Digitális égboltfelmérések- a számokká alakított fény

Kiss László
MTA CSFK

Polaris Csillagvizsgáló, 2015. október 27.

A csillagászat “nagy kérdései”

- **Mikor és hogyan keletkezett a Világegyetem? Mi a mindenség eredete?**
- **Hogyan alakulnak ki a kozmikus struktúrák (bolygók, csillagok, galaxisok)?**
- **Mennyire egyedi a Föld? Egyedül vagyunk az Univerzumban?**

A csillagászat mért mennyiségei

- **Égi pozíciók** - koordináták
- **Fényesség** - pontforrások és kiterjedt égitestek
- **Színkép** - folytonos és vonalas spektrumok
- **Nagy minták** - égfoltfelmérések

A minta növelésével új fizikai jelenségek fedezhetők fel!

Égboltfelmérések

Nagyságrendi ugrások:

- 5000 csillag: szabadszemes csillagok (ókori görögök)
- 100.000 csillag: távcsöves megfigyelések vizuális technikával (19. század) - a Tejútrendszer szerkezete
- 10 millió csillag: fotografikus felmérések (1950-es évektől)
- 1 milliárd csillag: digitális felmérések (2000-től)
- Pánkromatikus és spektroszkópiai felmérések: precíziós kozmológia (2020-)

Galaktikus archeológia

- A nagy vöröseltolódású Univerzum itt helyben
- A Tejútrendszer szerkezete
- Felmérések: képek, színek, spektrumok, távolságok
- Múltbéli események rekonstruálása (pl. galaktikus kannibalizmus)

EVIDENCE FROM THE MOTIONS OF OLD STARS THAT THE GALAXY COLLAPSED

O. J. EGGEN, D. LYNDEN-BELL,* AND A. R. SANDAGE
Mount Wilson and Palomar Observatories
Carnegie Institution of Washington, California Institute of Technology

Received May 17, 1962

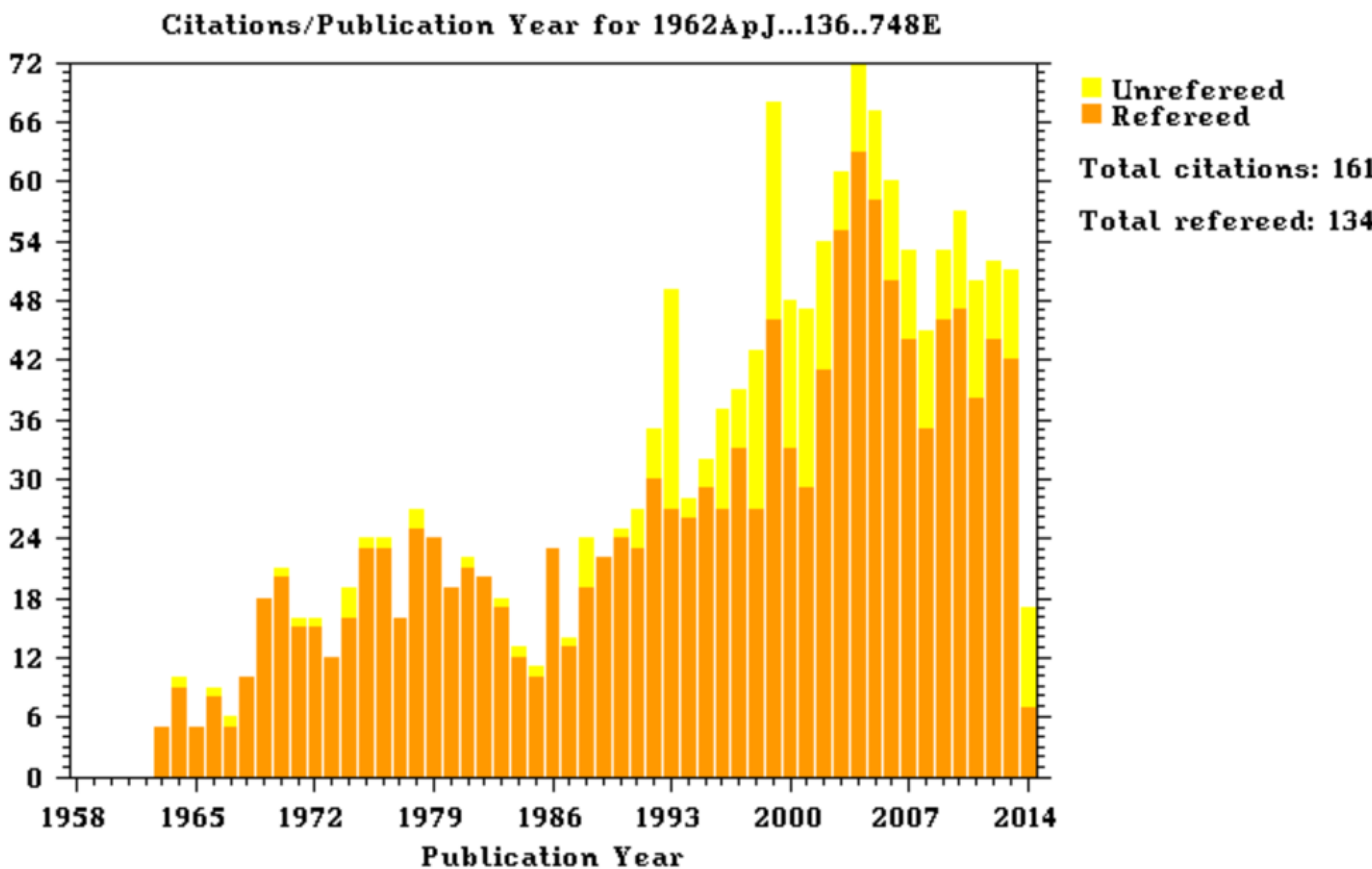
ABSTRACT

The (U, V, W)-velocity vectors for 221 well-observed dwarf stars have been used to compute the eccentricities and angular momenta of the galactic orbits in a model galaxy. It is shown that the eccentricity and the observed ultraviolet excess are strongly correlated. The stars with the largest excess (i.e., lowest metal abundance) are invariably moving in highly elliptical orbits, whereas stars with little or no excess move in nearly circular orbits. Correlations also exist between the ultraviolet excess and the W-velocity. Finally, the excess and the angular momentum are correlated; stars with large ultraviolet excesses have small angular momenta.

These correlations are discussed in terms of the dynamics of a collapsing galaxy. The data require that the oldest stars were formed out of gas falling toward the galactic center in the radial direction and collapsing from the halo onto the plane. The collapse was very rapid and only a few times 10^8 years were required for the gas to attain circular orbits in equilibrium (i e., gravitational attraction balanced by centrifugal acceleration). The scale of the collapse is tentatively estimated to be at least 10 in the radial direction and 25 in the Z-direction. The initial contraction must have begun near the time of formation of the first stars, some 10^{10} years ago.

I. INTRODUCTION

Beginning with Strömberg's early investigations of stellar motions, it has become


Citations/Publication Year for 1962ApJ...136..748E
72
66
60
54
48
42
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12
6
0
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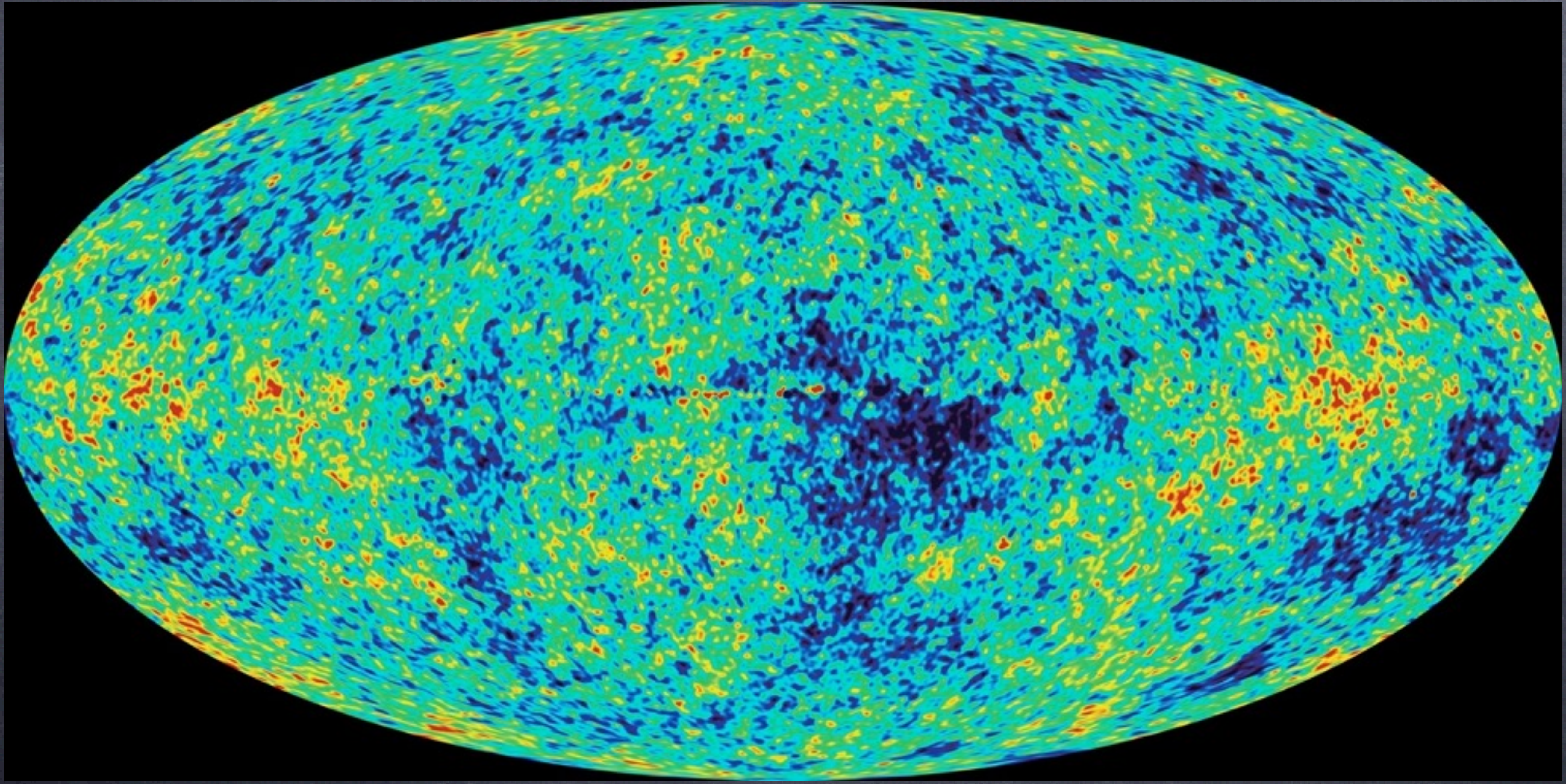
1965
1972
1979
1986
1993
2000
2007
2014
Publication Year
Unrefereed
Refereed
Total citations: 161
Total refereed: 134

WMAP eredmények a kozmikus mikrohullámú háttérsugárzásról: a korai fluktuációk irány szerinti eloszlása



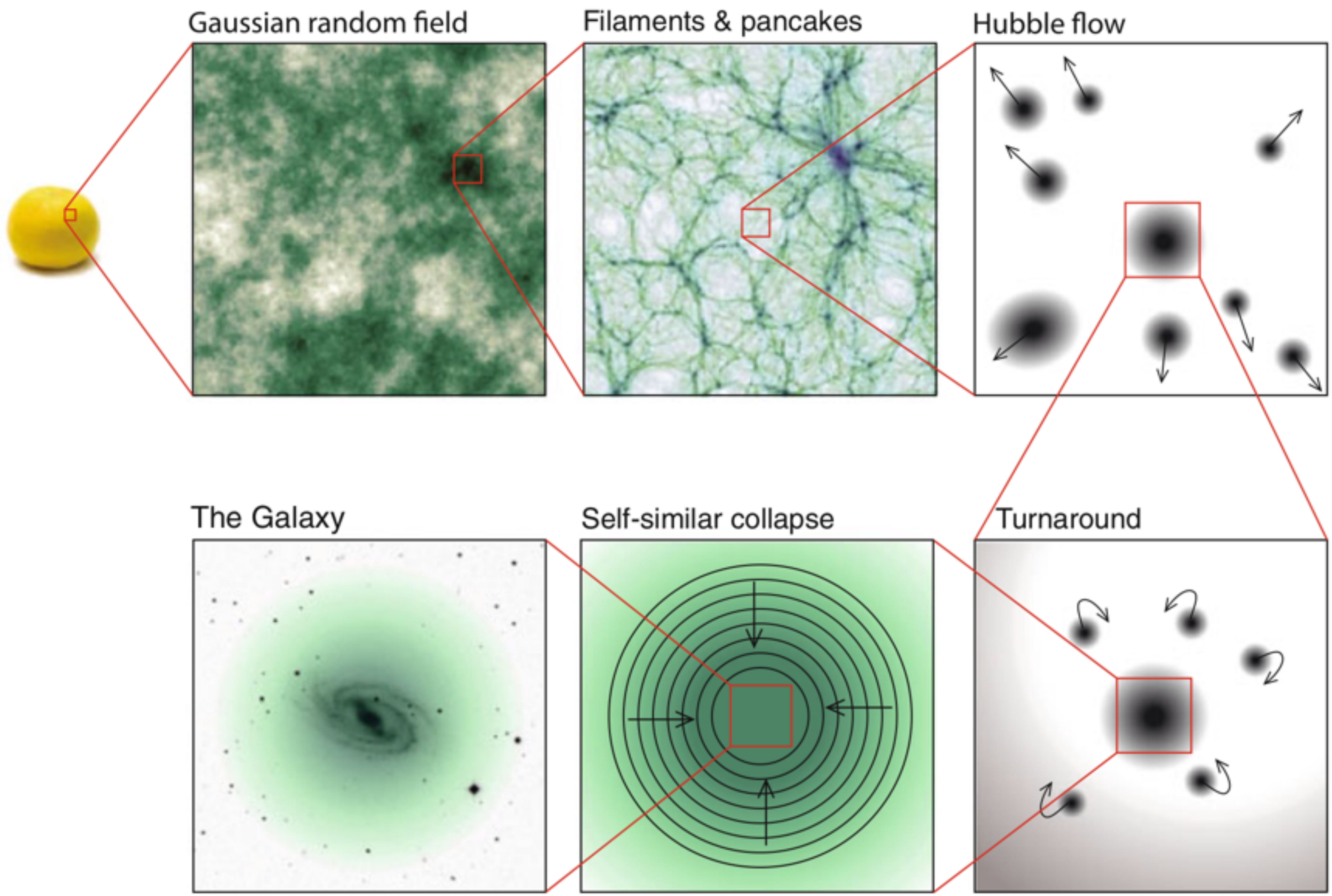
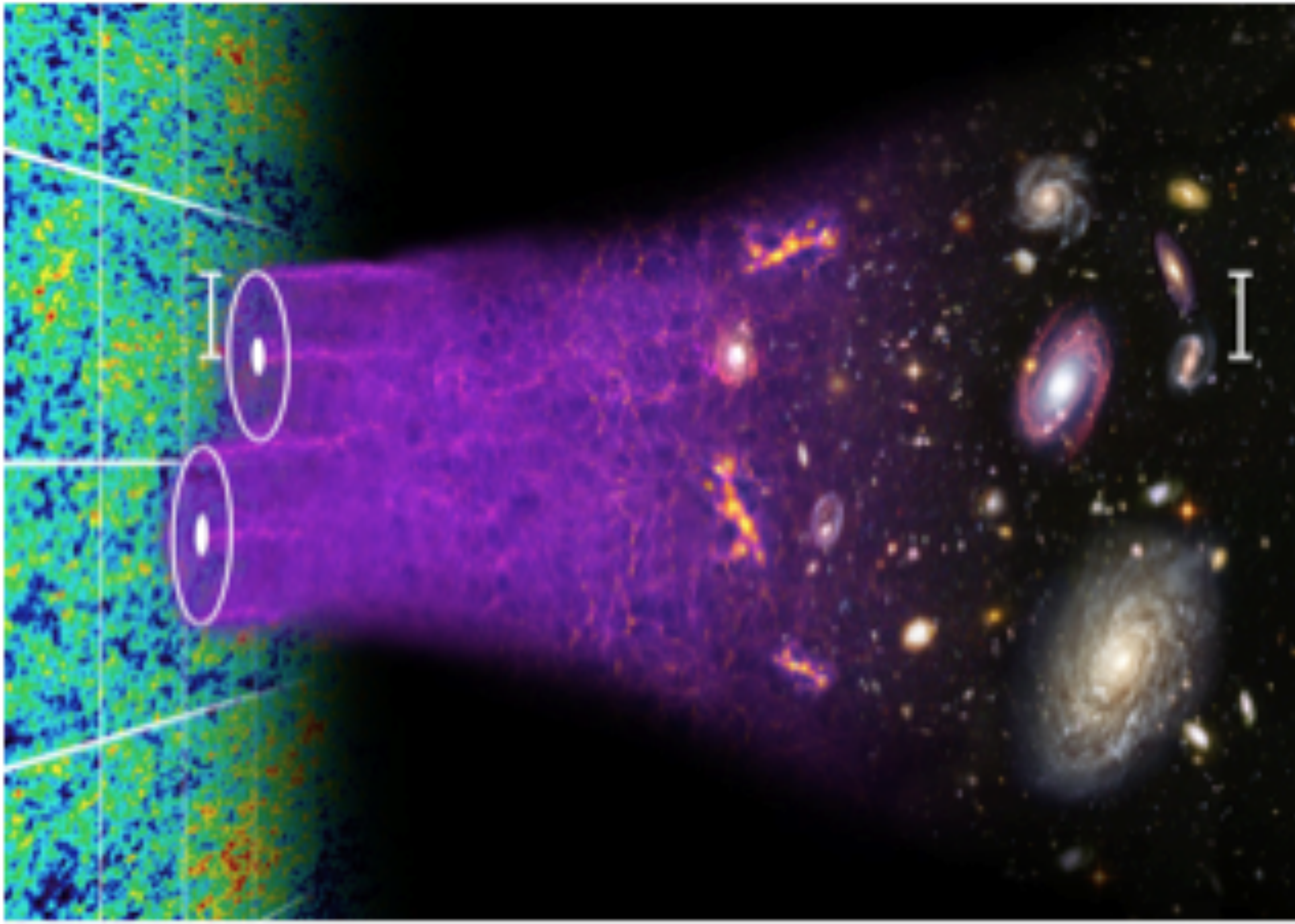


Fig. 1.15 A sequence of images depicting the major stages in the evolution of the Galaxy from the initial fluctuation spectrum—see text. This was preceded by inflation when the Universe went from sub-atomic scales to the size of a grapefruit in less than a picosecond



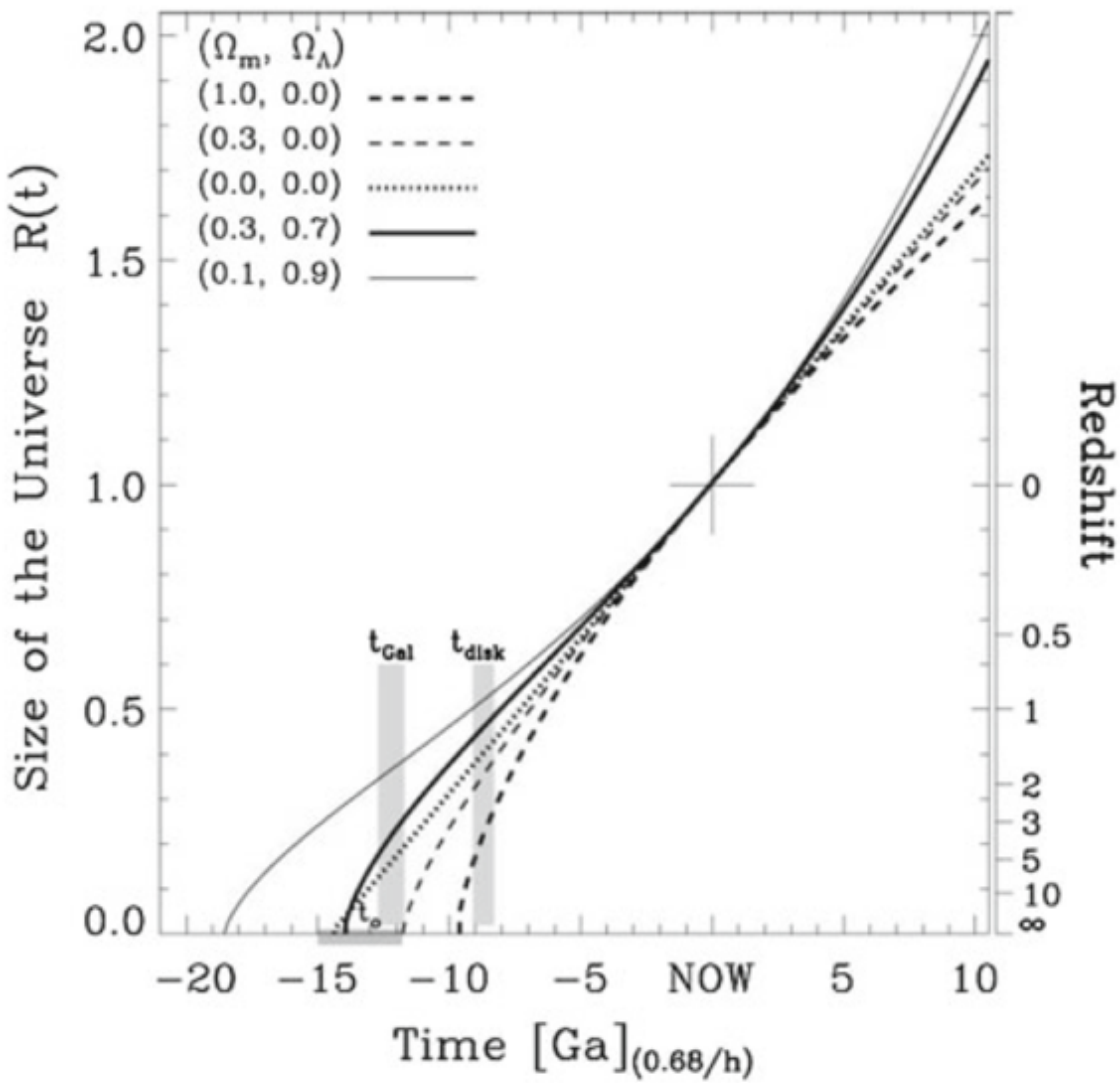


Fig. 1.14 Look-back time as a function of redshift and the size of the Universe for five different world models. The approximate ages of the Galactic halo and disk are indicated by hatched regions (we thank C. Lineweaver for modifying an earlier version of this figure for us)

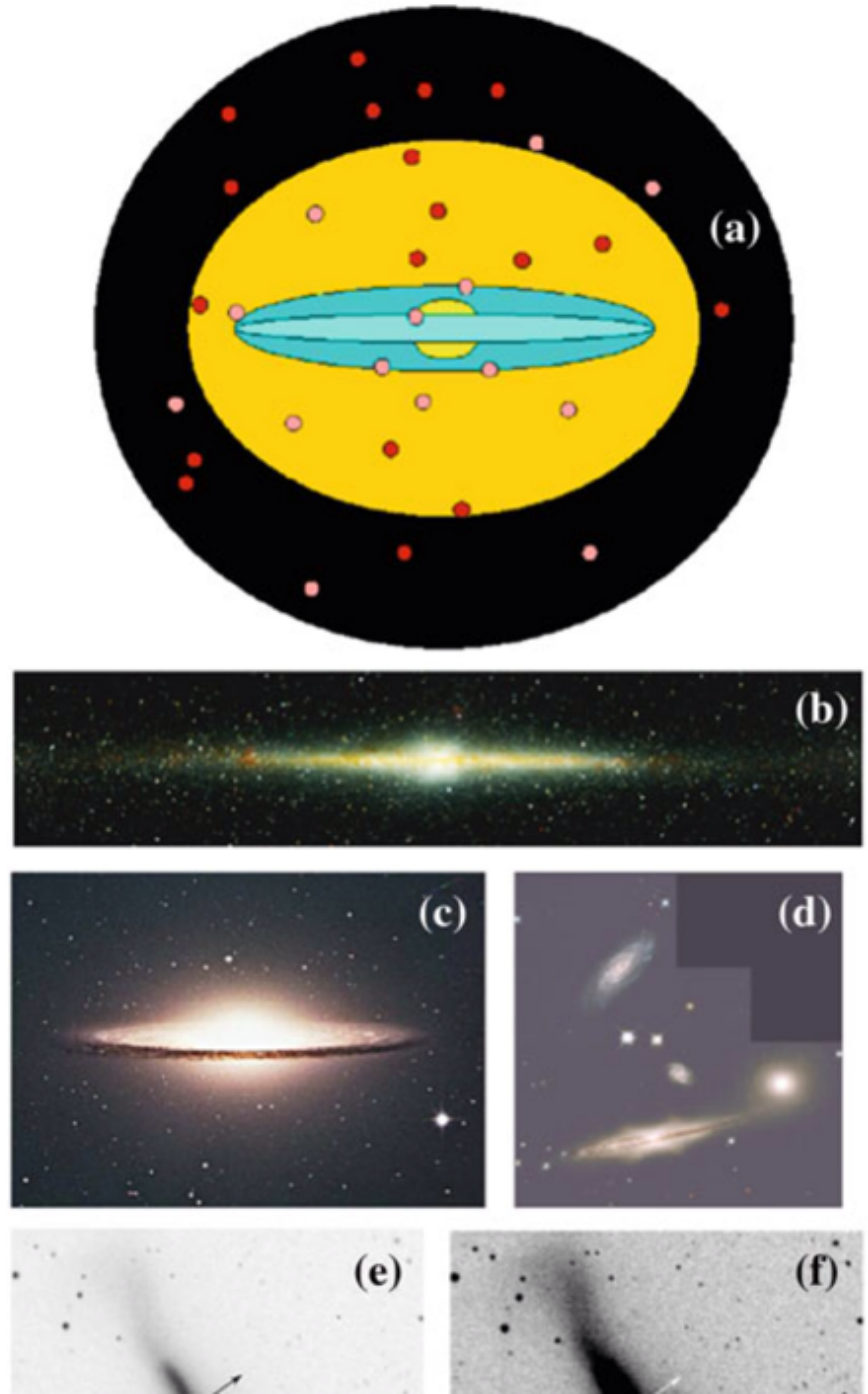
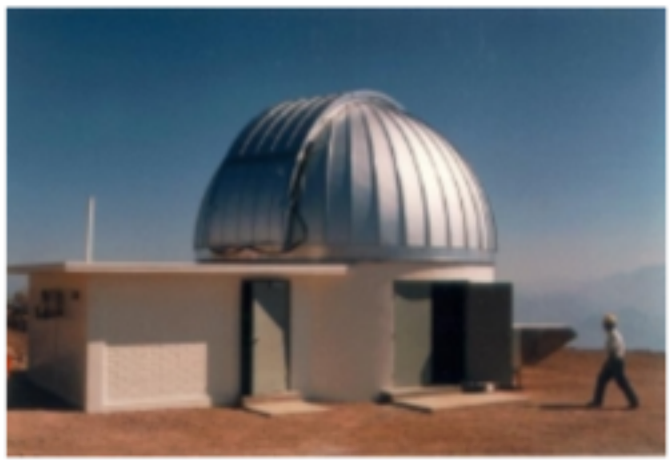
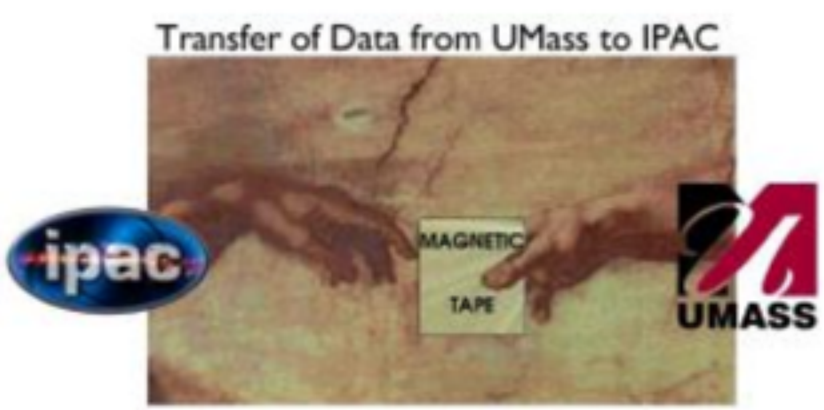


Fig. 1.19 **a** Sketch of Milky Way showing the stellar disk (*light blue*), thick disk (*dark blue*), stellar bulge (*yellow*), stellar halo (*mustard yellow*), dark halo (*black*) and globular cluster system (*filled circles*). The radius of the stellar disk is roughly 15 kpc. The baryon and dark halos extend to a radius of at least 100 kpc. **b** Infrared image of the Milky Way taken by the DIRBE instrument on board the Cosmic Background Explorer (COBE) Satellite (we acknowledge the NASA Goddard Space Flight Center and the COBE Science Working Group for this image). **c** M104, a normal disk galaxy with a large stellar bulge (from AAO). **d** Hubble Heritage image of the compact group Hickson 87; one galaxy has a peanut-shaped stellar bulge due to dynamical interaction with other group members. **e** Image of the SO galaxy NGC 4762 (Digital Sky Survey) shows its thin disk and stellar bulge. **f** A deeper image of NGC 4762 (DSS) shows

The two 2MASS Cassegrain-focus equatorial-mount reflector telescopes are identical in construction, and each has a primary mirror diameter of 1.3 meters. One telescope is located on Mt. Hopkins in Arizona (*left*), and the other on Cerro Tololo, along the Andes mountains in Chile (facility seen at *right*). Each telescope was equipped with a three-channel camera, each channel consisting of a 256-pixel × 256-pixel detector array, capable of observing the sky simultaneously at wavelength bands centered at wavelengths 1.25 micrometers, 1.65 micrometers, and 2.17 micrometers. (1 micrometer, abbreviated 1 µm, is one-millionth of a meter in length.) These bands are colloquially known by astronomers as "*J*", "*H*", and "*K-short*" (or "K_s"). The refrigerated dewar containing the camera is the brass canister hanging below the telescope. Computers operated each telescope's motion with respect to the sky; the motion of the much-smaller secondary mirror (seen near the top of the telescope); and the dark shutters of the three channels and digital "readout" of the three detector arrays.





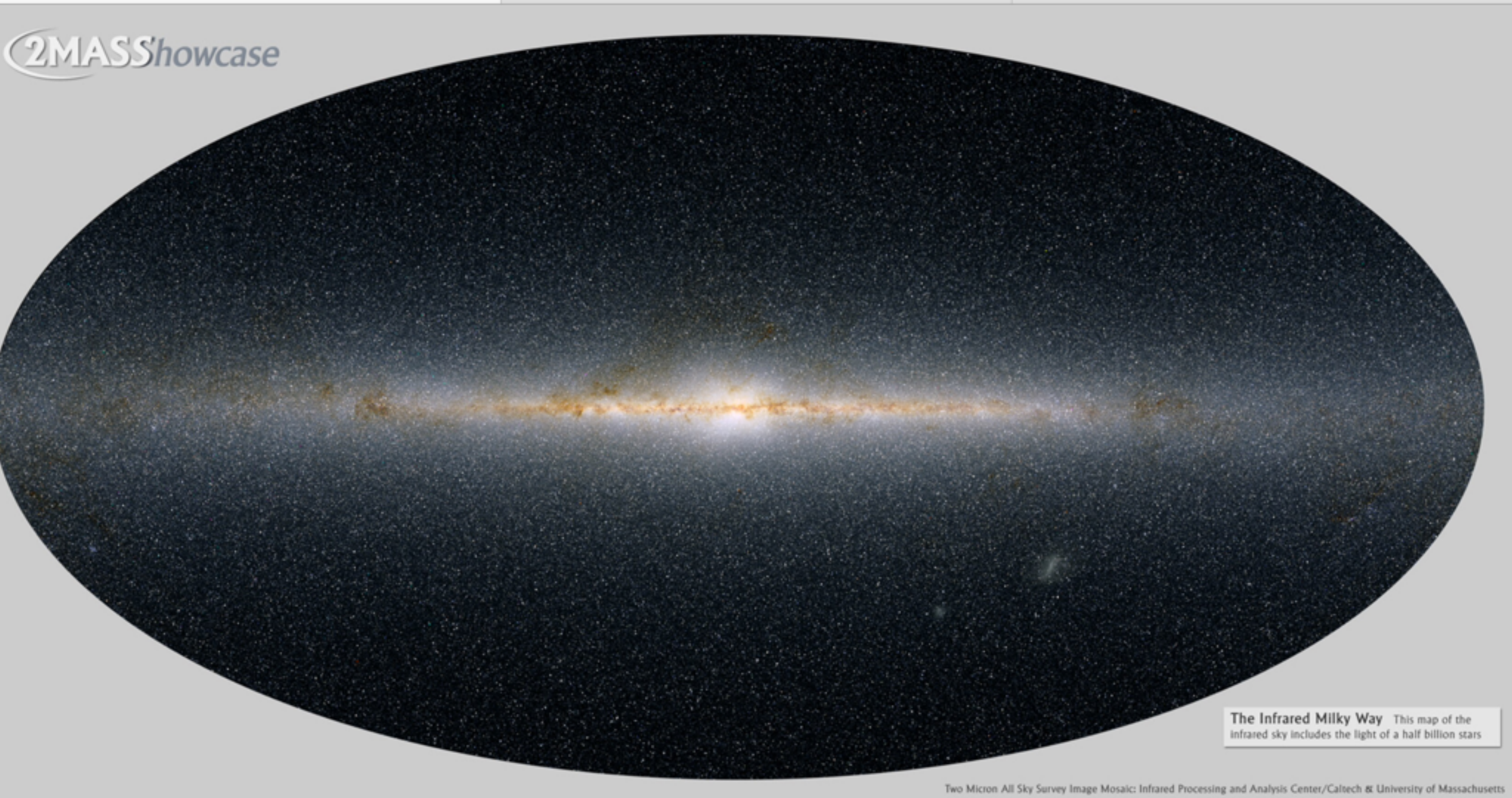
An observing "schedule file" was sent down from UMass to the telescope operator at each of the two facilities for each night. Computers used these files to automatically control the telescopes throughout the night. The operator at each facility monitored the telescope operations and the acquiring of data. Each morning the digital data were written to magnetic tape storage, and the tapes were sent to IPAC. Each night's data were put through an automated "*pipeline*" of computer programs, which convert the raw images made by the telescopes into final *processed* images and catalogs containing star and galaxy brightnesses and positions. These data were assessed for quality, through some human intervention. If these data passed muster, they were included as part of the enormous 2MASS *database*, from which a *digital image atlas of the sky* and *catalogs* of point sources and extended sources, freely available to astronomers and the public at large, were assembled and distributed.

iPad 22:53 39%

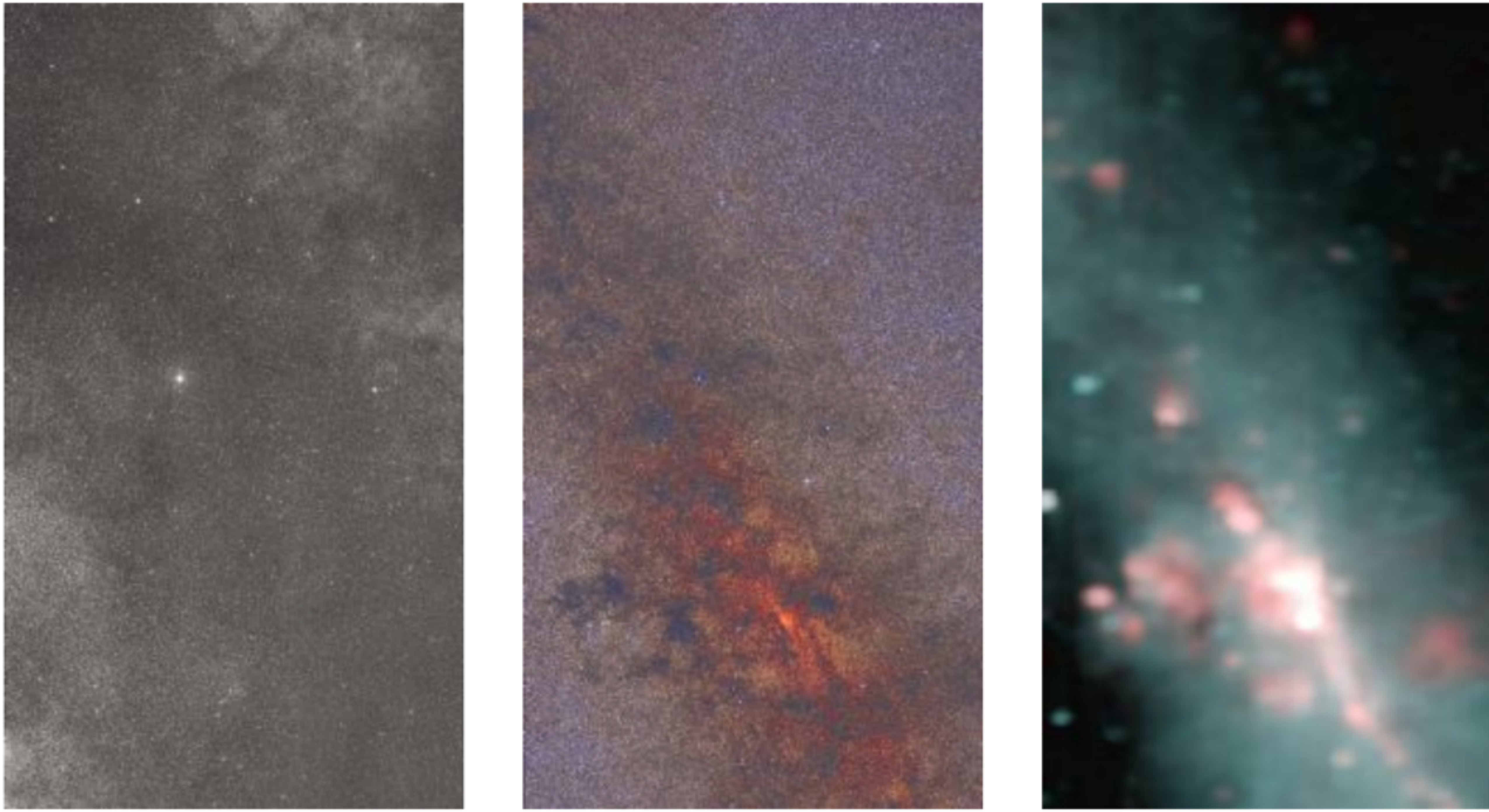
ipac.caltech.edu

Apple Yahoo! Google Maps YouTube Wikipedia Astropub Instapaper: Read Later Csatornák - Magyar online TV | EuropeStream.tv

Allsky-Stars_med2.jpg 1 700×875 képpont | milky way - Google Search | 1962ApJ...136..748E



POSS	2MASS	IRAS



Optical	Near-Infrared	Far-Infrared

Sloan Digital Sky Survey

Mapping the Universe

The Sloan Digital Sky Survey

The Sloan Digital Sky Survey (SDSS) is one of the most ambitious and influential surveys in the history of astronomy. Over eight years of operations (SDSS-I, 2000-2005; SDSS-II, 2005-2008), it obtained deep, multi-color images covering more than a quarter of the sky and created 3-dimensional maps containing more than 930,000 galaxies and more than 120,000 quasars.

SDSS data have been released to the scientific community and the general public in annual increments, with the final public data release from SDSS-II occurring in October 2008. That release, Data Release 7, is available through this website.

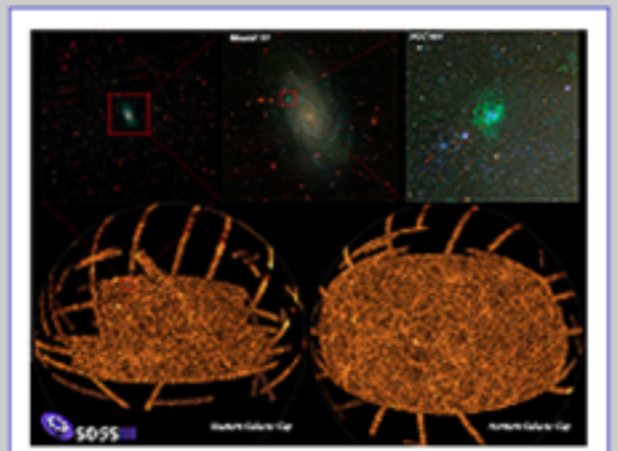
Meanwhile, SDSS is continuing with the Third Sloan Digital Sky Survey (SDSS-III), a program of four new surveys using SDSS facilities. SDSS-III began observations in July 2008 and released Data Release 8 in January 2011, Data Release 9 in August 2012, and Data Release 10 in July 2013. SDSS-III will continue operating and releasing data through 2014.

Data Release 10 contains the first release of APOGEE infrared Galactic spectroscopy as well as cumulative updates to the BOSS optical extragalactic spectroscopy archive.

Data Release 9 contains the first release of BOSS spectroscopy to the public as well as

Images of the SDSS

(click for more information)



The Final Survey

The Whirlpool Galaxy (M51)

Sloan Digital Sky Survey

- Új-Mexikó, 2,5m-es távcső Apache Point-ban
- Képalkotás öt színben több mint 100 millió objektumra
- Csillagok, galaxisok, kvazárok színképei
- Erős magyar részvétel (Szalay Sándor - JHU, Csabai István - ELTE és diákjaik)

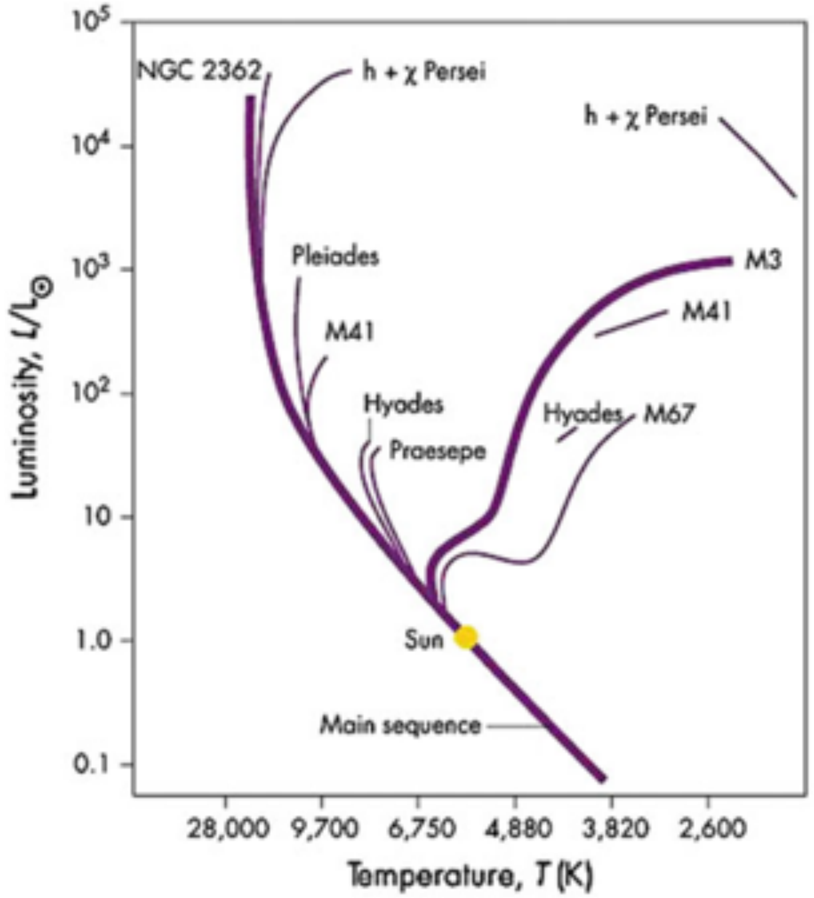
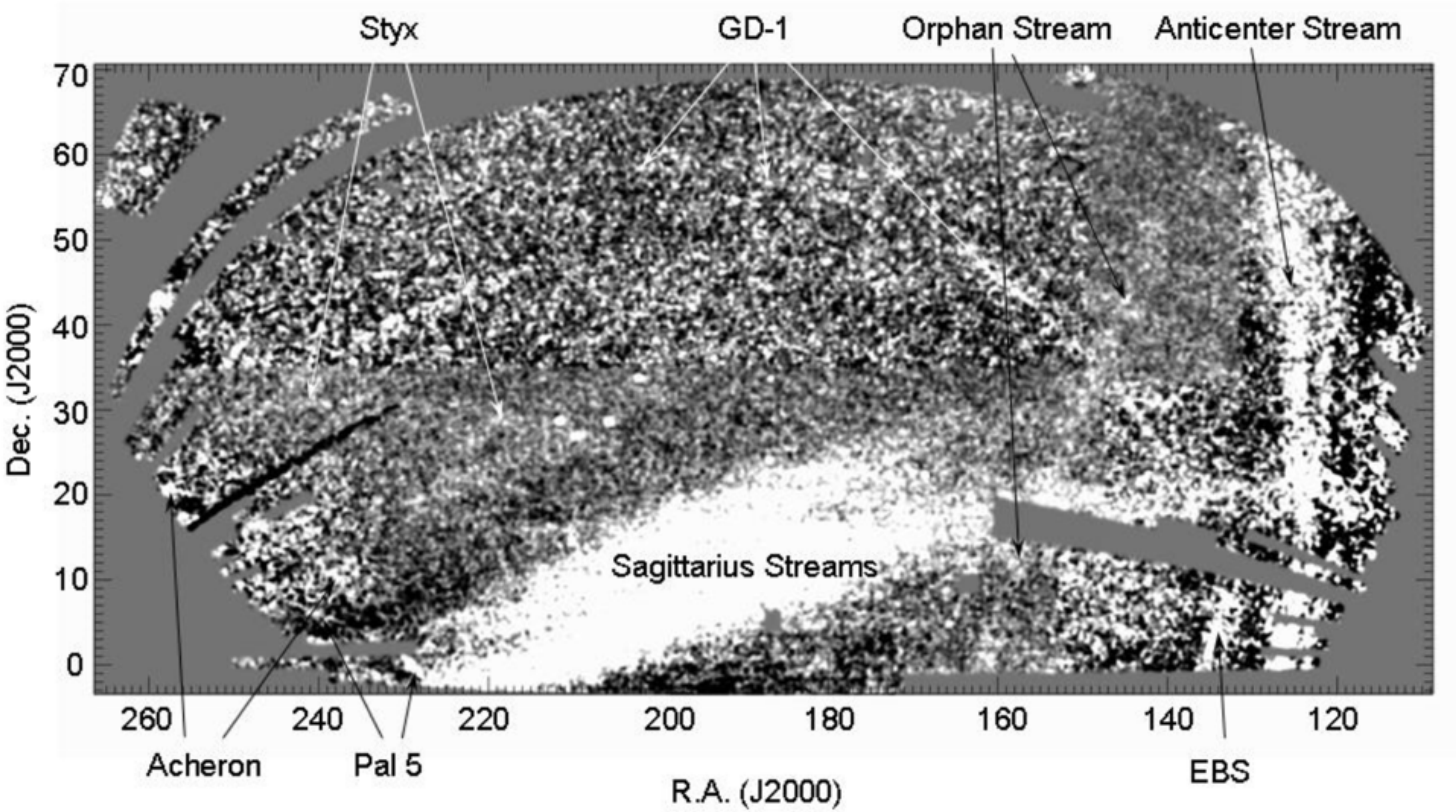
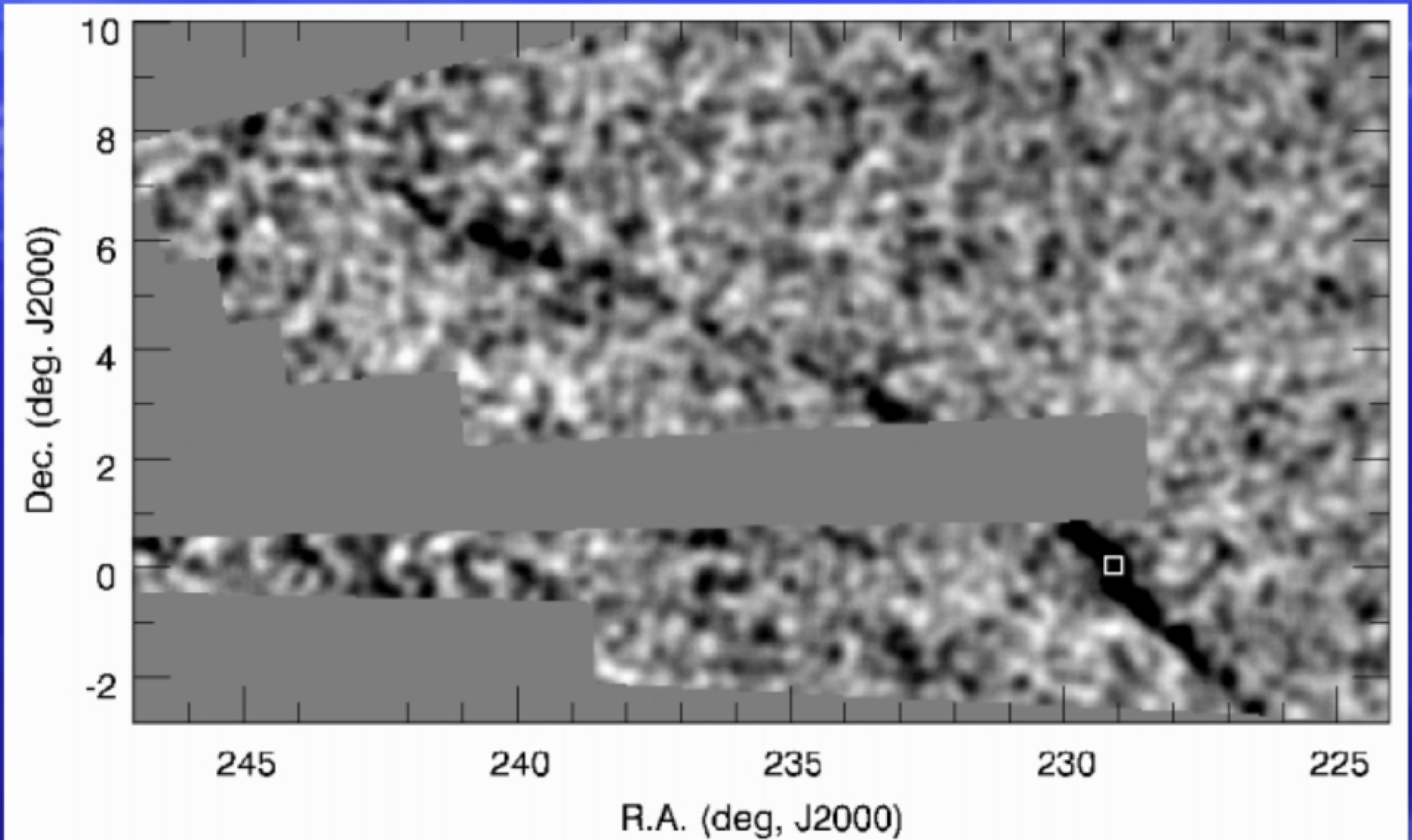


Fig. 1.21 *Upper* Hertzsprung-Russell diagram for stellar clusters over a wide range in age. *Lower* CFHT imaging of two open clusters M35 (NE) and NGC 2158 (SW) in Gemini. The young cluster M35 (NGC 2168) has a mass of roughly 2500 $M_{\odot}$ and is 850 pc from the Sun. The massive cluster NGC 2158 is four times further away and about 1 Gyr old



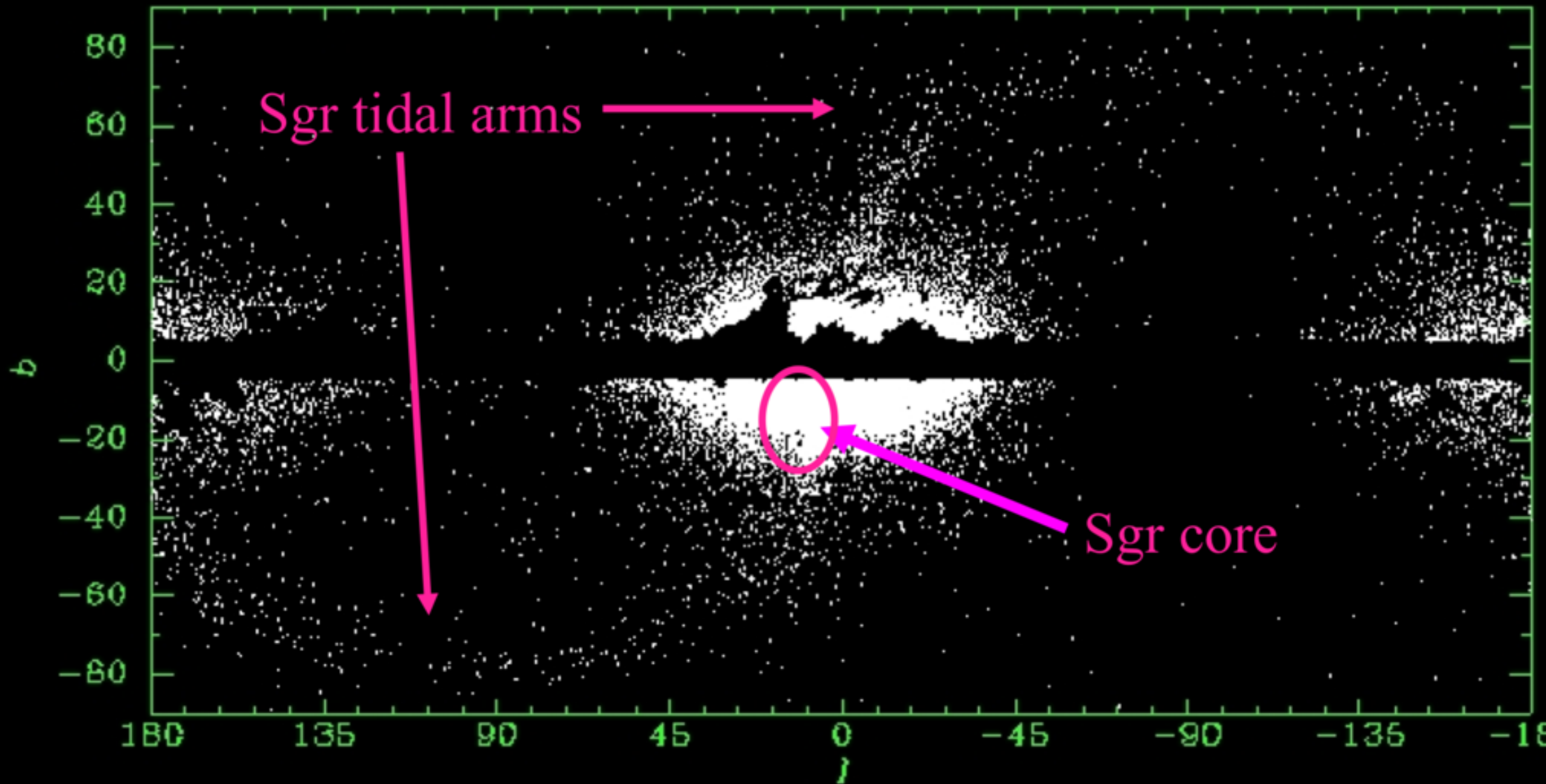
Styx
GD-1
Orphan Stream
Anticenter Stream
70
60
50
40
30
20
10
0
Dec. (J2000)
Sagittarius Streams
260
240
220
200
180
160
140
120
Acheron
Pal 5
EBS
R.A. (J2000)



Grillmair & Dionatos 2006

Sagittarius dSph cont'd

All-sky view of 2MASS M giant star distribution



Majewski et al. 2003

Table 1 Known Distant Galactic Streams

Designation	Progenitor	Selected References
Sagittarius	Sagittarius Dwarf Galaxy	Ibata et al. 1994, Mateo et al. 1996, Alard 1996, Toten & Irwin, 1998, Ibata et al. 2001, Martinez-Delgado et al. 2004, Majewski et al. 2004, Vivas et al. 2005, Belokurov et al. 2006b, Fellhauer et al. 2006, Bellazzini et al. 2006, Chou, M-Y et al. 2007, Law et al. 2009
Virgo Stellar Stream	NGC 2419?	Vivas et al. 2001, Duffau et al, 2006, Newberg et al. 2007
Palomar 5	Palomar 5	Odenkirchen et al. 2001, 2003, 2009, Rockosi et al. 2002, Grillmair & Dionatos 2006b
Monoceros Ring	Unknown (dwarf galaxy?)	Newberg et al. 2002, Yanny et al. 2003, Ibata et al. 2003, Rocha-Pinto et al. 2003, Penarrubia et al. 2005
NGC 5466	NGC 5466	Belokurov et al. 2006a, Grillmair & Johnson 2006, Fellhauer 2007
Orphan Stream	Unknown (dwarf galaxy?)	Grillmair 2006a, Belokurov 2007 Fellhauer et al. 2007, Sales et al. 2008, Newberg et al. 2010
GD-1	Unknown (globular cluster?)	Grillmair & Dionatos 2006b, Willet et al. 2009, Koposov, Rix, & Hogg 2009
AntiCenter Stream	Unknown (dwarf galaxy?)	Grillmair 2006b, Grillmair, Carlin, & Majewski 2008
EBS	Unknown (dwarf galaxy?)	Grillmair 2006, Grillmair, Carlin, & Majewski 2008
Acheron	Unknown (globular cluster?)	Grillmair 2009
Cocytos	Unknown (globular cluster?)	Grillmair 2009
Lethe	Unknown (globular cluster?)	Grillmair 2009
Styx	Bootes III dwarf?	Grillmair 2009
Cetus Polar Stream	NGC 5824?	Newberg, Yanny, & Willett 2009

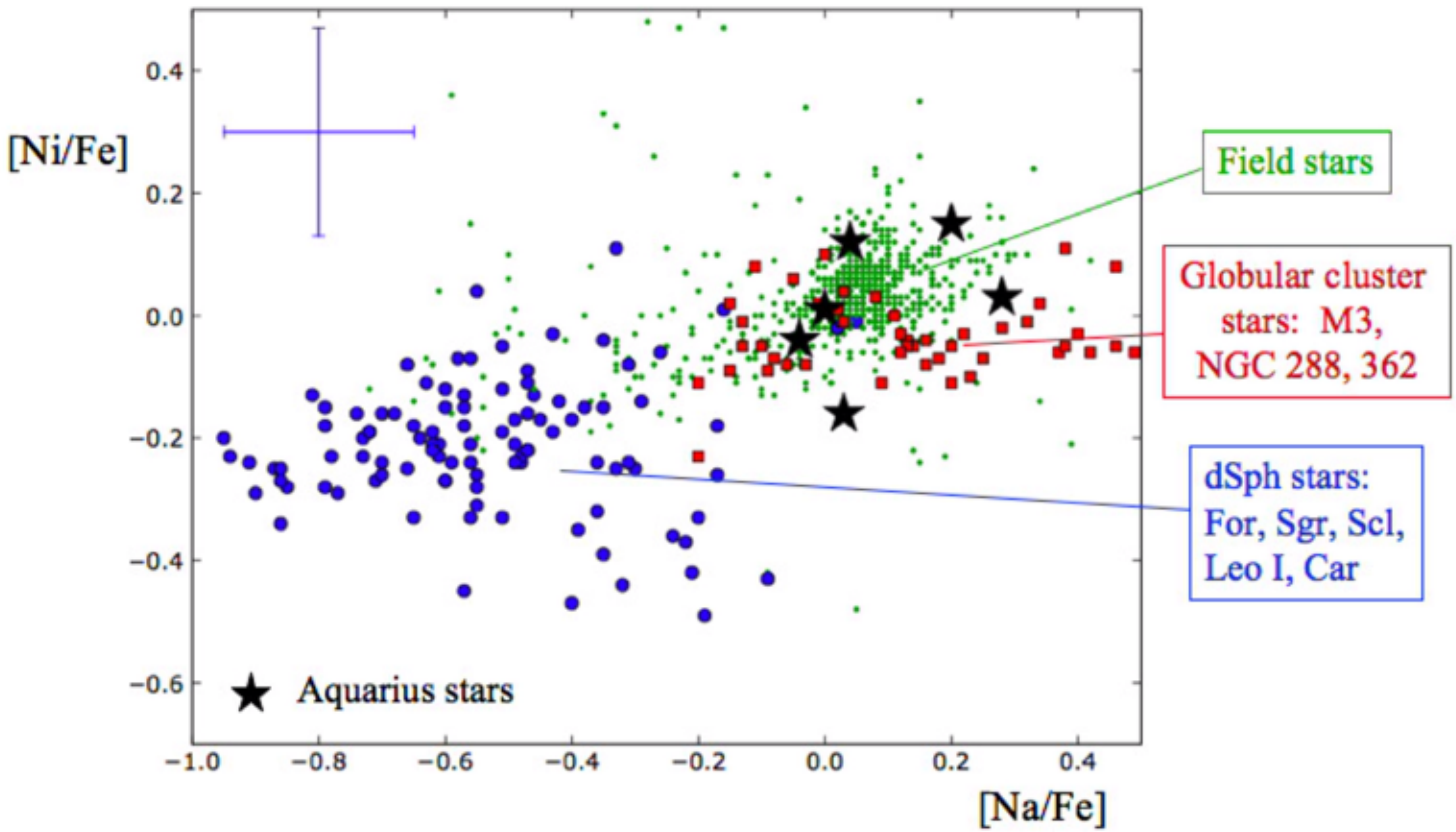
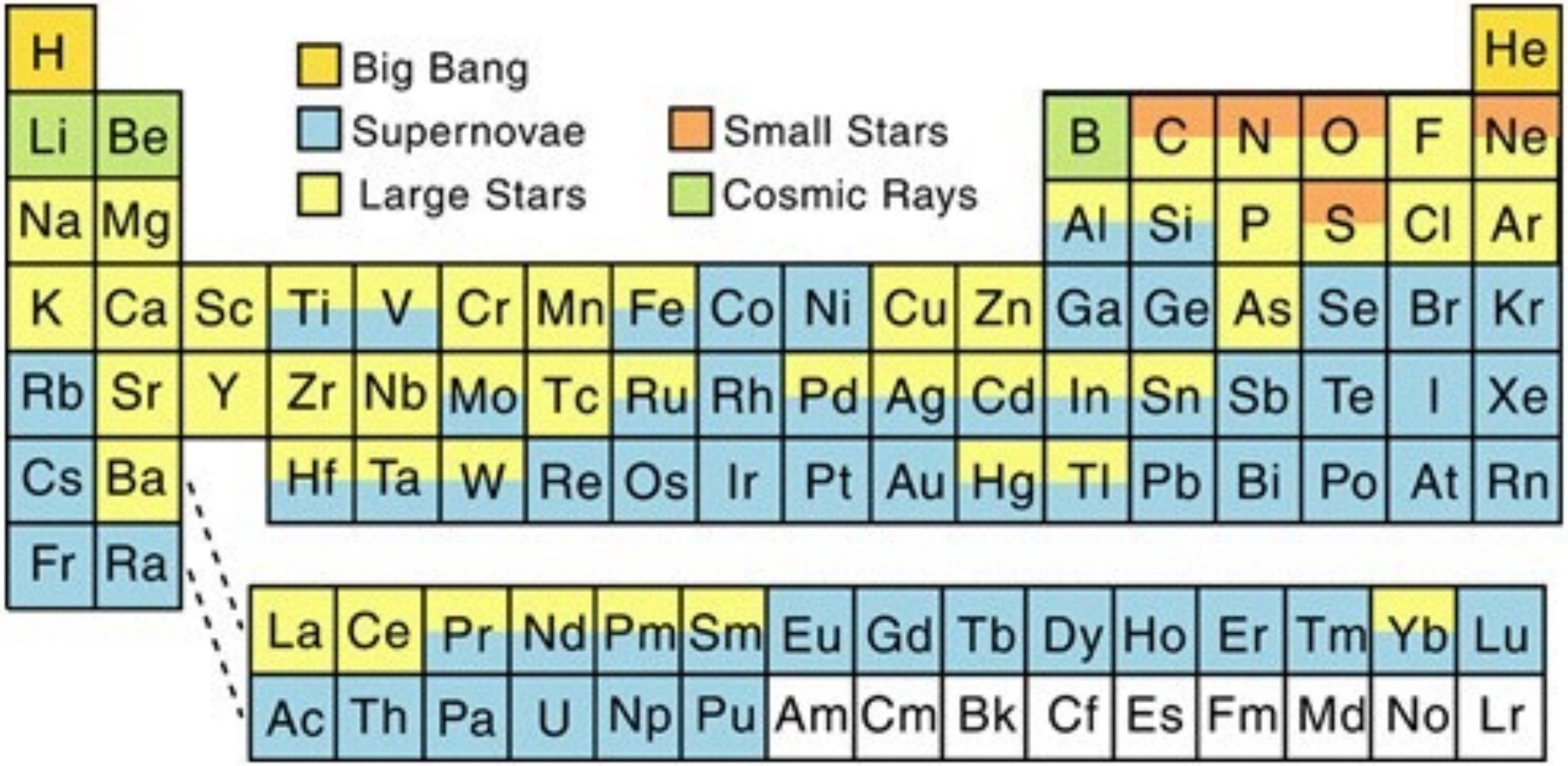
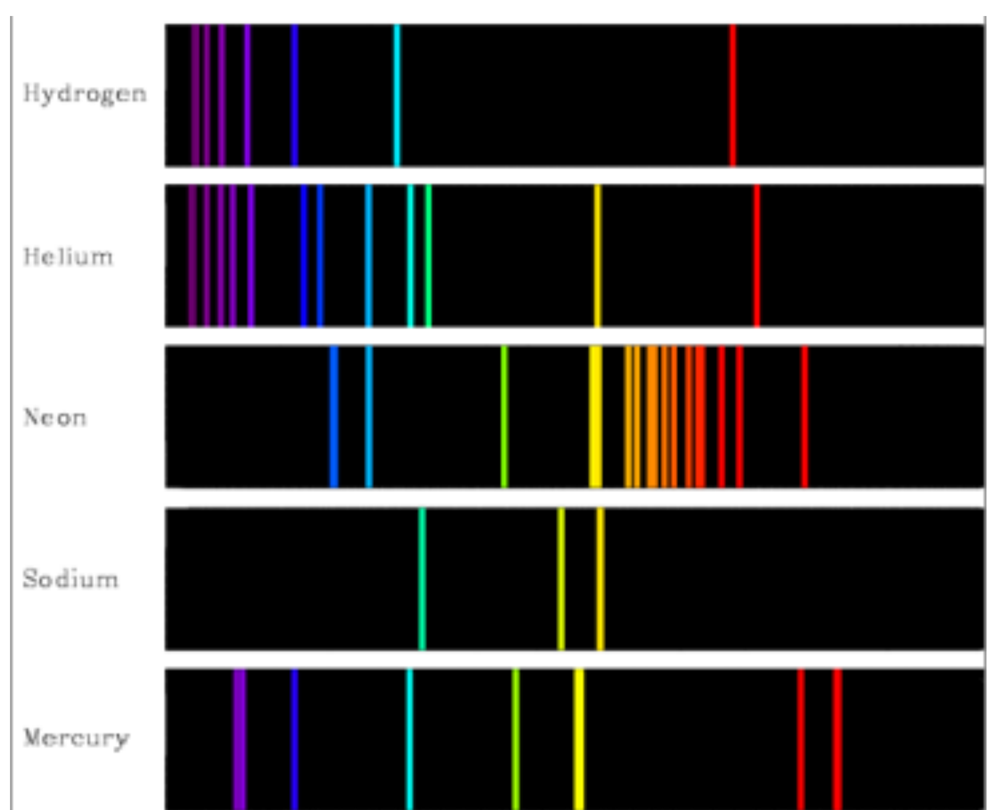


Figure 4: The Na-Ni distribution for globular cluster stars, dwarf spheroidal galaxy stars, field halo stars and stars of the Aquarius stream (black star symbols) (Wylie de Boer et al. 2012). The stars of the Aquarius stream are in the same part of the distribution as the globular cluster stars.

galaxies. The distribution of their stars in the [X/Fe]–[Fe/H] plane is well defined for an individual galaxy but differs in structure from galaxy to galaxy, depending on their star formation history


Big Bang
Supernovae
Large Stars
Small Stars
Cosmic Rays
H He
Li Be B C N O F Ne
Na Mg Al Si P S Cl Ar
K Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br Kr
Rb Sr Y Zr Nb Mo Tc Ru Rh Pd Ag Cd In Sn Sb Te I Xe
Cs Ba Hf Ta W Re Os Ir Pt Au Hg Tl Pb Bi Po At Rn
Fr Ra
La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu
Ac Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No Lr


Hydrogen
Helium
Neon
Sodium
Mercury

With GALAH, we will chemically tag stars into coeval groups, identifying individual members of star clusters which have long since dispersed. Using the stellar relics of ancient star formation and accretion events, we can reconstruct the Galactic accretion history, and dynamical and chemical evolution.

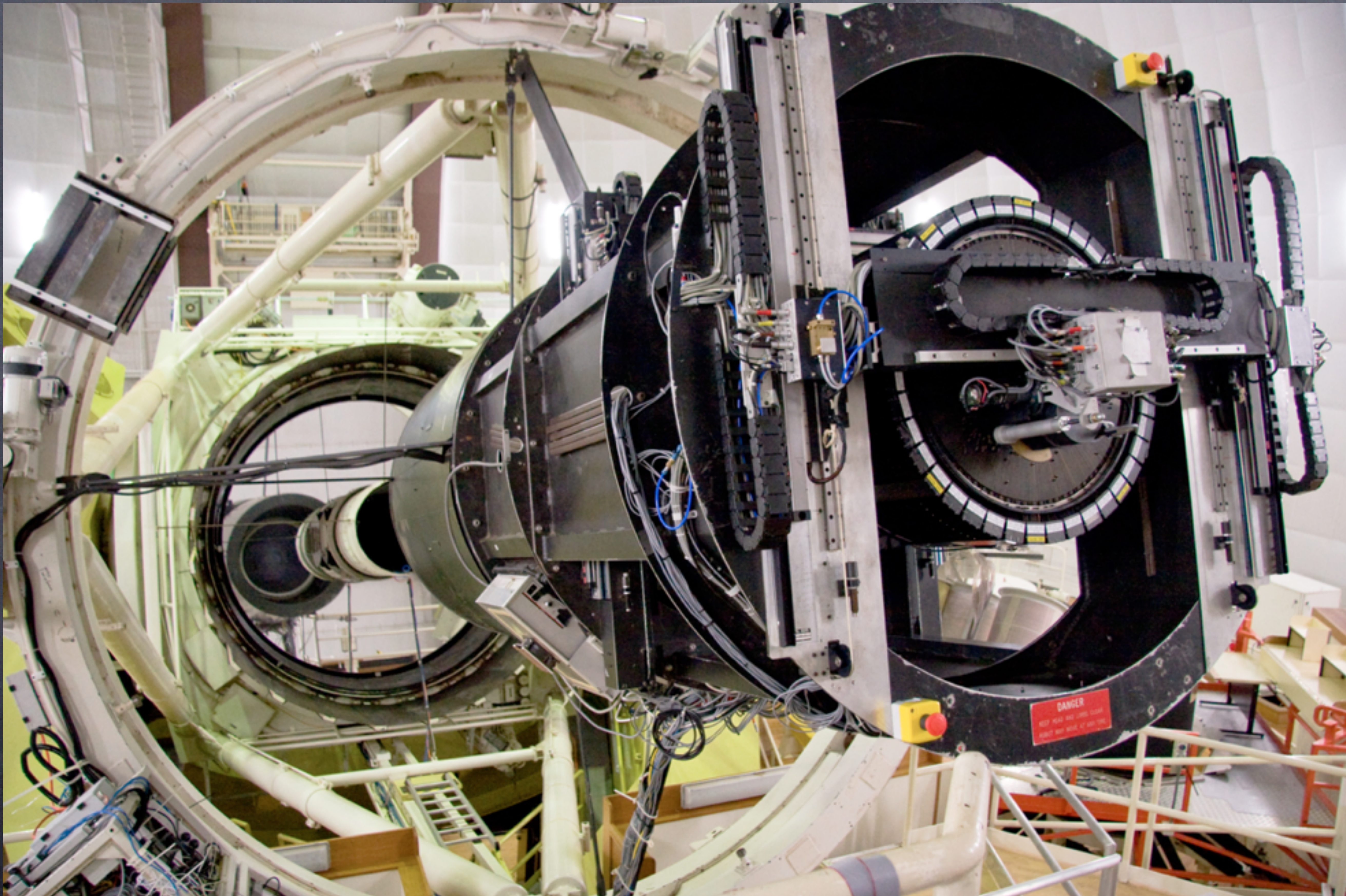
The GALAH data sets will yield a comprehensive view of the formation and evolution of the Milky Way disk and address the following basic questions:

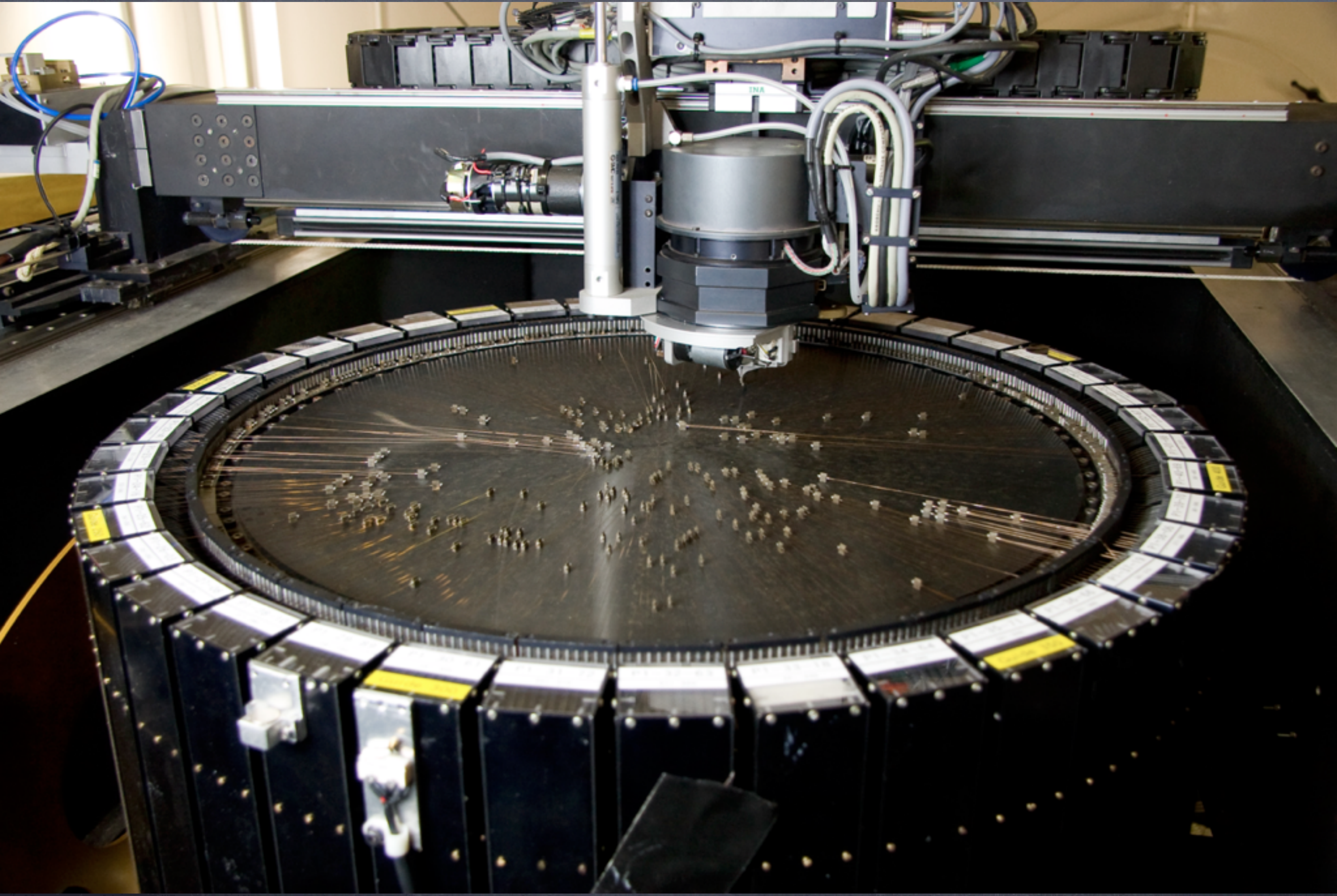
- What were the conditions of star formation during early stages of Galaxy assembly?
- When and where were the major episodes of star formation in the disk and what drove them?
- To what extent is the Galactic disk composed of stars from merger events?
- Under what conditions and in what types of systems did accreted stars form?
- How have the stars that formed *in situ* in the disk evolved dynamically since their birth?
- Where are the solar siblings that formed together with our Sun?

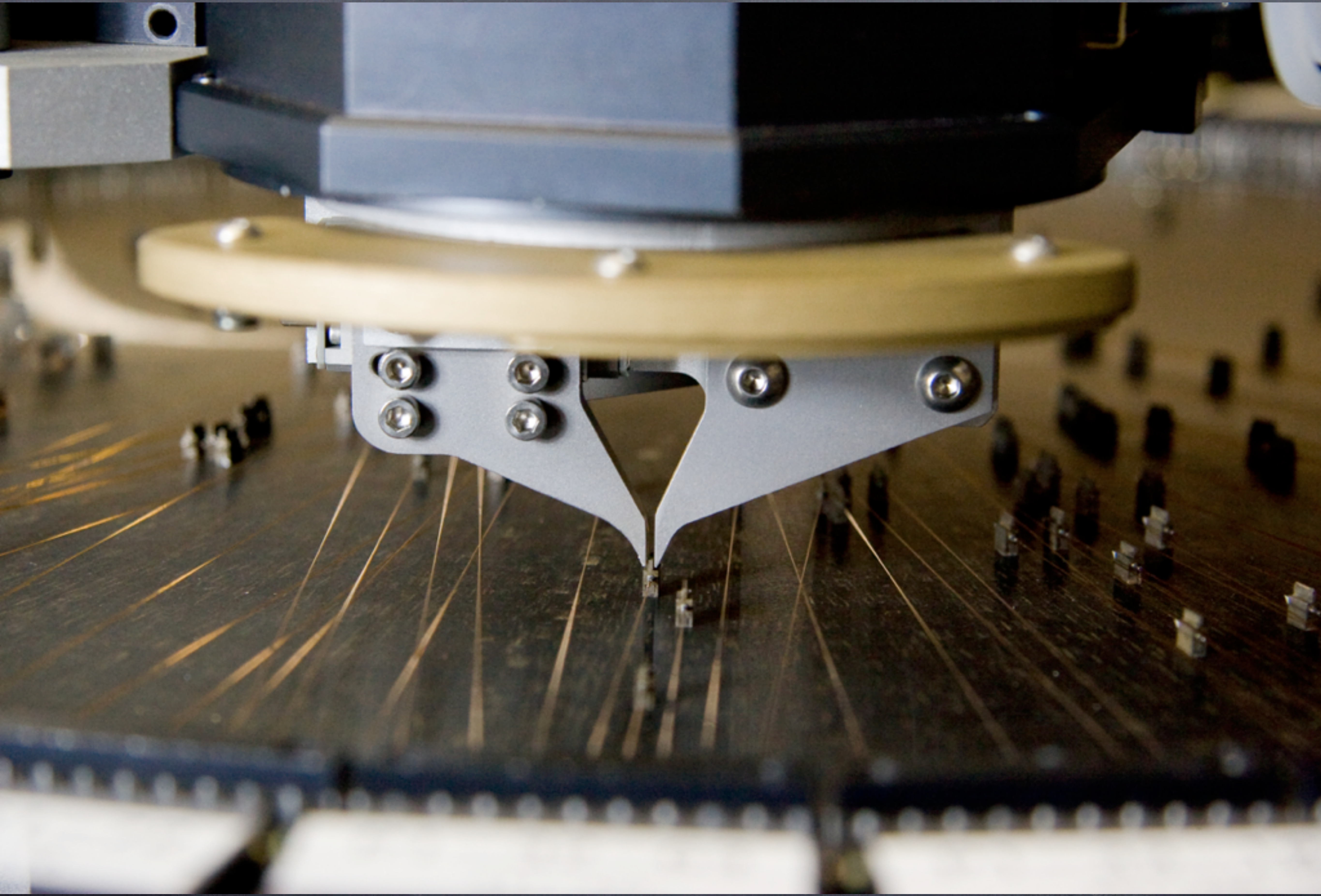
Our current priority is small scale projects that will allow us to test the HERMES instrument.

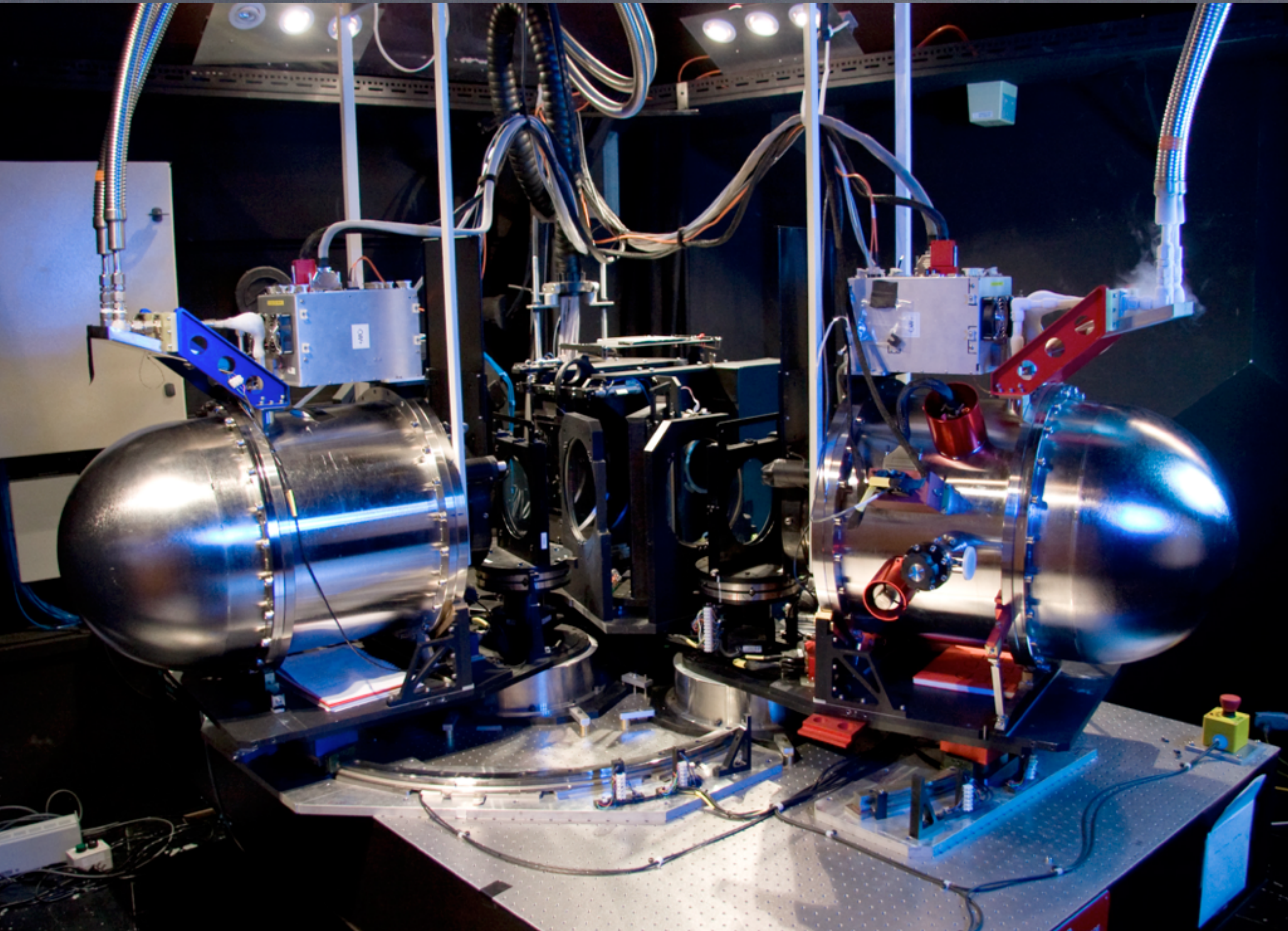
Scientific Goals

After their birth-clusters or birth-galaxies disperse, stars may change their dynamical behavior thanks to mechanisms like heating and radial migration. However, the chemical composition of these stars, which reflect the conditions of


DANGER

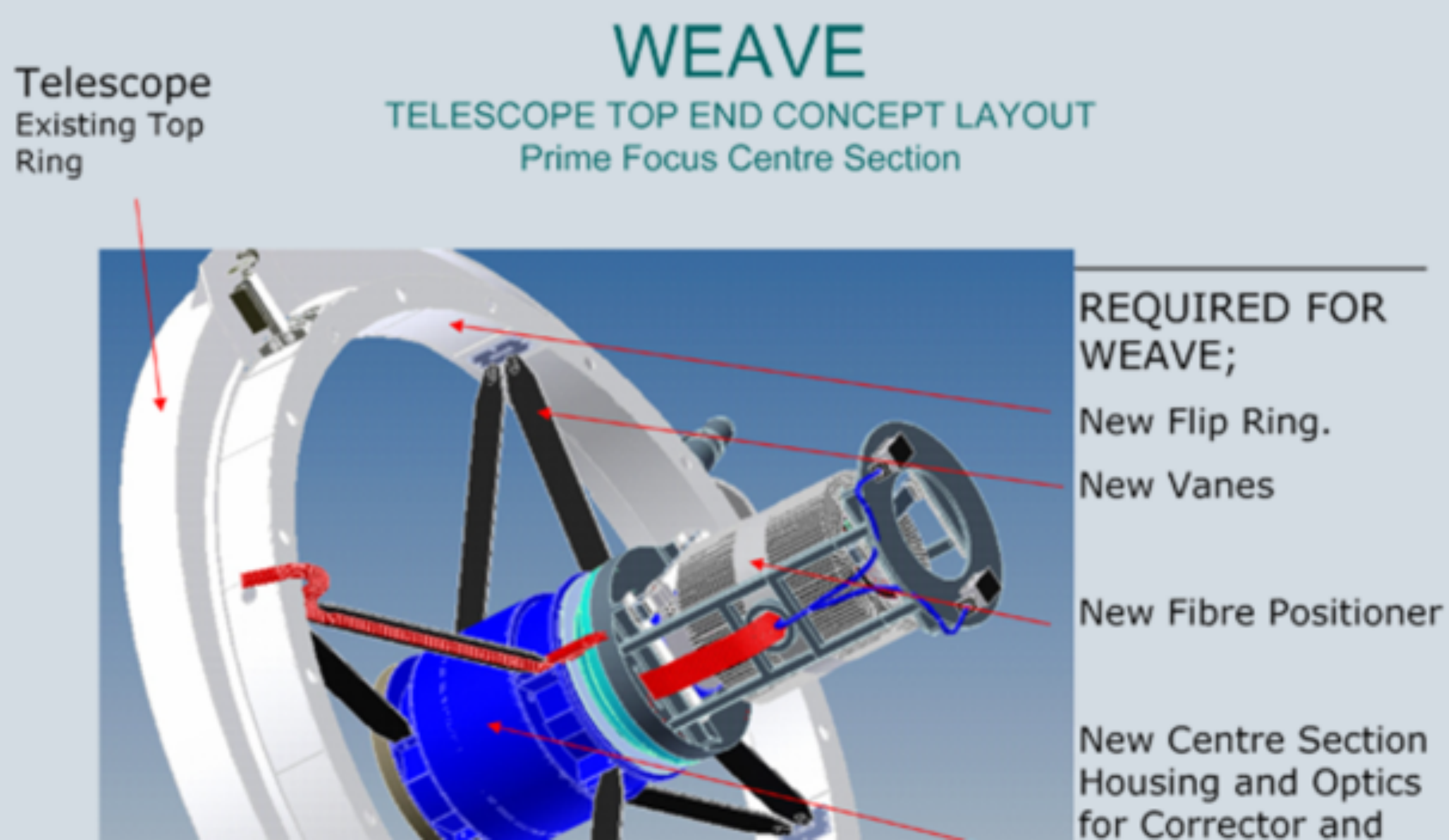


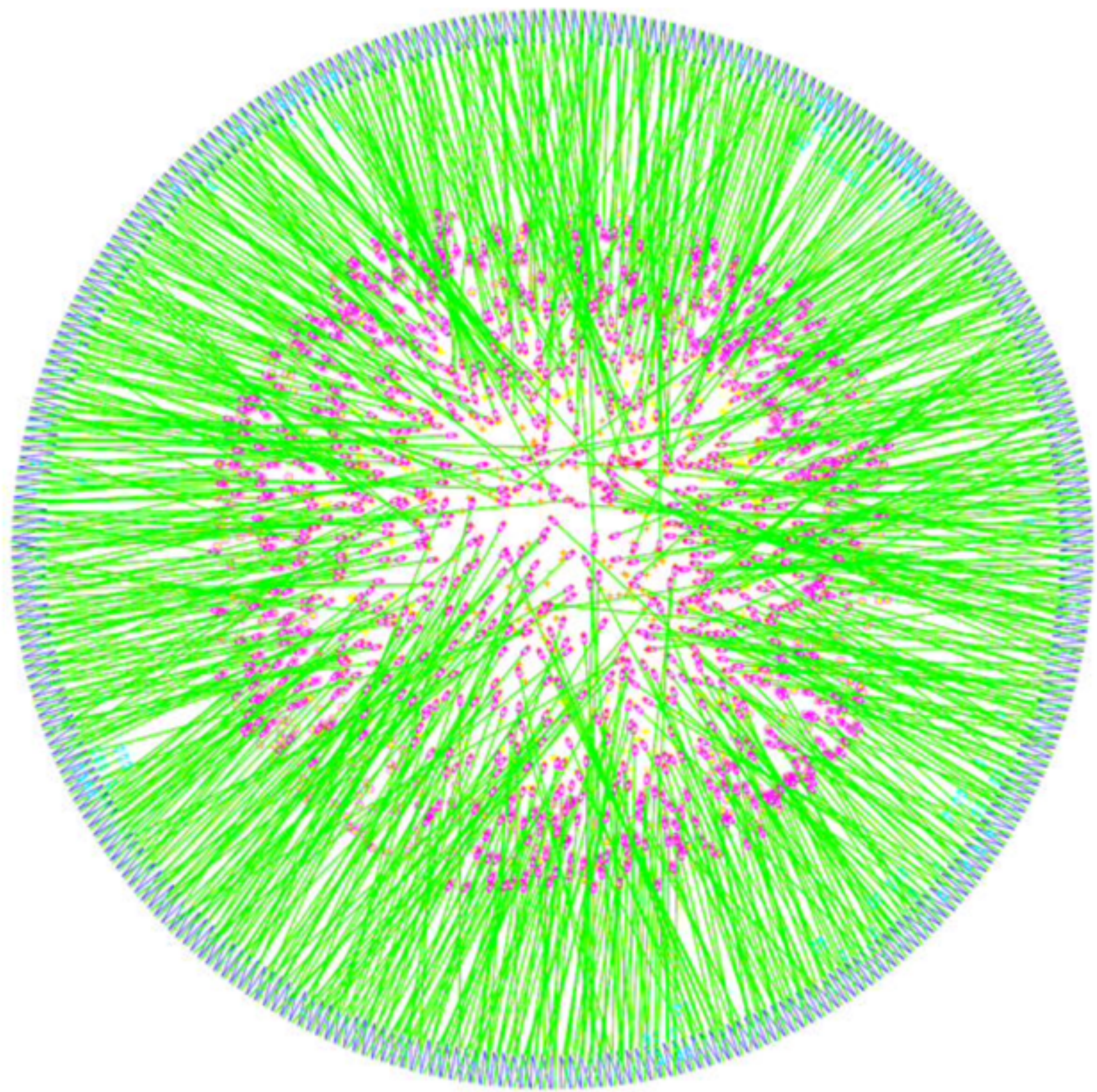




WEAVE

A new wide-field multi-object spectrograph
for the William Herschel Telescope

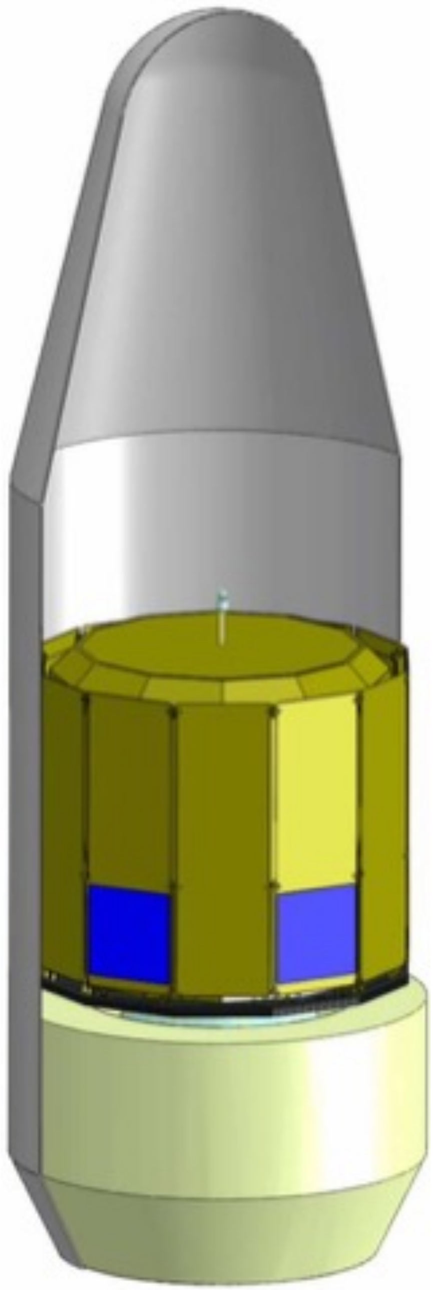




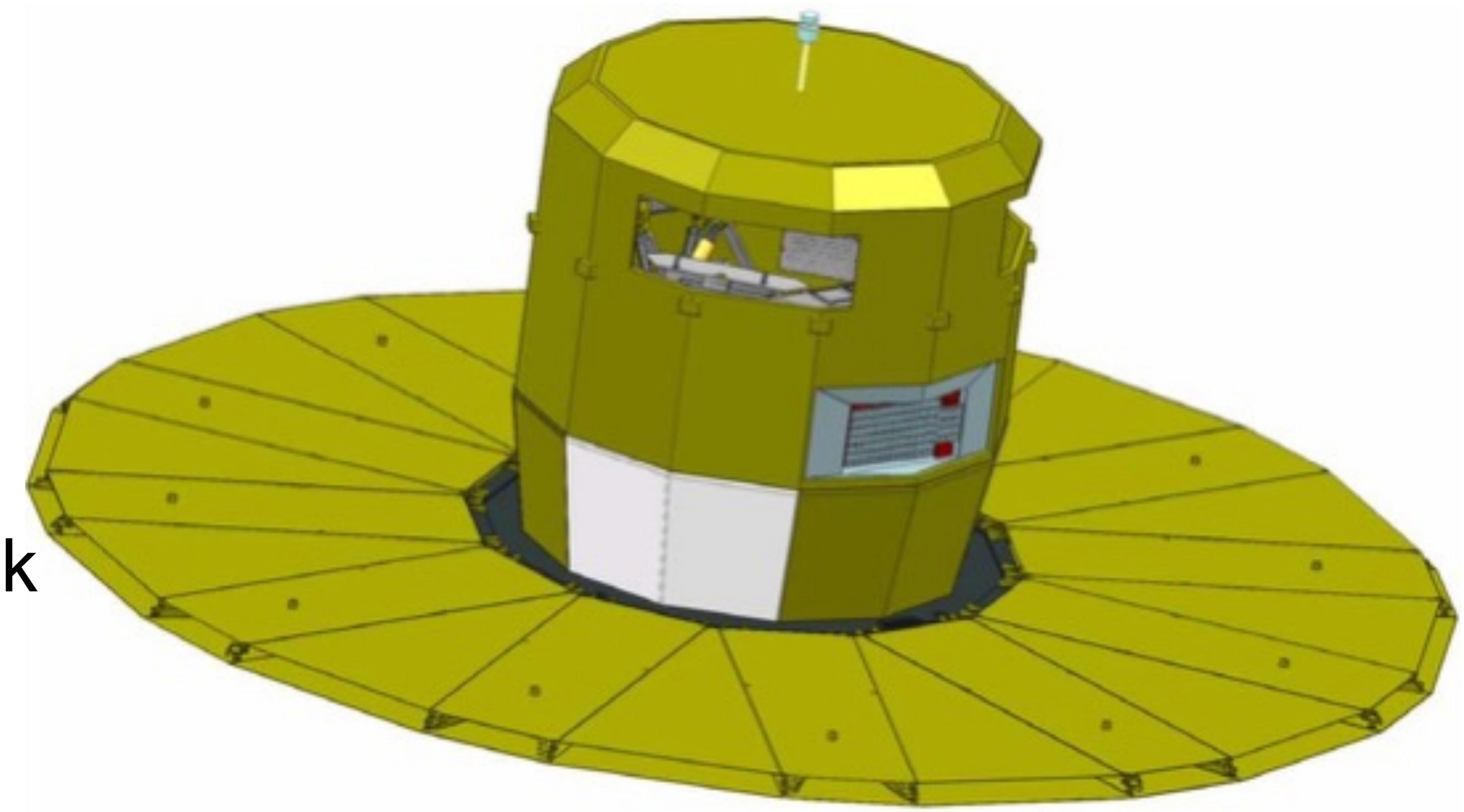
MOS with multiplex > 300

Project	Hemisphere	Tel. diam. (m)	FOV (sq deg)	Fibres / slits	Spectroscopic resolution	First light
AAT / AAOmega	S	3.9	3.14	392 fibres	1300 - 8000	2006
AAT / Hermes	S	3.9	3.14	400 fibres	28000	2012
CFHT / GYES	N	3.6	0.64	500 fibres	20000	Proposed
CTIO Blanco / DESpec	S	4.0	3.8	4000 fibres	2000	2012
GTC / GO-IRS	N	10.4	0.05	1000 fibres	5000 - 20000	2013
LAMOST	N	4.0	19.63	4000 fibres	1000, 10000	2009
Mayall / BigBOSS	N	3.8	7.07	5000 fibres	3000 - 4000	2016
MMT / HECTOSPEC	N	6.5	0.79	300 fibres	1000	2003
NTT or VISTA / 4MOST	S	4	7.1	3000 fibres	3000 - 5000	2017 - 2018
SDSS-III / BOSS	N	2.5	7.07	1000 fibres	1600 - 2700	2009
Subaru / PFS	N	8.2	1.78	2400 fibres	2000 - 5000	-
VLT / MOONS	S	8.2	0.14	500 fibres	3000 - 20000	2017
WHT / WEAVE	N	4.2	3.14	1000 fibres	5000, 20000	2016

Gaia: asztrometriai űrobszervatórium



- a legnagyobb ESA misszió (1 GEUR)
- pályára állítás: **2013. december 20.**
- 5 év adatgyűjtés (hosszabbítás lehetséges)
- hordozó: Szojuz–Fregat
- pálya: Lissajous típusú halópálya L2 körül
- első adatok: 2016. nyár



- tömeg: 2120 kg (fedélzeti eszközök 743 kg)
- teljesítmény: 1631 W

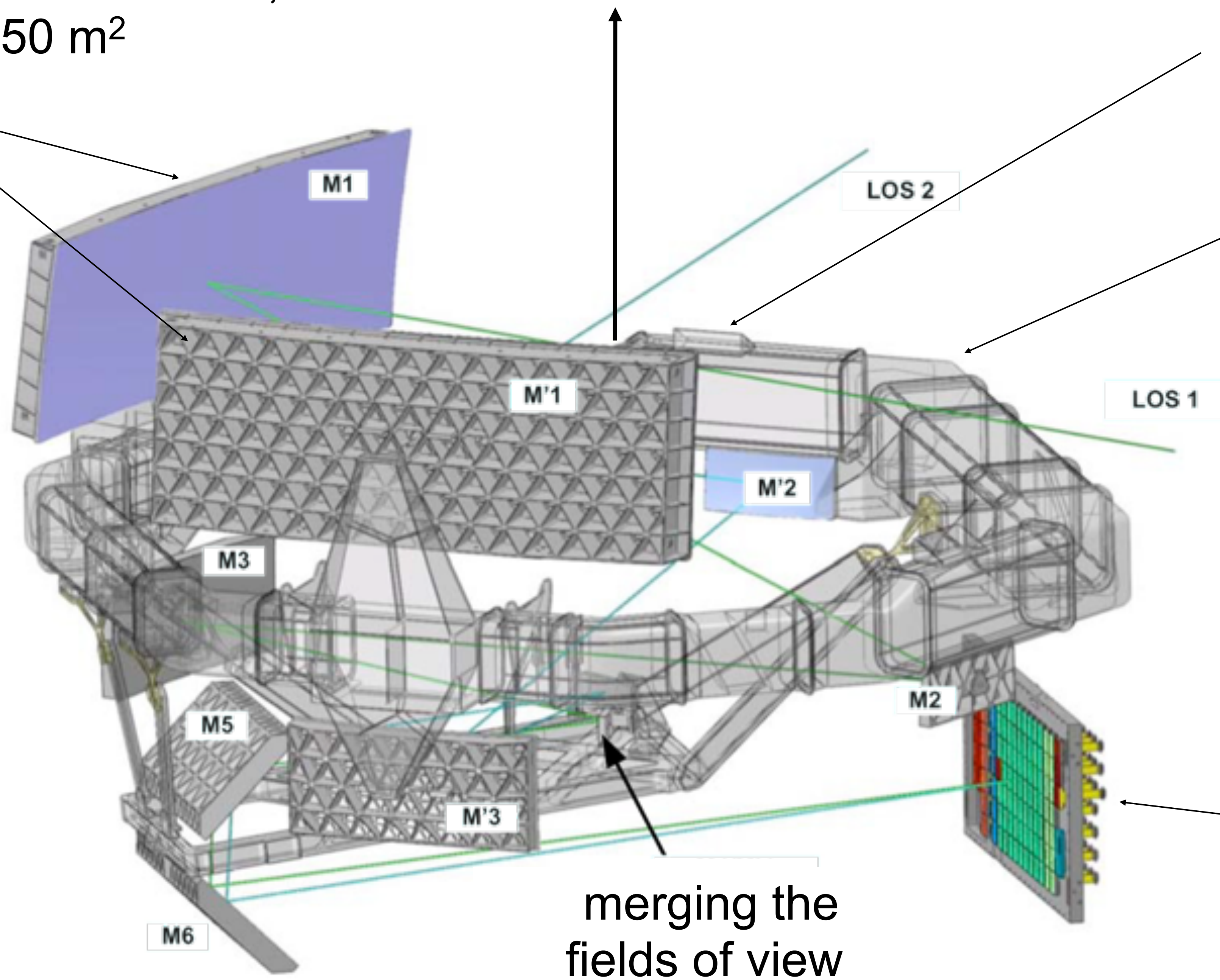
EADS-Astrium

A távcső és műszerei

two SiC primary mirrors at 106,5°
1,45 × 0,50 m²

axis of rotation (6 h)

SiC toroid
(optical bench)

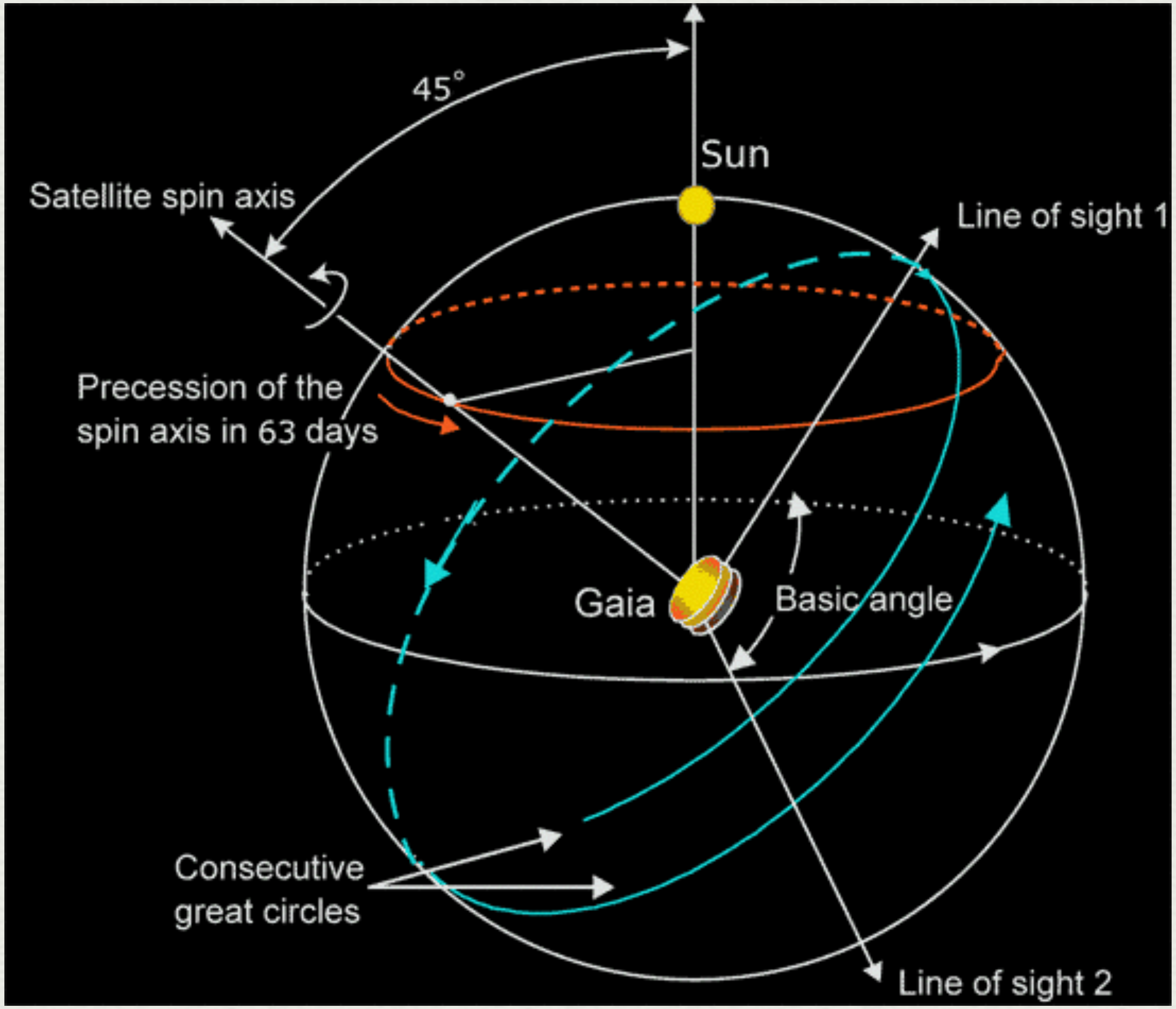


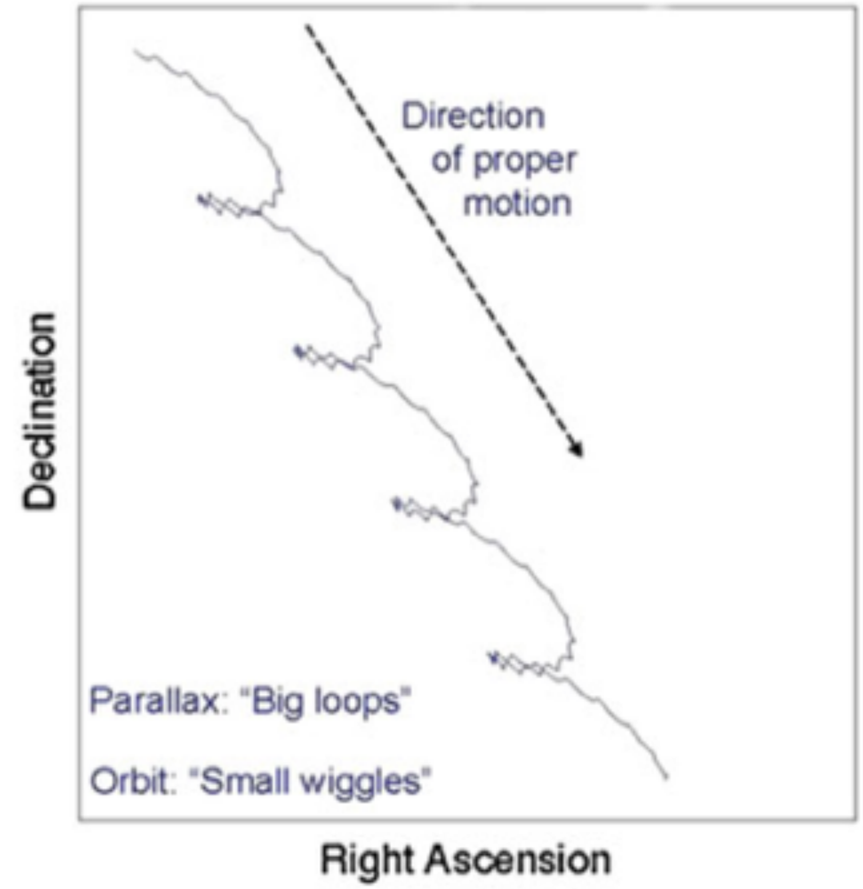
combined focal
plane
(CCDs)

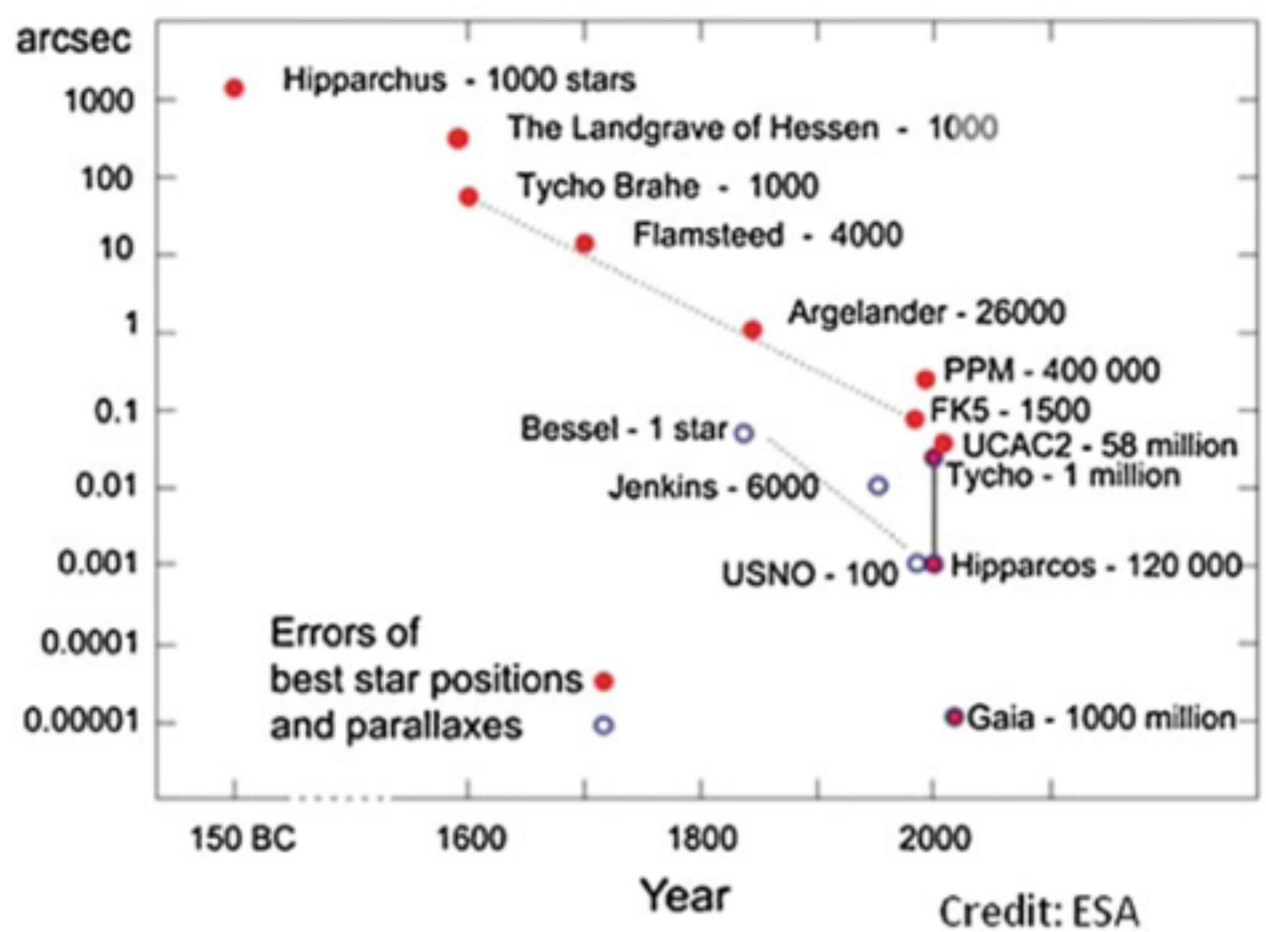
merging the
fields of view
(FoV)

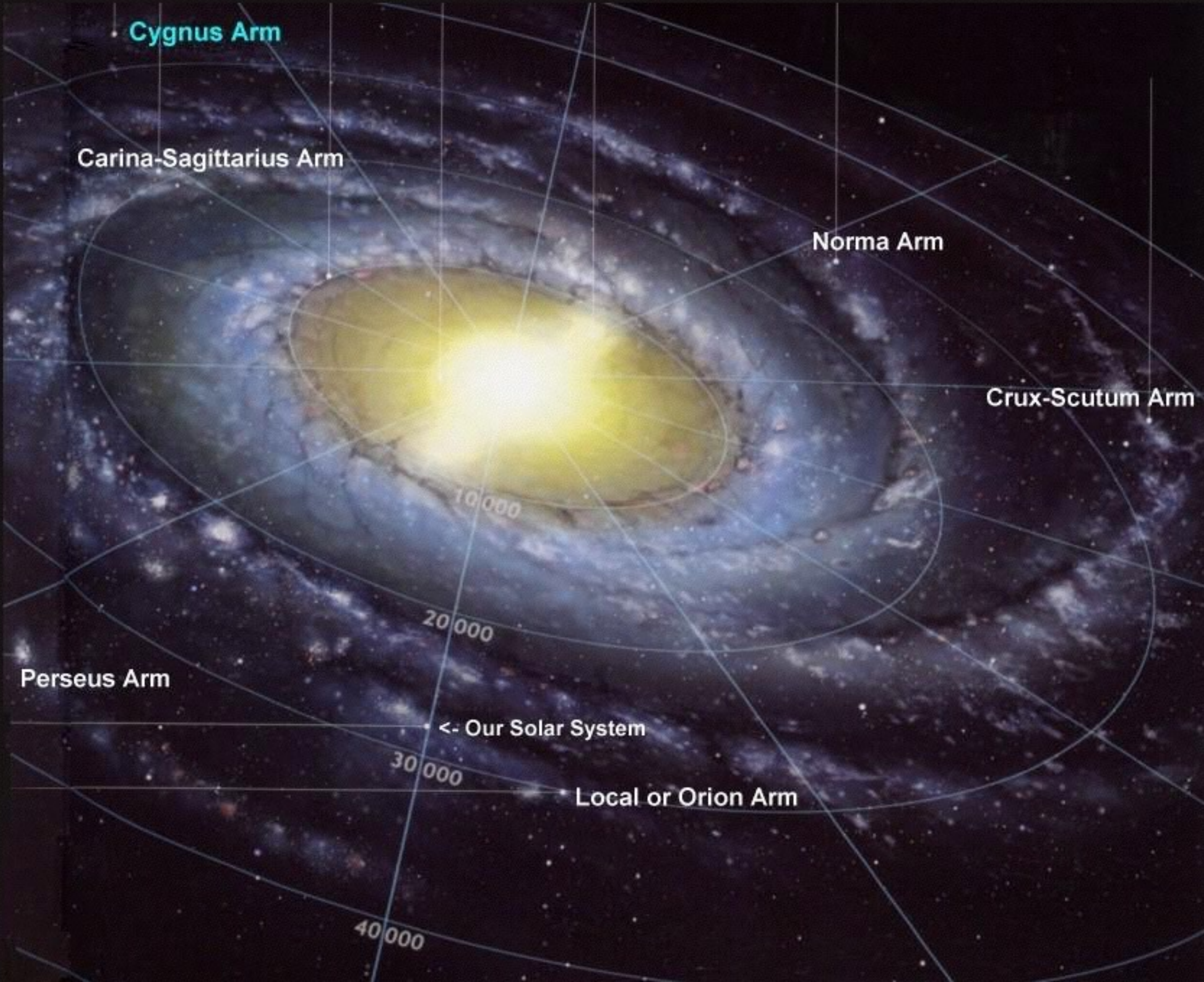
EADS-Astrium

A mérés elve


45°
Sun
Satellite spin axis
Line of sight 1
Precession of the
spin axis in 63 days
Gaia
Basic angle
Consecutive
great circles
Line of sight 2


Direction
of proper
motion
Declination
Parallax: "Big loops"
Orbit: "Small wiggles"
Right Ascension


arcsec
1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001
Hipparchus - 1000 stars
The Landgrave of Hessen - 1000
Tycho Brahe - 1000
Flamsteed - 4000
Argelander - 26000
PPM - 400 000
FK5 - 1500
Bessel - 1 star
UCAC2 - 58 million
Tycho - 1 million
Jenkins - 6000
USNO - 100
Hipparcos - 120 000
Errors of
best star positions
and parallaxes
Gaia - 1000 million
150 BC
1600
1800
2000
Year
Credit: ESA


Cygnus Arm
Carina-Sagittarius Arm
Norma Arm
Crux-Scutum Arm
10 000
20 000
Perseus Arm
<- Our Solar System
30 000
Local or Orion Arm
40 000

LSST:
Large Synoptic Survey Telescope

LSST: a digital color movie of the Universe

színes, digitális mozgókép az Univerzumról

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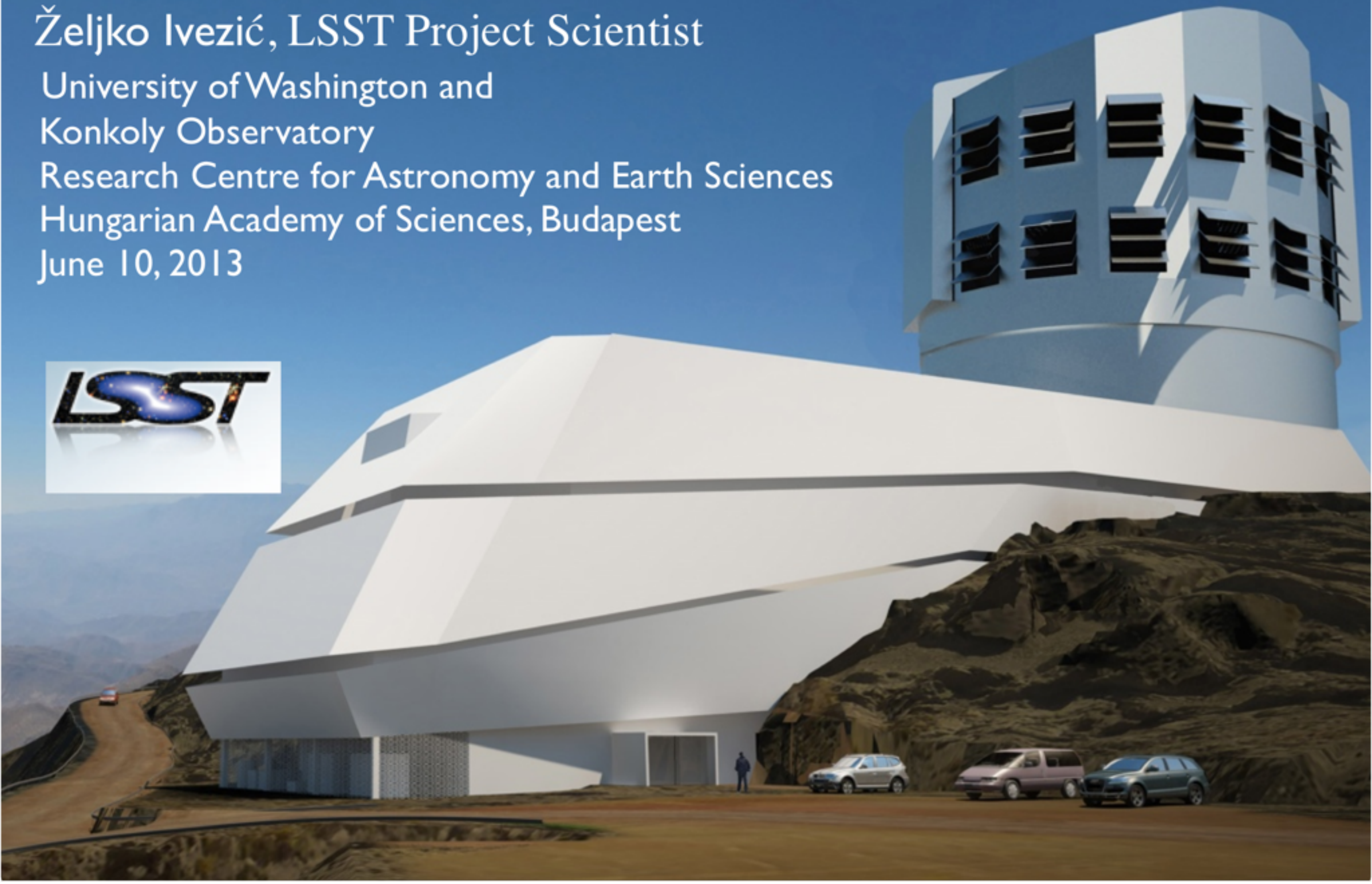
June 10, 2013



MEMORANDUM OF AGREEMENT

Regarding collaboration in the scientific exploitation of data acquired with LSST by specified Principal Investigators (PI) and scientists at the Konkoly Observatory.

BETWEEN

THE ASTRONOMICAL INSTITUTE (KONKOLY OBSERVATORY) OF THE RESEARCH CENTRE FOR ASTRONOMY AND EARTH SCIENCES OF THE HUNGARIAN ACADEMY OF SCIENCES
KONKOLY TH.M. UT 15-17., H-1121 BUDAPEST, HUNGARY
hereinafter referred to as **"THE KONKOLY OBSERVATORY",**

AND

THE LARGE SYNOPTIC SURVEY TELESCOPE CORPORATION,
933 N. Cherry Ave., Tucson, AZ 85721

a United States 501(c)3 non-profit corporation
incorporated in the State of Arizona

hereinafter referred to as **"LSSTC"**,

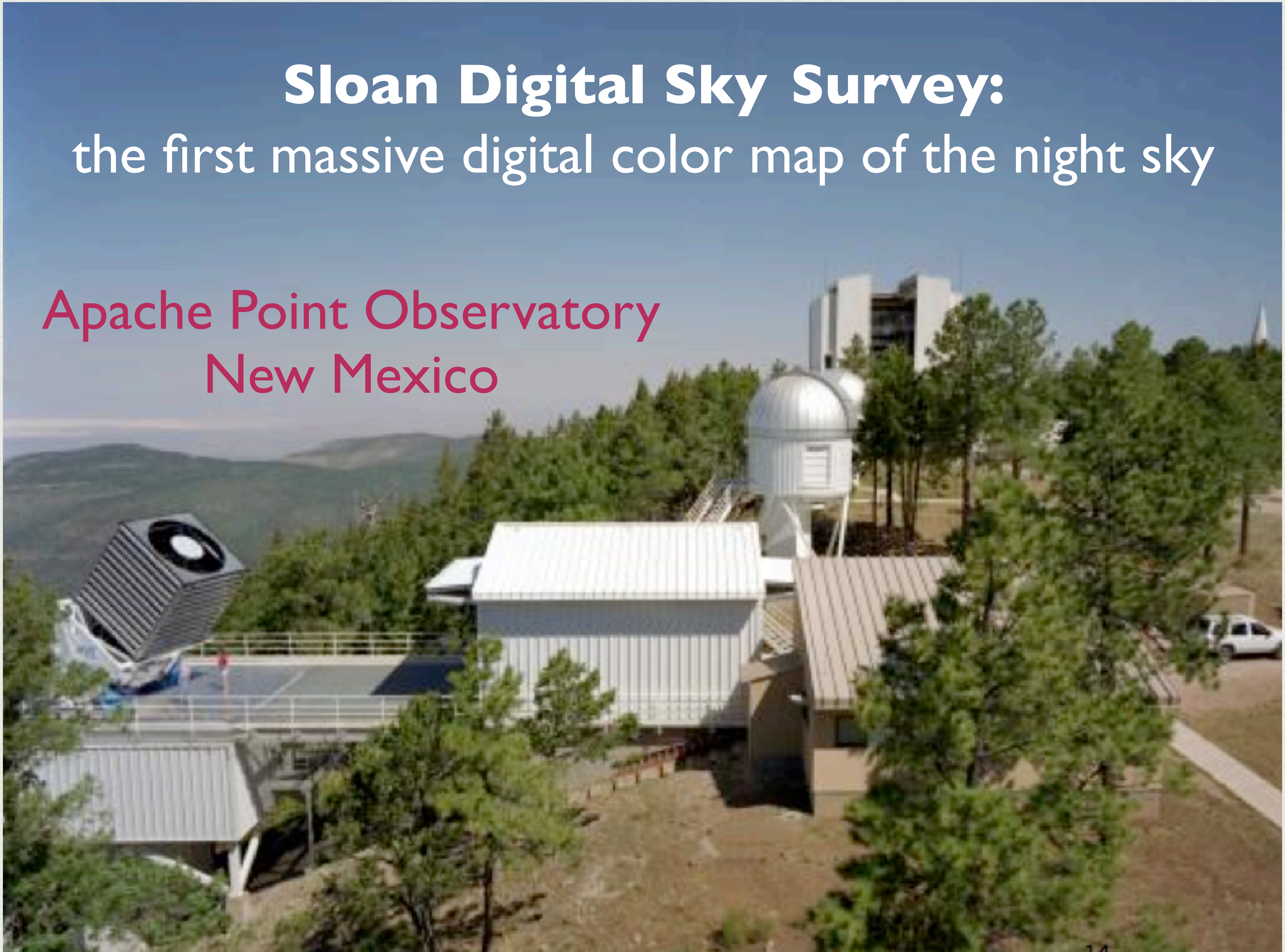
both hereinafter referred to collectively as **"the Parties"** or individually as **"the Party."**

RECITALS

WHEREAS LSSTC is a not-for-profit corporation established as a consortium of universities, United States national laboratories and other organizations to develop the LSST project and to raise private and federal funding, principally from United States agencies, to support LSST, and

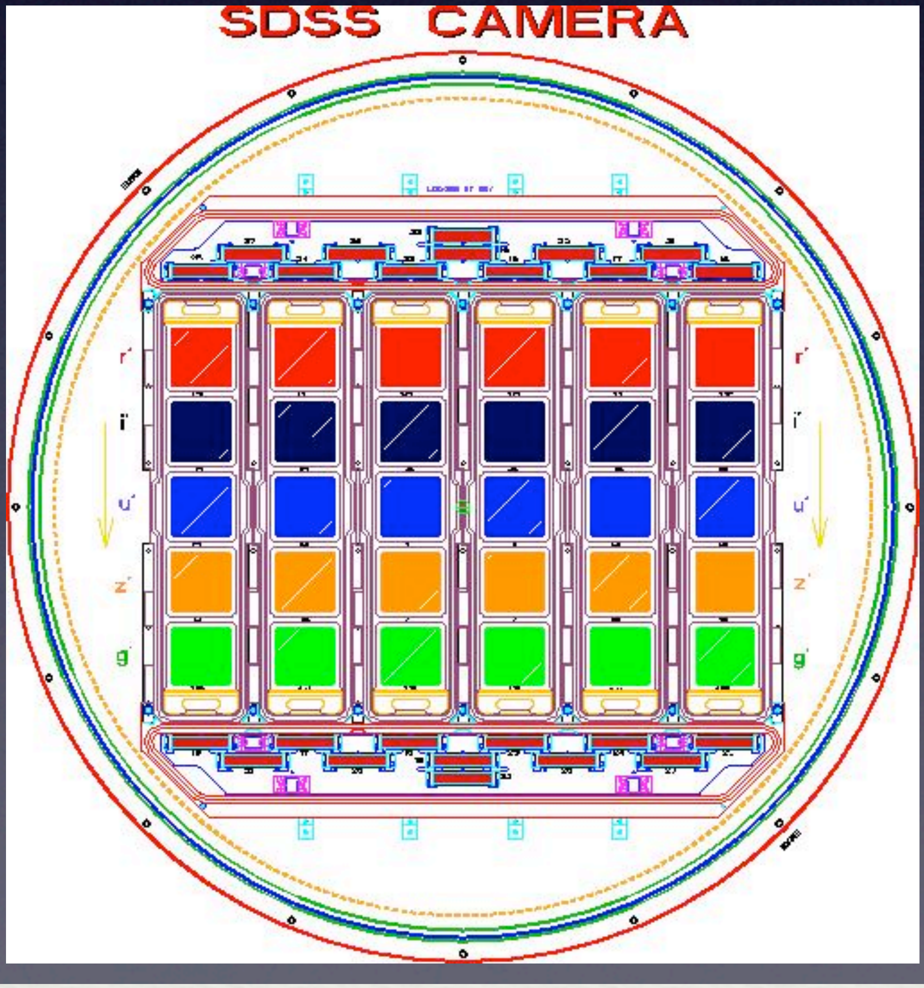
Sloan Digital Sky Survey:

the first massive digital color map of the night sky



The last decade: SDSS as an example

- Digital sky survey with a 120 Megapix CCD camera
- Precise measurements for 400,000,000 objects
- Revolution in astronomy: public databases released before a substantial fraction of analysis was done by the project team



As a result of SDSS public data releases:

- Several thousands of refereed papers, a majority authored by scientists not associated with SDSS
- Delivered >100 times the total data volume

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

- Over 300,000,000 web hits in 6 years with over a million unique users (vs. 10,000 astronomers)

The 2010 SDSS-III collaboration meeting in Paris

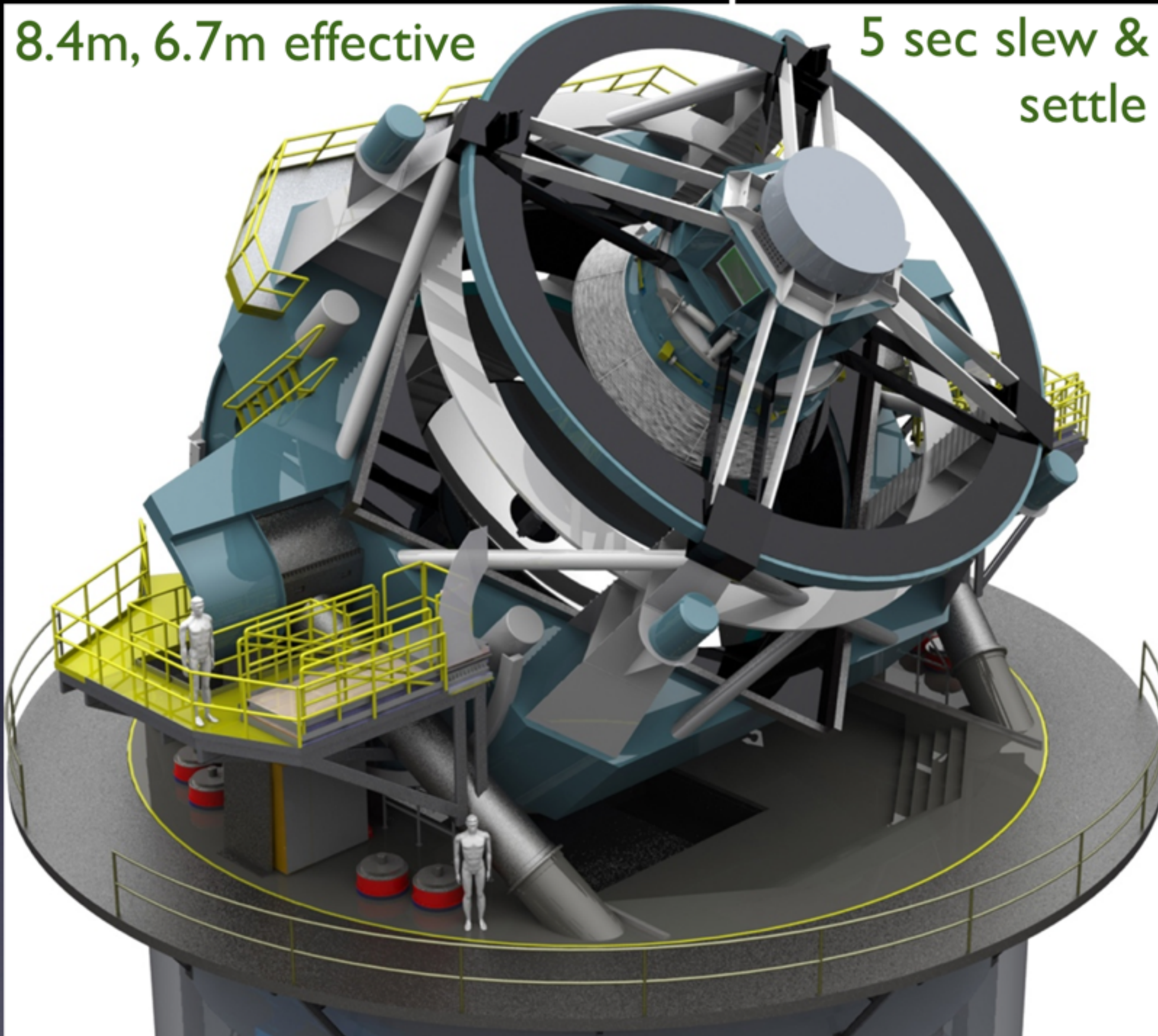
Surveys are made by real people

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



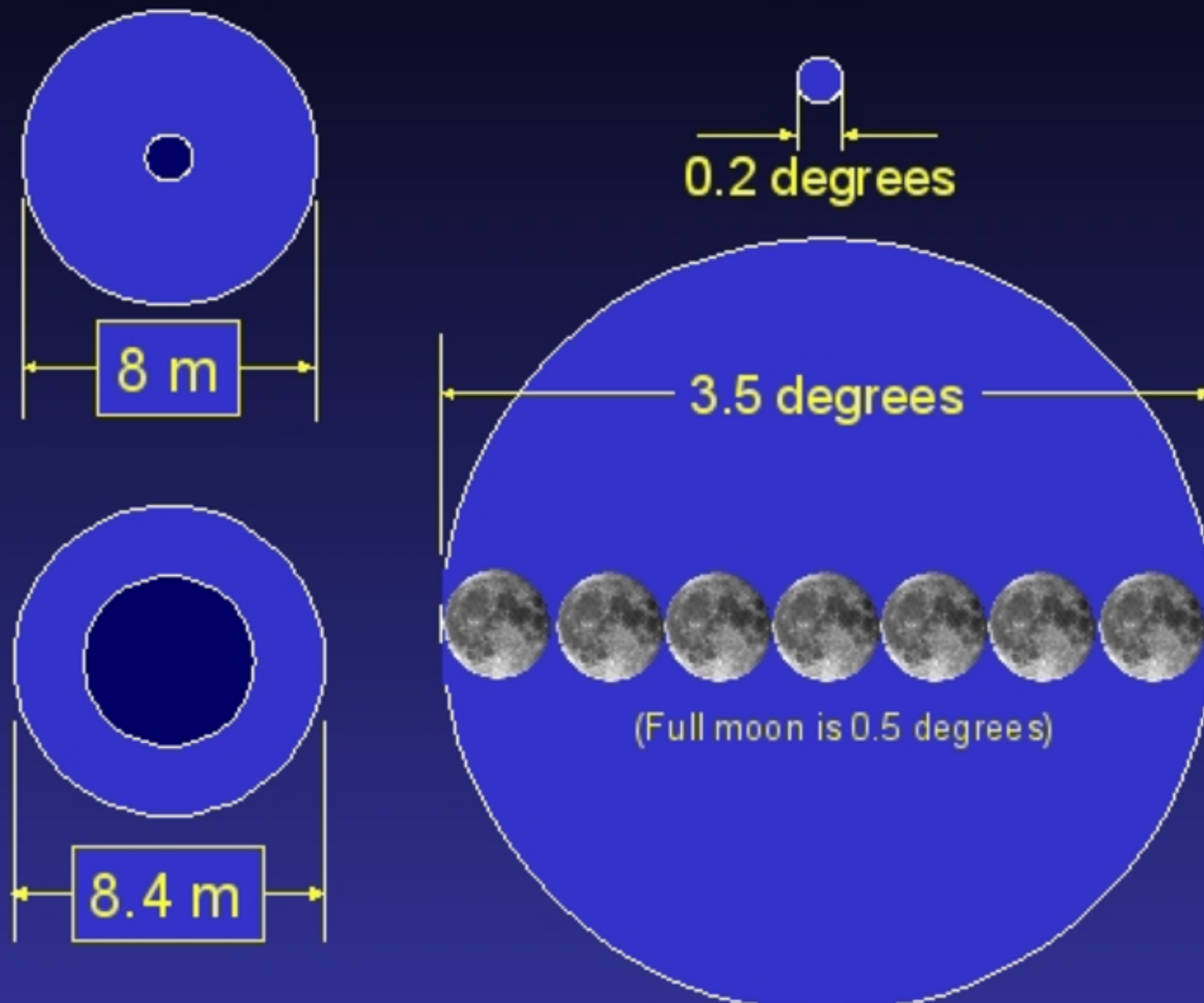
The field-of-view comparison: Gemini vs. LSST

Primary Mirror Diameter

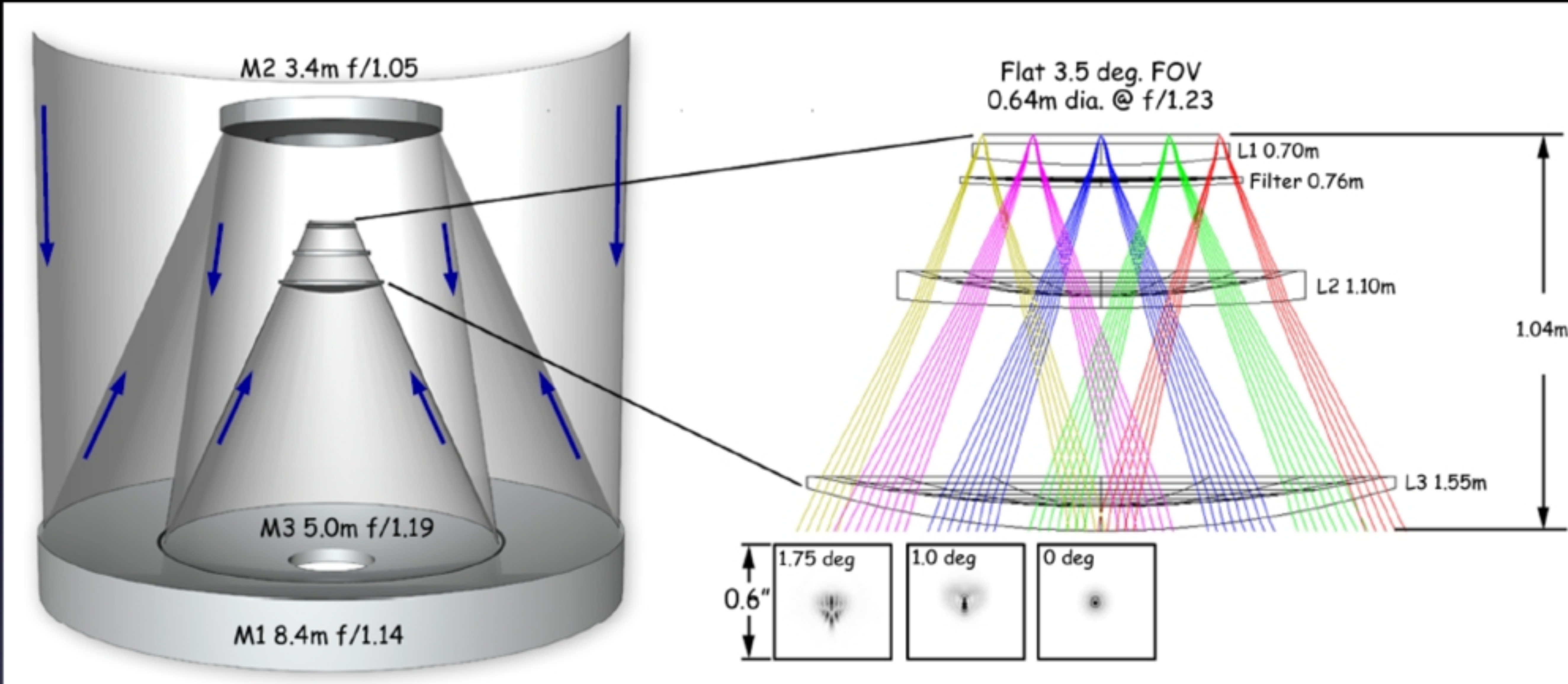
Field of View

Gemini South Telescope

LSST

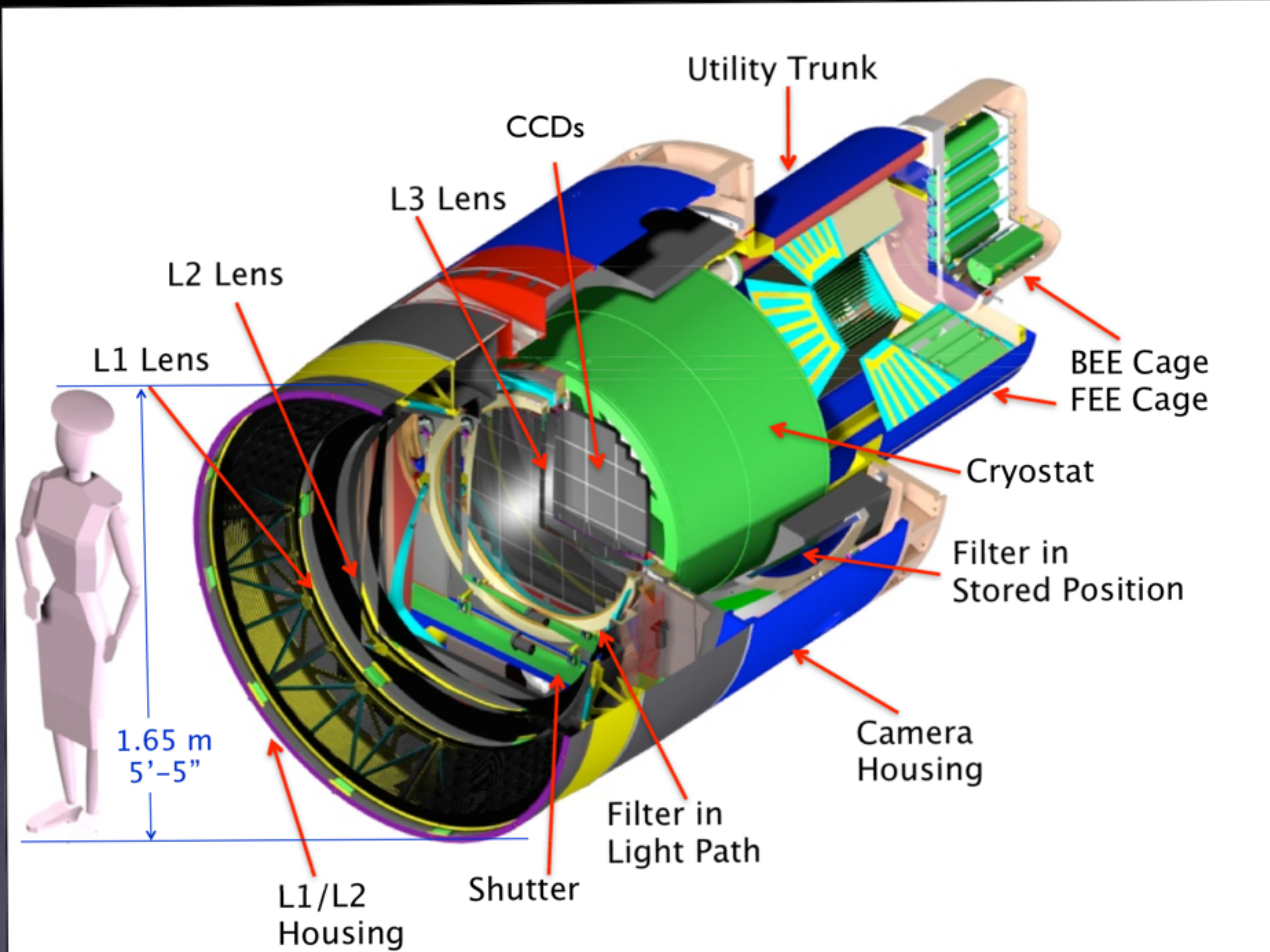


Optical Design for LSST

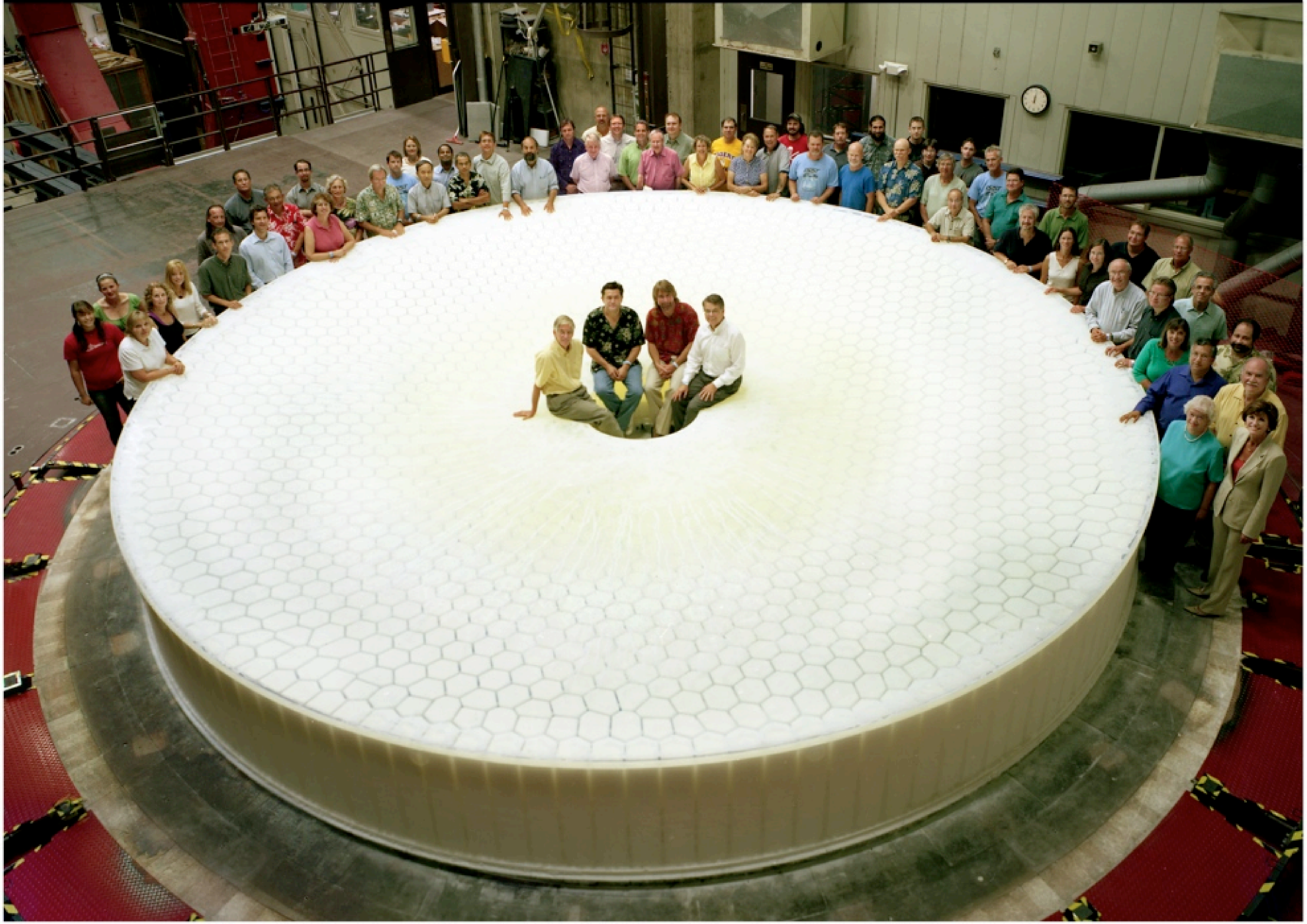


Three-mirror design (Paul-Baker system)
enables large field of view with excellent image quality:
delivered image quality is dominated by atmospheric seeing

The largest astronomical camera: 2800 kg, 3.2 Gpix



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 First Stone Ceremony
April 14, 2015

and while dignitaries are celebrating…

some are happily doing real work!

LSST Construction – Above Ground on Pachón!

Software: the subsystem with the highest risk

- 20 TB of data to process every day
- 100 PB of data
- 1000 measurements for 20 billion objects during10 years
- Existing tools and methods (e.g. SDSS) do not scale up to LSST data volume and rate

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- 20 TB of data to process every day
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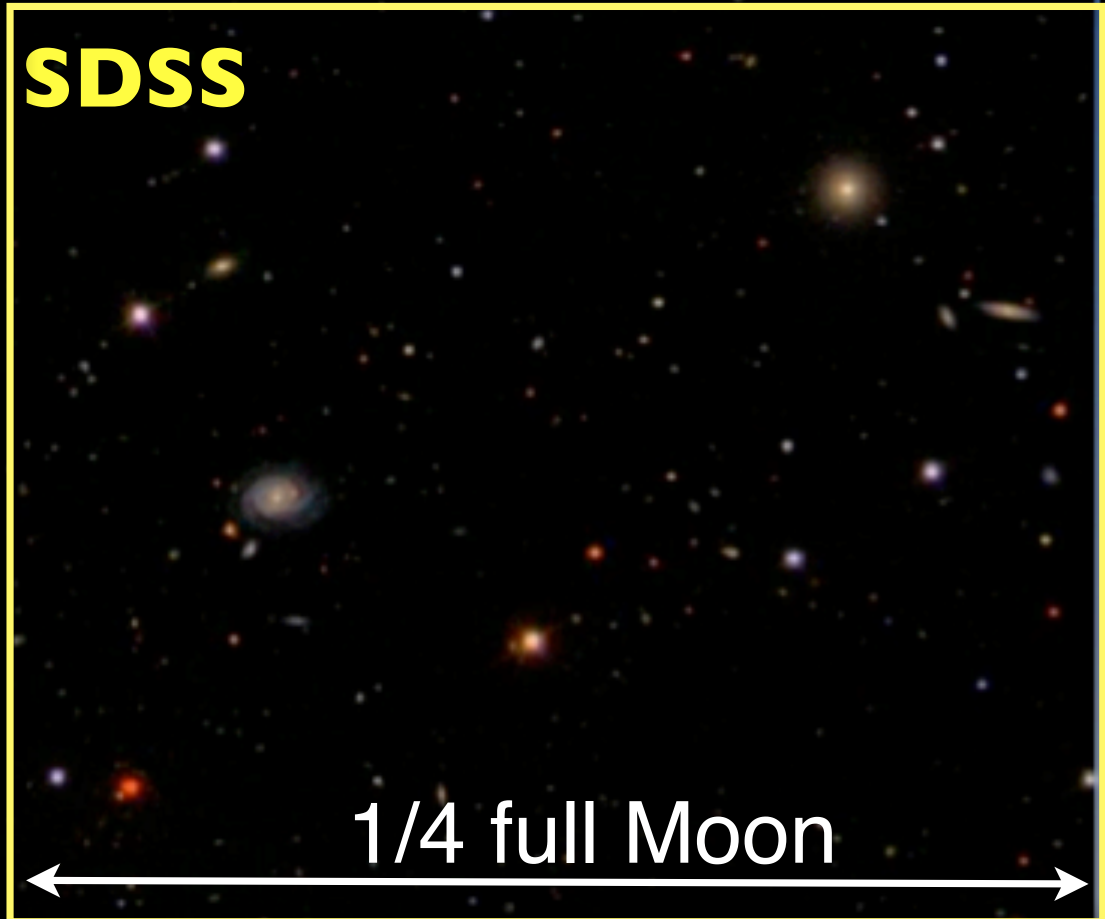
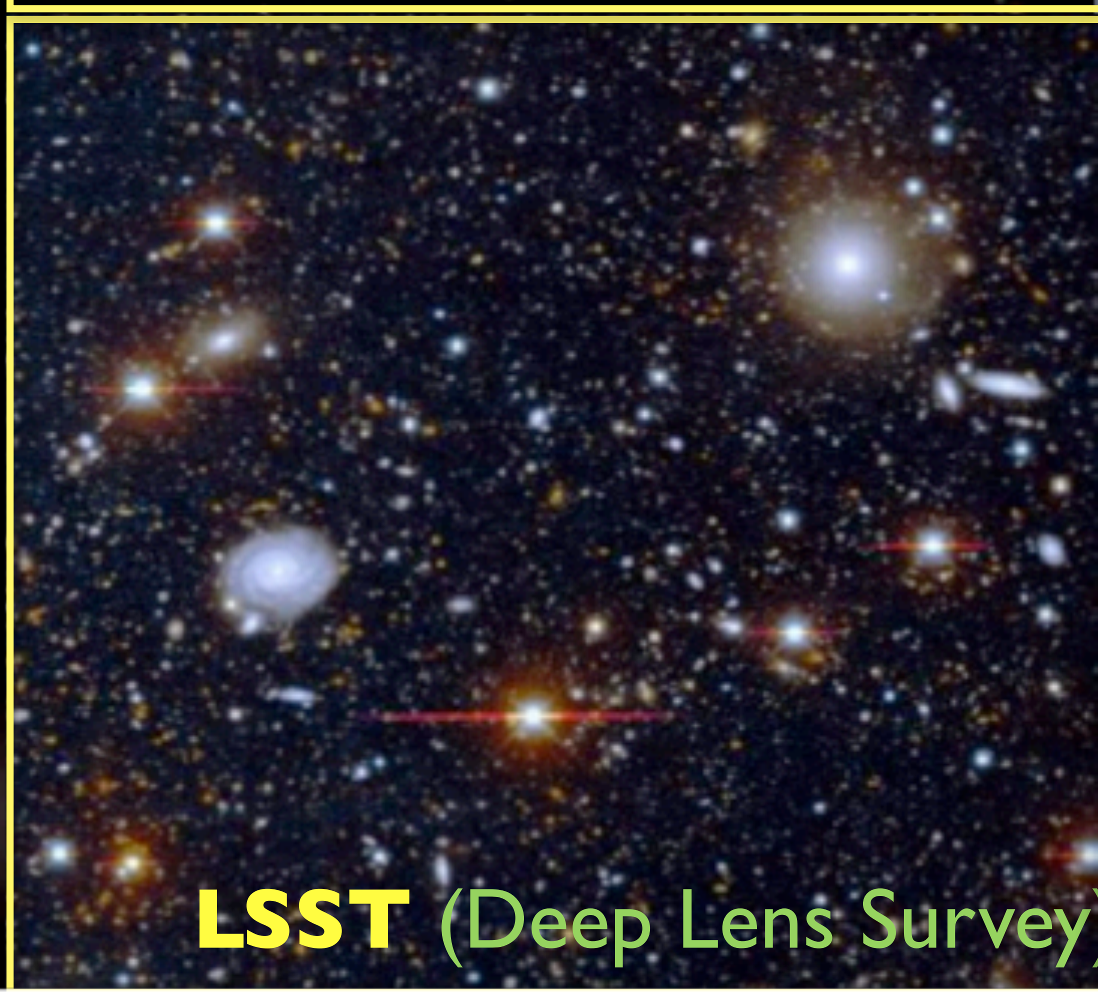
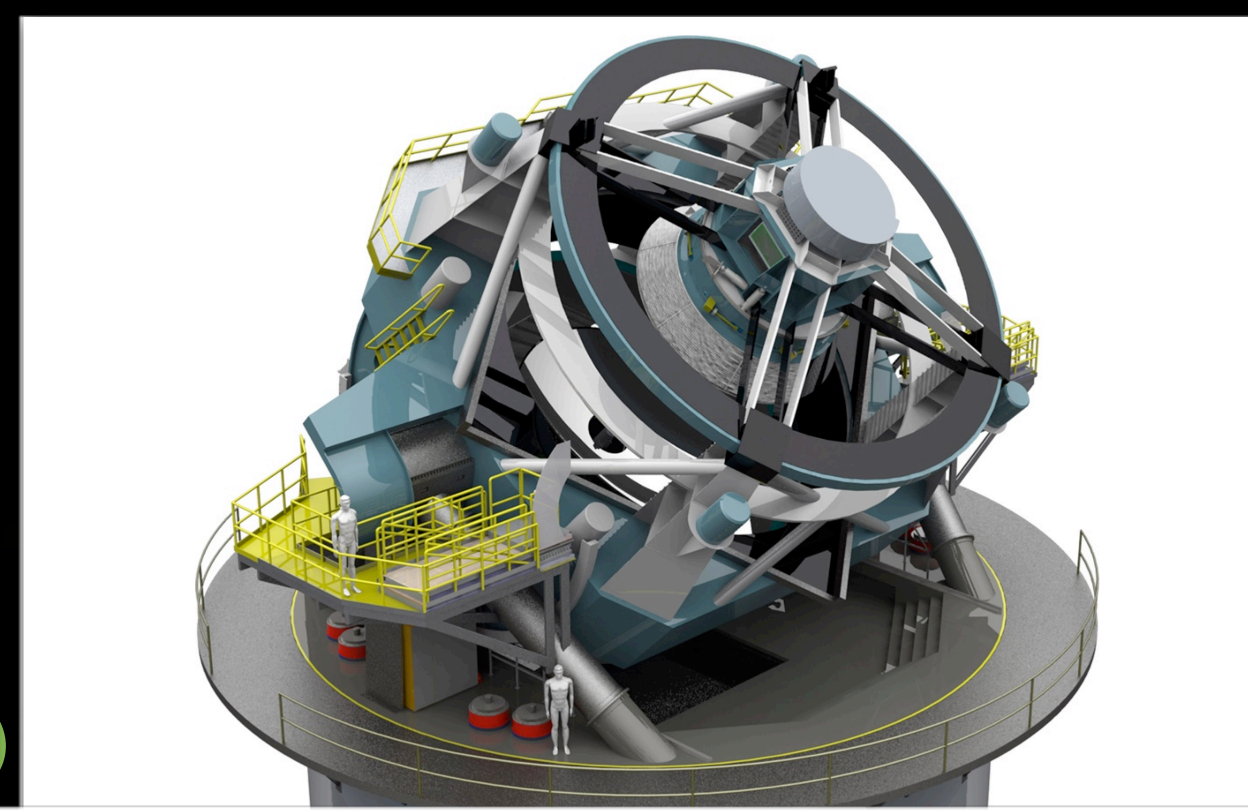
- About 5-10 million lines of new code
- C++/python
- A collaboration of astronomers, physicists and professional programmers





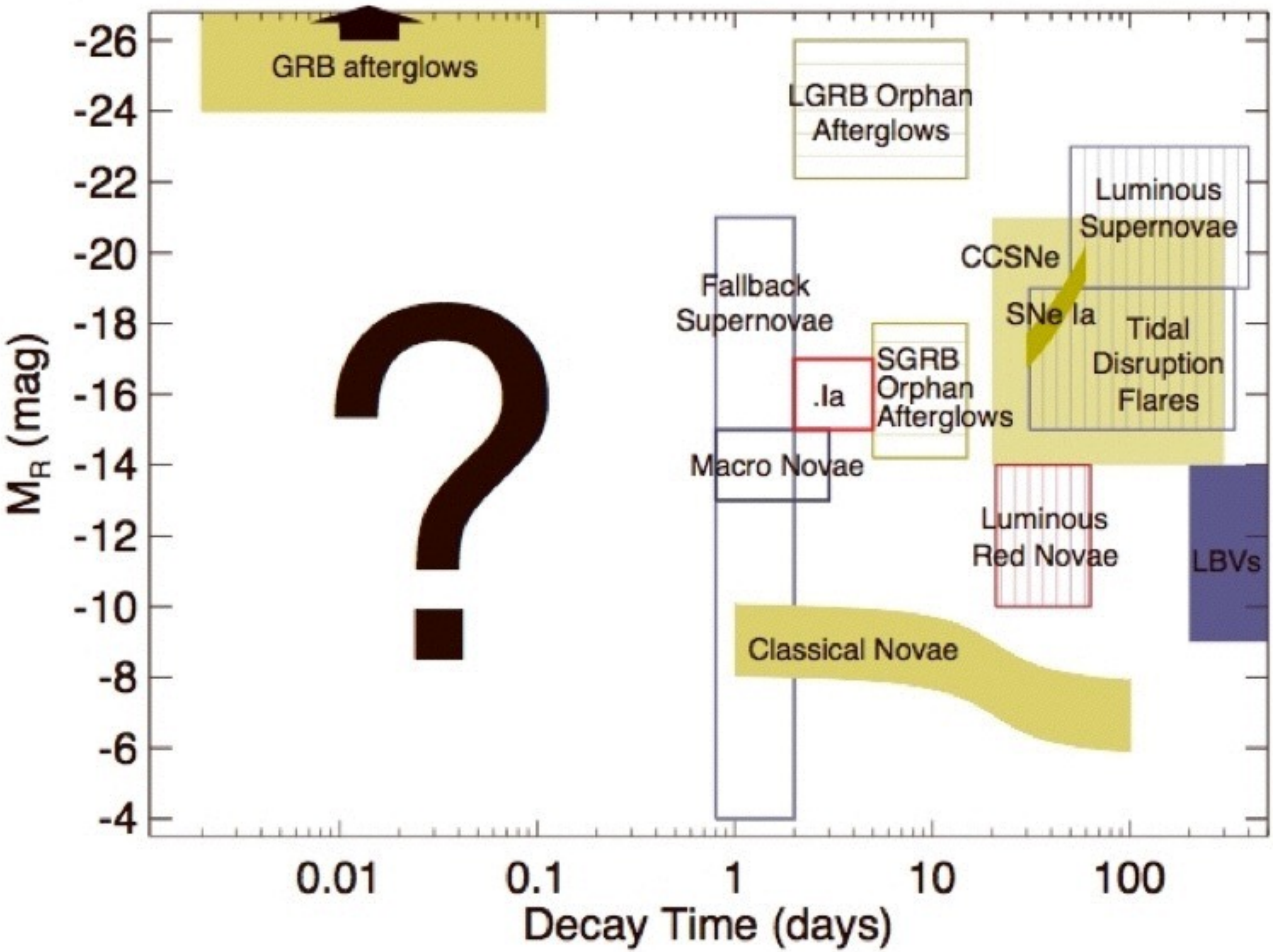
SDSS: one US Library of Congress worth of data

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

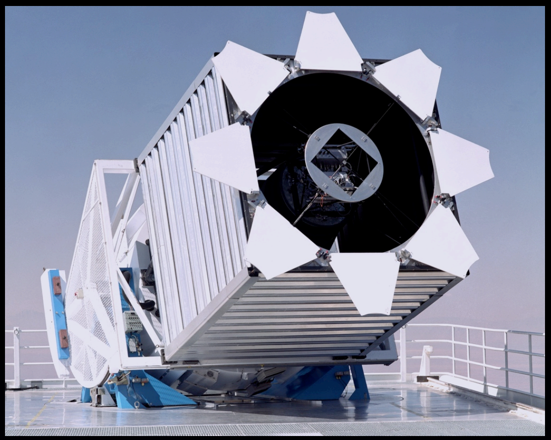


LSST tudományos témák

- Sötét anyag, sötét energia, kozmológia (galaxistérképek, szupernóvák, kvazárok)
- Időtartománybeli csillagászat (tranziensek, változócsillagok)
- A Naprendszer szerkezete (kis égitestek)
- A Tejútrendszer szerkezete (csillagok)



GRB afterglows
LGRB Orphan Afterglows
Luminous Supernovae
CCSNe
Fallback Supernovae
SNe Ia
Tidal Disruption Flares
SGRB Orphan Afterglows
.Ia
Macro Novae
Luminous Red Novae
LBVs
Classical Novae
?
-26
-24
-22
-20
-18
-16
-14
-12
-10
-8
-6
-4
M_R (mag)
0.01
0.1
1
10
100
Decay Time (days)



More information at
www.lsst.org
and arXiv:0805.2366

The Excitement of LSST

- **The Best Sky Image Ever:** 60 petabytes of astronomical image data (resolution equal to 3 million HDTV sets)
- **The Greatest Movie of All Time:** digital images of the entire observable sky every three nights, night after night, for 10 years (11 months to "view" it)
- **The Largest Astronomical Catalog:** 20 billion sources (for the first time in history more than living people)

2015 – A FÉNY NEMZETKÖZI ÉVE

KISS L. LÁSZLÓ

A számokká alakított fény

Digitális égboltfelmérések

A jelenkor csillagászata számos apró részletkérdésre keresi a választ. A földi légkörön túli térség objektumainak természete, a kapcsolódó fizikai jelenségek értelmezése komplex szaktudást igénylő tudományos munka, melynek hatékony elsajátításához évekig tartó szakosodásra van szükség. Ha azonban kicsit hátrébb lépünk és felmérjük a tájat, kirajzolódik három jól elkülönülő terület, amelyeket jól megfogalmazható alapkérdések jellemeznek.

A csillagászat nagy kérdései...

ul a kozmosz szerkezete és eredete a korai forró Univerzum vizsgálatain keresztül erősen kapcsolódik a nagyenergiájú fizikához és a részecskefizikához, addig a földi élet kozmikus tükörképének keresése földtudományi, kémiai, biológiai, klimatológiai területeket érintve keresi a filozófiai aspektusokkal is bíró nagy kérdésre a lehetséges válaszokat. Nem véletlen, hogy a kutatások egyre inkább nagy nemzetközi együttműködésekben folynak, hiszen a sikerhez fontos a tudományterületeken átívelő tudás, amit csak széles spektrumú kutatócsoportok képesek biztosítani.

A csillagászatban mindmáig nagyon erős irány az égi jelenségek egyre részletesebb

Természet Világa, megjelenés alatt