISE) : IPAC
  http://www.ipac.caltech.edu

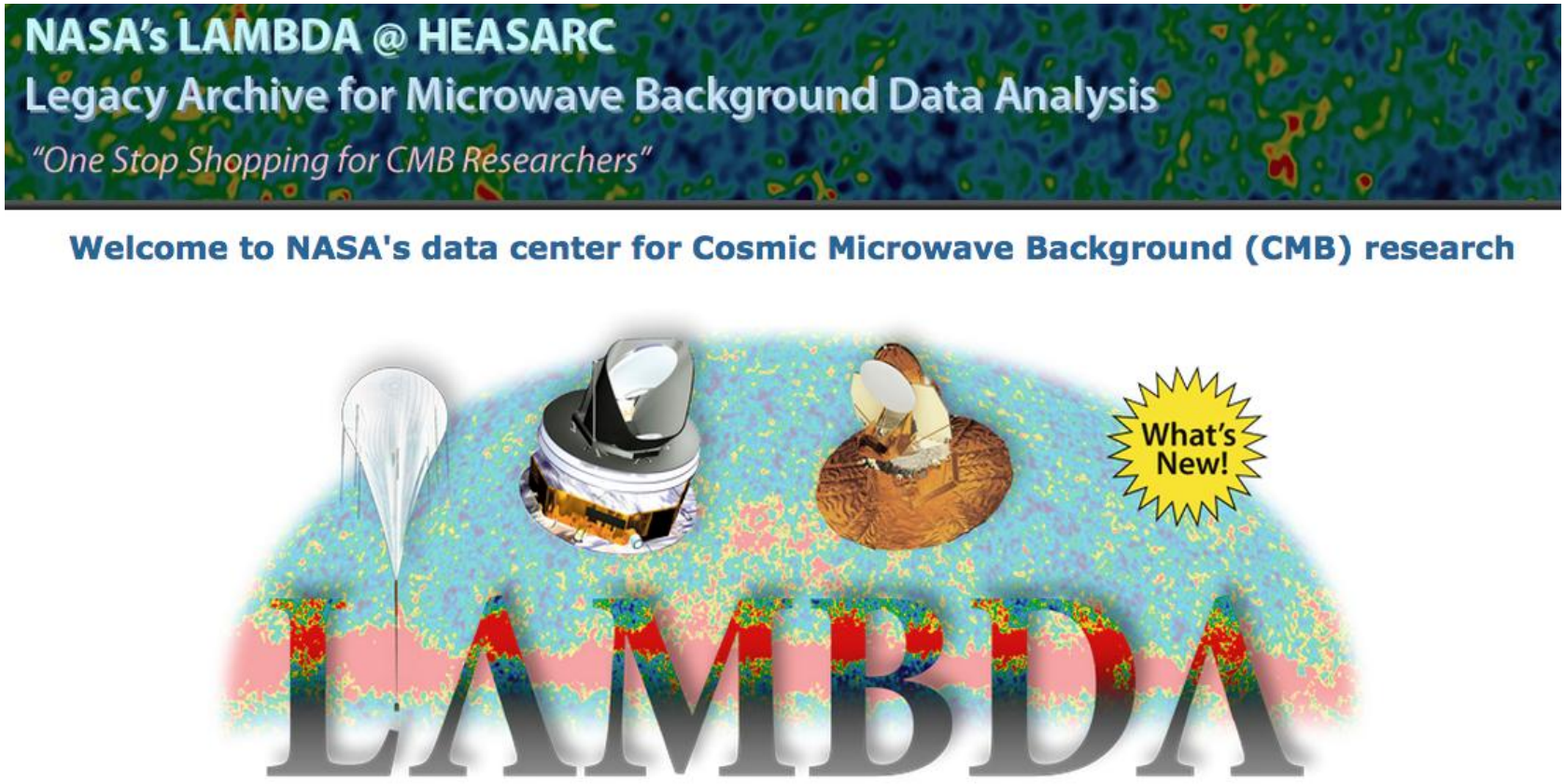
- **Highenergy**: NASA HEASARC http://heasarc.gsfc.nasa.gov

  - Information and latest news about HEASARC Catalogs
  - Mission information
  - Search catalogs & retrieve data
  - Download analysis software
  - Access documentation
  - Astronomical Web site links
  - Public outreach & education



Web-based data archives

- Cosmic Microwave Background (CMB)



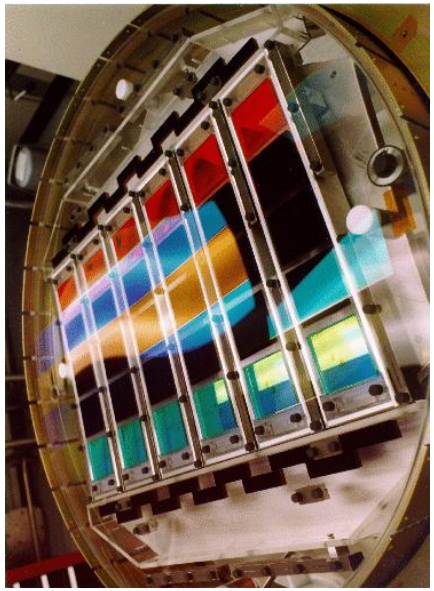
Planck Data Products at IRSA

Planck is a European Space Agency (ESA) mission with significant NASA involvement in hardware and science, managed by the Jet Propulsion Laboratory, California Institute of Technology. Planck data products are provided by the Planck Consortium. Products are released by ESA through the archive at ESA Planck Legacy Archive (http://www.sciops.esa.int/index.php?project=planck&page=Planck_Legacy_Archive) and by NASA through the NASA/IPAC Infrared Science Archive (http://irsa.ipac.caltech.edu/), which is maintained at IPAC, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

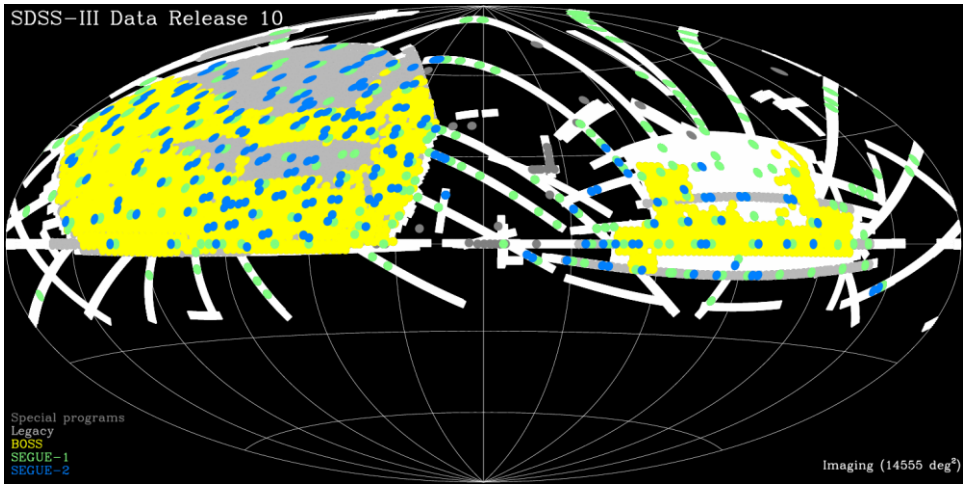
The links in the first two tables below lead directly to Planck data at IRSA.

Data Release 1		
Product Download Page	Description	No. Of Files/Size
All Sky Maps	Temperature and component separated maps.	72 files
Catalog and Map Visualization	Visualization and enhanced access to the Planck All Sky Maps and the ERCSC	N/A
Catalog Query	Access to the ERCSC through IRSA's Catalog Search service.	N/A
Planck SZ Catalogs	Download the Planck Sunyaev Zeldovich Cluster sample.	1 file1
Entire PCCS	Download the Planck Catalog of Compact Sources	1 file
Planck Ancillary Data	Power spectra, masks and instrument parameters	78 files
External Datasets	Multiwavelength maps useful for analysis of Planck data	38 files
Software and Analysis Products	Useful software and products for analysis of Planck data	11 files
Data Release 1 Explanatory Supplement	Documentation for Data Release 1	1 file

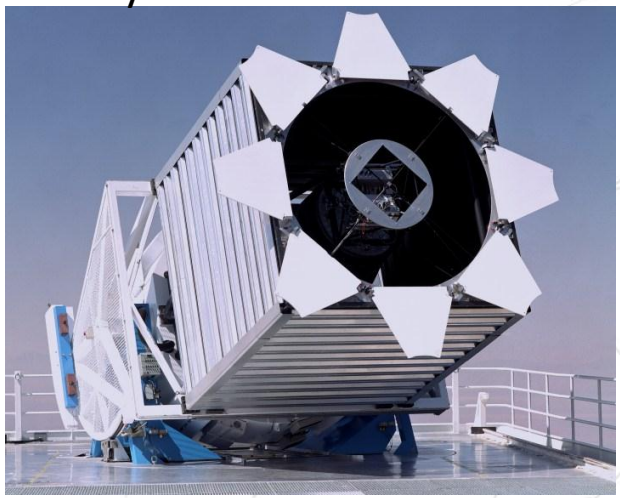
The Sloan Digital Sky Survey



- 30 2k x 2k
- 6col. x 5 filt
- Drift scan mode
- FOV 2.5deg
- 200GB/ngt



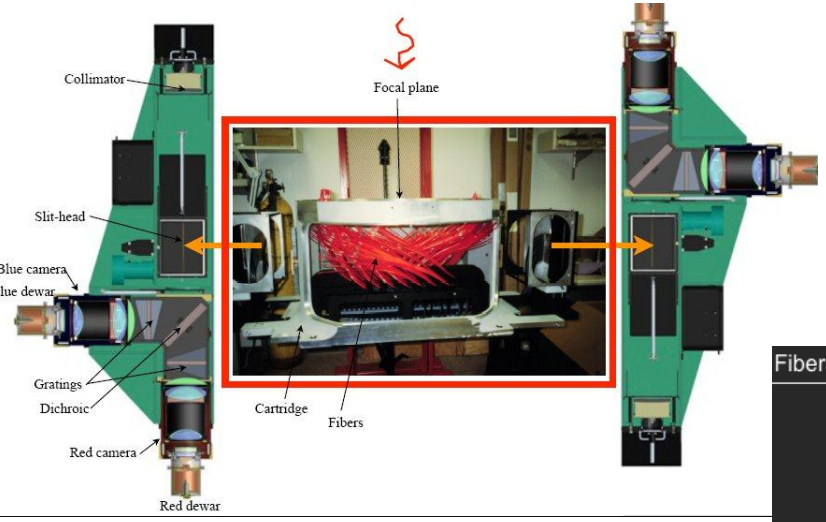
2.5m @ Apache Point Obs. since year 2000



Imaging data statistics

Total unique area covered	14,555 square degrees
Total area of imaging (including overlaps)	31,637 square degrees (excluding supernovae runs)
Individual image field size	1361x2048 pixels (0.0337 square degrees)
Number of individual fields	938,046 (excluding supernovae runs)
Number of catalog objects	1,231,051,050
Number of unique detections	932,891,133
Number of unique, primary sources	Total 469,053,874 Stars 260,562,744 Galaxies 208,478,448 Unknown 12,682

SDSS Spectroscopic survey



BOSS spectrograph

- 1000 fibers
- 2 separate blue & red channel
- R ~ 2000
- Dark Energy experiment with BAO
- 1.5 millions LRGs
- 160,000high-z quasars (Ly-alpha forest)

SDSS spectrograph BOSS spectrograph

Fibers per plate	640				1000
Numbers of spectra	Category	Total	On good or marginal plates	Unique	
	All programs	1,843,200	1,768,960	1,629,129	
	Main galaxy targets	778,410	755,111	711,726	
	LRG targets (excluding Main)	106,650	103,662	95,990	
	SEGUE-1 targets	250,422	242,008	220,851	
	SEGUE-2 targets	128,112	128,112	118,151	
	Stars	600,967	577,157	521,990	
	Galaxies	952,740	921,007	860,836	
	Quasars	130,300	126,368	116,003	
	Skies	110,288	103,046	93,187	
	Unknown	48,905	41,382	37,113	

Category	Total	Unique
Total	1,507,954	1,391,792
Stars	159,327	144,968
Galaxies	927,844	859,322
Quasars	182,009	166,300
Sky	144,503	138,491
Unknown	101,550	89,003

Many great results from SDSS

- 5800 peer-reviewed publication over 15 years
- These paper in turn have been cited a total 245,000 times

Shaw Laureates 2014

ASTRONOMY

SDSS

Daniel Eisenstein

2dFGRS (UK + Aus)

Shaun Cole

John A Peacock

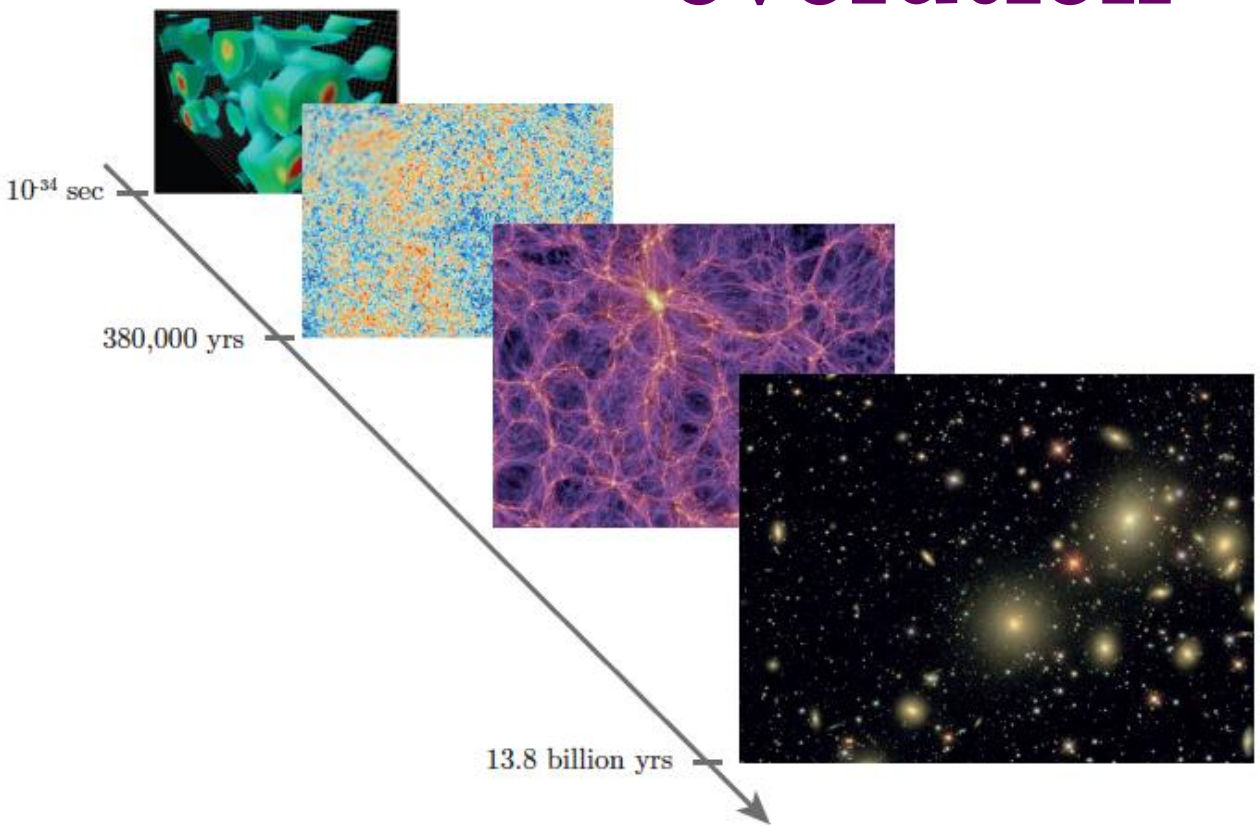
"for their contributions to the measurements of features in the large-scale structure of galaxies used to constrain the cosmological model including baryon acoustic oscillations and redshift-space distortions."

Multi-mission & multi-wavelength data archives

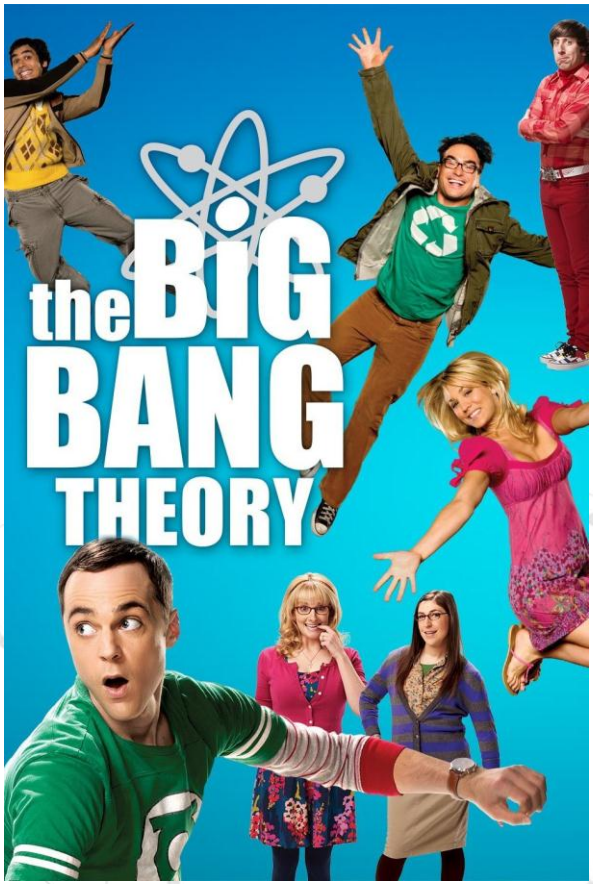
- NED http://ned.ipac.caltech.edu/
- CDS http://cds.u-strasbg.fr/
- MAST https://archive.stsci.edu/
- SkyView http://skyview.gsfc.nasa.gov/

SkyView
The Internet's Virtual Telescope

Cosmology and structures evolution



"It all started with a Big Bang"



The Big Bang Theory

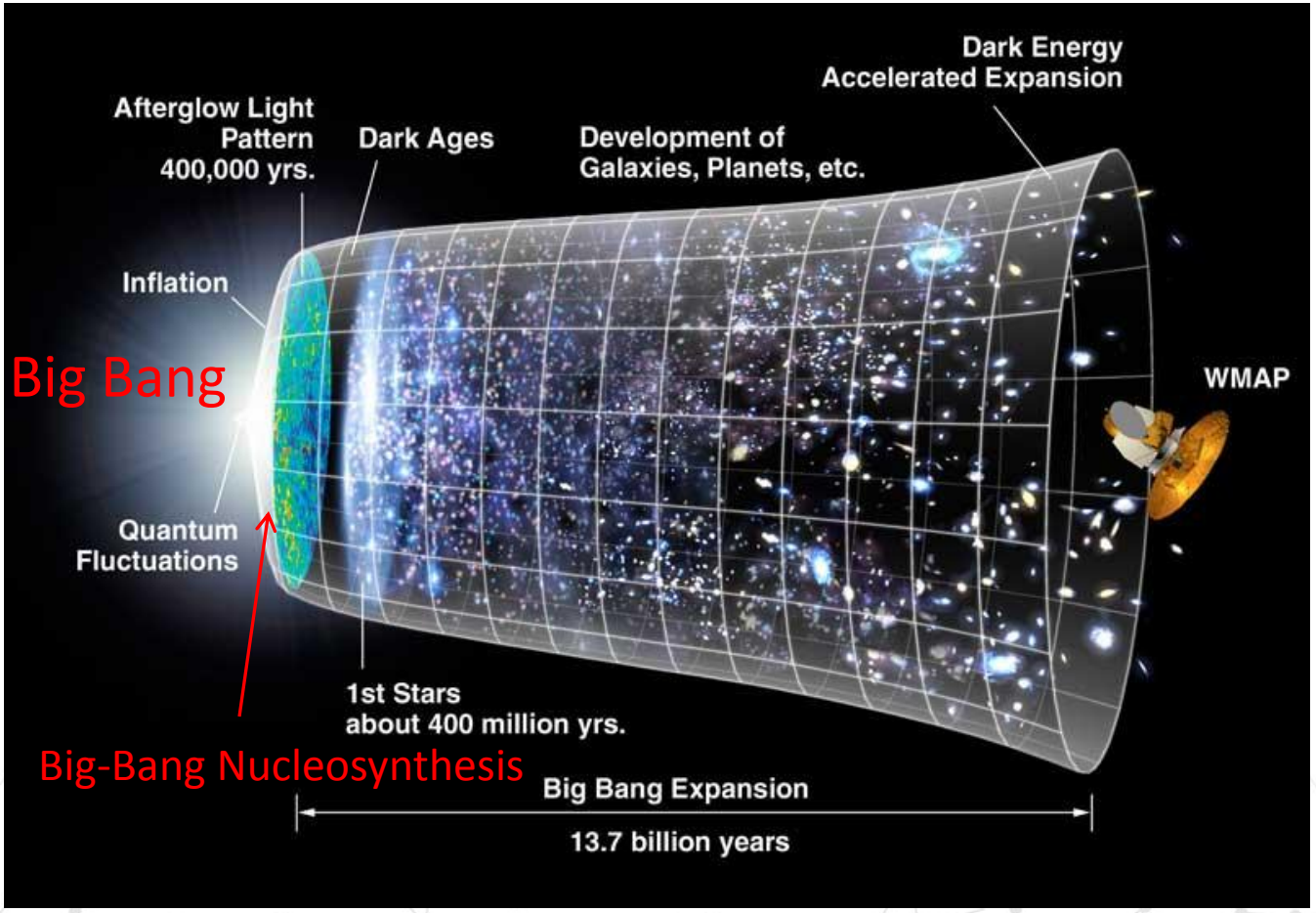
- This implies that all the matter in the Universe was once (14 billion years ago) **very close together in an extremely hot dense state** of the so called 'Big Bang' theory (a term coined by Sir Fred Hoyle)

- Proposed by G. Lemaitre (1931) "**Hypothesis of the primeval atom**"

- The universe has since expanded and cooled down to temperature of **2.725 Kelvin**

- What we learned about the universe is now called **modern cosmology** which began with observations made by Edwin Hubble

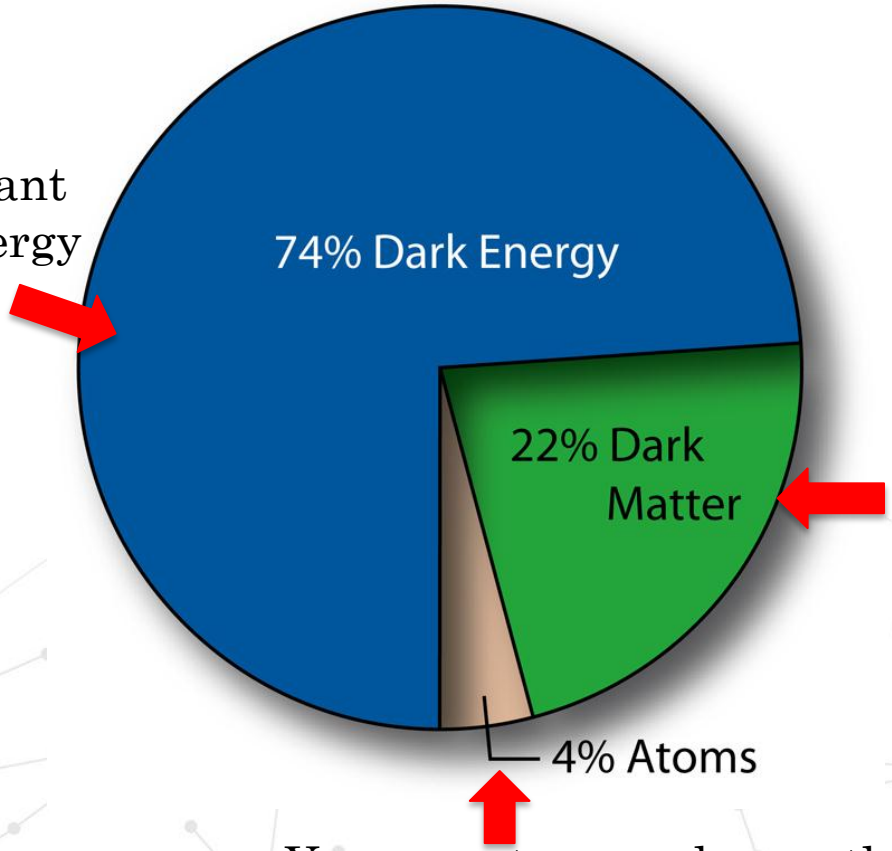
Quick overview of the past 14 billion years



Credit: Nick Strobel

What the Universe is made of?

Cosmological Constant or exotic form of energy or new physics ?



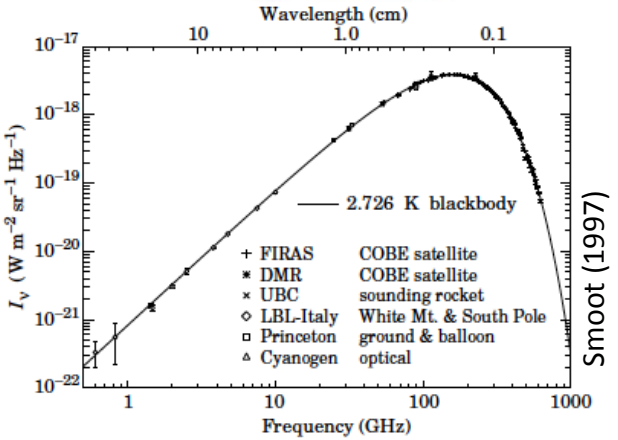
Many proposed candidates including SUSY particle BUT Yet to be detected in the Lab!

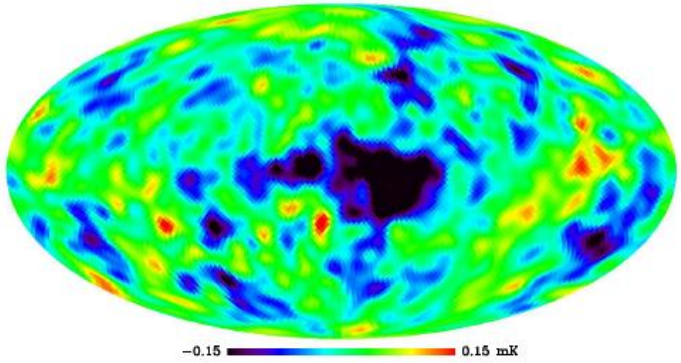
You, me, stars and everything else we see

Cosmic Microwave Background (CMB)

Brief History

- Discovered **by chance** as the "Noise" by Penzias and Wilson (1964), T ~3K (c.f. ~5K prediction from BBN by Alpher & Herman 1948), **Nobel prize 1978**
- Interpret as the **relic radiation left from the Hot Big Bang** (Dicke, Peebles, Roll & Wilkinson 1965)
- 1990, FIRAS on the COBE mission measured **the near-perfect blackbody spectrum**
- 1992, DMR on the COBE mission **measured for the first time the 10^{-5} primary fluctuation**
- Late 1990s and early 2000s, the "precision" measurements for anisotropy begin in earnest (balloon, ground-based & Space)



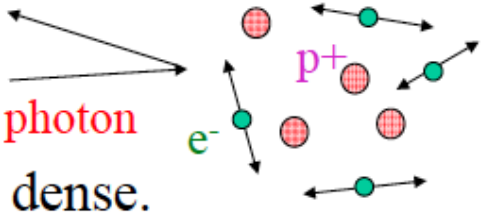


Cosmic Michrowave Background

Universe was "fire ball" 14 billion years ago (redshift~1000)

Everywhere was plasma gas → electrons scattered photons

→ Everywhere was in "fog".

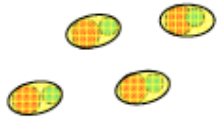


↓

Universe expanded, got cooler and less dense.

→ Protons and electrons "decoupled" after 380000 years

Universe became "Transparent"



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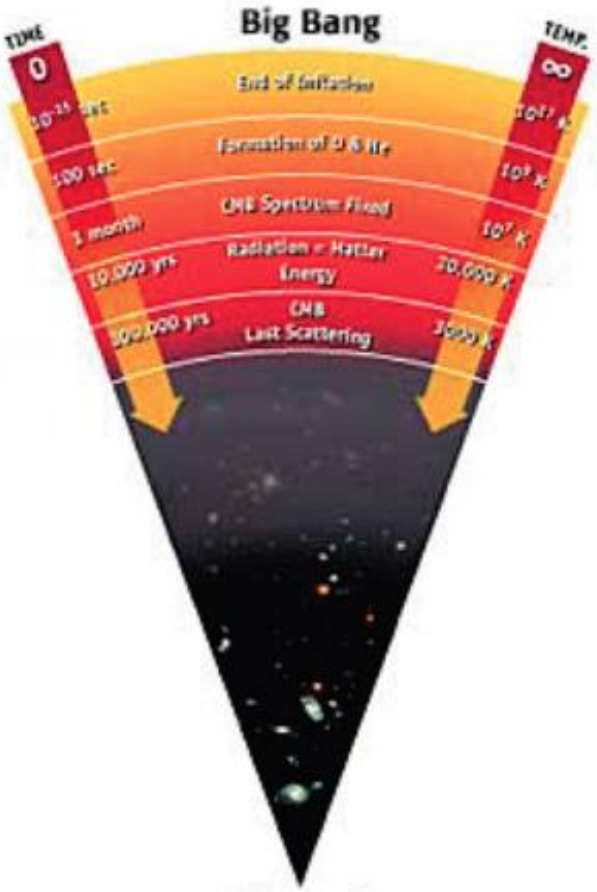
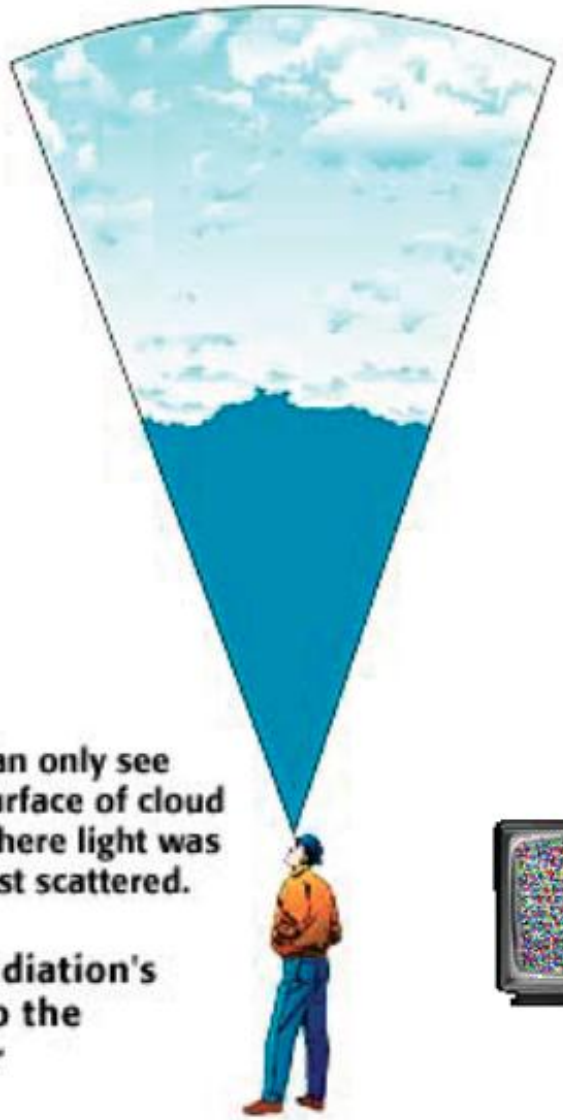
We can observe the last scattering surface toward all directions at the same distance

The last scattering surface: a snapshot of the early universe





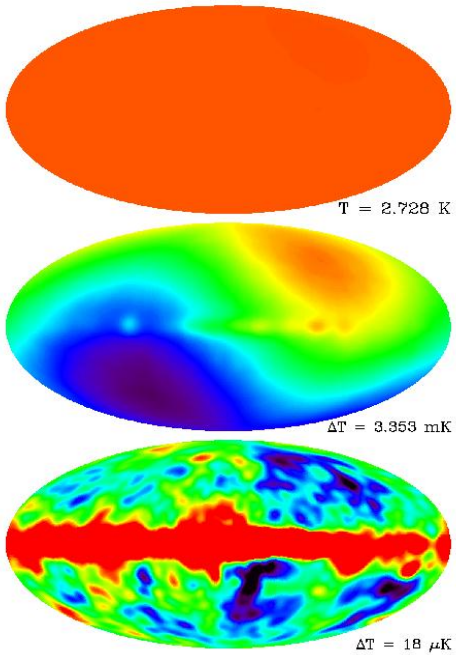
Can only see surface of cloud where light was last scattered.

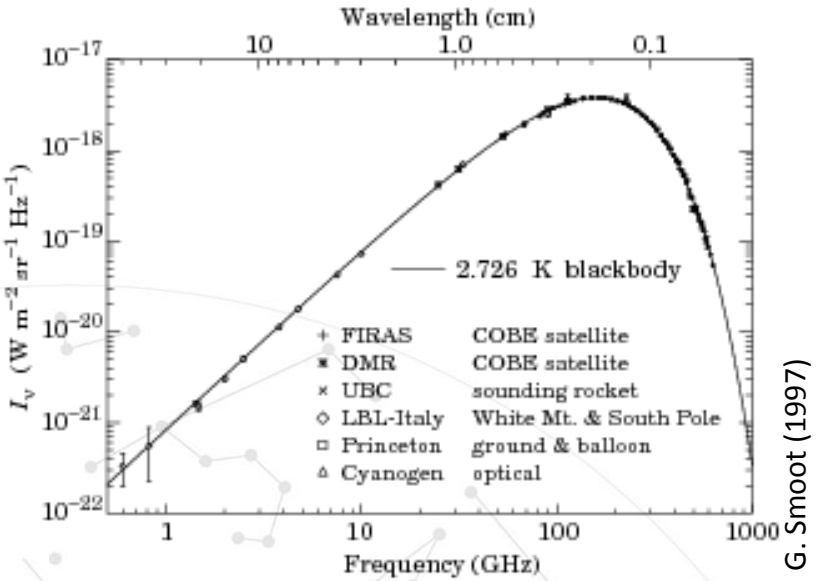
The Cosmic Microwave Background Radiation's "surfact of last scatter" is analogous to the light coming through the clouds to our eye on a cloudy day.

Golden Age of Observational Cosmology

- Cosmic Microwave Background (CMB)

  Remnant of heat radiation left over from the hot Big Bang B.B. spectrum, T_0=2.725 K consistent with the BBN prediction

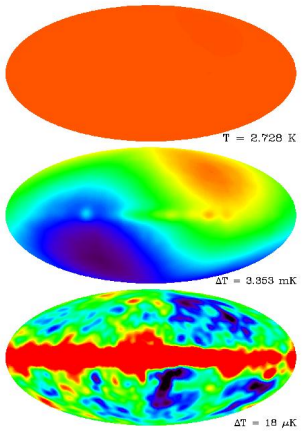


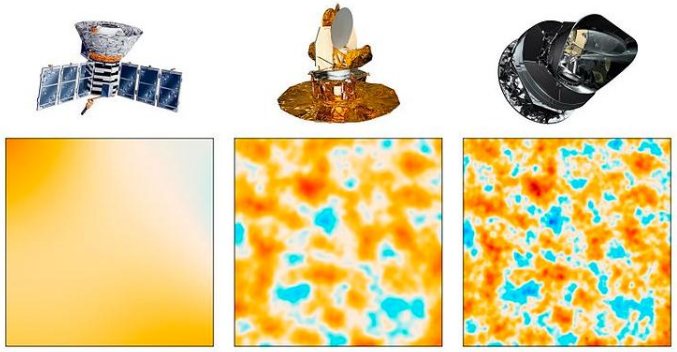


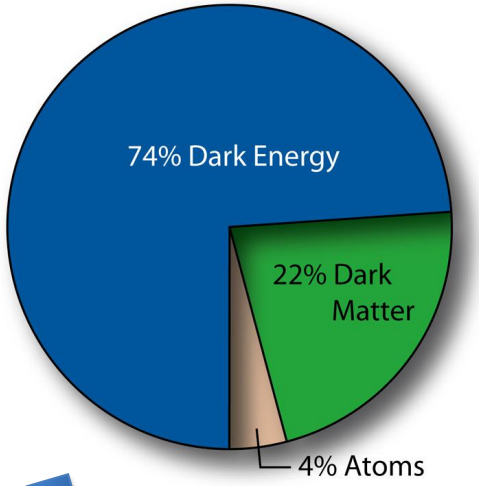
G. Smoot (1997)

Nobel prize in Physics 2006

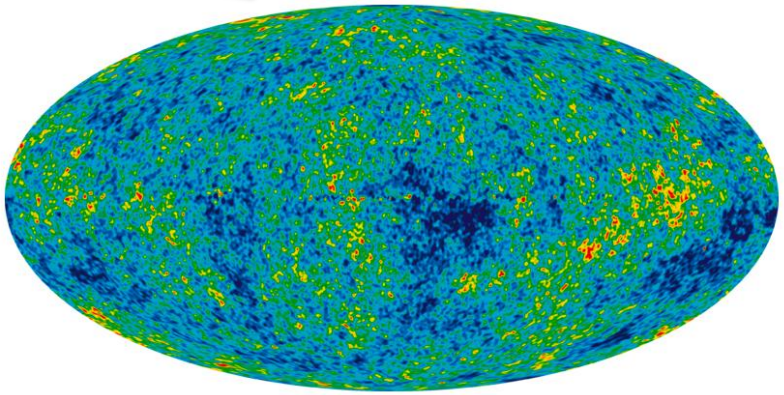
The Golden Age of Observational Cosmology

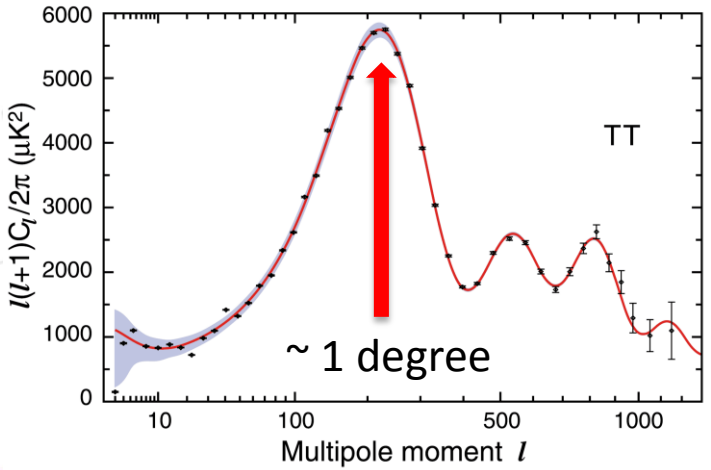




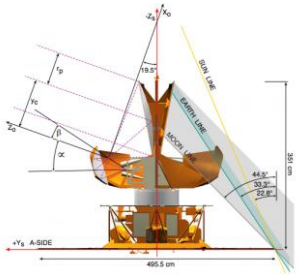


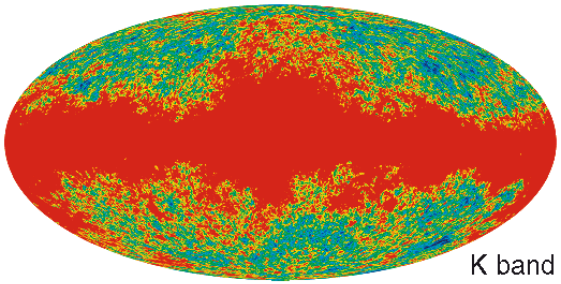
+ LSS, SNIa, H_0 etc.

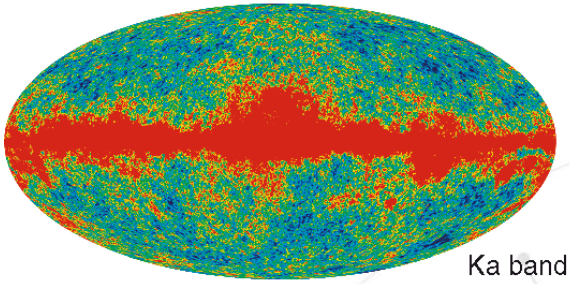


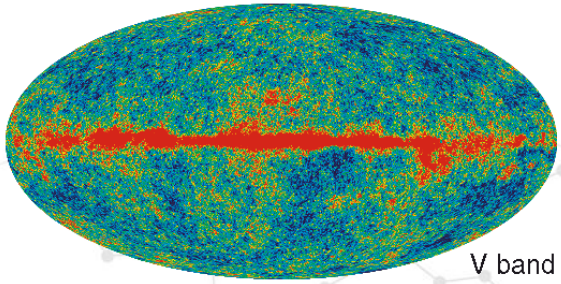


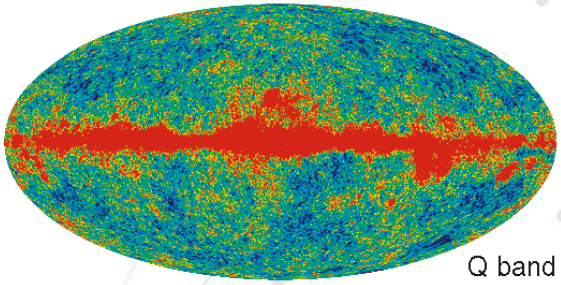
The Wilkinson Microwave Anisotropy Probe (WMAP) mission

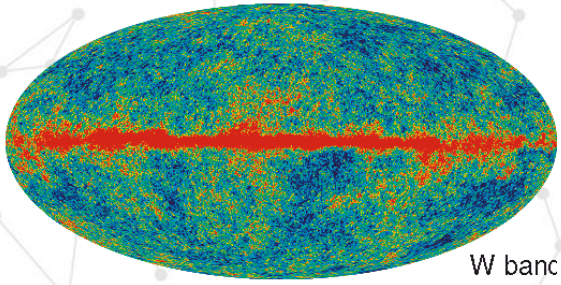


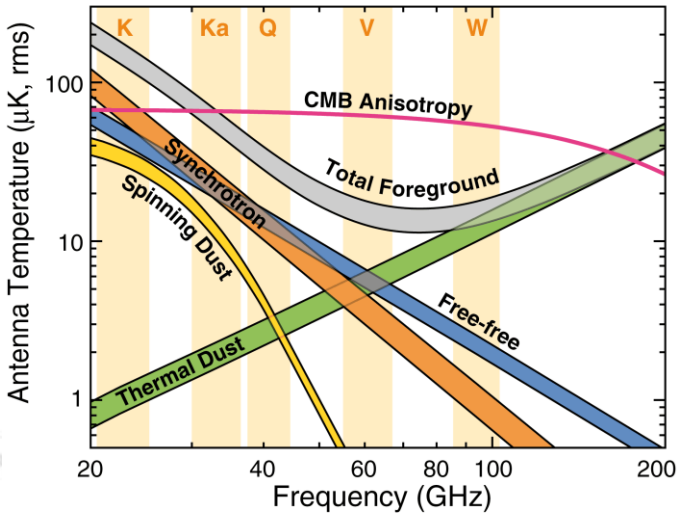




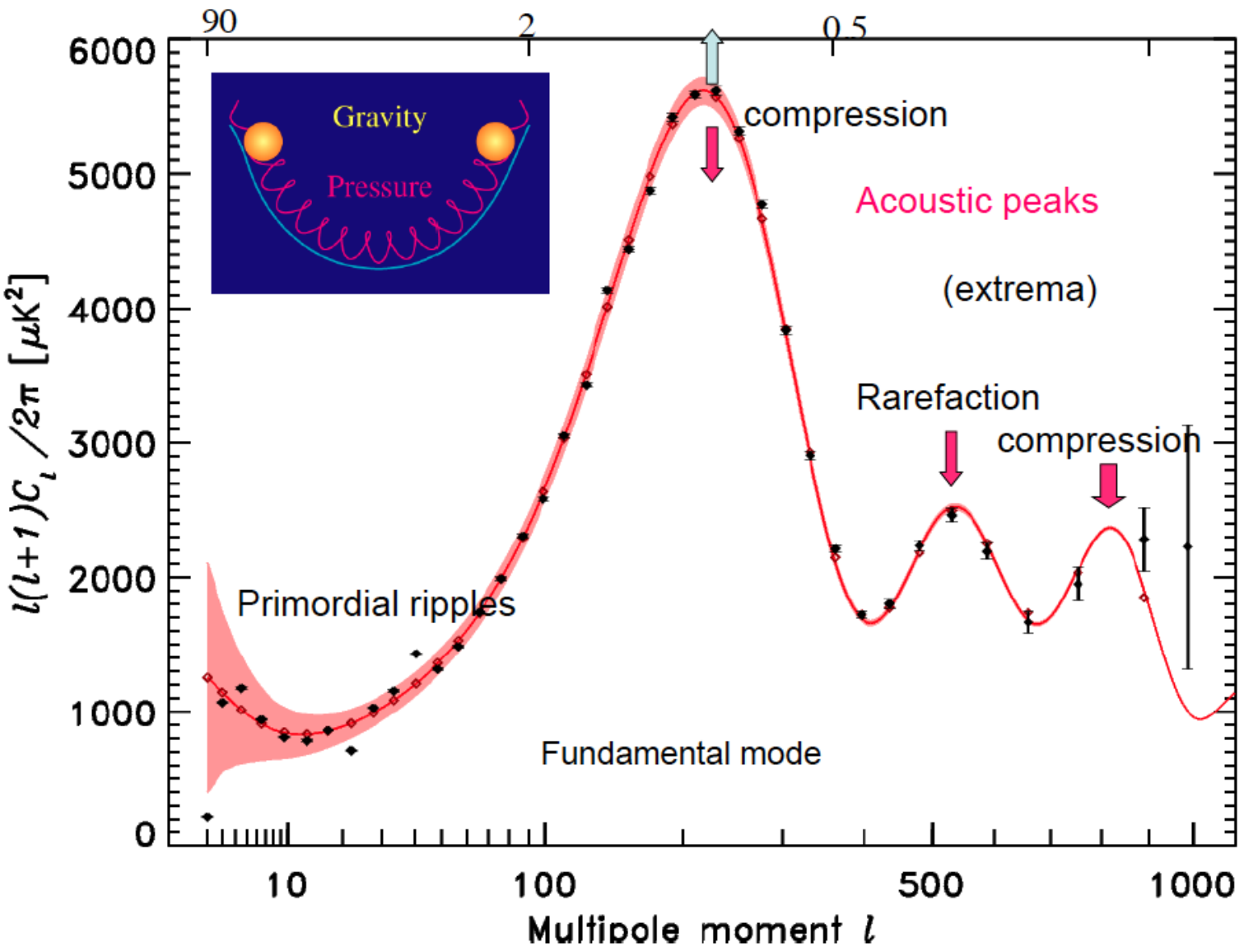




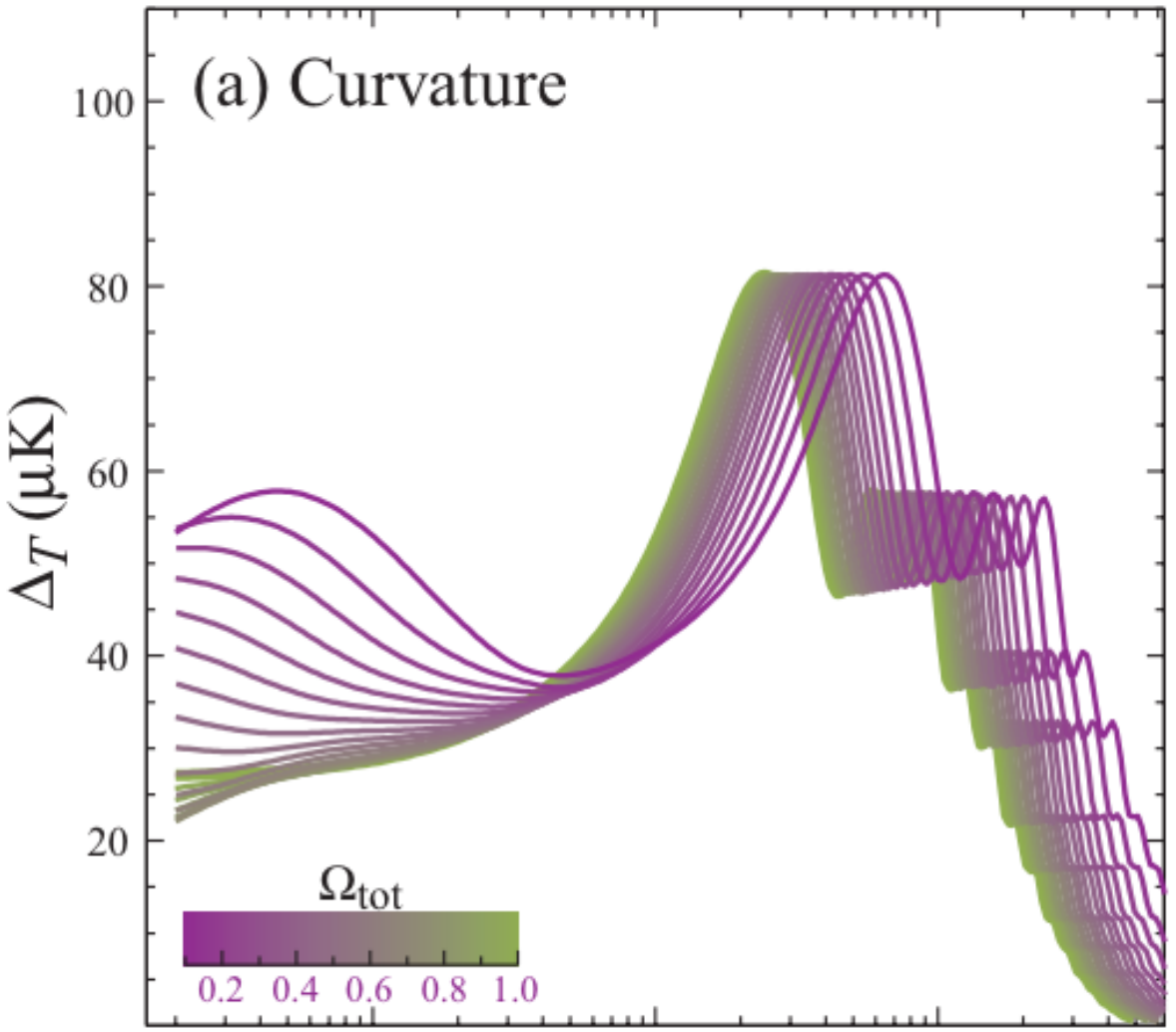




CMB + Foreground radiation


90
2
0.5
6000
5000
4000
3000
2000
1000
0
$l(l+1)C_l/2\pi$ [μK^2]
Gravity
Pressure
compression
Acoustic peaks
(extrema)
Rarefaction
compression
Primordial ripples
Fundamental mode
10
100
500
1000
Multipole moment l

Measuring curvature from the CMB acoustic peak



Hu and Dodelson (2002)

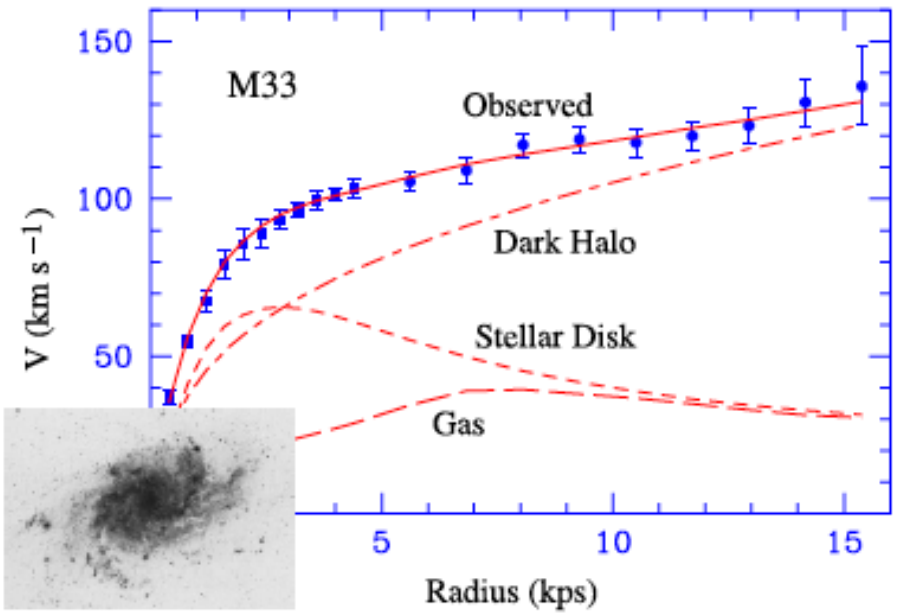
larger scales

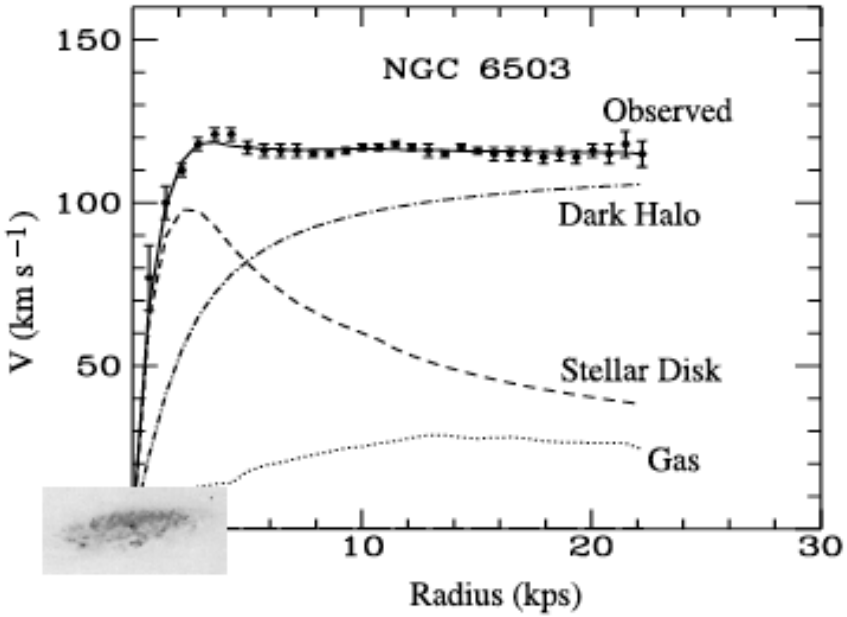
Smaller scales

The Dark Universe

Dark Matter

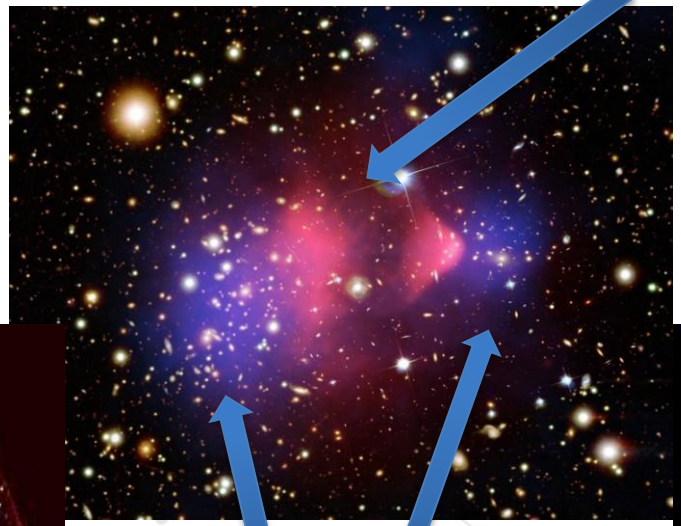
- Proposed by Fritz Zwicky (1933) to explain the missing mass in the galaxy rotation curve
- The missing mass inferred from Mass-to-light ratio is about factor of 10 for galaxy and a few 100s for galaxy cluster
- Now a key ingredient in making the LSS we see today

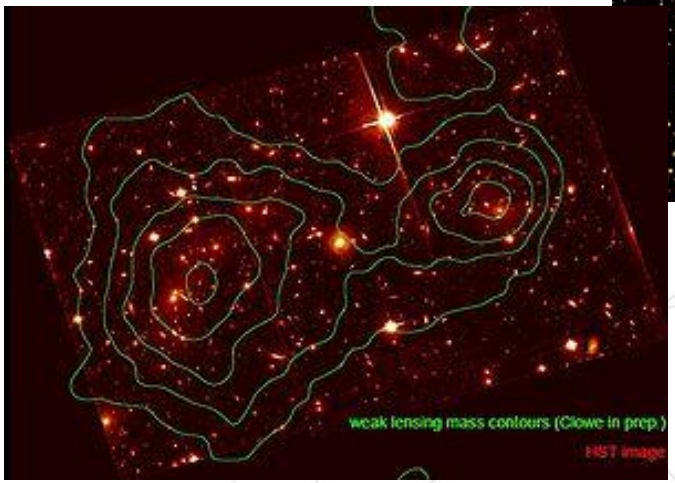




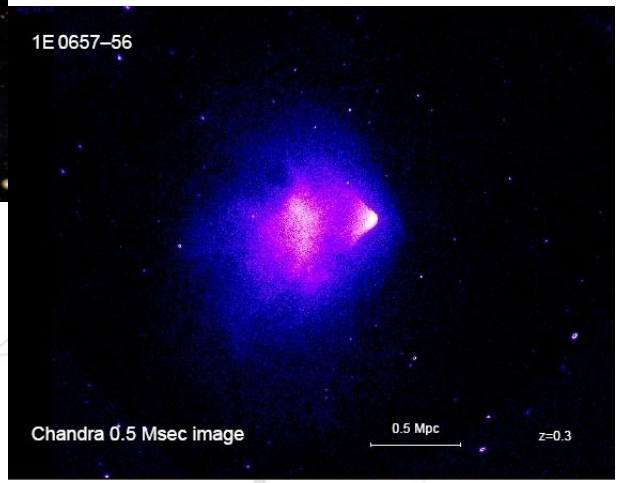
Smoking Gun for Dark Matter

Bullet Cluster (1E 0657-558) (Cowe et al.)



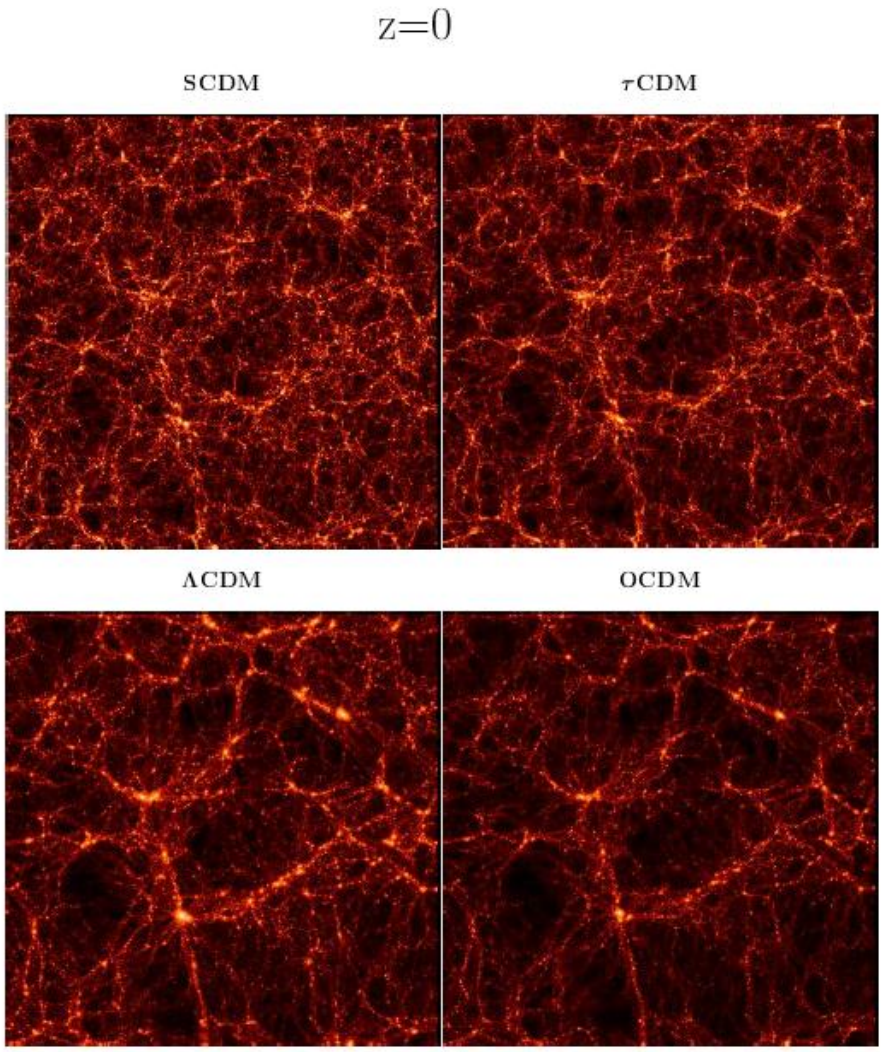


Weak lensing, DM map



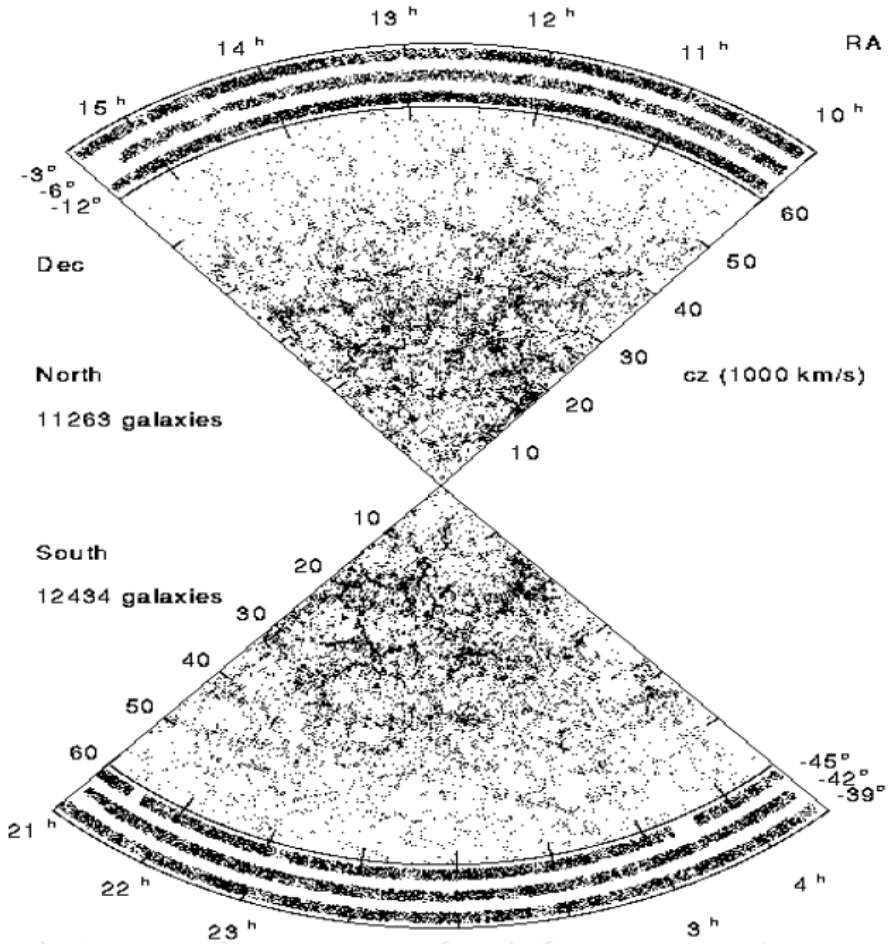
X-ray data, gas/normal matter map

simulations



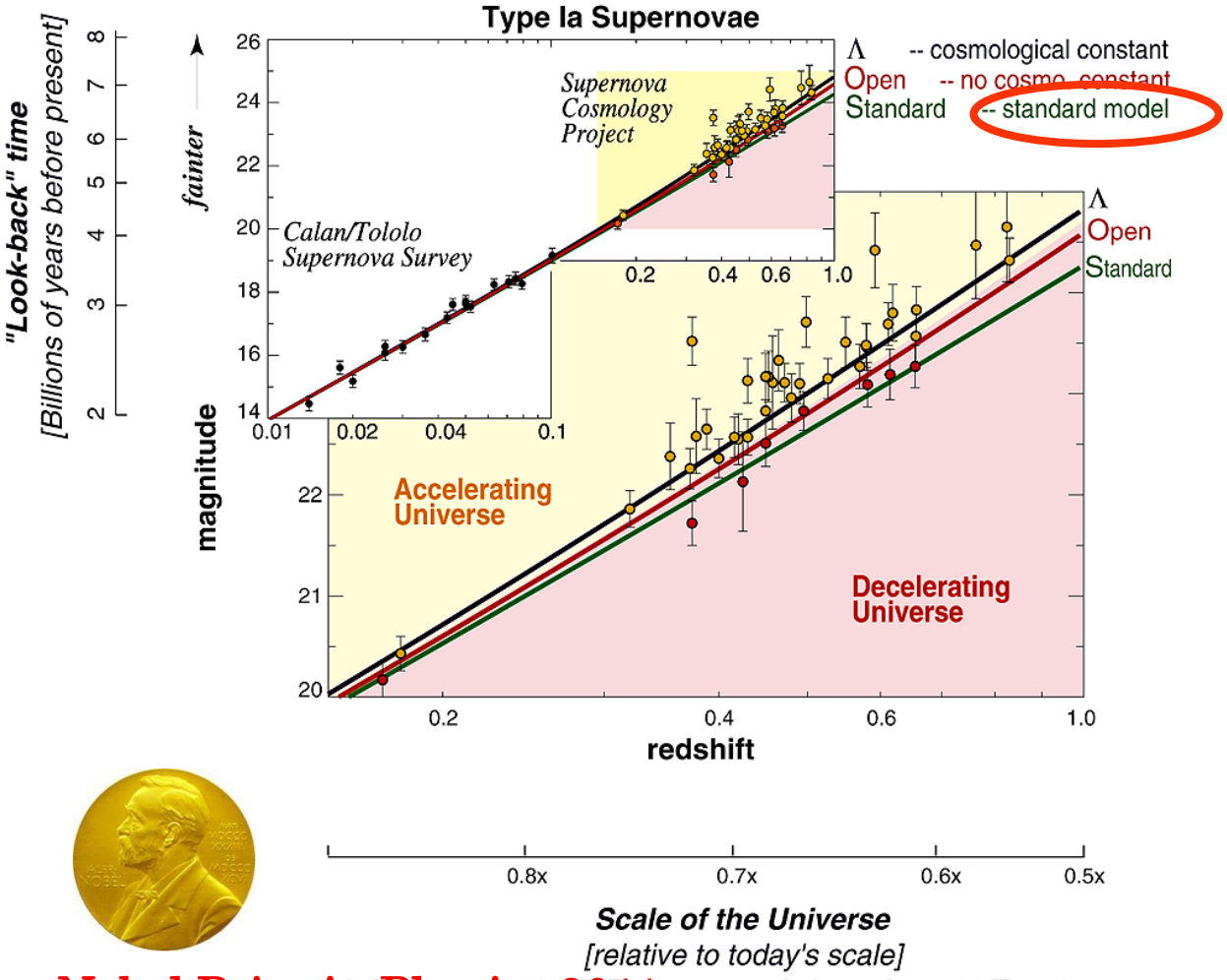
The VIRGO Collaboration 1996

observations



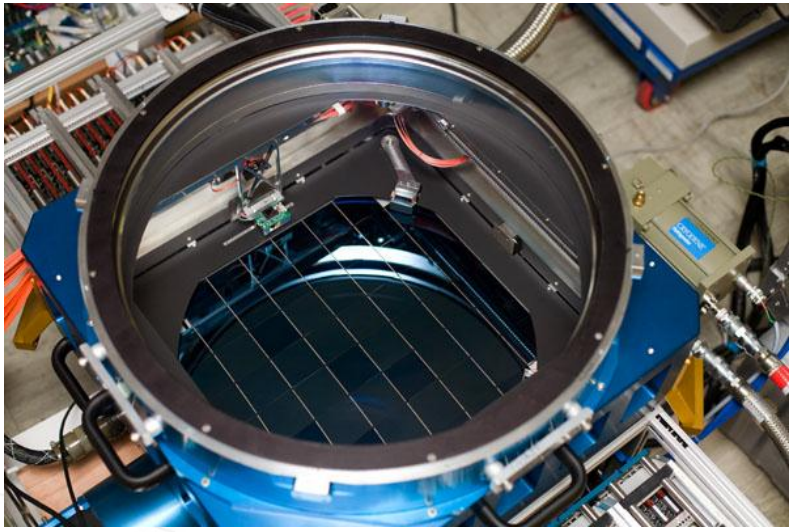
Accelerated expansion; Dark Energy or New Physics?

- In 1998, the first Hubble diagram using Type Ia supernovae was constructed
- It showed that expansion of the universe is accelerating!
- Result by Perlmutter et al quickly confirmed by Riess et al

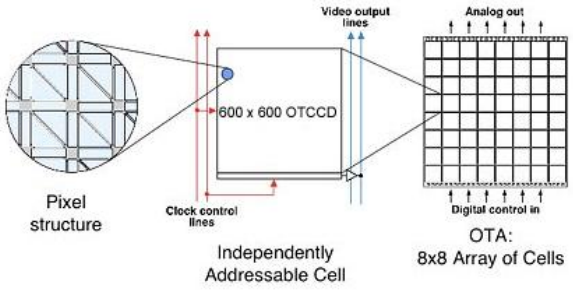


Nobel Prize in Physics 2011

The Panoramic Survey Telescope and Rapid Response System



1.4 Gigapixels Camera
(600 x 600) pixels x (64 x 64) arrays



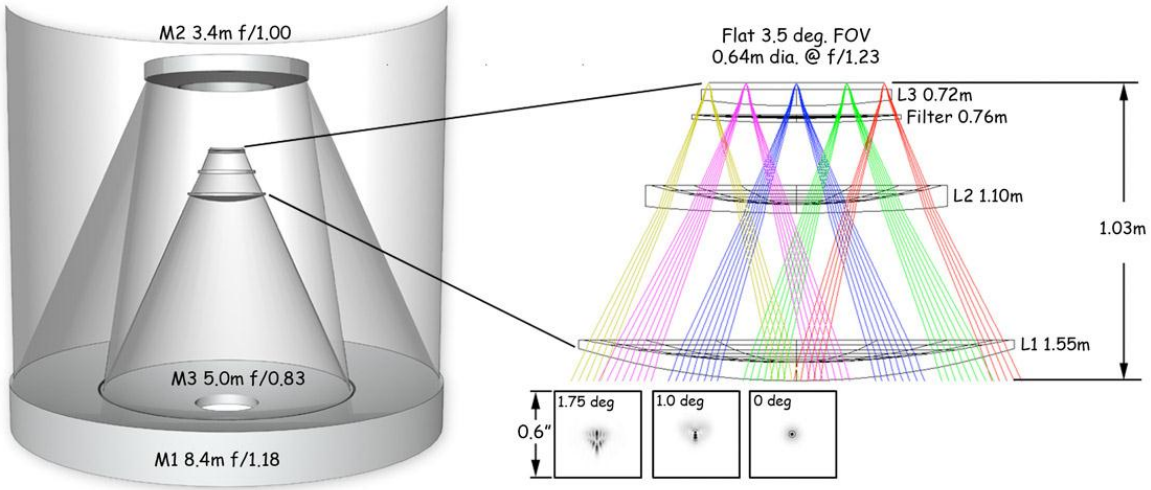
2GB /raw img
~ several TB/nt

M5

Large Synoptic Survey Telescope

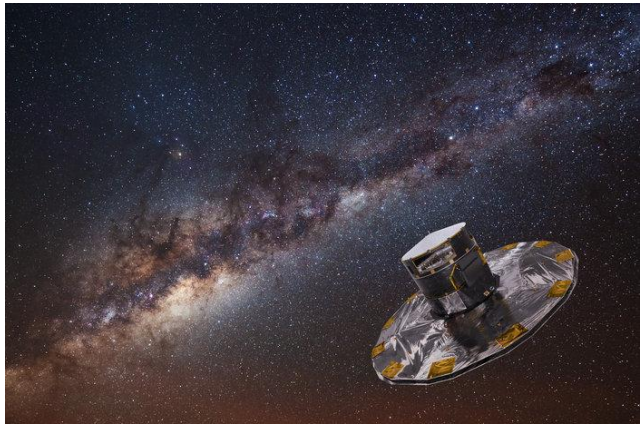
the widest, fastest, deepest eye of the new digital age

Construction started Aug.1, 2014
First light around 2022
Dark Matter + Dark Energy surveys



- FOV 3.5deg
- 3.2 Giga-pixels

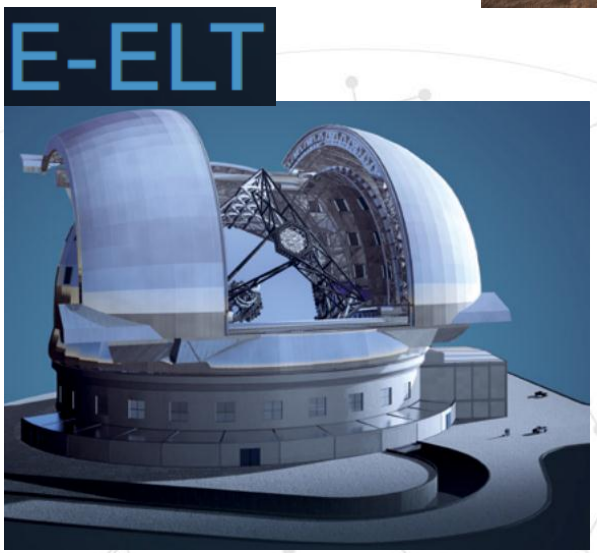
Space Missions

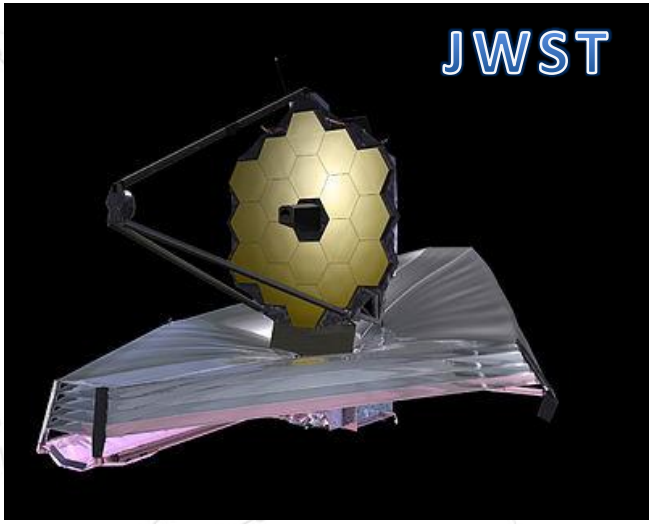


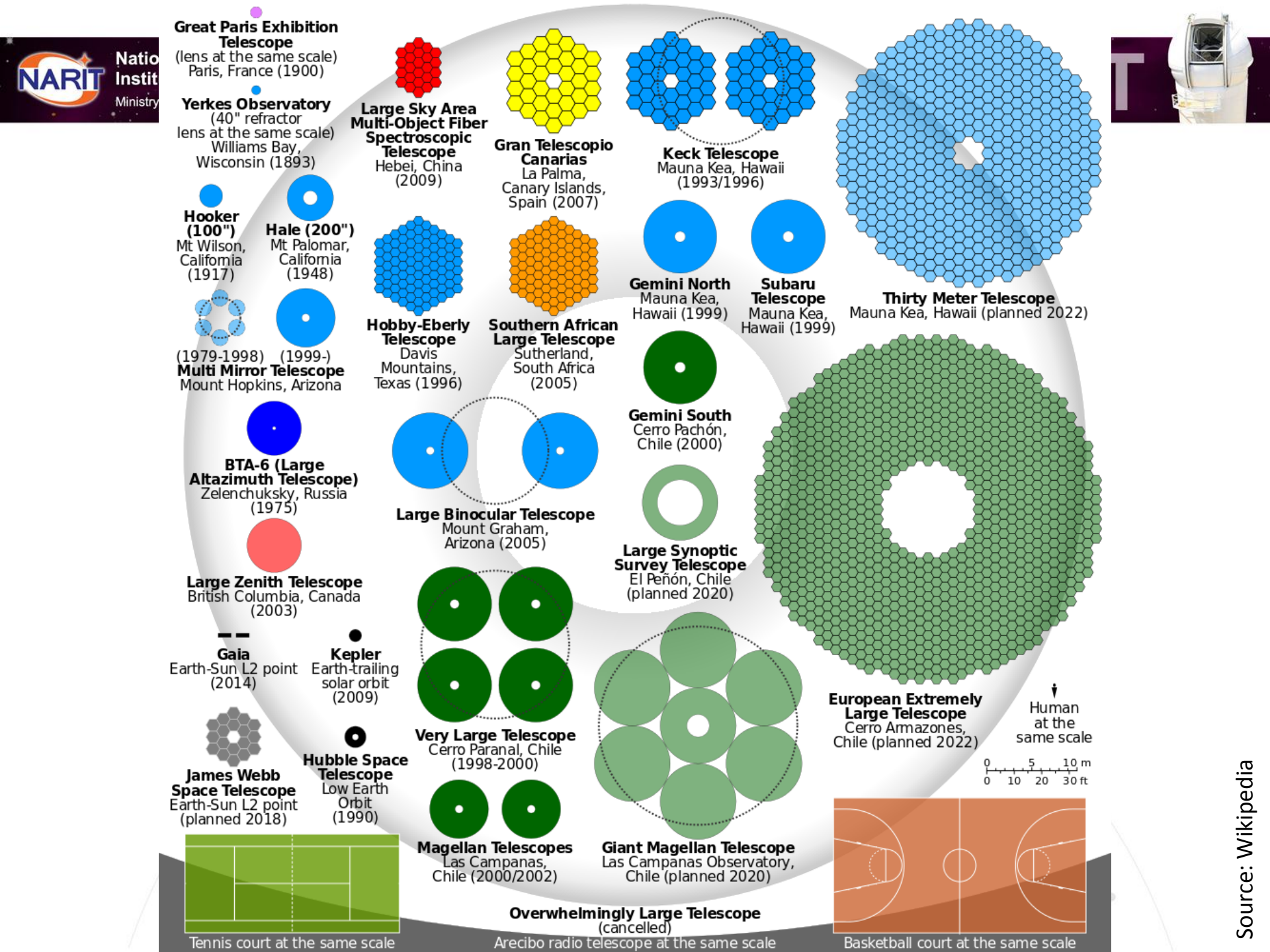
GAIA launched December 2013
Aims to construct a 3D space catalog of Approx. 1 billions stars in the MW from L2

Euclid planned launch in 2020
To study the the origin of the accelerating Universe from L2 for 6 years

And many more to come …







Source: Wikipedia

National Astronomical Research Institute of Thailand

Established since 1 January 2009

under the Ministry of Science and Technology

Key Sciences & Research Direction

1. Effects from Space to Earth and Mankind
2. Understanding the Physics of astronomical phenomena
3. A Study of Planets and signs of lives outside the Solar System
4. The Understanding on the Origin of the Universe

Infrastructures of NARIT

1) The Thai National Observatory

2) Regional Observatories for the Public (in 5 provinces)

3) The Astro Park

4) Thai Robotic Telescope Network (Thai Robonet)

The Thai National Telescope

At Km. 44 on Doi Inthanon (the highest mountain in Thailand), Chiang Mai, Thailand, which is also renowned for the superb climate and tourist attraction. At 2,457 meters above the mean sea level

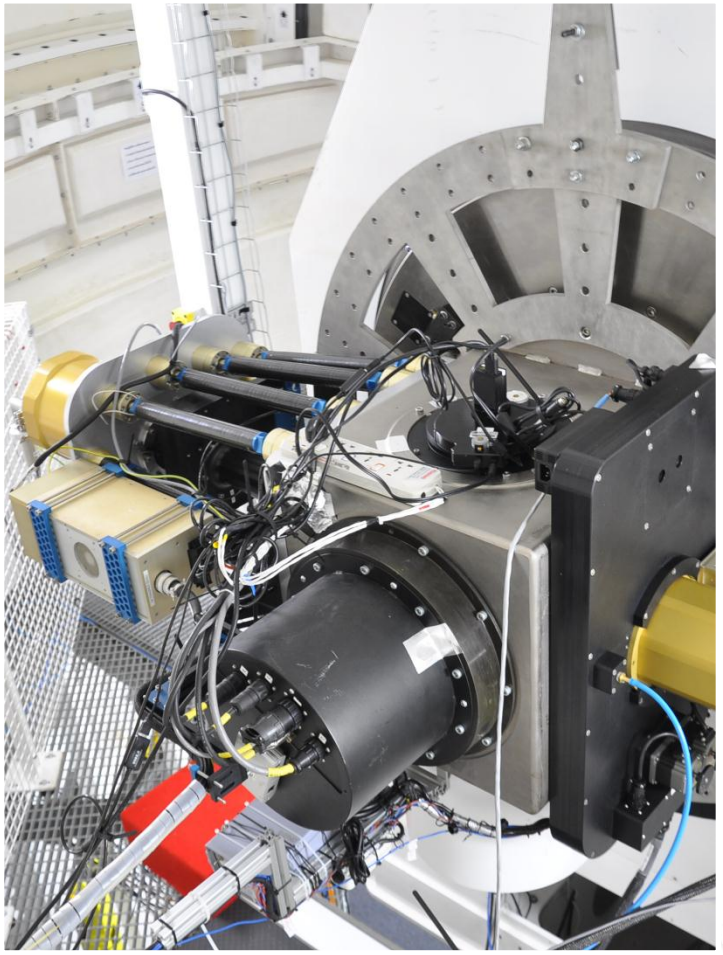
TNO inauguration by HRH Princess Maha Chakri Sirindhorn

on 22 January 2013

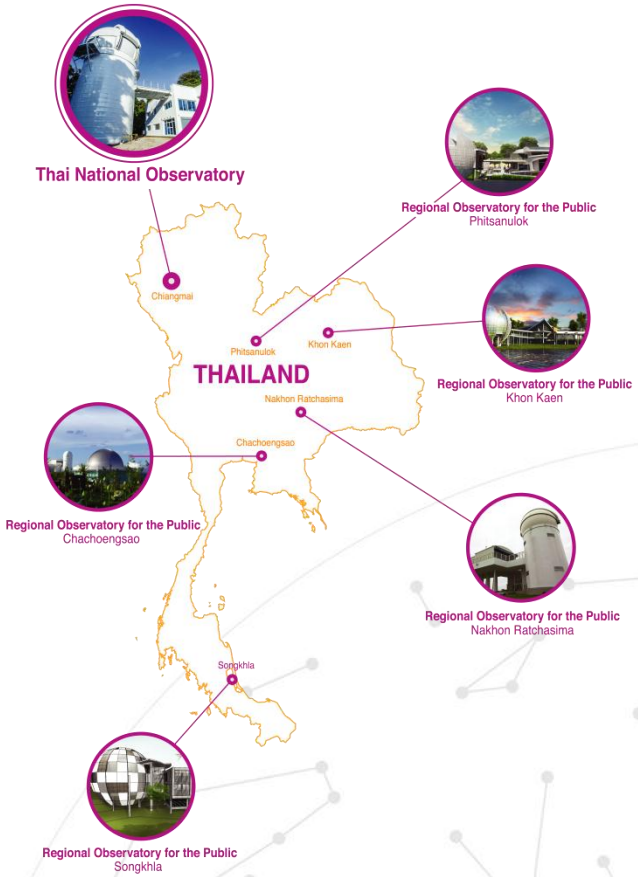
The 2.4-m Thai National Telescope (TNT)

Major Instruments

- ULTRASPEC
- 4k x 4k CCD Camera
- Medium Resolution Spectrograph (MRES)



Regional Observatories for the Public



Province	Year Completed
Nakorn Rachasima	2013
Chachoengsao	2016
Songkla	2017
Pitsanulok	2020
Kon Kaen	2022

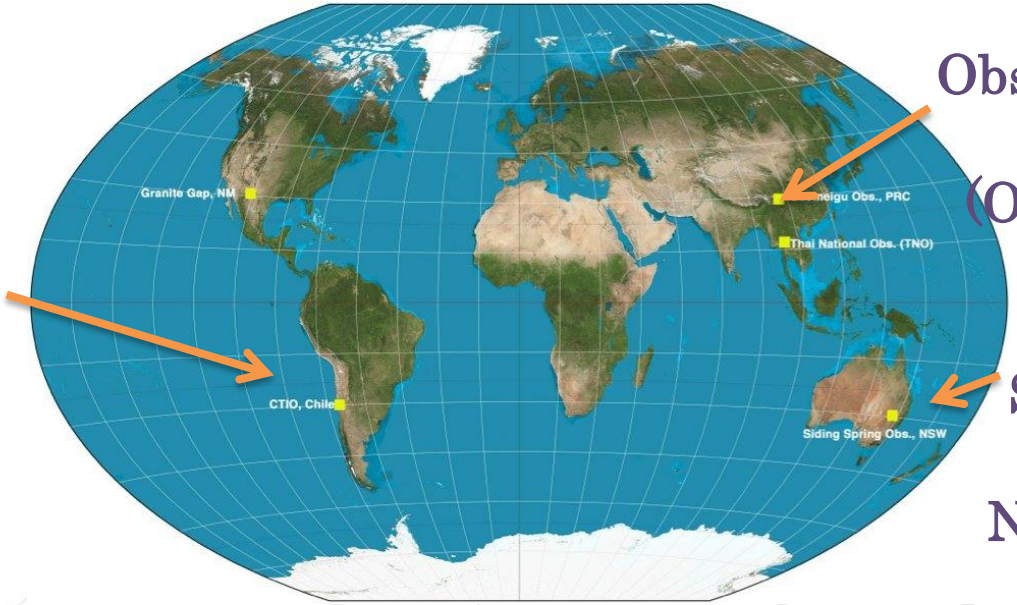
The Astro Park

Location: Don Kaew, Mae Rim, Chiang Mai (22 Acres)

Thai Robotic Telescope Network

(Thai Robonet)

Gao Mei Gu Observatory, Lijiang, PR. China (Operated in 2015)

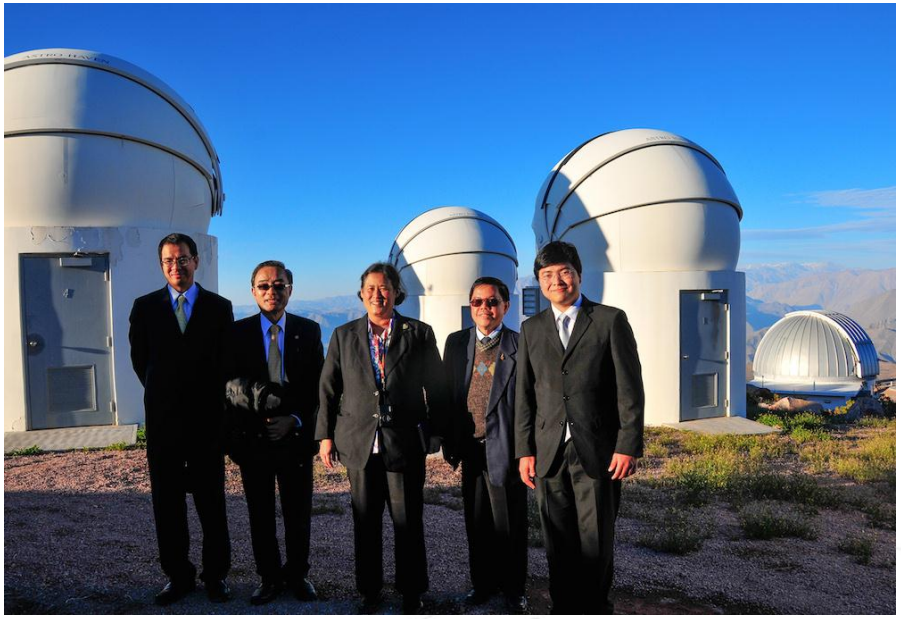


Cerro Tololo Inter-American Observatory, Chile (Operated in 2013)

Siding Spring Observatory, NSW, Australia

0.6-0.7 meter reflecting telescopes

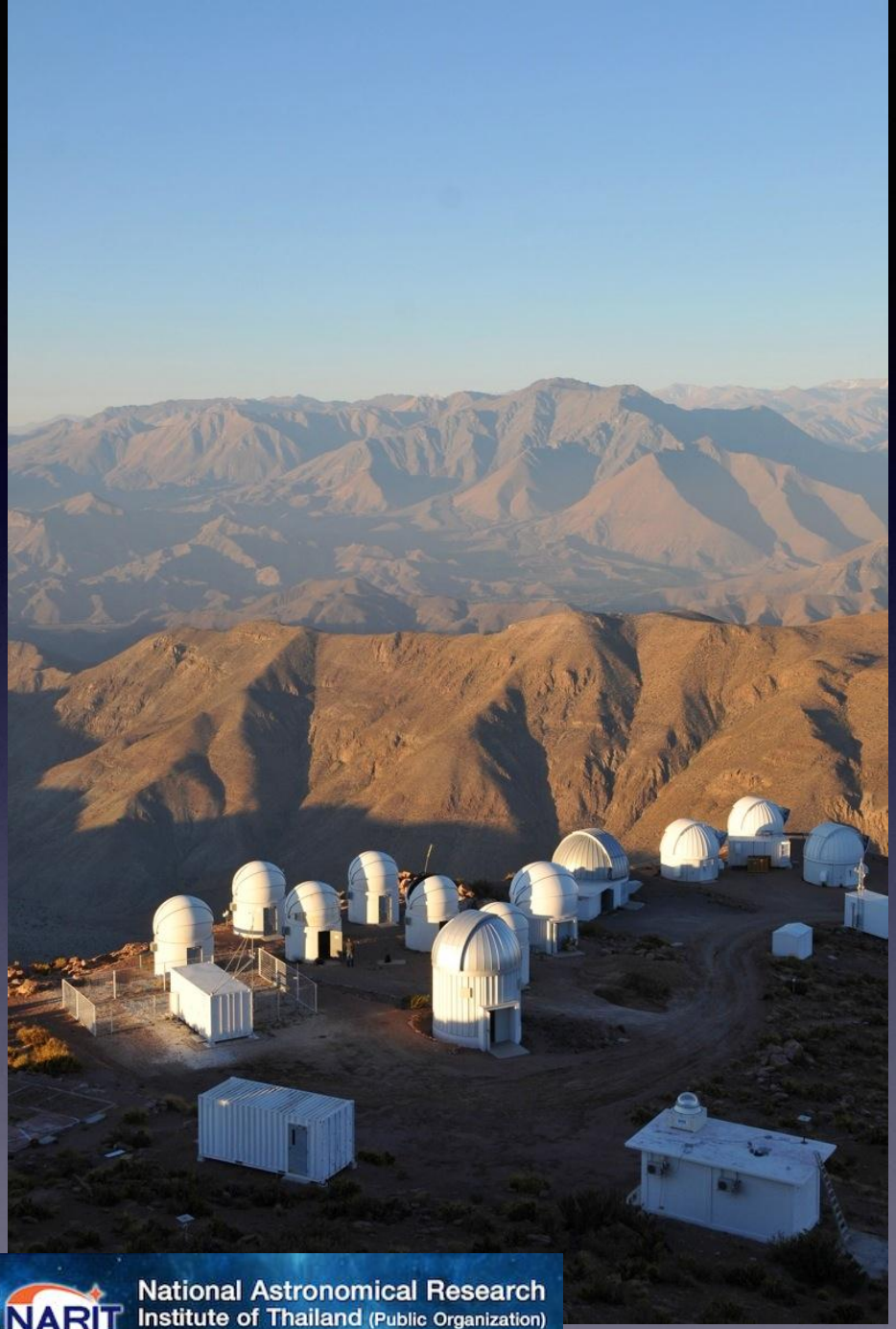
Thai Southern hemisphere telescope



Location: CTIO, Chile

Altitude : 2,207 meters above the sea level

Telescope : 0.61 meter



National Astronomical Research Institute of Thailand (Public Organization)
Ministry of Science and Technology of Thailand

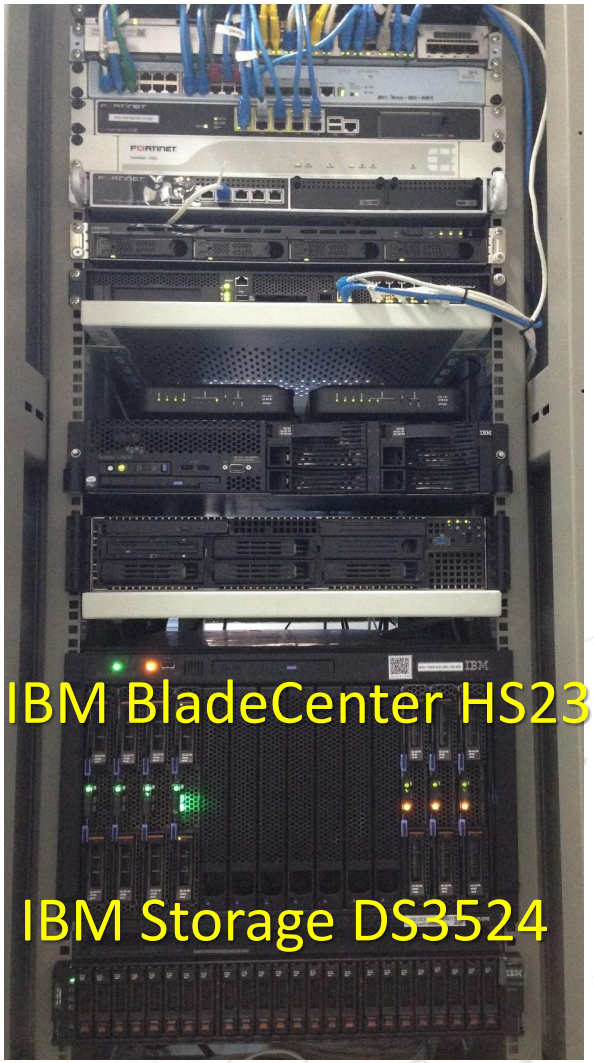
Thai Robotic Telescope in Li Jiang, PR. Of China

The 0.7-meter Reflecting Telescope

Observatory at the Air Force Report Center, Doi Inthanon

NARIT High Performance Computer (HPC) cluster

Development and test node "Pleione"



Hardware

- 4 Nodes (1 management + 3 compute) IBM HS23
  - Total 28 cores, RAM 160 GB (DDR3 RDIMM 1.6GHz)
  - 2x6 cores, 2.6GHz Intel Xeon E5-2630 v2
  - 2x8 cores, 2.0GHz Intel Xeon E5-2650
  - 1 CPU/node (due to Blade chassis power supply limit)
  - Storage14 TB (NAS)
  - Network switch Gigabit Ethernet

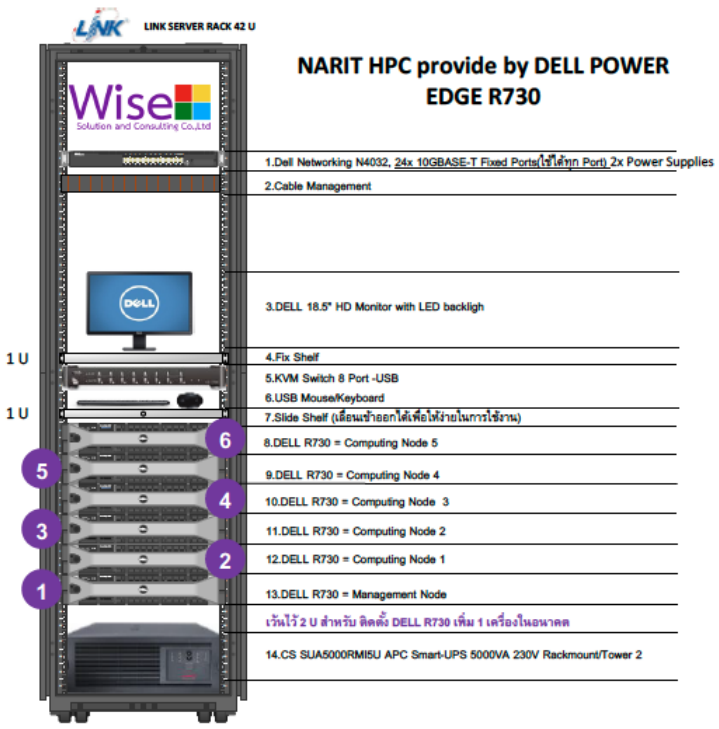
Performance

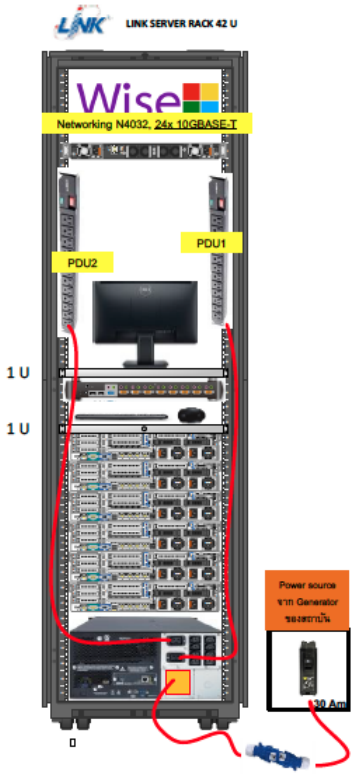
- R_{peak}= 380 GFLOPS, R_{max}=75-80% R_{peak} running Intel optimized High Performance Linpack (HPL)

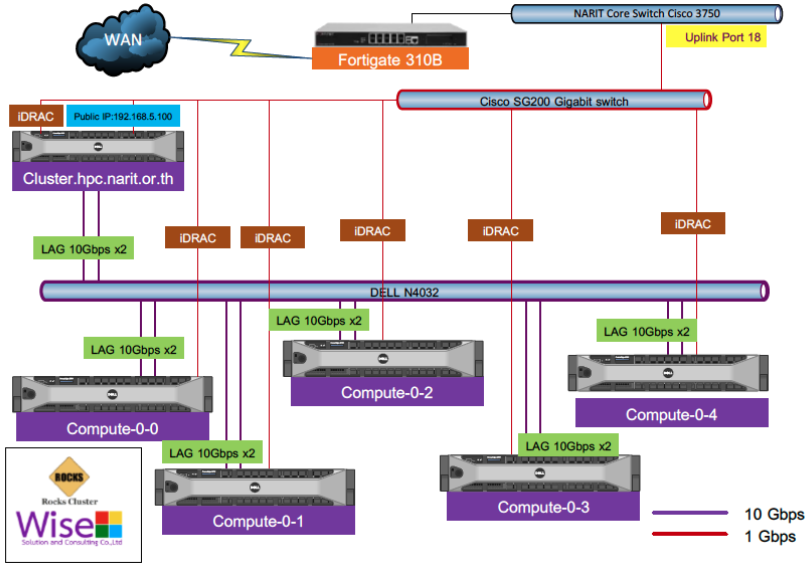
NARIT High Performance Computer (HPC) cluster

- Installed Feb-Mar 2015
- Testing and commissioning late Mar – April 2015
- Announced to Thai astronomical community during TNAM May 2015
- Open for community use in June/July 2015

CASTOR





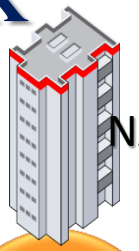


Hardware

- 1 Management node (12 cores, 2.4 GHz Intel Xeon E5-26xx v3, 32GB RAM)
- **5 compute nodes**, rack servers
  - Total 80 cores (5 x 16 cores 2.6 GHz Intel Xeon E5-26xx v3)
  - RAM 5 x 64 GB (320GB, 4GB per core) DDR4 RDIMM 2.13 GHz
  - Dual-port 10 Gbps Ethernet, with teaming connections
  - Each rack is compatible with up to 2 GPU cards upgrade
- Storage 7.2 TB SAS 10K rpm 6Gbps (RAID5, 2GB cache)
- Network Switch 10 Gigabit Ethernet
- Expected R_{max}= 2.26 TFLOPS

NARIT NETWORK

Diagram



NARIT HQ

Internet

True 100 Mbps Cable
True 100 Mbps Cable
TOT 6 Mbps Lease line

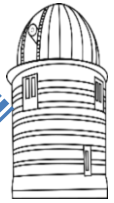
Firewall , Core Switch

18 Mbps

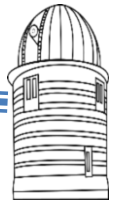
TOT IP-VPN Lease line

4 Mbps
3 Mbps
3 Mbps
3 Mbps
3 Mbps
4 Mbps

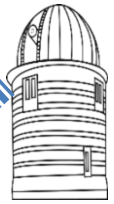
Thai National Observatory



Nakhon Ratchasima Observatory



Chachoengsao Observatory

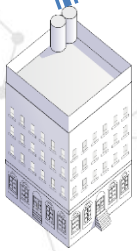


ศูนย์บริการข้อมูลสารสนเทศและฝึกอบรมทางดาราศาสตร์

Server , DATA

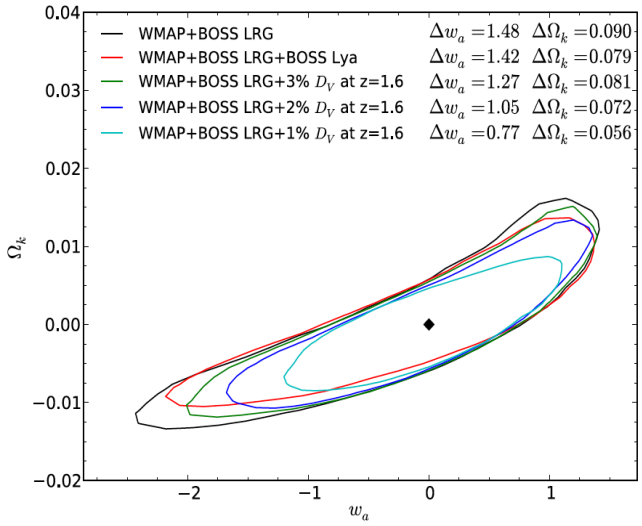
1 Gbps

True Colocation
NARIT Web Server
www.narit.or.th

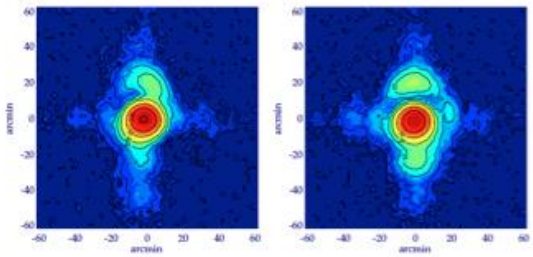


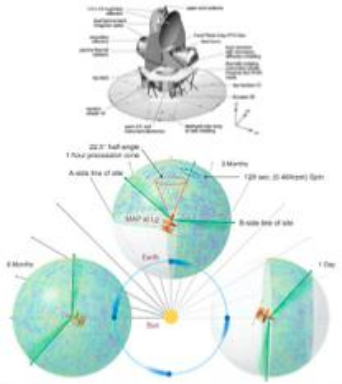
Astro Park (Backup Site)

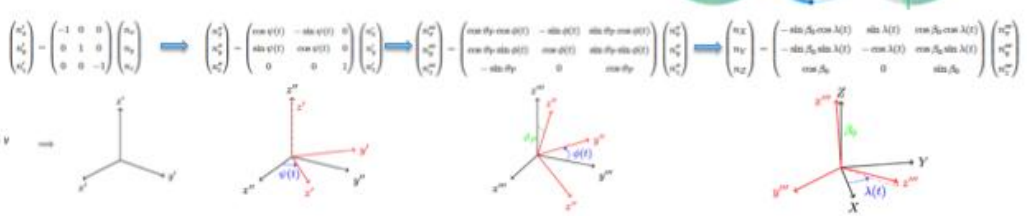
Bangkok coordinating office

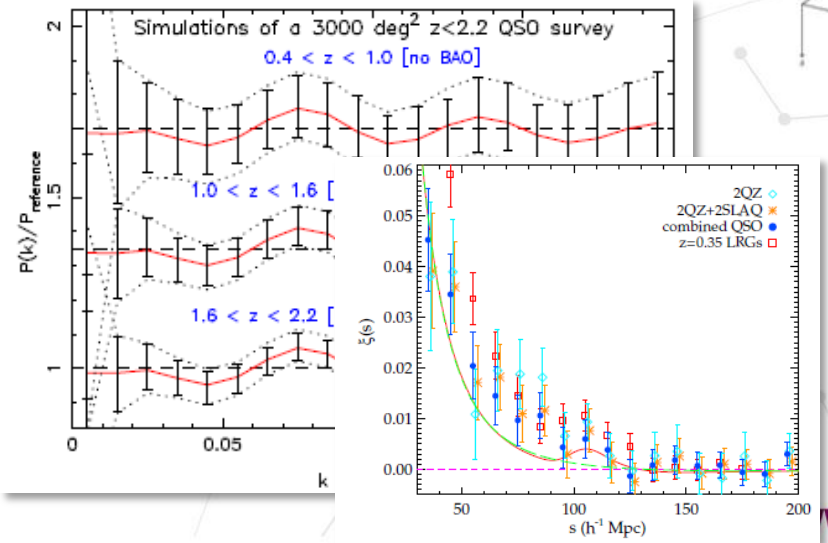


Cosmological Surveys and modelling Analysis (Dr. Sawangwit)

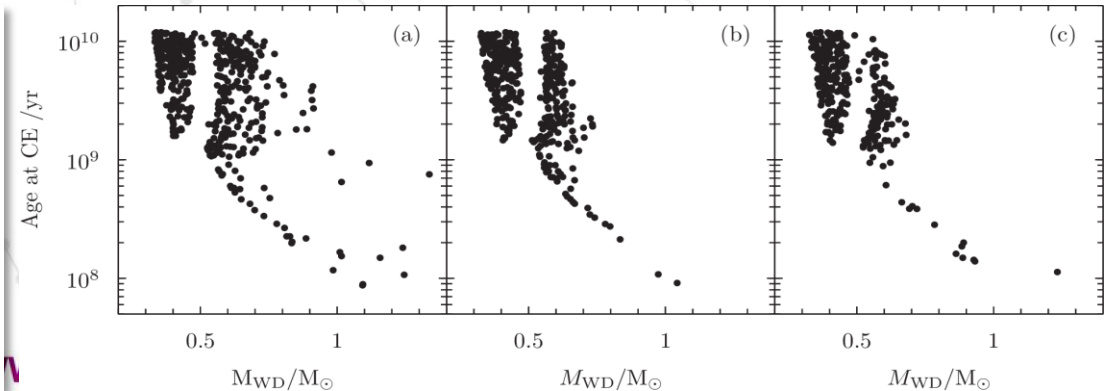


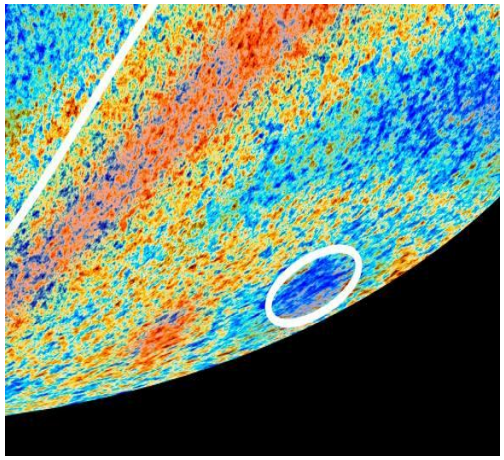






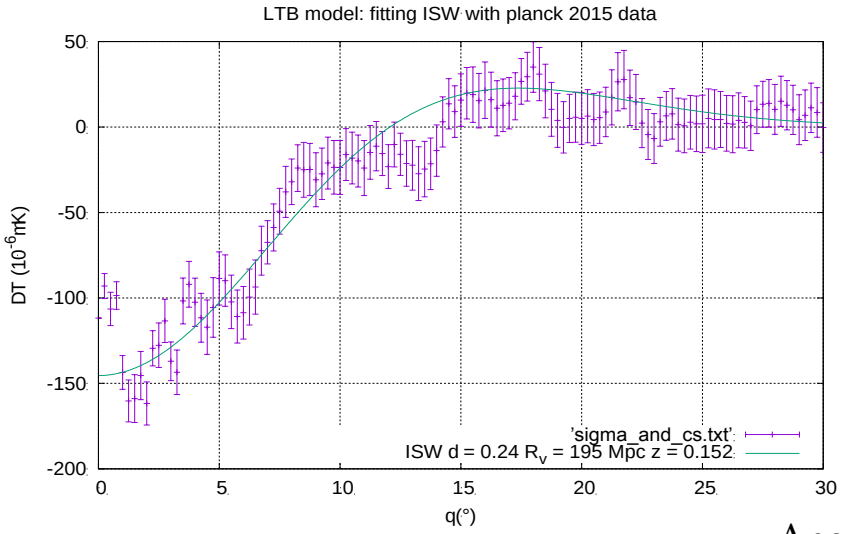
Stellar population Synthesis (Dr. Irawati)





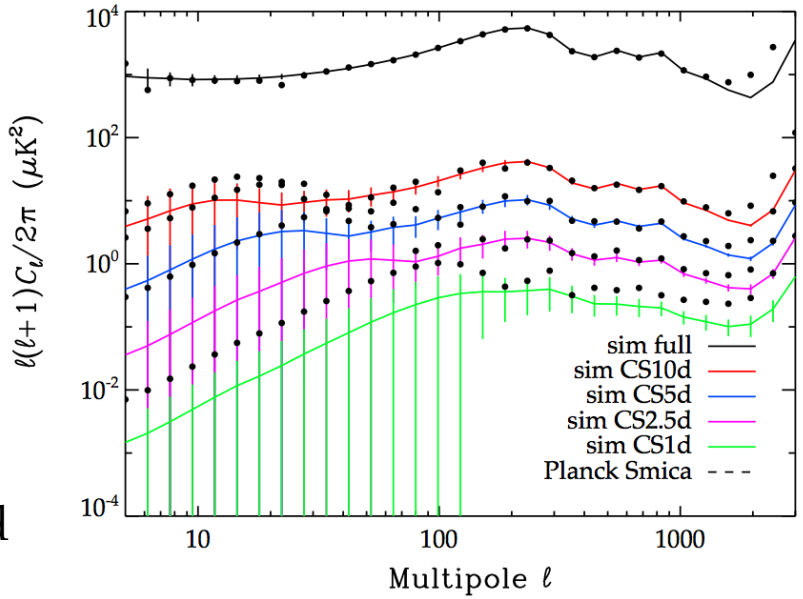
Planck CMB map

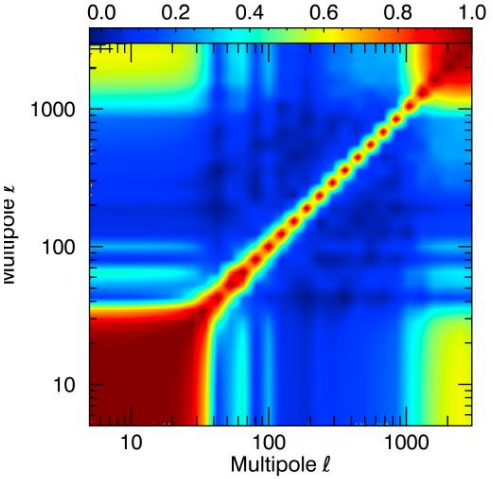
Example region of a void



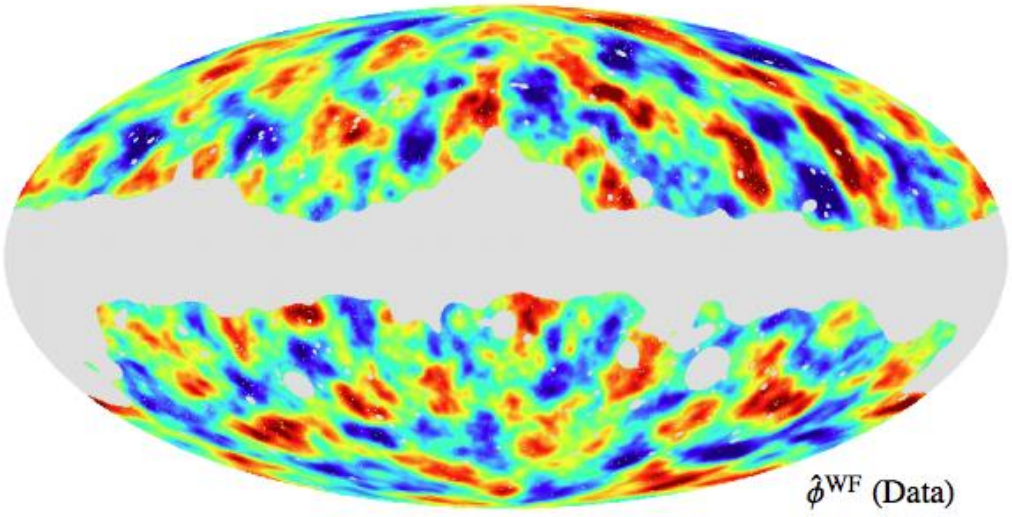
Temperature Profile fitted to a single Super-void model (Mr. Anut Sangkla, SUT)

Angular Power Spectrum & correlation matrix from 1000 simulations

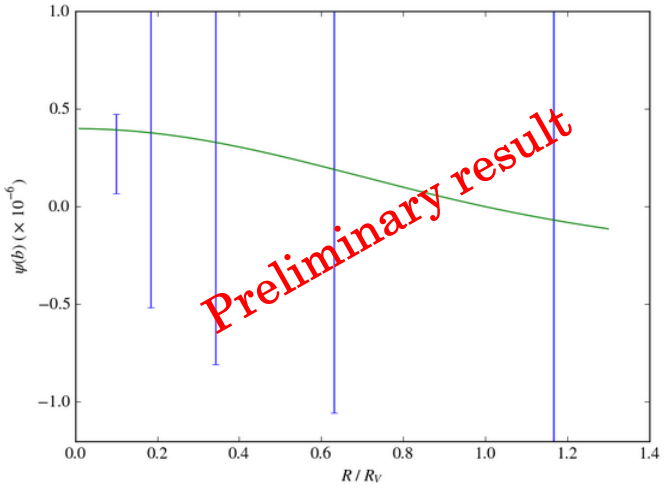




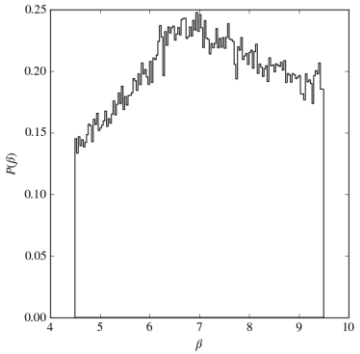
Gravitational lensing of the CMB by voids

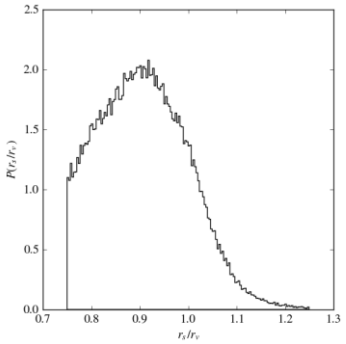


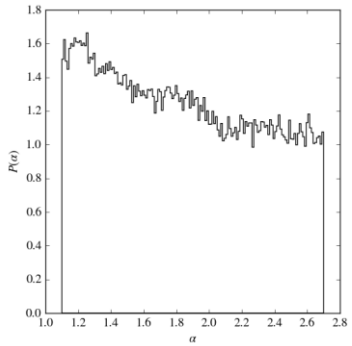
(Planck collaboration, 2015)

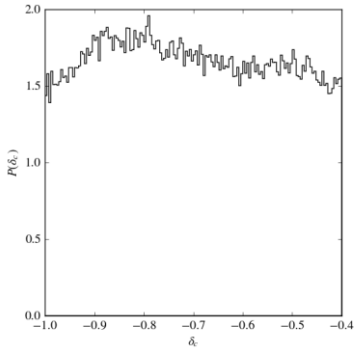


Monte Carlo Markov Chain results (preliminary) running with NARIT HPC



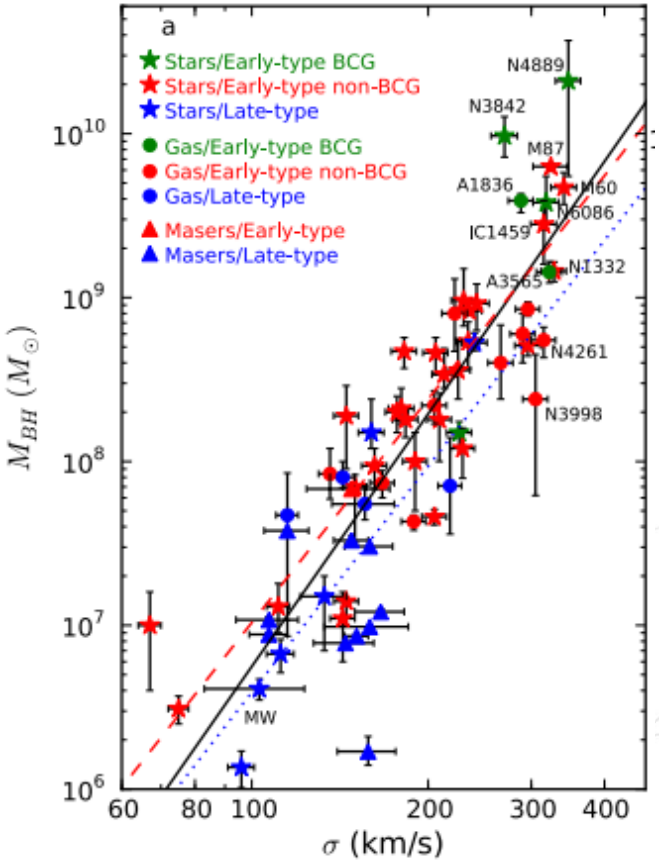






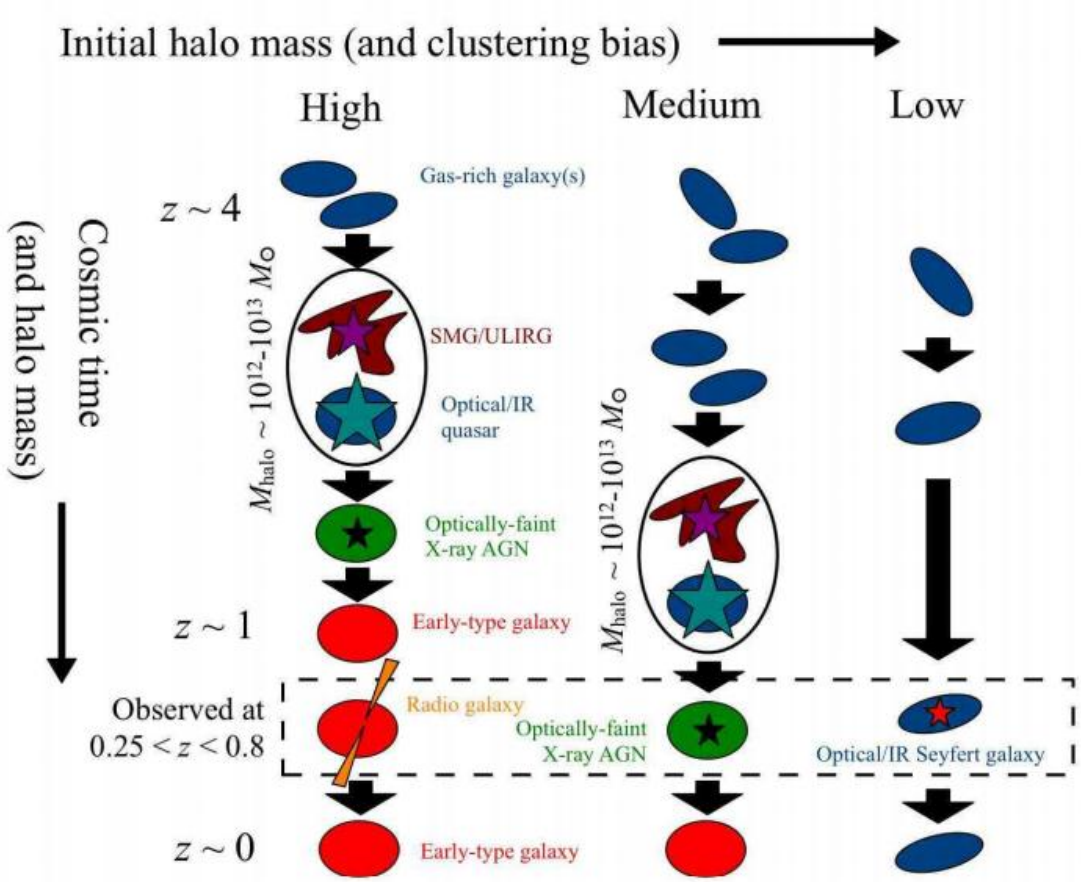
Galaxy evolution: AGN feedback

SMBH – Host galaxy co-evolution



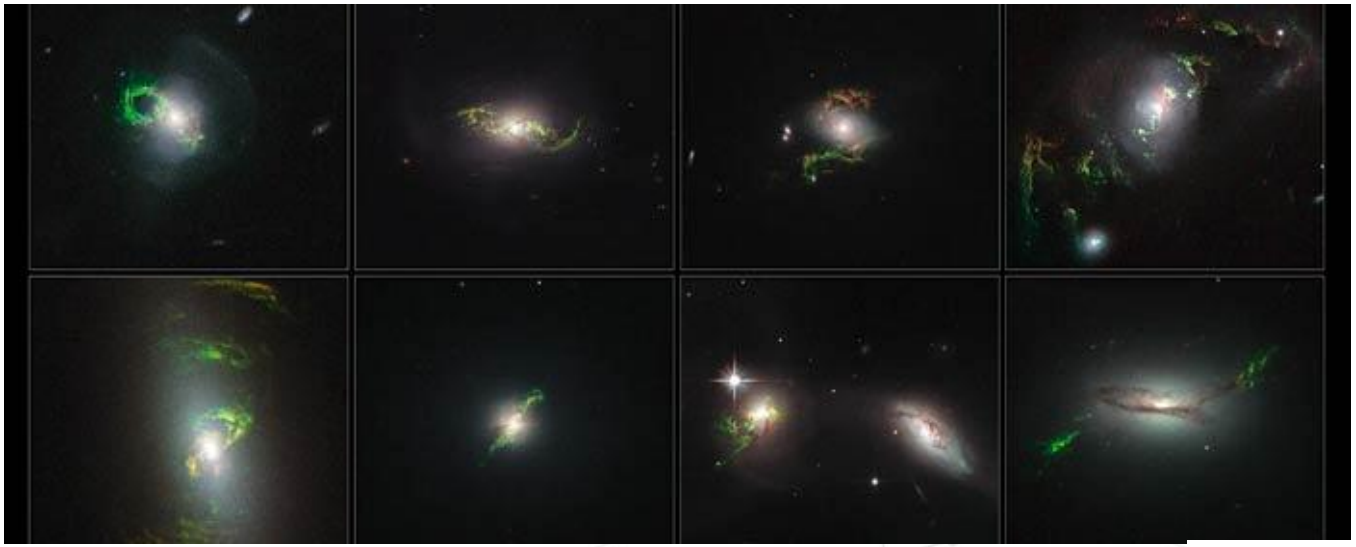
McConnell +(2011, Nature)

Broad and simplified picture

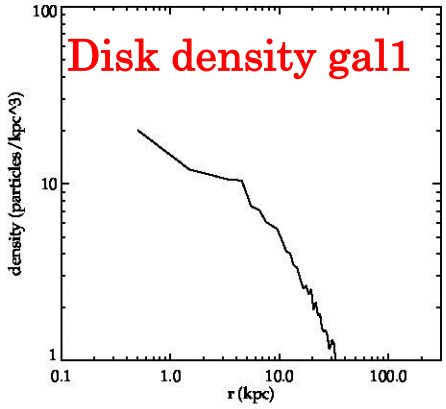


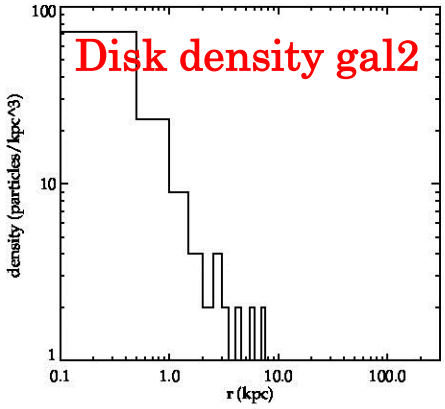
Hickox et al. (2009, ApJ)

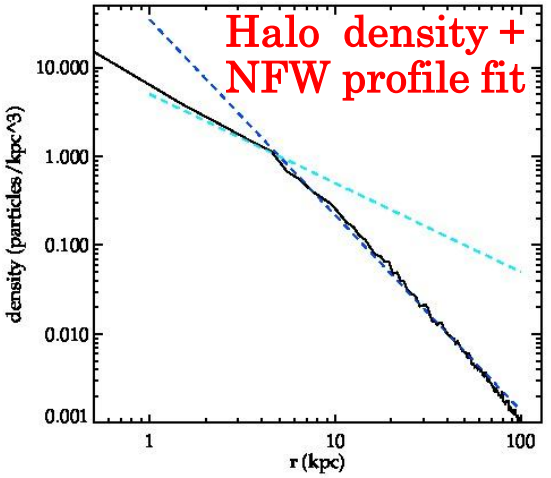
AGN feedback + interactions with IGM simulations



Images from HST
(Keel et al, 2015, ApJ)







Intermittent and Mode-switching Pulsars

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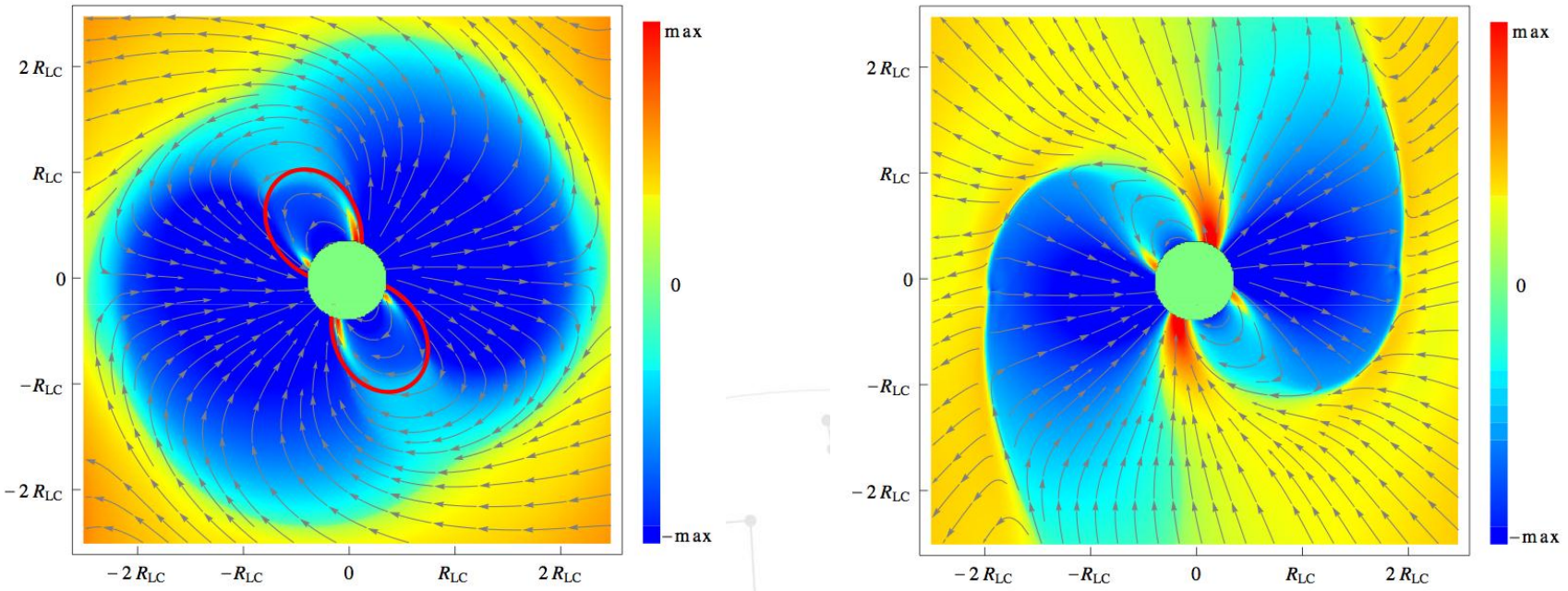

Simulation of the magnetosphere in the off and on state (Li et al. 2012)

"Pulsar Search with PMPS dataset" search through 10TB of data to look For pulsar in the radio data