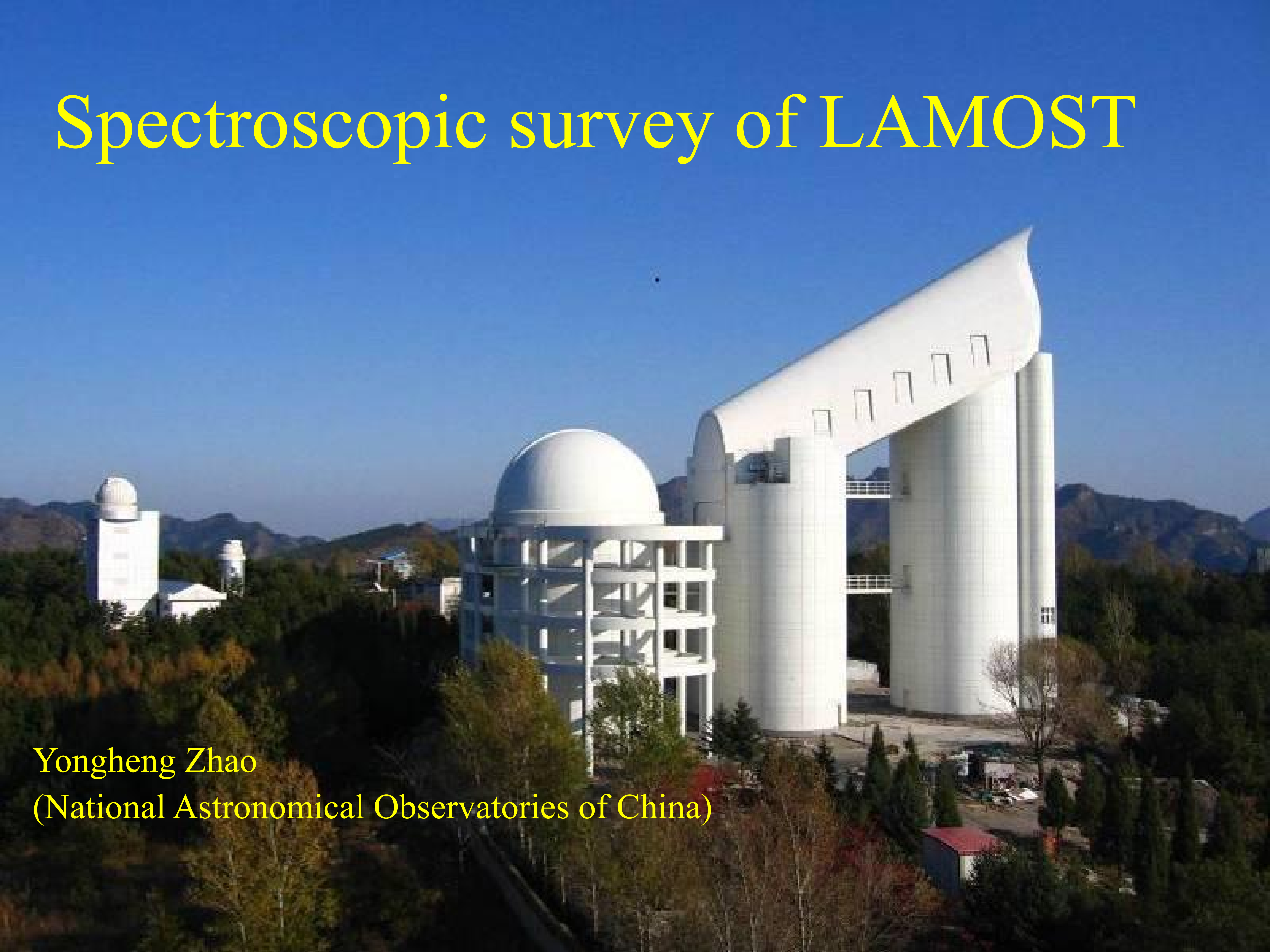
Spectroscopic survey of LAMOST



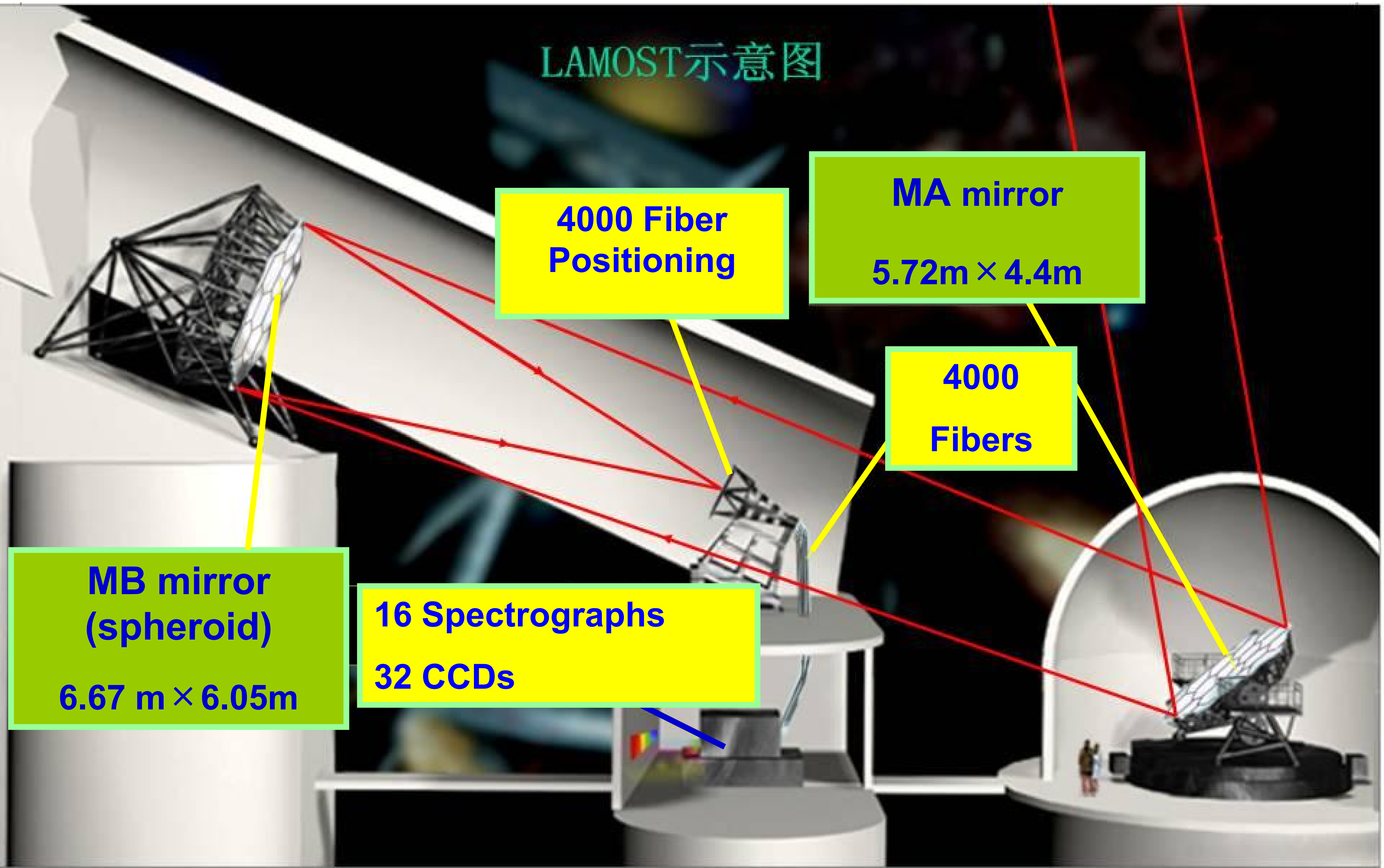
Yongheng Zhao
(National Astronomical Observatories of China)

Outline

- LAMOST
- Spectroscopic Survey of LAMOST
- LAMOST Sciences

LAMOST – A unique survey telescope

Structure of LAMOST



Innovations in LAMOST

a active reflecting Schmidt telescope

the Wang-Su type telescope which could get the largest aperture for wide field of view

large field of view (5 deg) +large aperture (4m)

achieved by new type of active optics — thin deformable segmented mirrors active optics

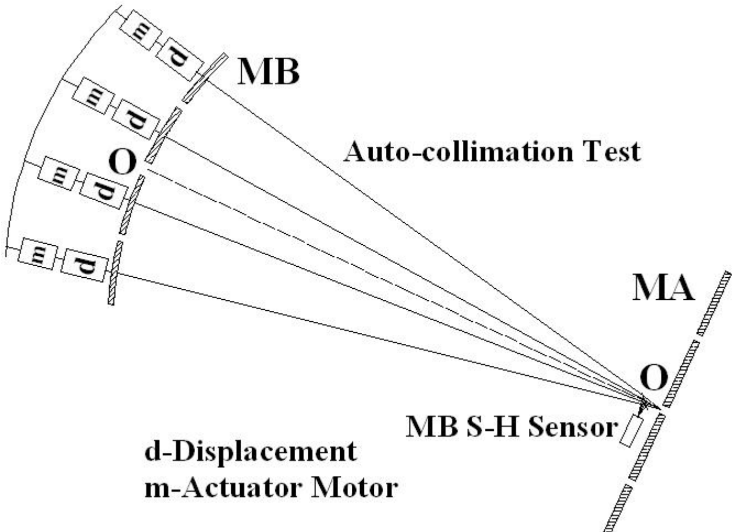
4000 optical fibers on focal surface

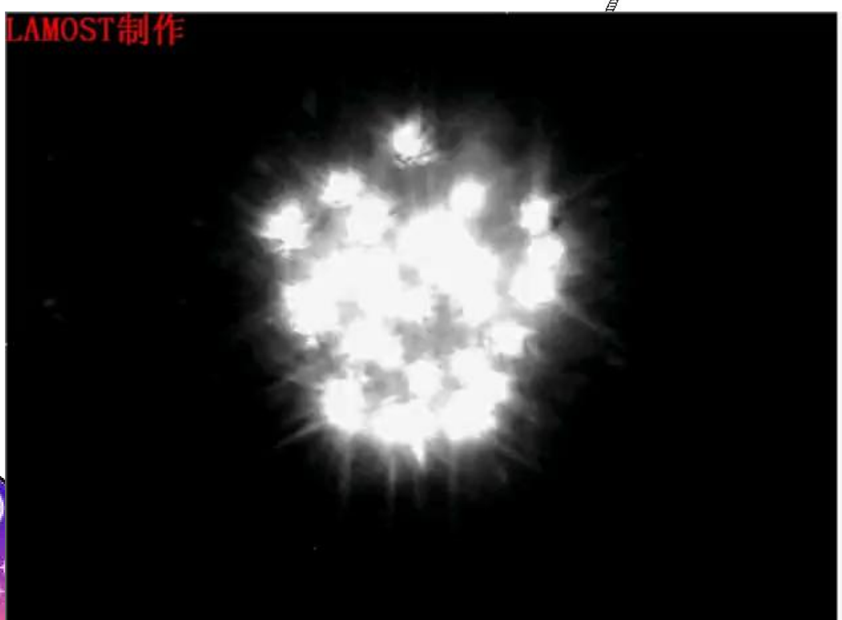
Parallel controllable fiber positioning opened the way to take thousands optical fibers observing in short time

MB: 37 sub-mirrors (6.67m x 6.05m)

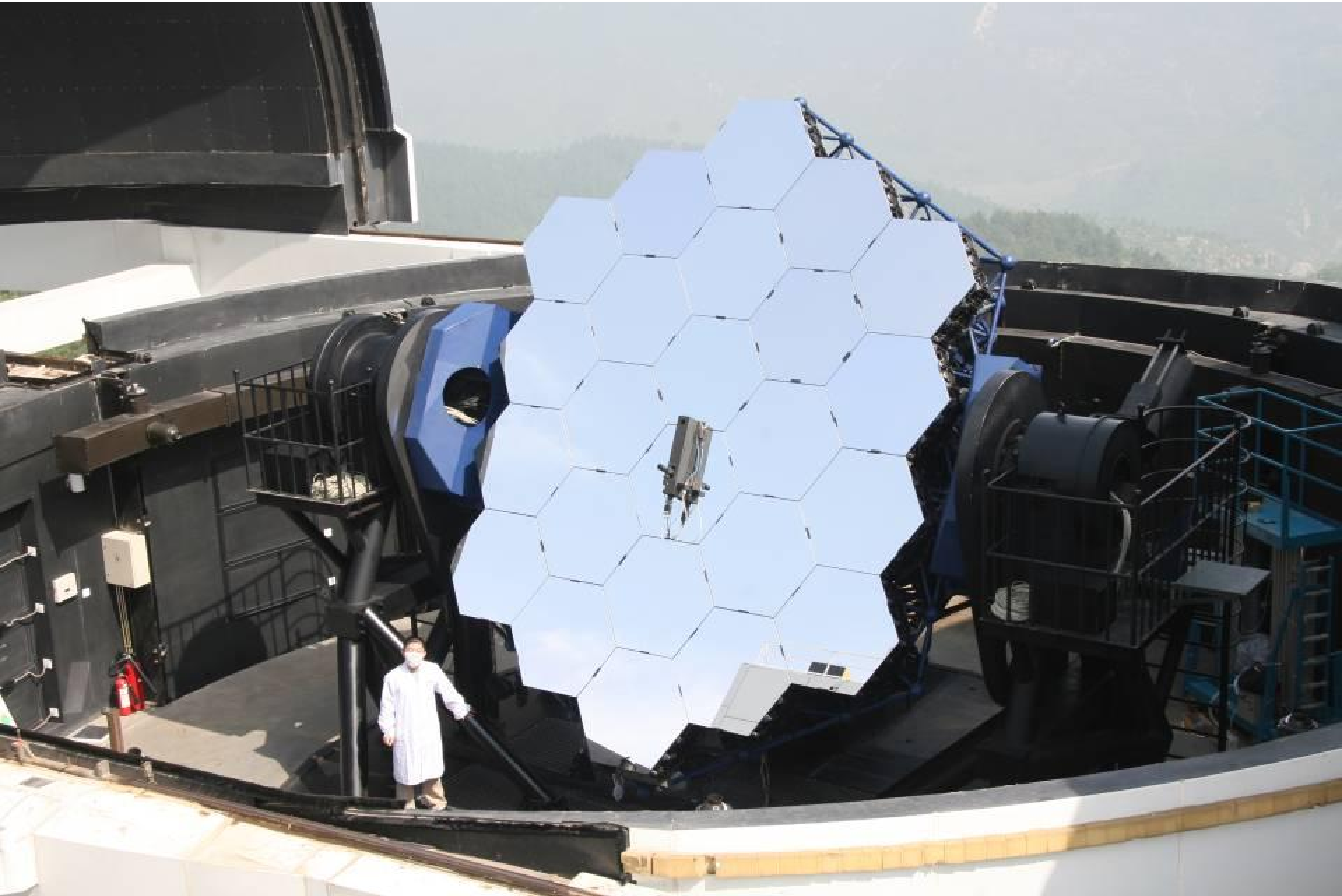
- **Active optics for segmented**

37 MB sub-mirrors

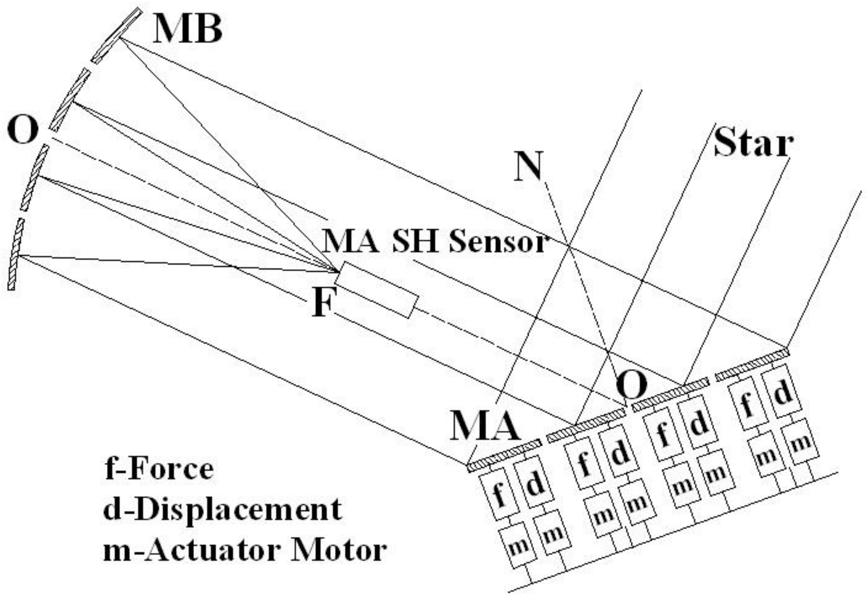


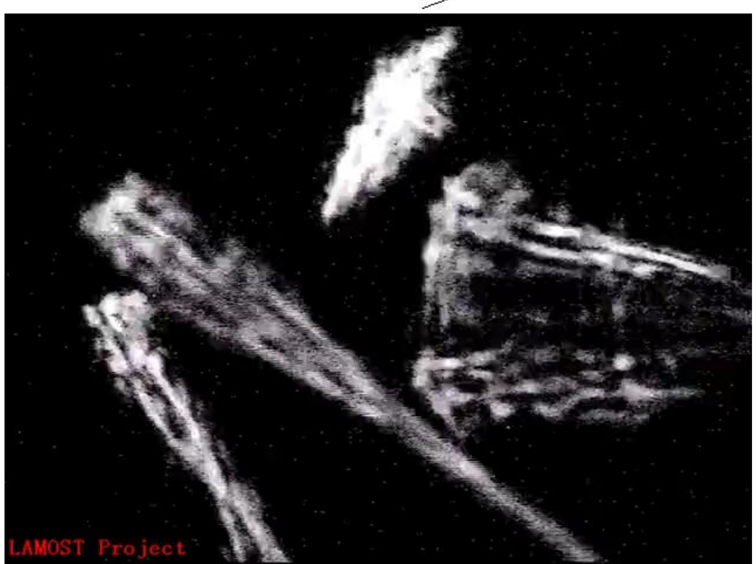


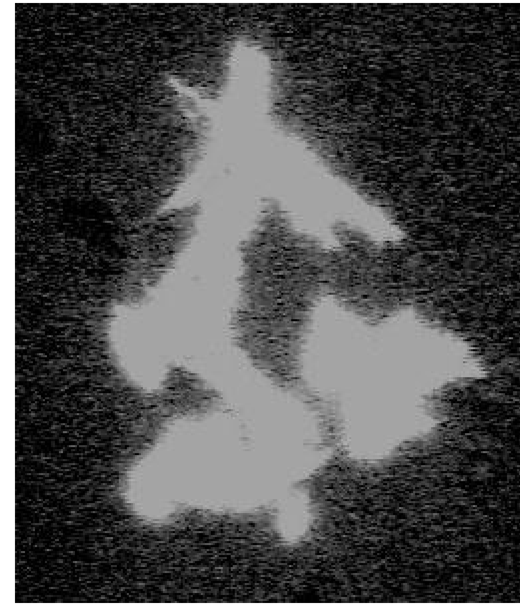
MA: 24 sub-mirrors (5.72m x 4.4m)

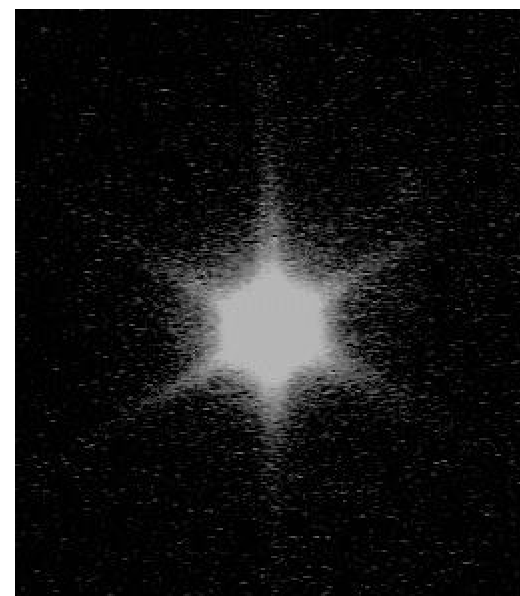


Active reflecting Schmidt optical system
Ma (24 sub-mirrors) + Mb (37 sub-mirrors)





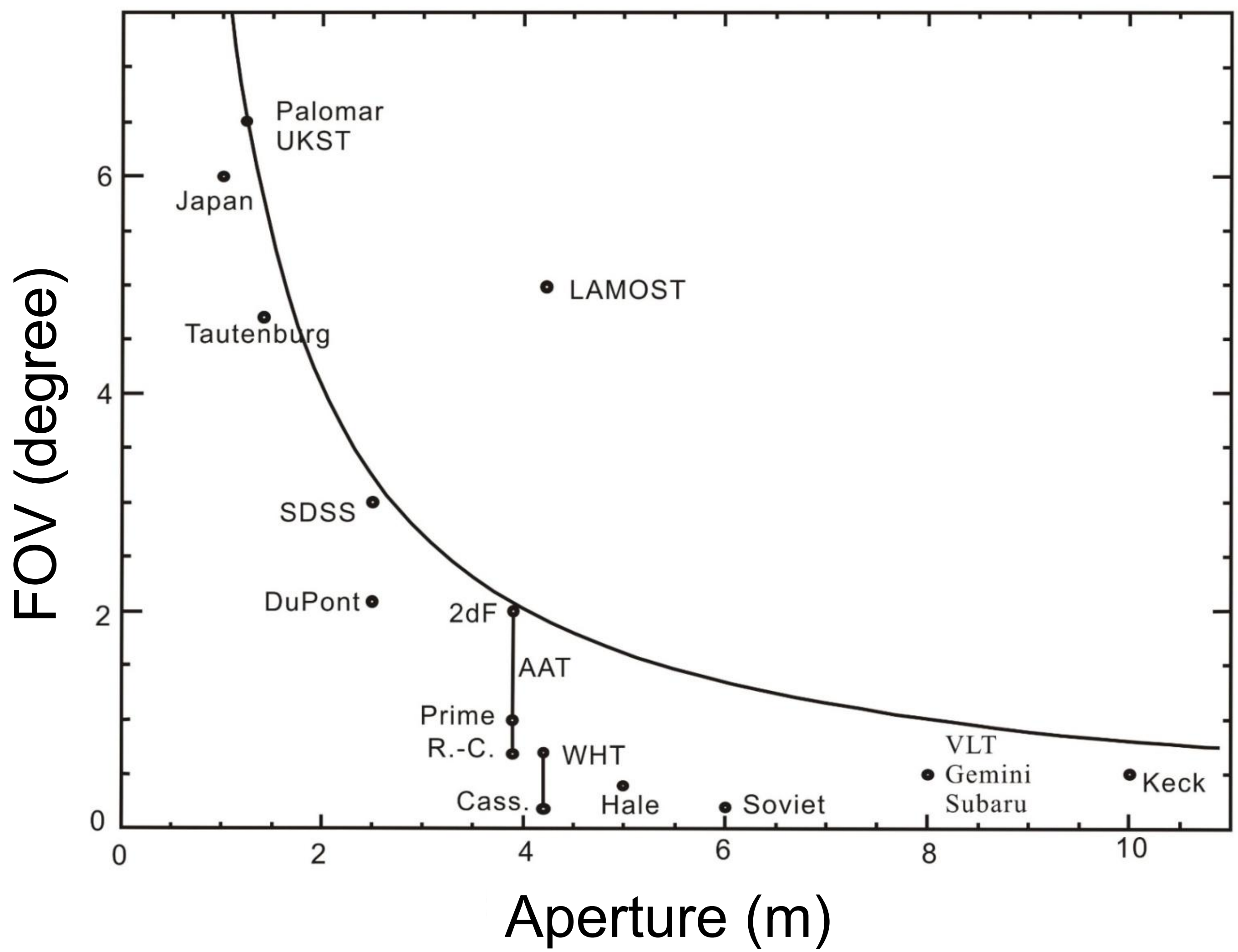




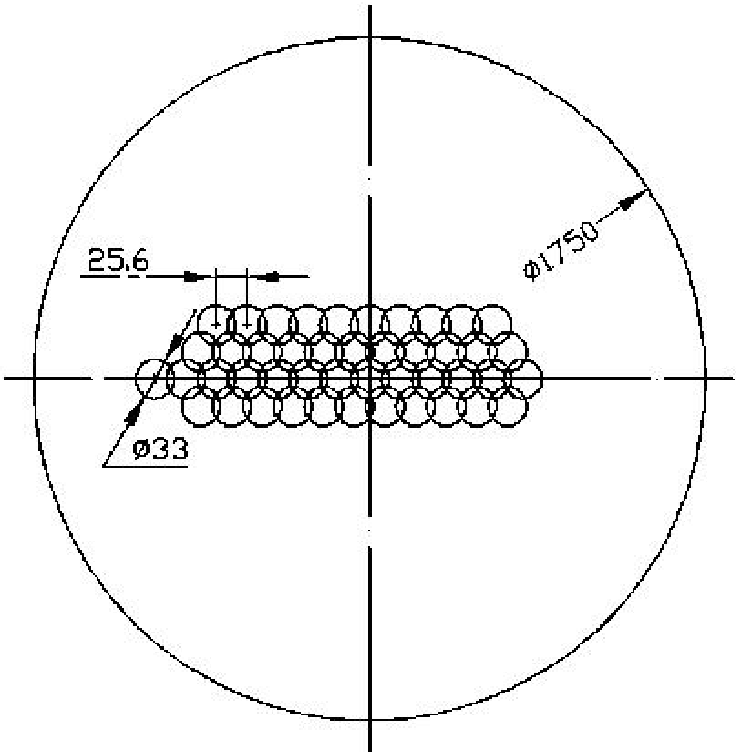
Aperture – field of view

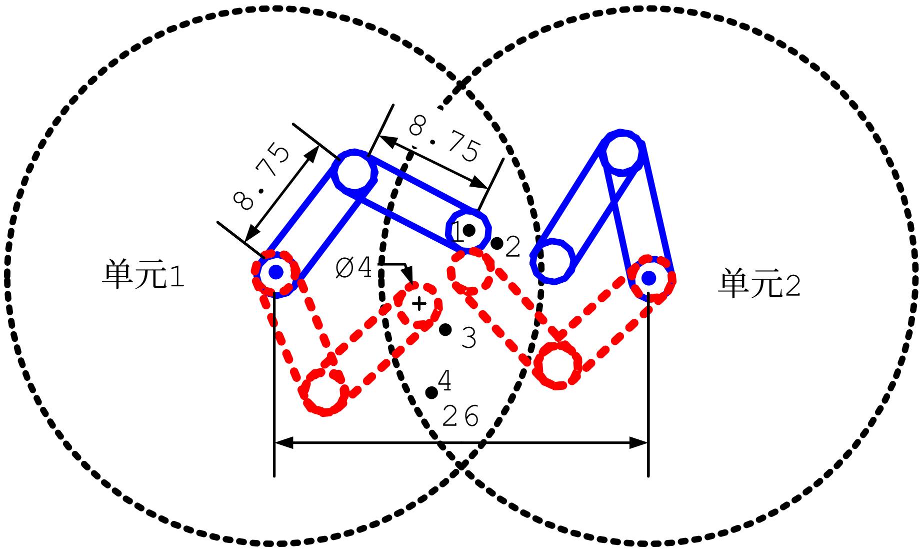
(prof. Wilstrop in Cambridge University)

《Astronomical Optics and Elasticity Theory》，2009，p. 41

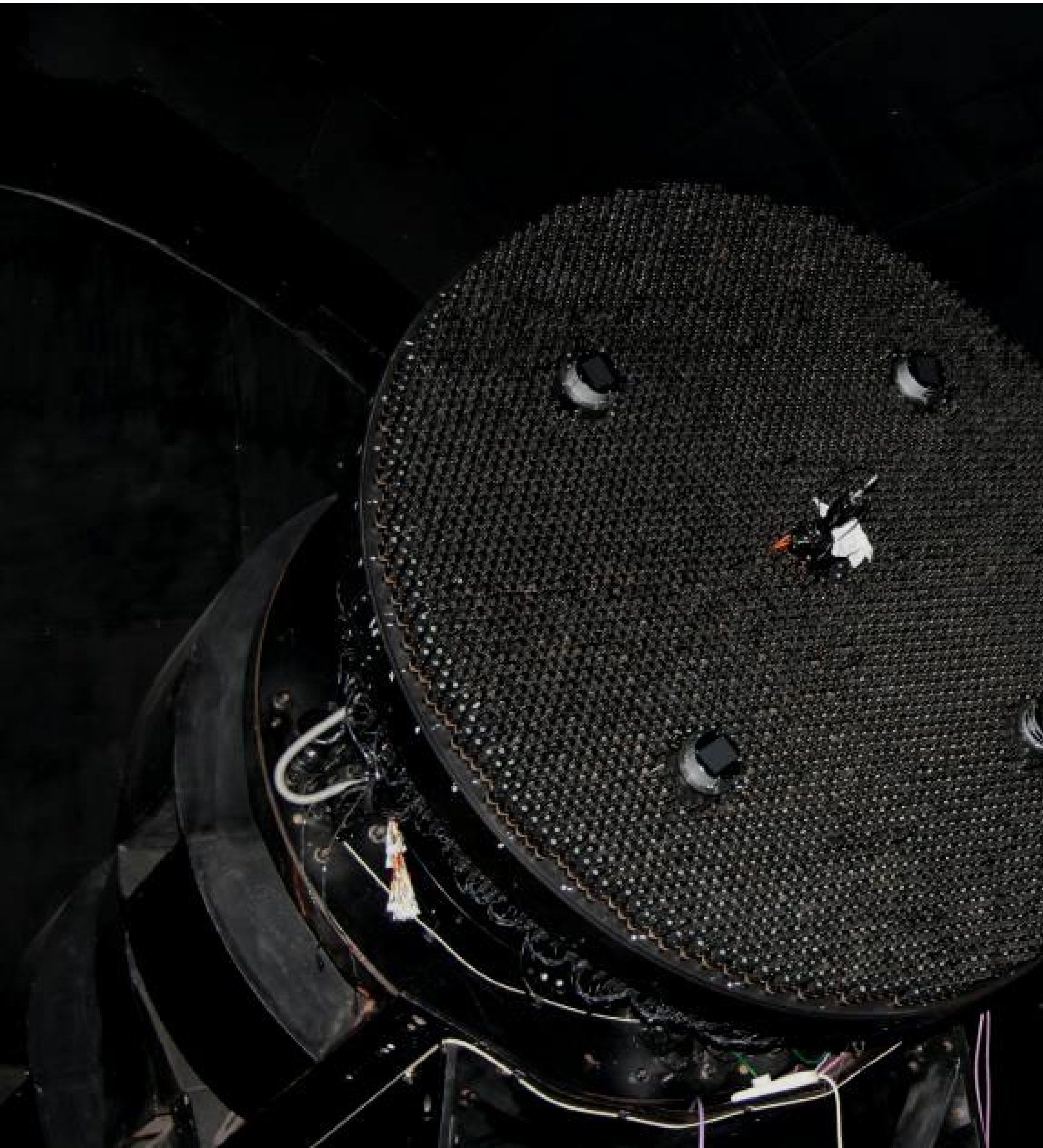


New technique:
Parallel controllable fiber positioning





4000 fiber positioning units



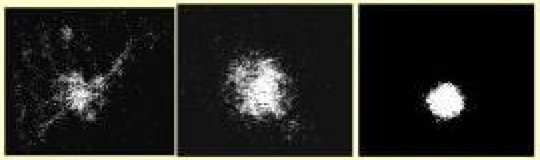
建设历程

1996年7月　国务院科技领导小组批准立项
1997年4月　国家计委批复项目建议书
1997年8月　国家计委批复项目可行性研究报告
1999年6月　中国科学院批复项目初步设计及概算
2001年8月　国家计委批复项目开工报告
2008年8月　完成全部建设任务
2008年10月　落成典礼
2009年6月　国家验收

建设历程

	2000	2001-2003	2004-2005	2006	2007	2008
望远镜		1米			3米	6米
主动光学		1:1		0:3	6:9	24:37
光纤定位	1		19		250	4000

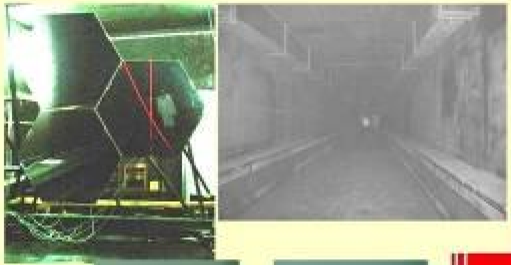
1Ma+1Mb

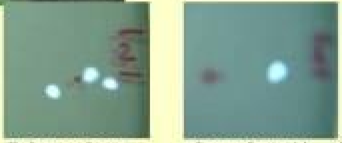


FWHM~4.8″ FWHM~3.6″ FWHM~1.98″

From 2001 to 2004, an experiment equipment built in Nanjing was been using for testing of thin mirror active optics.

3Mb





Before co-focus after co-focus (d_{80} ~ 0.42″)

In April 2004, an experiment equipment built in Nanjing was been using for testing of segmented mirror active optics.

6Ma+9Mb

In May of 2007, a small system of LAMOST was finished. It has 6 Ma and 9 Mb sub-mirrors with aperture of 2 meters, a small focal plane with field of view of 1.2 degrees, a small fiber positioning system with 250 fibers, and the first spectrograph with two 4k x 4k CCD cameras.
The first spectrum of a star observed by the small system of LAMOST in May 27 of 2007. From June of 2007, it is doing some test observations to sky and stars by the small system of LAMOST.

24Ma+37Mb

In the LAMOST schedule, all 24 Ma and 37 Mb sub-mirrors will be installed and tested in June of 2008. Large focal plane with 4000 fibers and all 16 low resolution spectrographs with 32 CCD cameras will be installed and tested in August of 2008. The first light of LAMOST for whole aperture (4 m) and full field of view (5 degree) would be obtained in August of 2008.

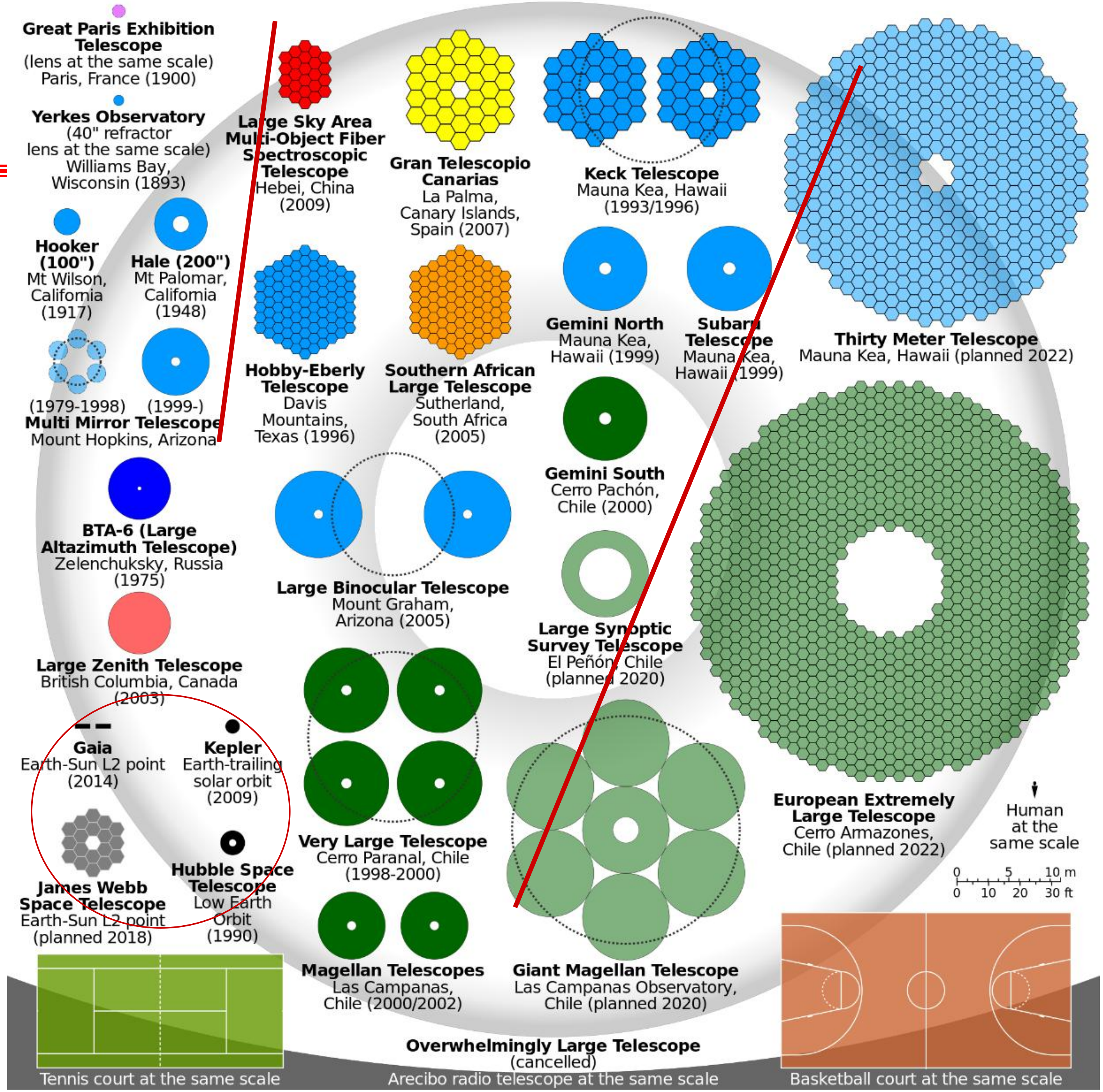
1单元

19单元

250单元

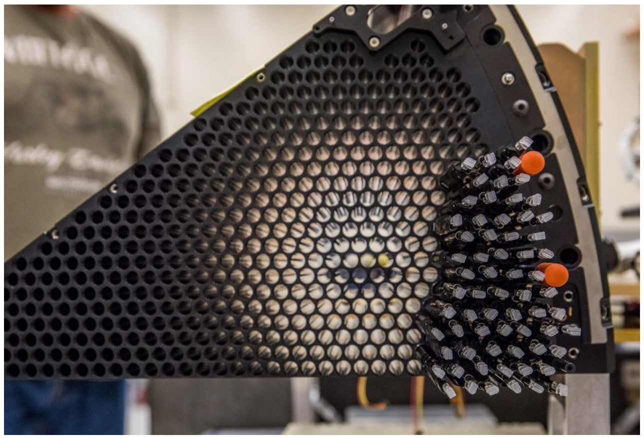
4000单元

光学望远镜



Great Paris Exhibition Telescope
(lens at the same scale)
Paris, France (1900)
Yerkes Observatory
(40" refractor
lens at the same scale)
Williams Bay,
Wisconsin (1893)
Hooker (100")
Mt Wilson, California (1917)
Hale (200")
Mt Palomar, California (1948)
(1979-1998) (1999-)
Multi Mirror Telescope
Mount Hopkins, Arizona
Large Sky Area Multi-Object Fiber Spectroscopic Telescope
Hebei, China (2009)
Gran Telescopio Canarias
La Palma, Canary Islands, Spain (2007)
Keck Telescope
Mauna Kea, Hawaii (1993/1996)
Thirty Meter Telescope
Mauna Kea, Hawaii (planned 2022)
Hobby-Eberly Telescope
Davis Mountains, Texas (1996)
Southern African Large Telescope
Sutherland, South Africa (2005)
Gemini North
Mauna Kea, Hawaii (1999)
Subaru Telescope
Mauna Kea, Hawaii (1999)
Gemini South
Cerro Pachón, Chile (2000)
BTA-6 (Large Altazimuth Telescope)
Zelenchuksky, Russia (1975)
Large Binocular Telescope
Mount Graham, Arizona (2005)
Large Synoptic Survey Telescope
El Peñón, Chile (planned 2020)
Large Zenith Telescope
British Columbia, Canada (2003)
Gaia
Earth-Sun L2 point (2014)
Kepler
Earth-trailing solar orbit (2009)
James Webb Space Telescope
Earth-Sun L2 point (planned 2018)
Hubble Space Telescope
Low Earth Orbit (1990)
Very Large Telescope
Cerro Paranal, Chile (1998-2000)
Magellan Telescopes
Las Campanas, Chile (2000/2002)
Giant Magellan Telescope
Las Campanas Observatory, Chile (planned 2020)
European Extremely Large Telescope
Cerro Armazones, Chile (planned 2022)
Human at the same scale
0 5 10 m
0 10 20 30 ft
Overwhelmingly Large Telescope
(cancelled)
Tennis court at the same scale
Arecibo radio telescope at the same scale
Basketball court at the same scale

New spectroscopical survey projects



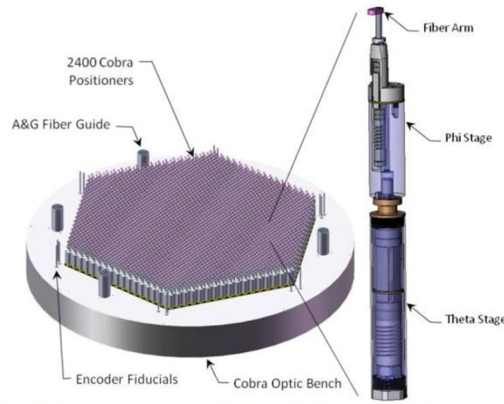
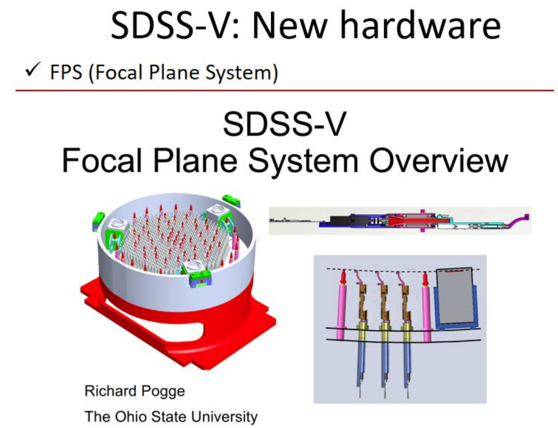


Figure 3.10-1. Positioner Bench Populated with One Module and a Single Positioner



DESI (USA)

SUBARU / PFS (Japan)

SDSS-V (USA)

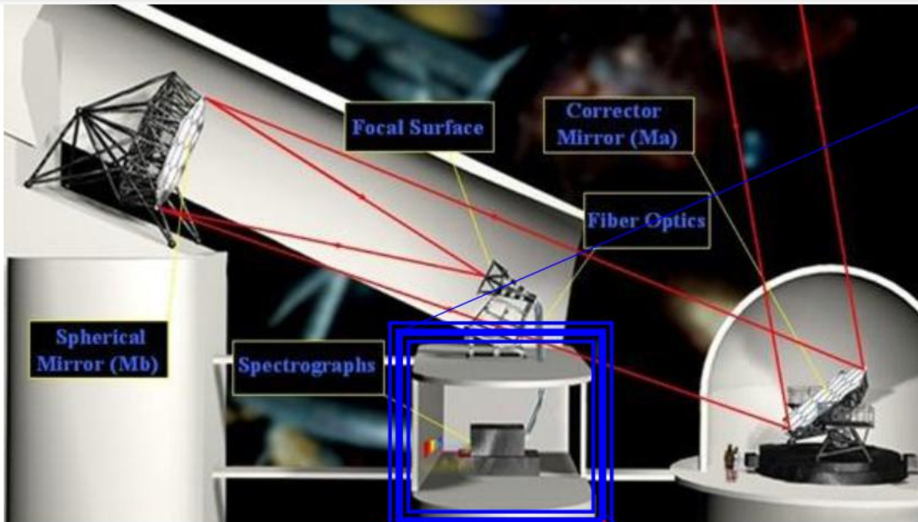
>~ 1000 fibers → Parallel controllable fiber positioning

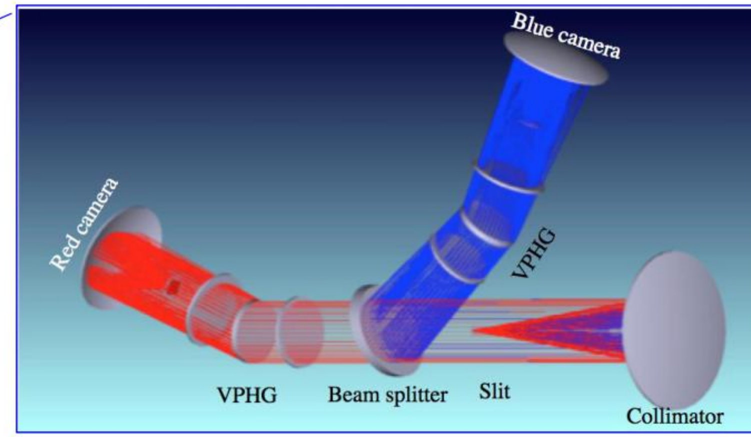
Spectroscopic Survey of LAMOST

		low resolution mode	medium resolution mode
Sep. 2011 – Jun. 2012	1 year	pilot survey	
Sep. 2012 – Jun. 2017	5 years	**1st regular survey**	
Sep. 2017 – Jun. 2018	1 year	continue	test survey
Sep. 2018 – Jun. 2023	5 years	**2nd regular survey**	**2nd regular survey**

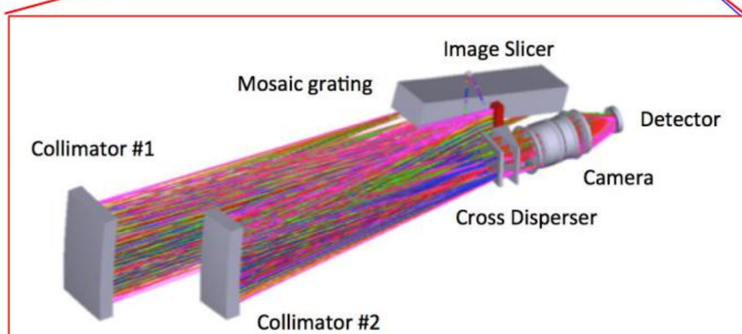
- **Scientific goals:**
  - **Structure & evolution of the Milky Way**
  - **Stellar astrophysics**
  - **Quasars & galaxies**

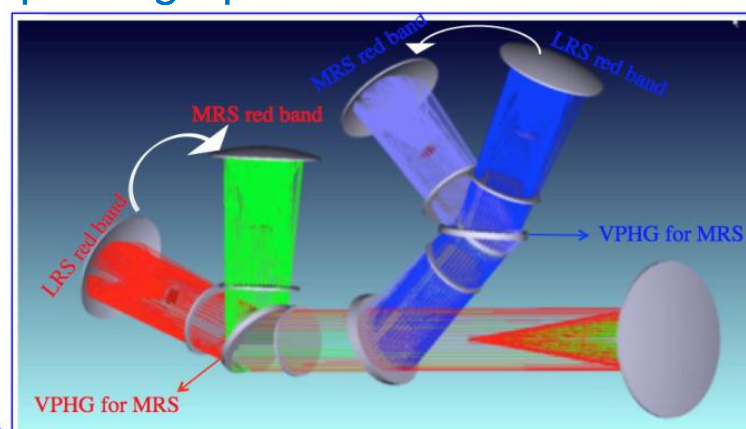
low & medium resolution modes





16 spectrographs in low-resolution mode





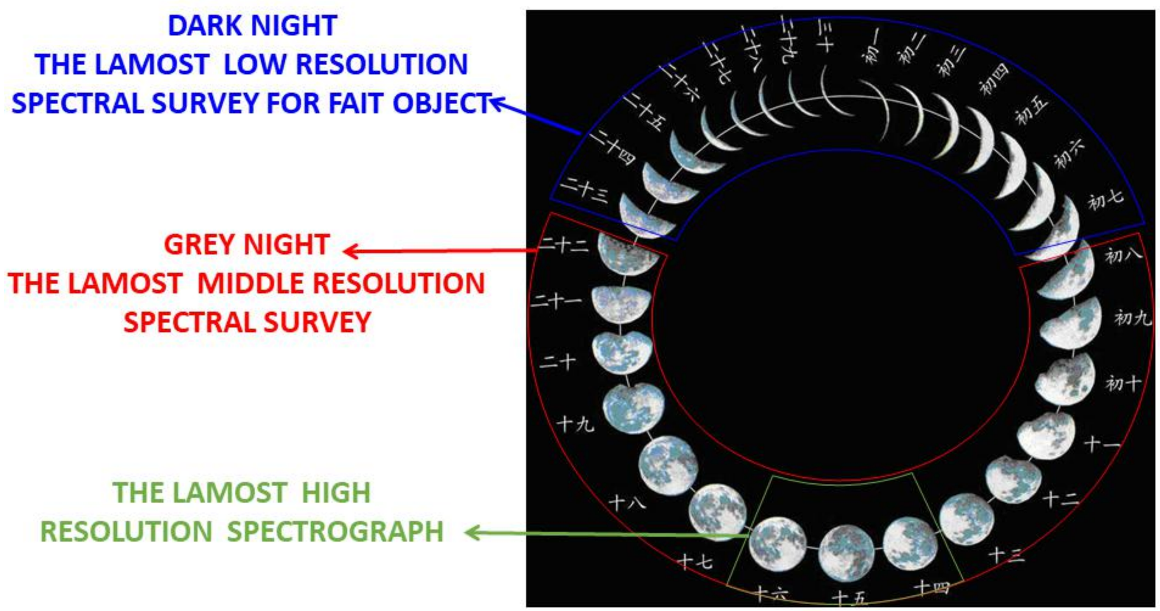
16 spectrographs in medium-resolution mode

1 spectrographs in high-resolution mode

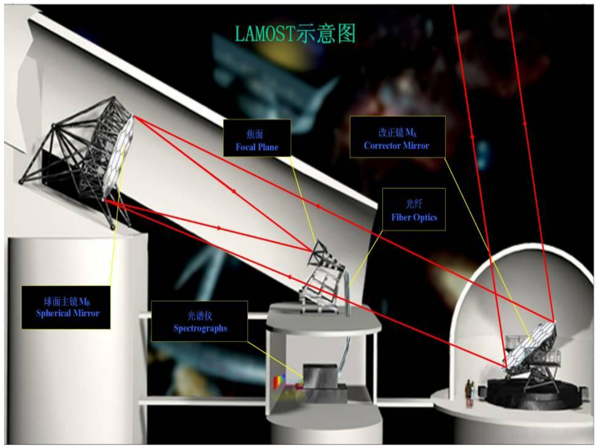
The 2nd regular survey of LAMOST

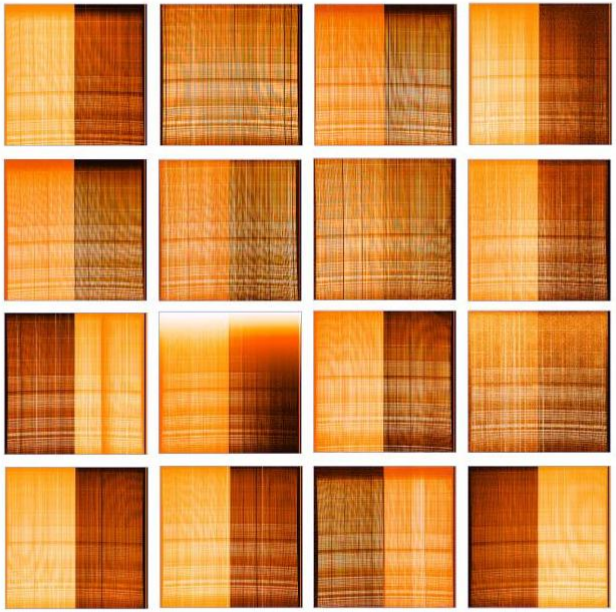
2018.9 - 2023.6:

- survey in low-resolution (dark nights)
- survey in median-resolution (bright nights)
- observations in high-resolution (full moon nights)

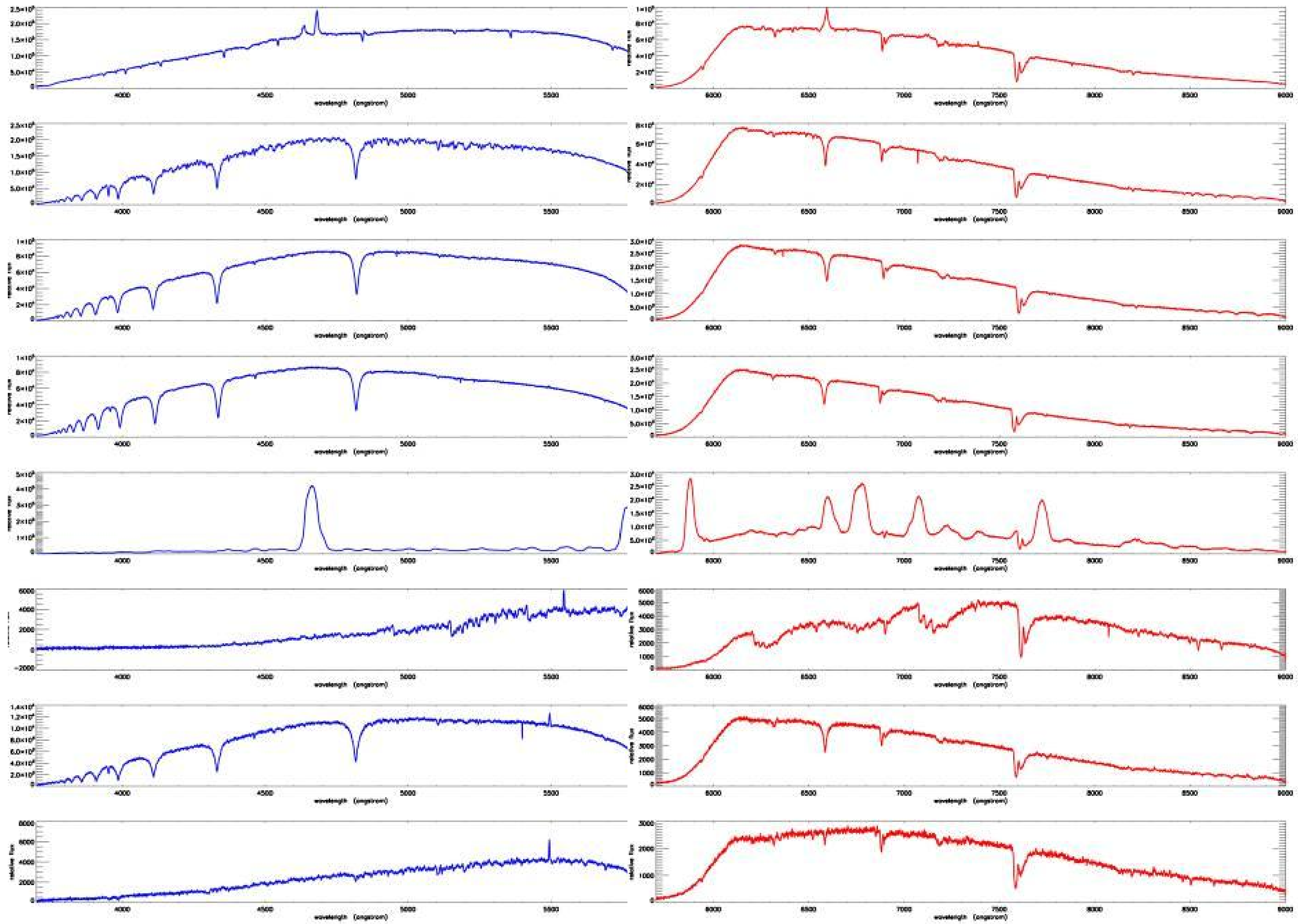


Raw data by LAMOST

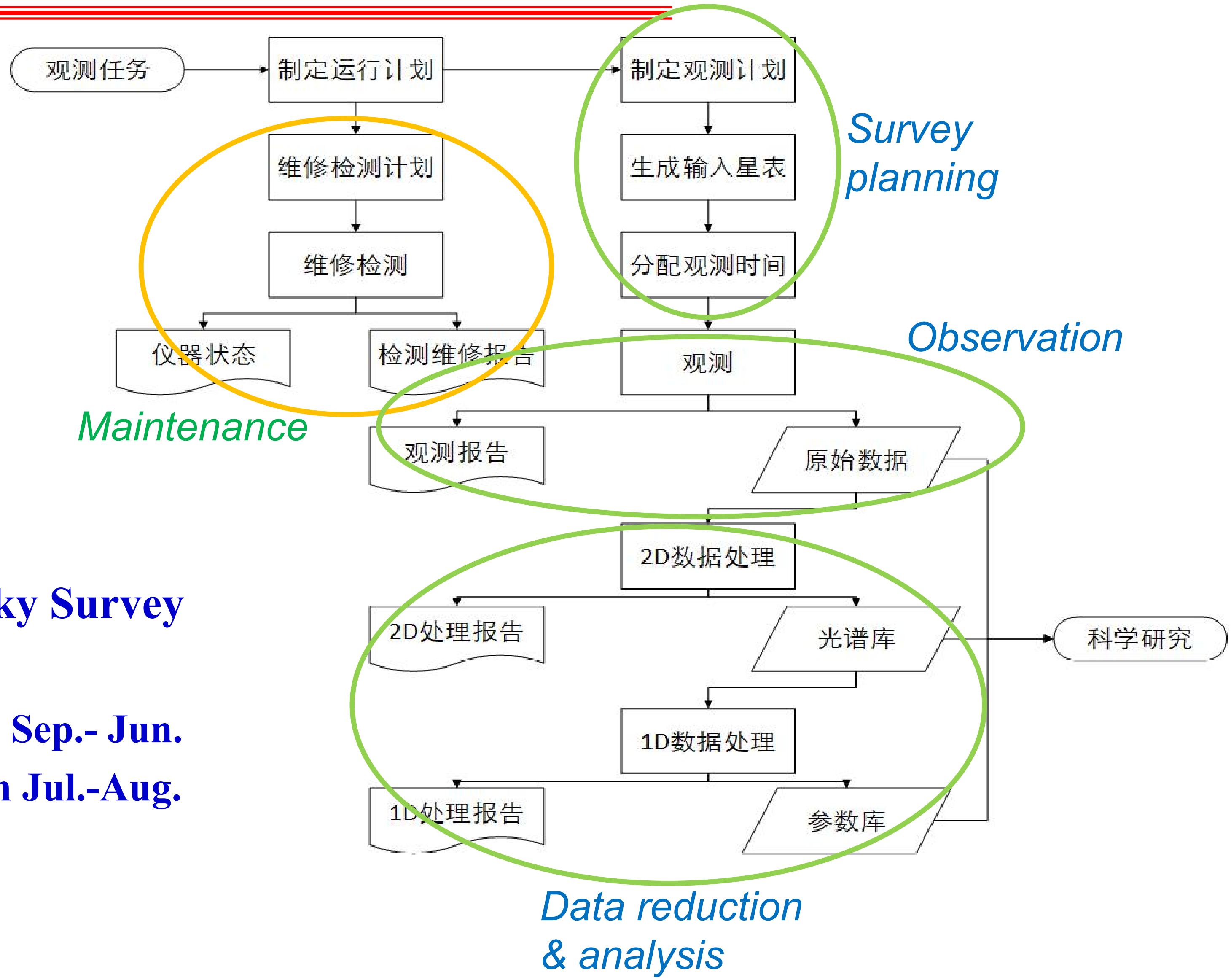




Data reduction



Operation of LAMOST



Observation of Sky Survey

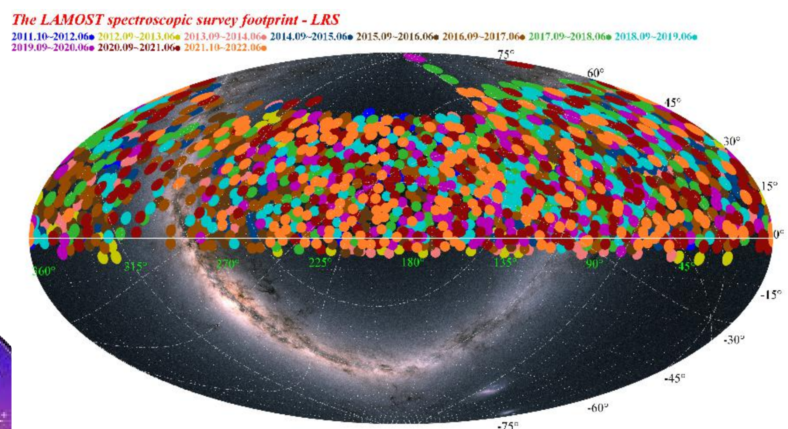
- **Observation in Sep.- Jun.**
- **Maintenance in Jul.-Aug.**

~ 20,000,000 spectra by LAMOST

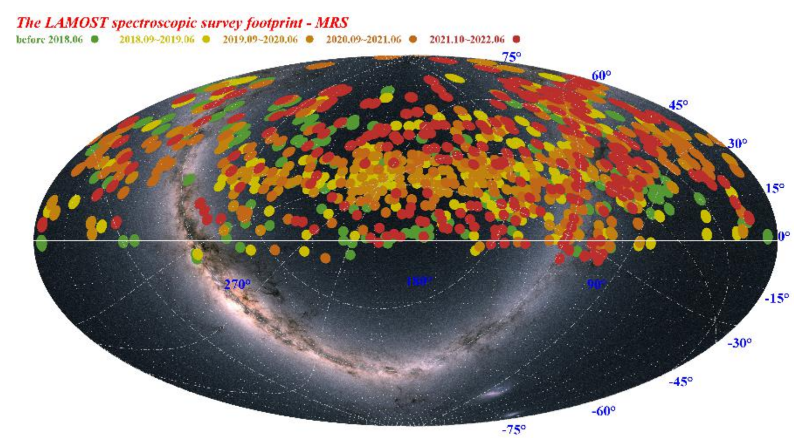
- **DR9 dataset (Mar. 2022)**
  - **Observed: Sep. 2011 – Jun. 2021**

2.6 x others

	Low-resolution data	Medium-resolution non time-domain data	Medium-resolution time-domain data	Total
Total spectra	11226252	1841959	6384475	**19452686**
Spectra (S/N>10)	10109779	1194264	3662548	14966591
Star parameter	7060436	906003	771211	8737650



Low resolution obs. of LAMOST DR10



Midium resolution obs. of LAMOST DR9

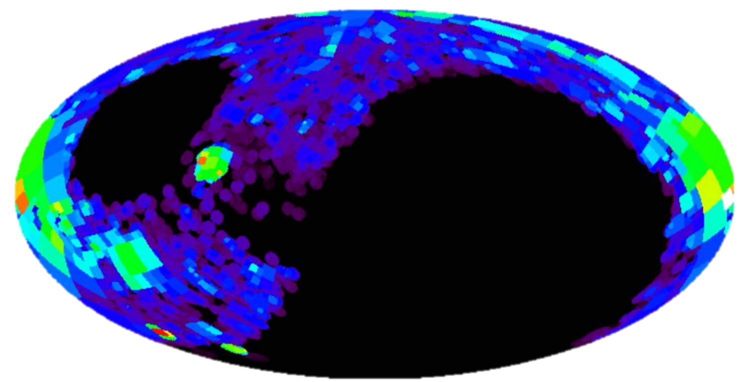
Data release of LAMOST

- **Data police:**
  - **Released to Chinese astronomers and international parteners**
  - **Released to Public after 18 months**

Dataset	Spectra with S/N>10	Stellar parameters	Data release to domestic / public
Pilot survey (PDR)	0.55 M	0.36 M	2012.08 / 2012.08
Pilot + 1 year Normal survey: (DR1)	1.74 M	1.06 M	2013.09 / 2015.03
Pilot + 2 year Normal survey: (DR2)	3.27 M	2.20 M	2014.12 / 2016.07
Pilot + 3 year Normal survey: (DR3)	4.66 M	3.17 M	2015.12 / 2017.07
Pilot + 4 year Normal survey: (DR4)	6.21 M	4.20 M	2016.12 / 2018.07
Pilot + 5 year Normal survey: (DR5)	7.77 M	5.34 M	2017.12 / 2019.07
Pilot + 6 year Normal survey: (DR6)	9.37 M	6.36 M	2019.03 / 2020.10
Pilot + 7 year Normal survey: (DR7)	14.48 M	7.00 M	2020.03 / 2021.10
Pilot + 8 year Normal survey: (DR8)	17.23 M	7.75 M	2021.03 / 2022.10
Pilot + 9 year Normal survey: (DR9)	**19.45 M**	**8.73 M**	2022.03 / *2023.10*

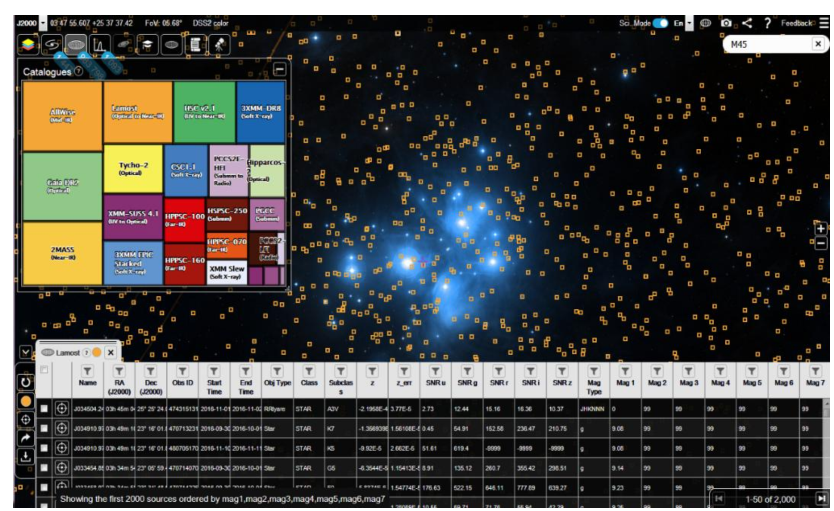
Collaborations with CDS & ESA

- **LAMOST datasets collected by ViziR/CDS from 2016**



LAMOST DR5 in VizieR

- **Fusion with ESASky astronomical data system**



Publications by used of LAMOST data

No. of papers: 1,149

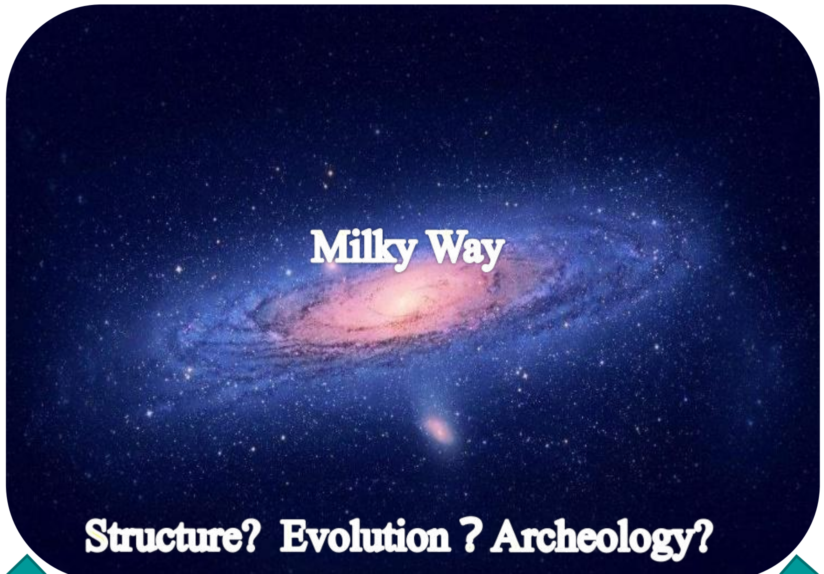
No. of citations: 13,233

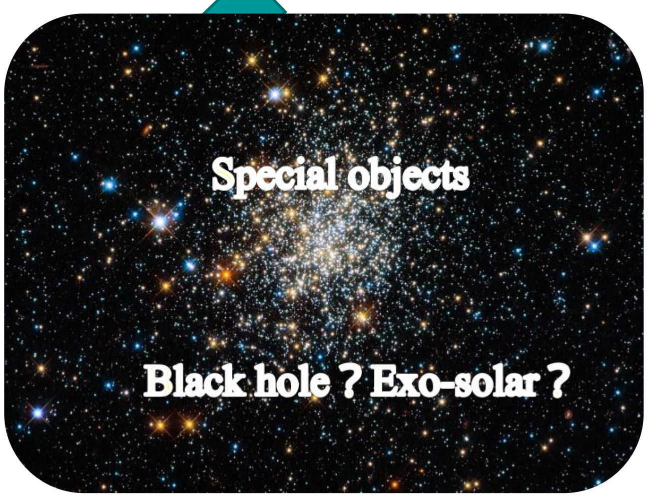
2022年1-9月，发表SCI论文203篇，其中Nature 3篇，Nature Astronomy 2篇

No. of papers by foreign astronomers

	2017	2018	2019	2020	2021	2022/1-9
No. of SCI by foreign astronomers	35	37	50	60	**112**	**88**
No. of SCI by Chinese astronomers	55	77	89	97	120	115
Ratio	38.9%	32.5%	36.0%	39.3%	**48.3%**	**43.3%**

LAMOST sciences





Structure of the galactic disk: radius

- In textbook

  50,000 light years

- 2017:

  Liu et al. RAA

  62,000 light years

- 2018:

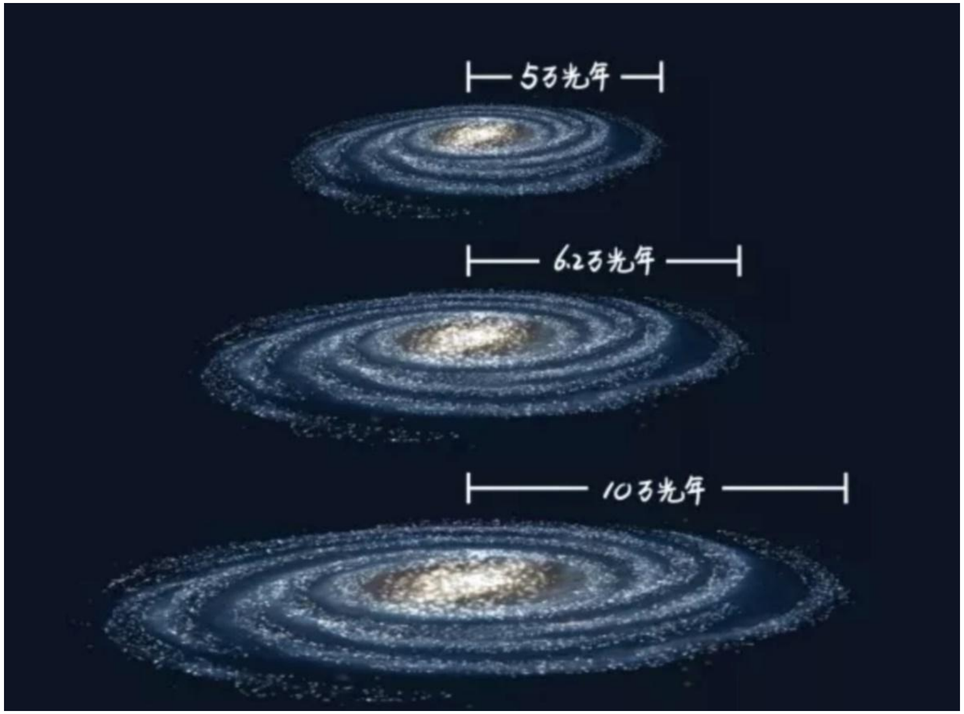
  Lopez-Corredoira et al. AA

  100,000 light years

- 2021:

  Li et al. ApJ

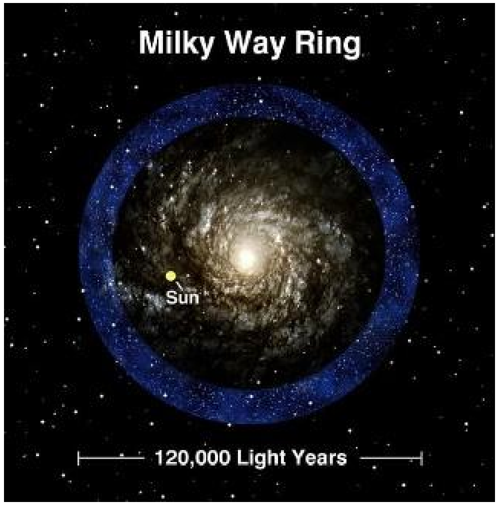
  97,800 light years

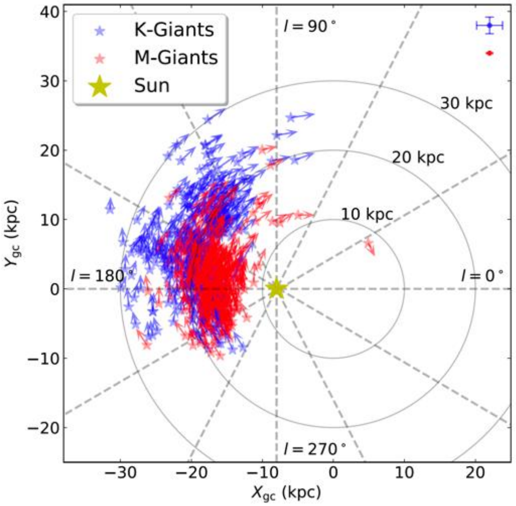


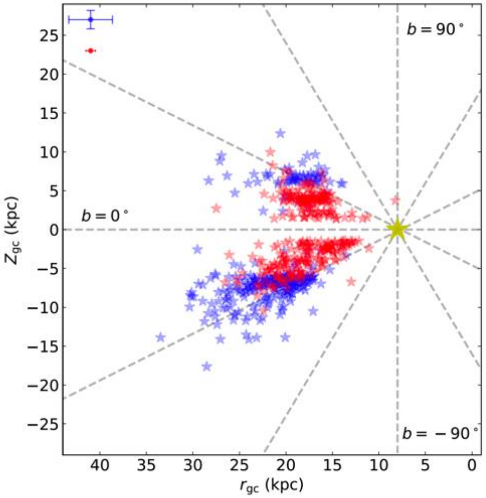
银盘半径大小变化示意图

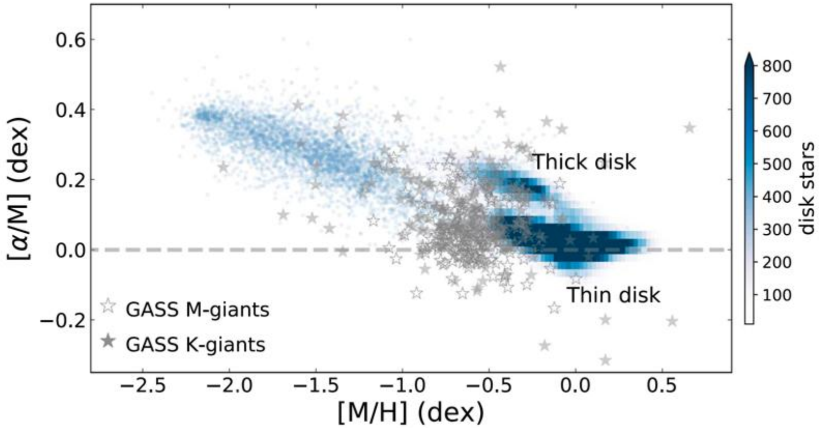
Monoceros ring

- **Origin from disk**
- **Extended to 30 kpc**



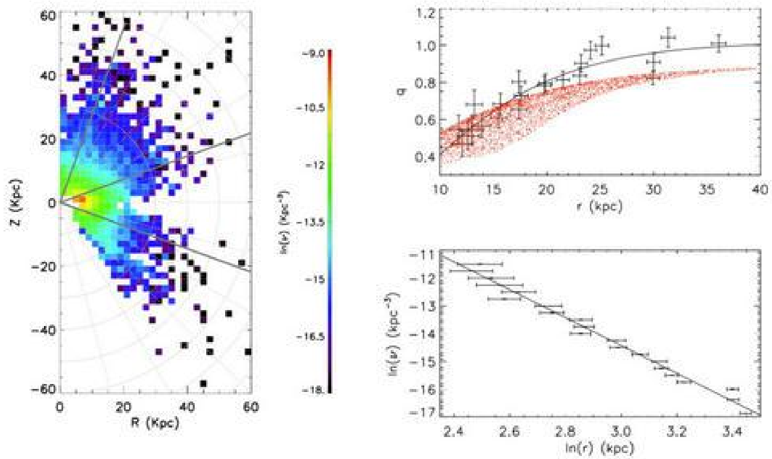


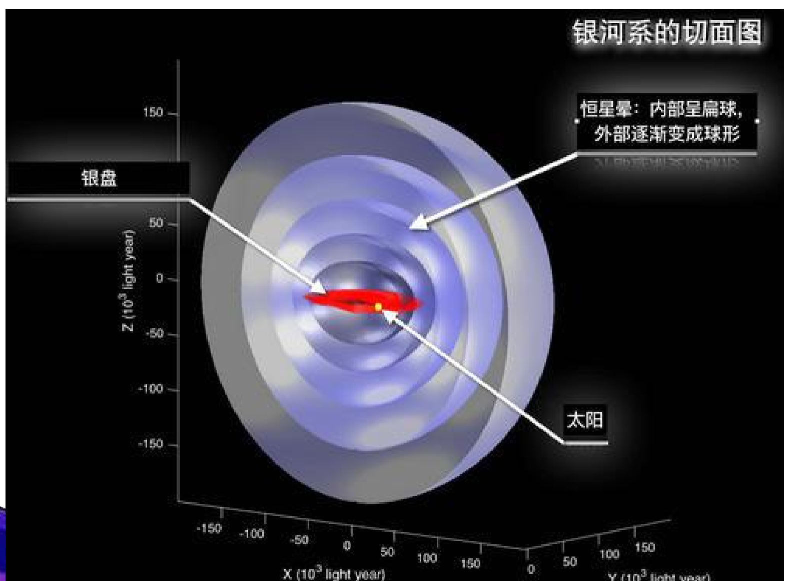




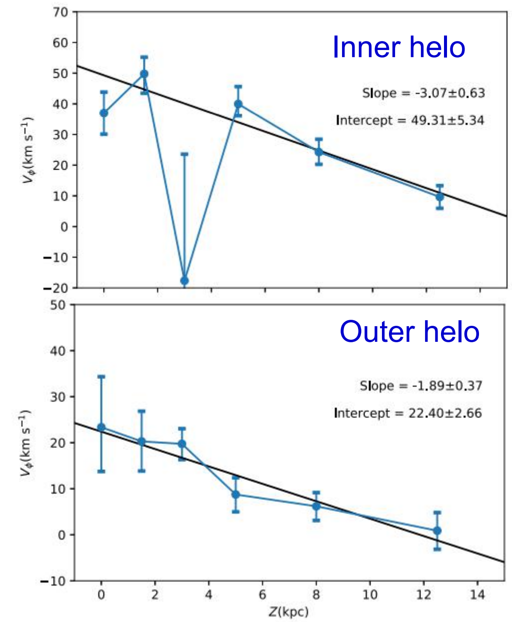
Li, Xue+ ApJ, 2021

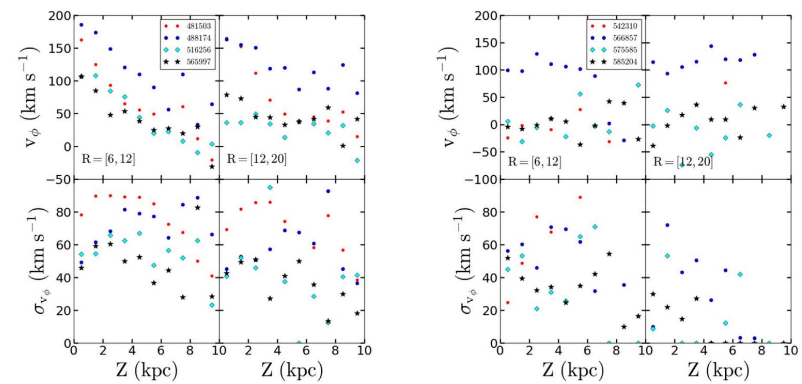
Structure of the halo





Xu et al. 2018, MNRAS, 473, 1244



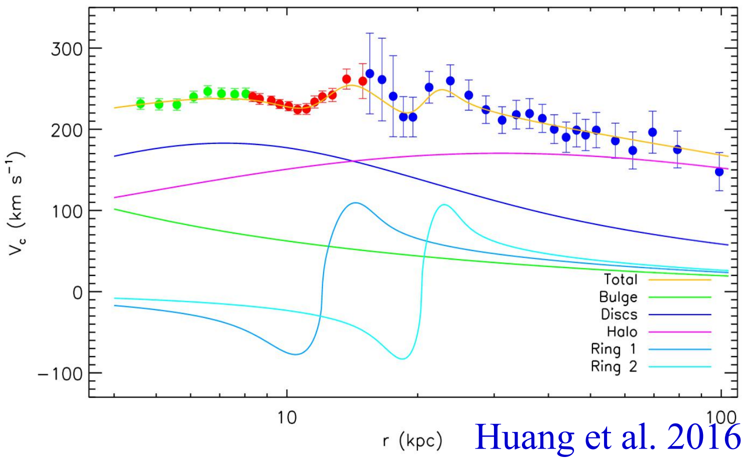


Tian+2020 ApJ

Total Mass of the Milky Way

Galactic rotation curve

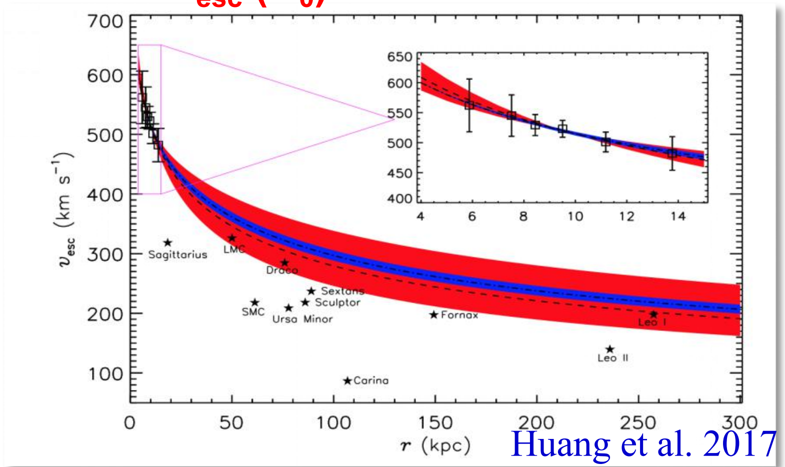
M_{Vir} = 0.90 (+0.07, −0.08)×10^{12} $M_\odot$
ρ_{DM} = 0.32 (+0.02, −0.02) GeV cm^{-3}



Huang et al. 2016

Galactic escape velocities

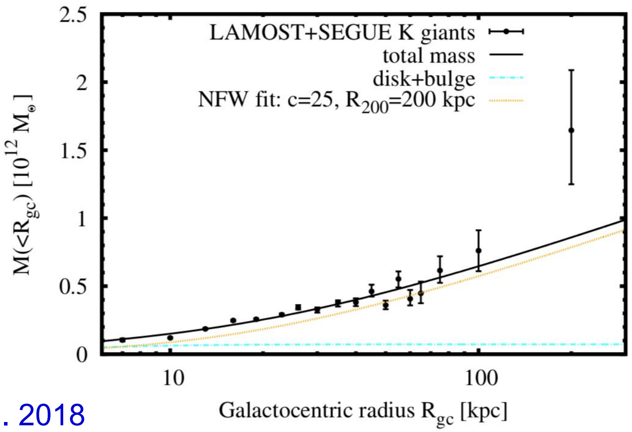
M_{vir} = (0.91 ± 0.05) ×10^{12} $M_\odot$
v_{esc} (R_0) = 529 ± 29 km/s



Huang et al. 2017

Star counts:

M_{200}=0.85±0.05 10^{12} Msun



Bird, Xue, Liu et al. 2018

银河系可能比科学家认为的更“苗条”


中国科学报
CHINA SCIENCE DAILY

在本职工作中践行“四个表率”

把创新作为引领发展的第一动力
——科技工作者加快推进高水平科技自立自强

量子力学基础研究获新进展

喜迎二十大

“黑黄金”生产不再受制于人

银河系可能比科学家认为的更“苗条”

- 利用我国郭守敬望远镜（LAMOST）以及欧空局“盖亚”（Gaia）卫星的数据，
- 一支国际研究团队精确测量出银河系的质量约为5500亿倍太阳质量。
- 该结果相比国际其他团队测量的平均值（约1万亿倍太阳质量）小了近一半，精度提高了近一倍。
- 相关研究成果日前发表于英国《皇家天文学会月刊》。

大、小麦哲伦星系可能并非银河系的卫星星系，而只是目前刚好在银河系附近的‘匆匆过客’。

Bird, Xue, Liu et al. 2022 MNRAS 516 731B

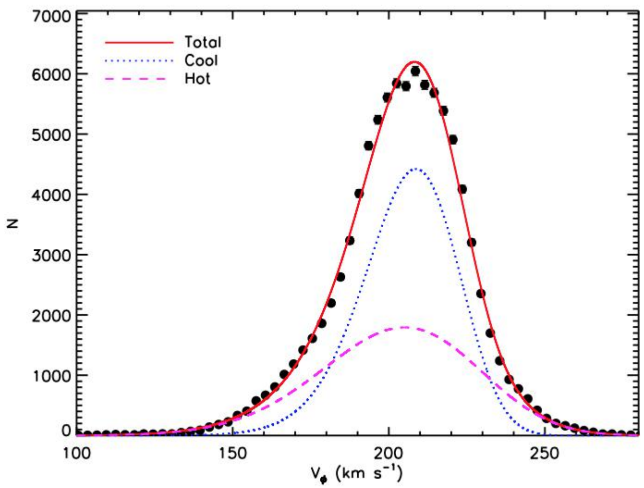
The Local Standard of Rest

Table 1. Measurements of the LSR in the literatures and from the current work.

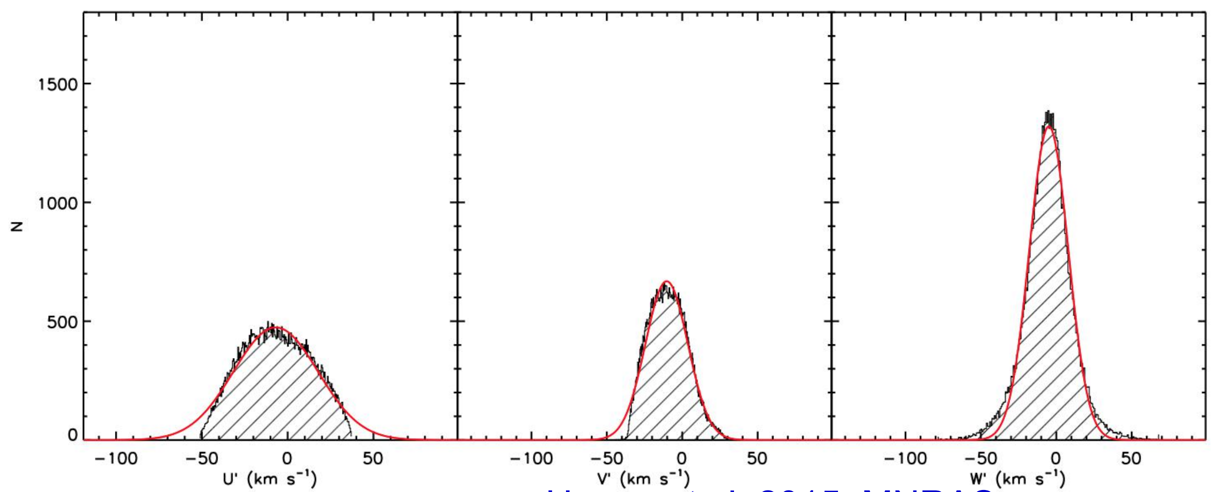
Source	Data	$U_\odot$ (km s^{-1})	$V_\odot$ (km s^{-1})	$W_\odot$ (km s^{-1})
This study (2014)	LSS-GAC DR1	7.01 ± 0.20	10.13 ± 0.12	4.95 ± 0.09
Bobylev & Bajkova (2014)	Young objects	6.00 ± 0.50	10.60 ± 0.80	6.50 ± 0.30
Coşkunoğlu et al. (2011)	RAVE DR3	8.50 ± 0.29	13.38 ± 0.43	6.49 ± 0.26
Bobylev & Bajkova (2010)	Masers	5.50 ± 2.2	11.00 ± 1.70	8.50 ± 1.20
Breddels et al. (2010)	RAVE DR2	12.00 ± 0.60	20.40 ± 0.50	7.80 ± 0.30
Schönrich et al. (2010)	*Hipparcos*	$11.10^{+0.69}_{-0.75}$	$12.24^{+0.47}_{-0.47}$	$7.25^{+0.37}_{-0.36}$
Reid et al. (2009)	Masers	9.0	20	10
Francis & Anderson (2009)	*Hipparcos*	7.50 ± 1.00	13.50 ± 0.30	6.80 ± 0.10
Bobylev & Bajkova (2007)	F & G dwarfs	8.70 ± 0.50	6.20 ± 2.22	7.20 ± 0.80
Piskunov et al. (2006)	Open clusters	9.44 ± 1.14	11.90 ± 0.72	7.20 ± 0.42
Mignard (2000)	K0-K5	9.88	14.19	7.76
Dehnen & Binney (1998)	*Hipparcos*	10.00 ± 0.36	5.25 ± 0.62	7.17 ± 0.38
Binney et al. (1997)	Stars near South Celestial Pole	11.00 ± 0.60	5.30 ± 1.70	7.00 ± 0.60
Mihalas & Binney (1981)	Galactic Astronomy (2nd Ed.)	9.00	12.00	7.0
Homann (1886)	Solar neighbourhood stars	17.40 ± 11.2	16.90 ± 10.90	3.60 ± 2.30

- Based on 94,332 thin disk FGK dwarfs within 600 pc of the Sun.
- $(U_\odot, V_\odot, W_\odot)$ = (7.01±0.20, **10.13±0.12**, 4.95±0.09) km/s
- V is **2 times** of one in "Galactic Dynamics" (Dehnen & Binney 1998)

Method I: VDF



Method II: CTDS

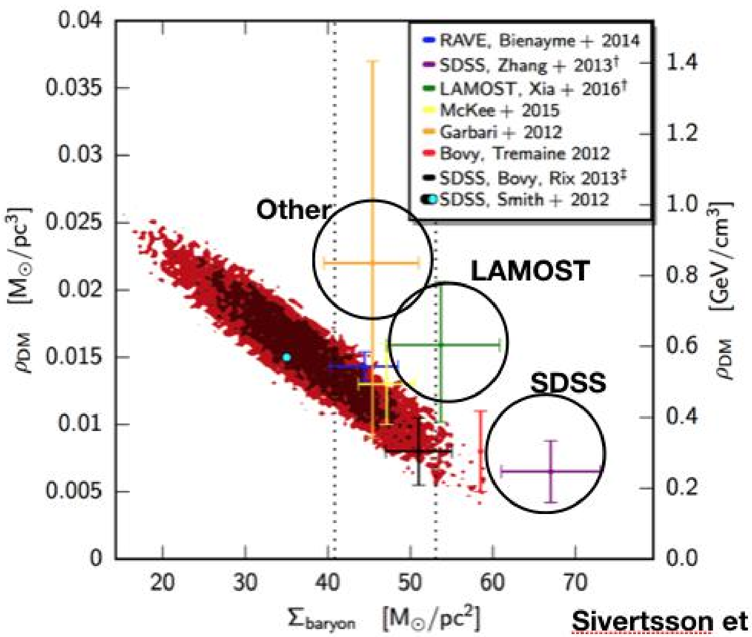


Huang et al. 2015, MNRAS

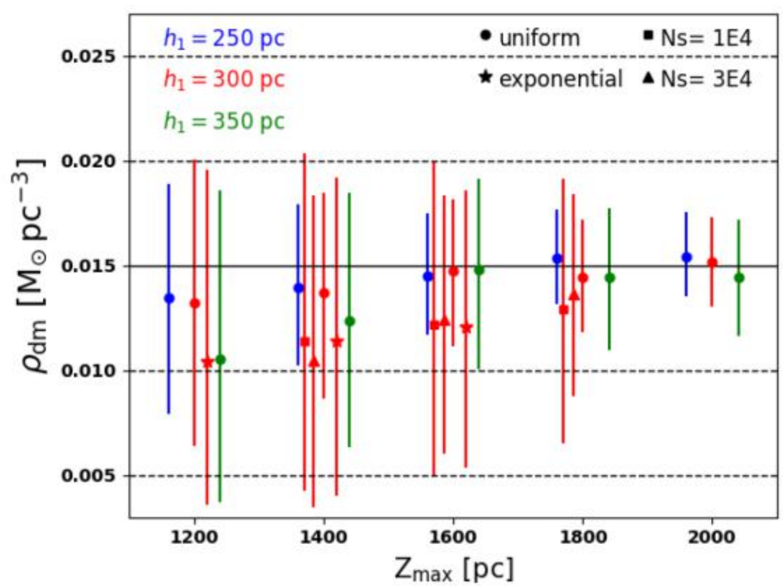
Dark matter mass density in the solar neighborhood

- **With LAMOST data and a simple analytical Kz force model depending on less assumptions**
- **the volume density of the dark matter around us is 0.018±0.005$M_{\odot}pc^{-3}$**

We apply the vertical Jeans equation to the kinematics of Milky Way stars in the solar neighbourhood to measure the local dark matter density. More than 90 000 G- and K-type dwarf stars are selected from the cross-matched sample of LAMOST (Large Sky Area Multi-Object Fibre Spectroscopic Telescope) fifth data release and *Gaia* second data release for our analyses. The mass models applied consist of a single exponential stellar disc, a razor thin gas disc, and a constant dark matter density. We first consider the simplified vertical Jeans equation that ignores the tilt term and assumes a flat rotation curve. Under a Gaussian prior on the total stellar surface density, the local dark matter density inferred from Markov chain Monte Carlo simulations is $0.0133^{+0.0024}_{-0.0022}$ $M_{\odot}$ pc^{-3}. The local dark matter densities for subsamples in an azimuthal angle range of $-10° < \phi < 5°$ are consistent within their 1σ errors. However, the



Sivertsson et al. 2017

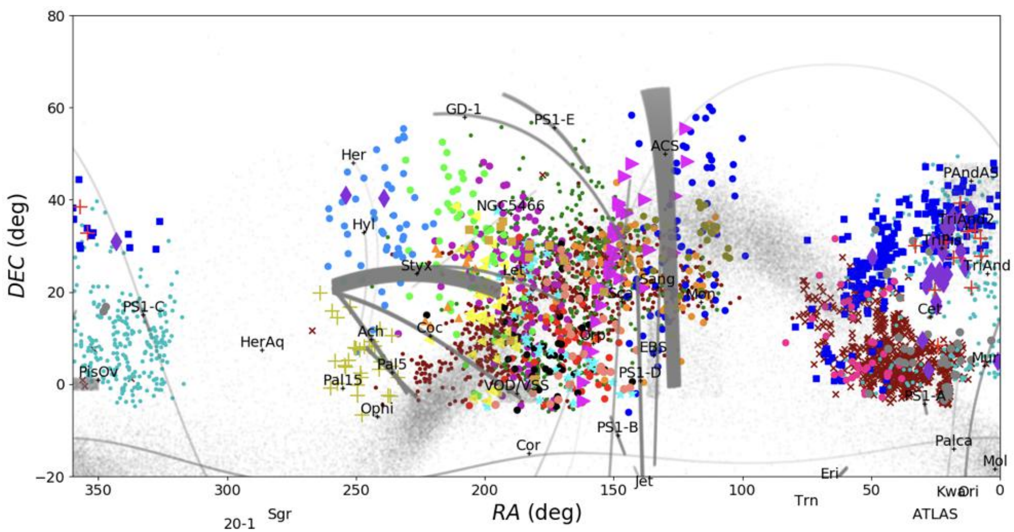


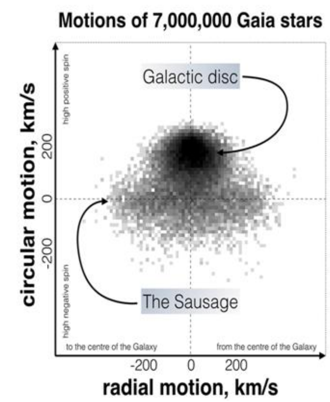
Xia, Liu, et al., MNRAS,2016

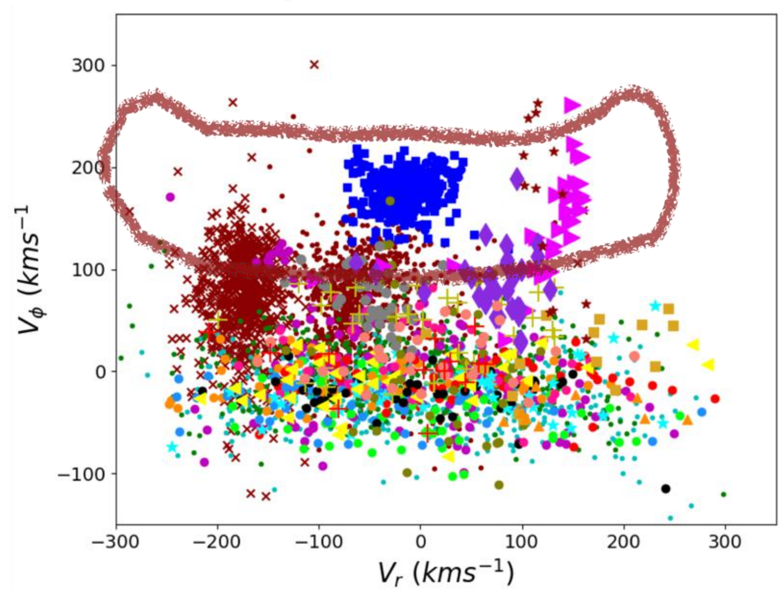
Guo, Liu, et al., MNRAS,2020

Steller stream in the halo

LAMOST K giants





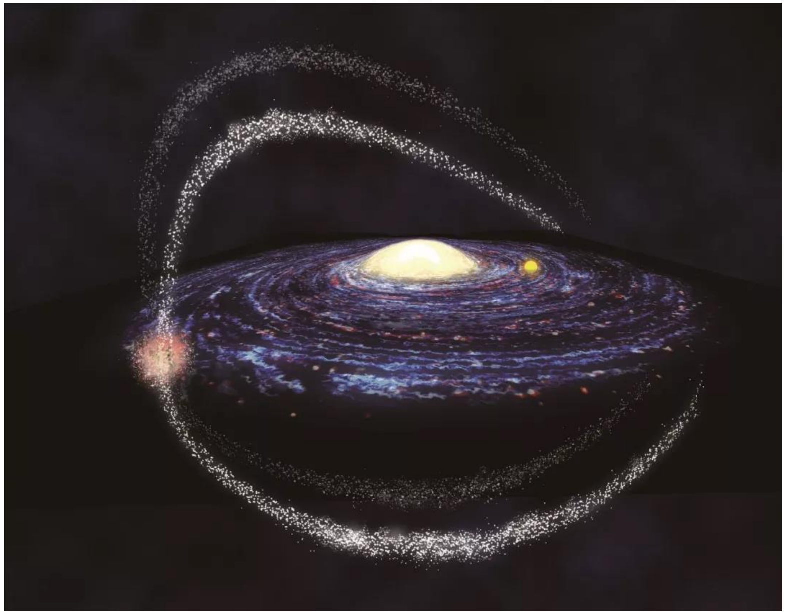


- Ø Monoceros Ring
- Ø Sagittarius streams
- Ø Orphan stream
- Ø Cetus stream
- Ø Gaia-Sausage

Yang, Xue et al. ApJ, 2019

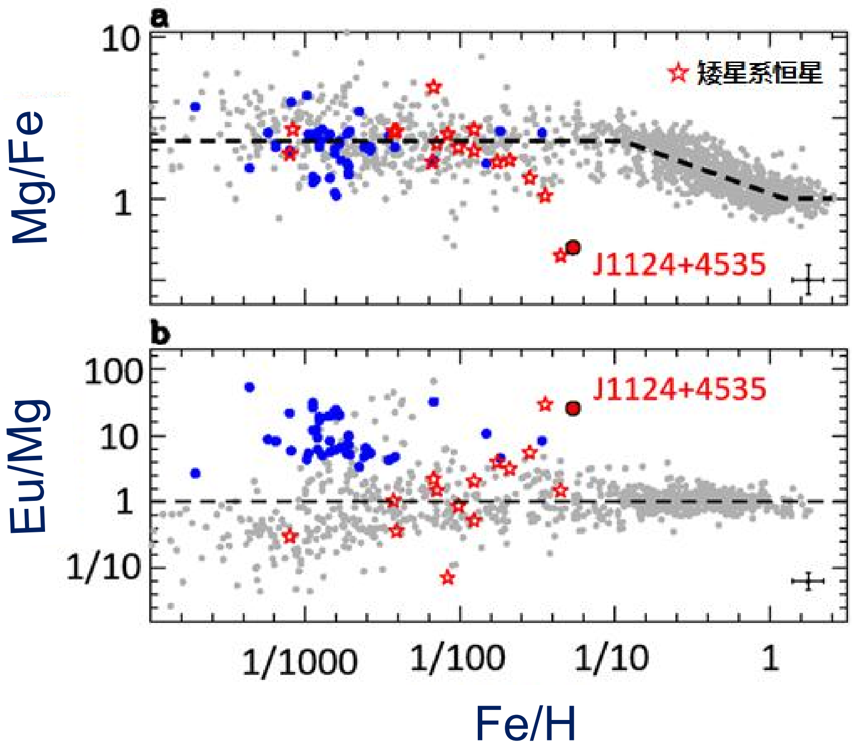
Steller stream in the halo

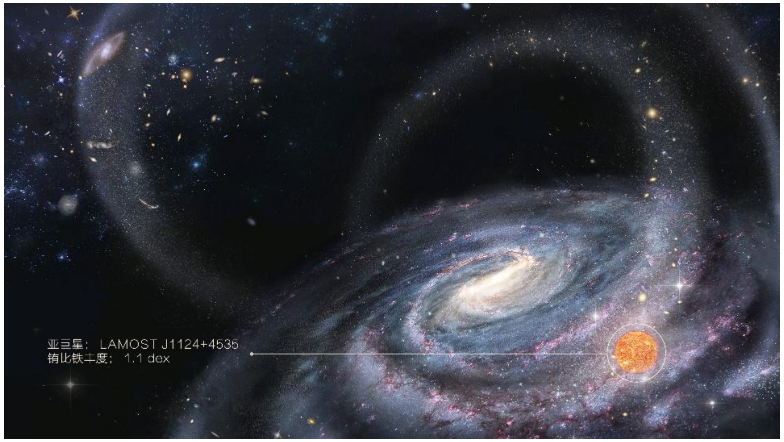
- 33000 M giants in DR4
- 3d space orbit of the Sgr stream
- The far side in 130 kpc from the Sun

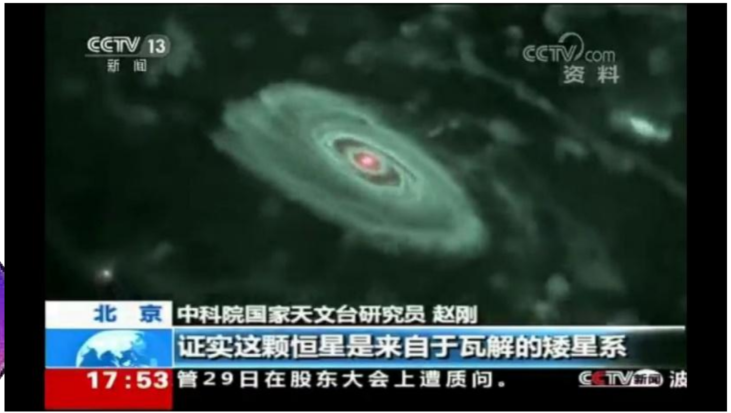


Li et al. 2019, ApJ, 874, 138

Evidence for the accretion origin of a holo star








nature astronomy
LETTERS
https://doi.org/10.1038/s41550-019-0764-5

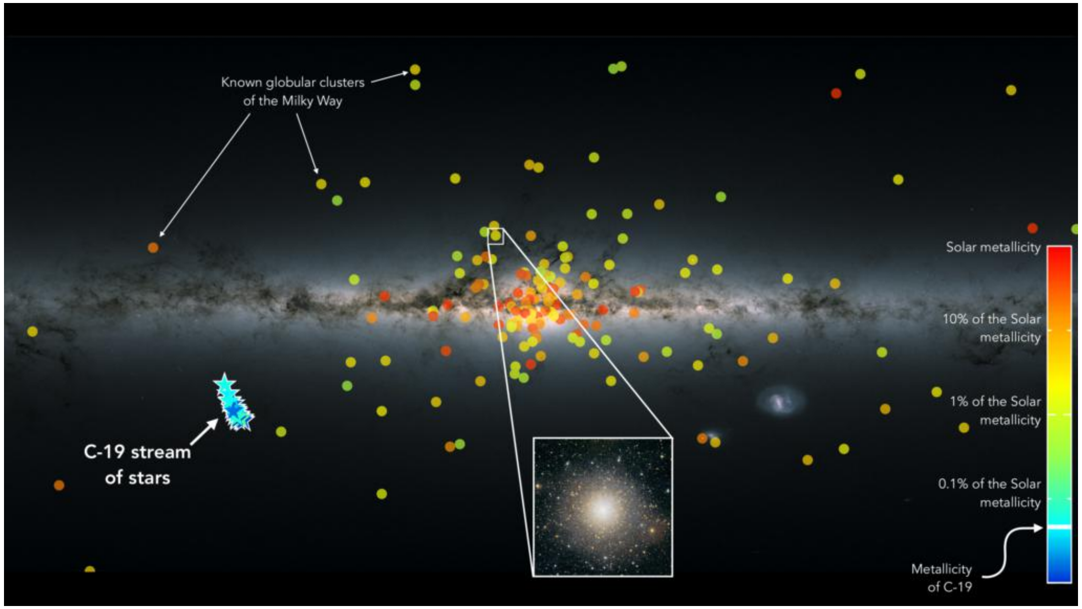
Evidence for the accretion origin of halo stars with an extreme r-process enhancement

Qian-Fan Xing[1*], Gang Zhao[1*], Wako Aoki[2,3], Satoshi Honda[4], Hai-Ning Li[1], Miho N. Ishigaki[5] and Tadafumi Matsuno[2,3]

Xing et al. 2019, *Nature Astronmy*, 3, 631

发现宇宙中金属含量最低的球状星团遗迹

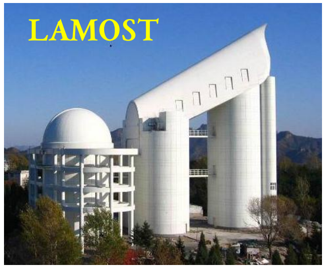
- C-19星流是银河系内球状星团瓦解形成的遗迹，该星团是在宇宙初期形成；
- 在LAMOST光谱中发现了该星流中的一颗恒星，金属丰度约为太阳的1/2500，挑战了传统认知中球状星团的金属丰度下限；

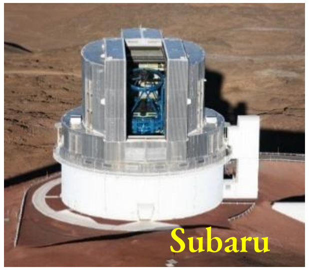


- 为该星团的后续研究提供了重要的参考价值。

Nicolas et al. 2022, Nature, 601, 45

Metal-poor stars

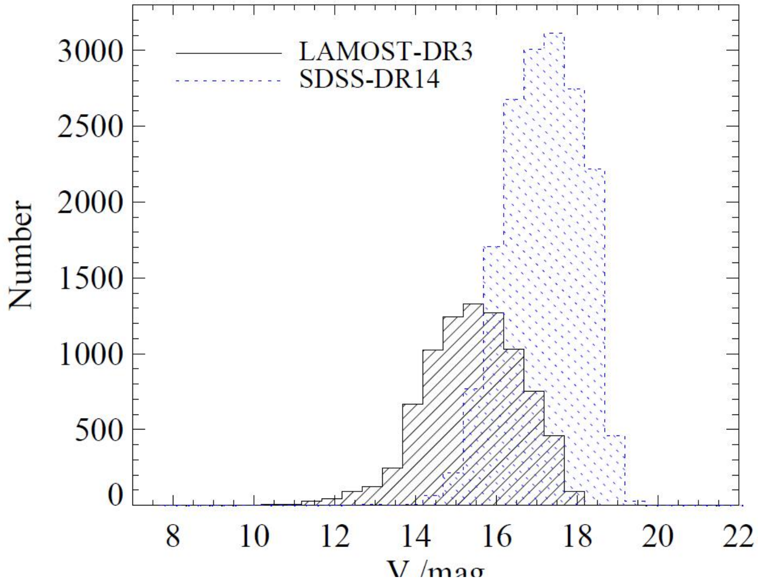


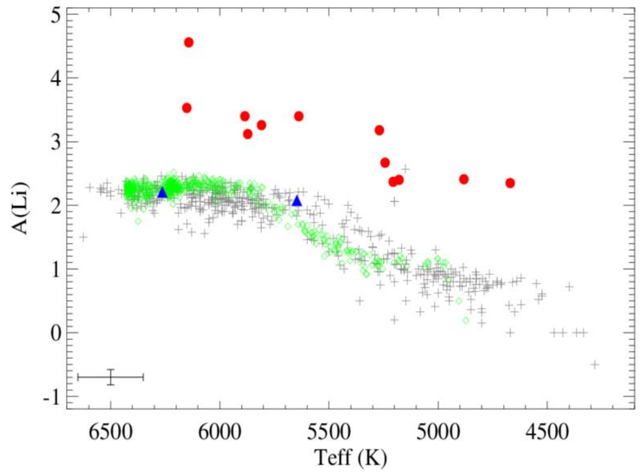


- **100,000 candidates of bright metal-poor stars**
- **90% to search [Fe/H]<-2**

- **"Millstone" sample:**

400 high resolution spectra



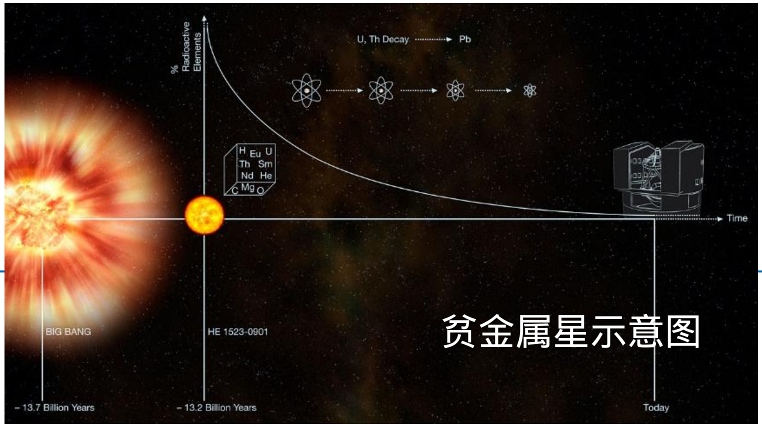


Li et al. 2020, ApJ

第一代恒星的“里程碑式”的样本

400余颗贫金属星的高信噪比光谱进行分析

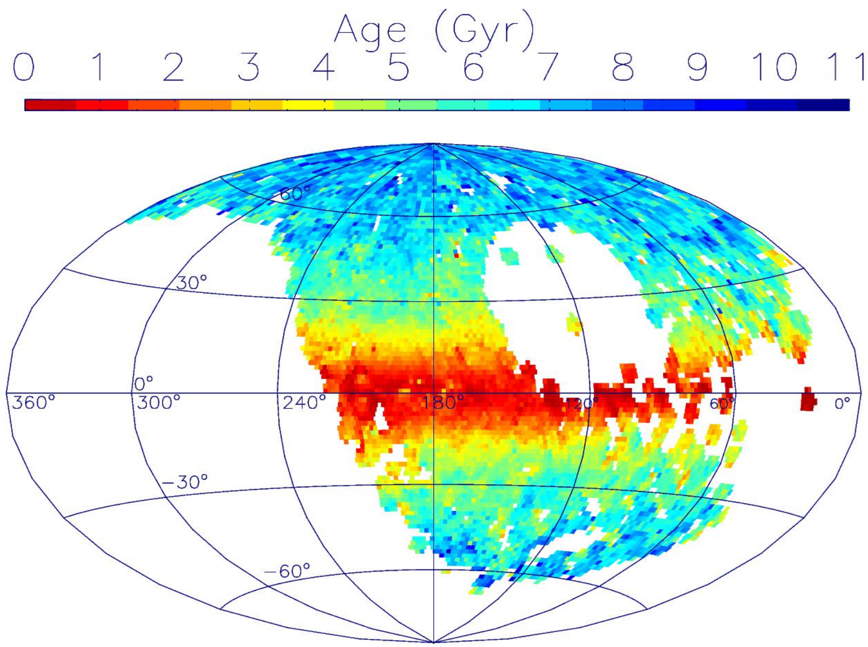
- **3颗超贫金属星和约100颗极端贫金属星：极大地扩充第二代恒星数据库**
- **世界上最大最均匀的高分辨率样本：检验银河系化学演化模型的关键依据**
- **关键元素更小的测量弥散：更准确的约束第一代恒星性质**

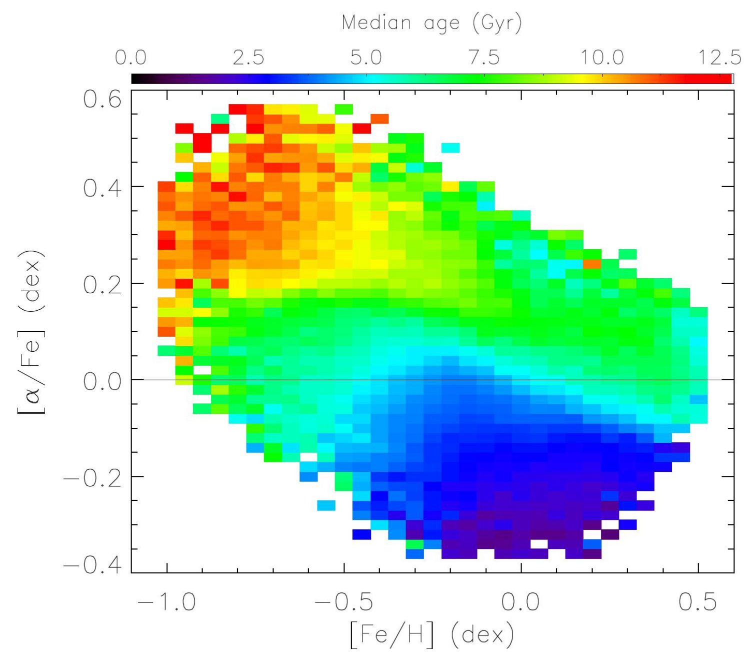


Li et al. 2020, ApJ, Accepted

Ages of 1,000,000 stars

- **Turn-off stars: 1 M** **(Xiang et al. 2015, 2017)**
- **RC stars: 0.2 M**
- **Red giants : 0.64 M**





Reviewer's Comments: This is a solid body of work that makes a significant contribution to the field, and which is especially valuable as a benchmark for Galactic evolution modeling.

Xian

Article

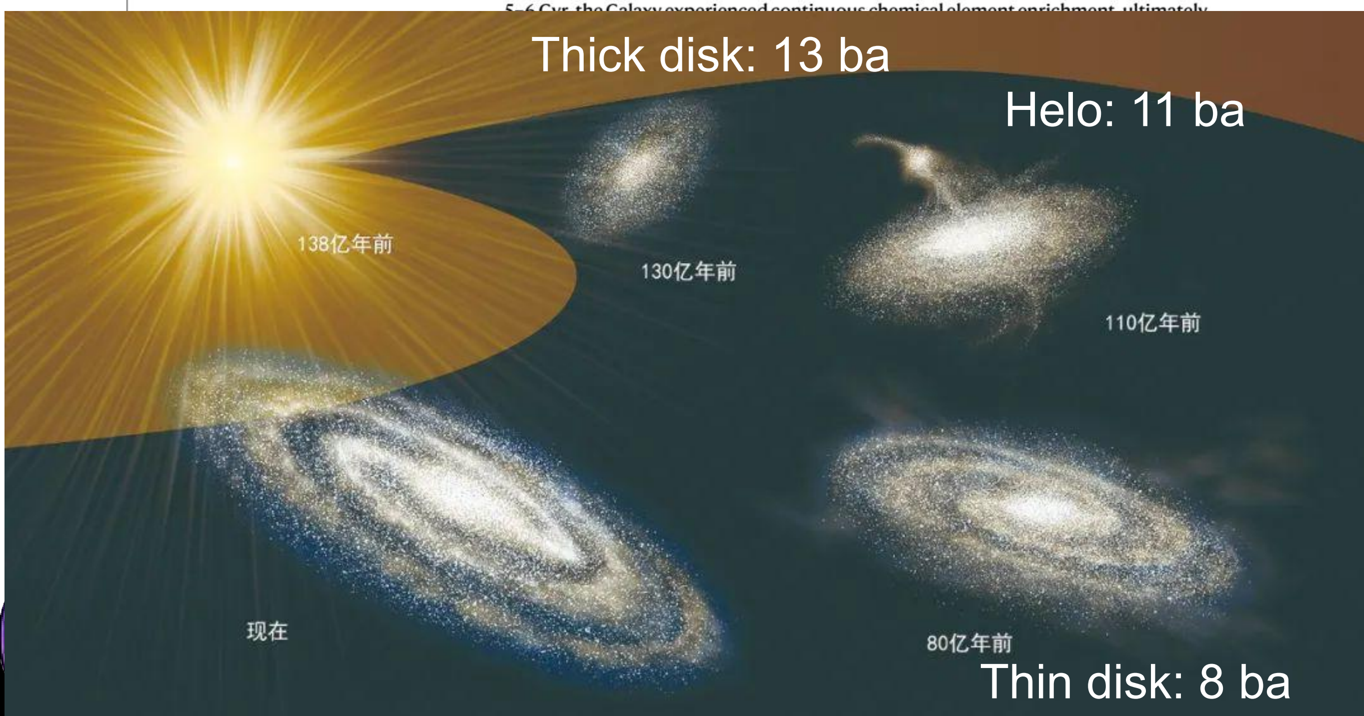
A time-resolved picture of our Milky Way's early formation history

https://doi.org/10.1038/s41586-022-04496-5
Received: 1 November 2021
Accepted: 1 February 2022
Published online: 23 March 2022
Open access
Check for updates

Maosheng Xiang[1✉] & Hans-Walter Rix[1✉]

M. Xiang: LAMOST fellow

The formation of our Milky Way can be split up qualitatively into different phases that resulted in its structurally different stellar populations: the halo and the disk components[1–3]. Revealing a quantitative overall picture of our Galaxy's assembly requires a large sample of stars with very precise ages. Here we report an analysis of such a sample using subgiant stars. We find that the stellar age–metallicity distribution $p(\tau, [Fe/H])$ splits into two almost disjoint parts, separated at age $\tau \simeq 8$ Gyr. The younger part reflects a late phase of dynamically quiescent Galactic disk formation with manifest evidence for stellar radial orbit migration[4–6]; the other part reflects the earlier phase, when the stellar halo[7] and the old α-process-enhanced (thick) disk[8,9] formed. Our results indicate that the formation of the Galaxy's old (thick) disk started approximately 13 Gyr ago, only 0.8 Gyr after the Big Bang, and 2 Gyr earlier than the final assembly of the inner Galactic halo. Most of these stars formed around 11 Gyr ago, when the Gaia-Sausage-Enceladus satellite merged with our Galaxy[10,11]. Over the next



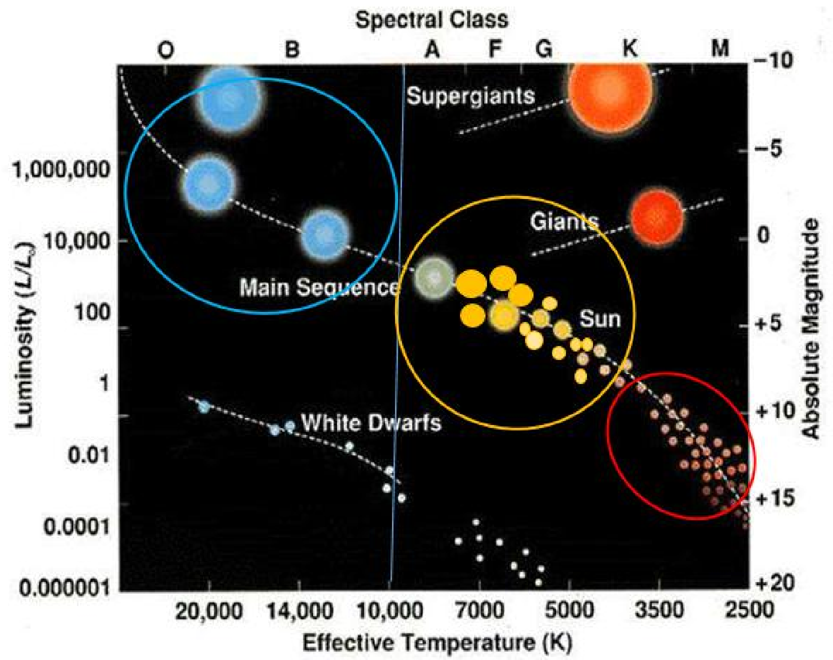
- **LAMOST DR7**
- **Gaia eDR3**

- **250,000 sub-giants**
- **age < 7%**

Xiang et al. 2022, Nature, 603, 599

The largest OB catalog

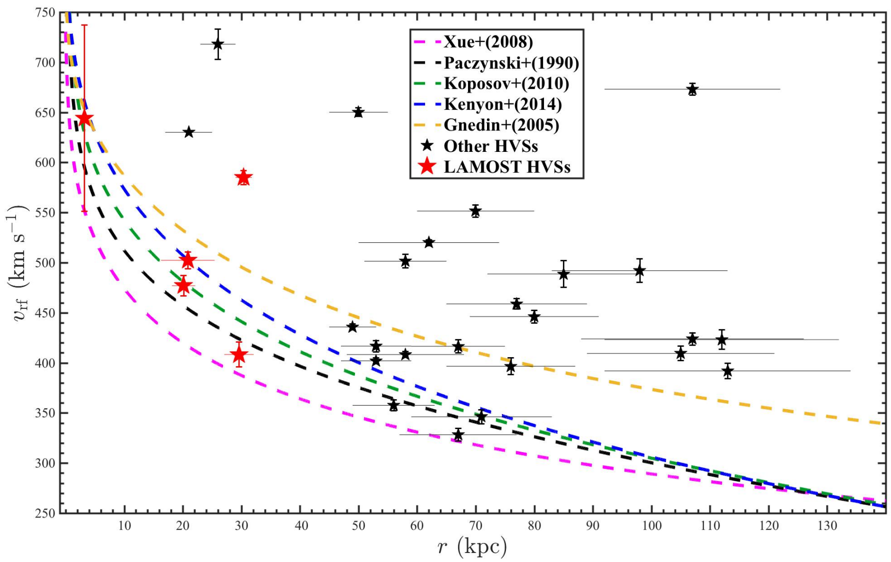
- OB stars: high tepereture, high mass, short life, rare
- 16032 OB stars discoveried by LAMOST
- The fundamental data for young stars in the out disk of the Galaxy



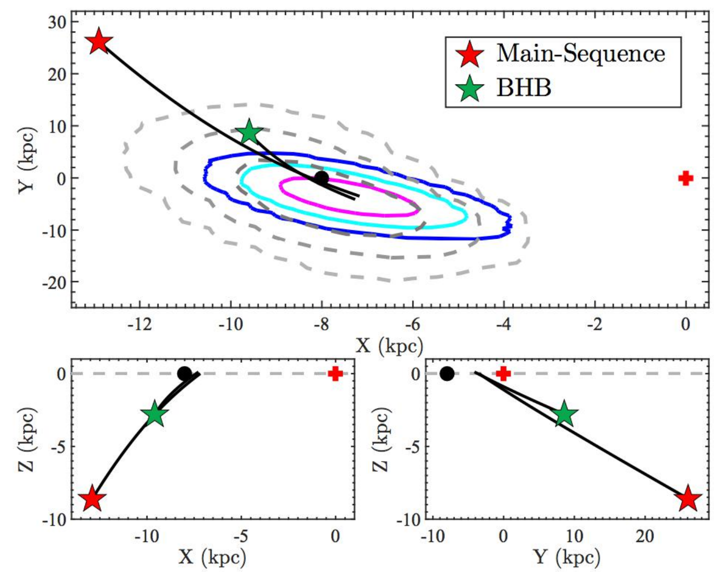
Liu et al. 2019, ApJS, 241, 32

Hyper-velocity stars: 4 from LAMOST

- Letter of prof. Brown:"an exciting pair of hypervelocity star discoveries"
- Websites: Universe Today, Phys.org, AAS Nova



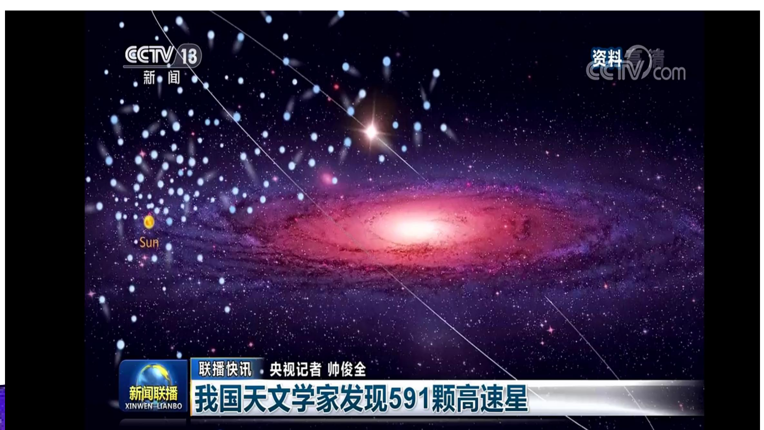
Huang et al. 2017

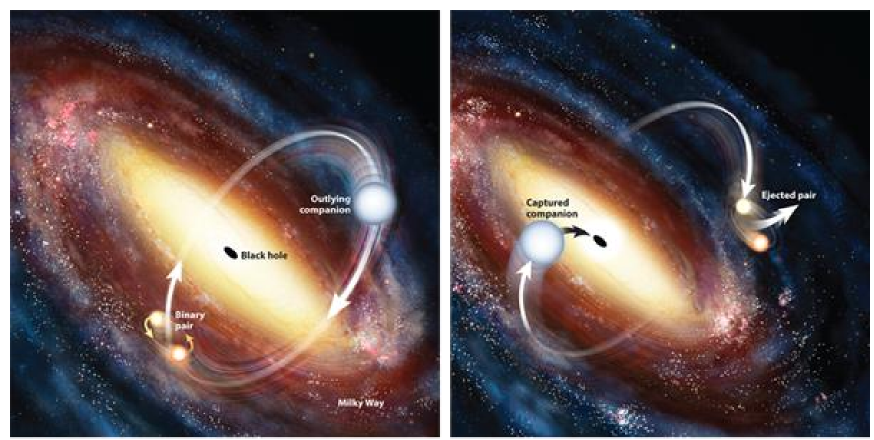


Li et al. 2018

High-velocity stars

- **591 high-velocity stars (2x before)**
- **42 candidates of hyper-velocity stars (2x before)**





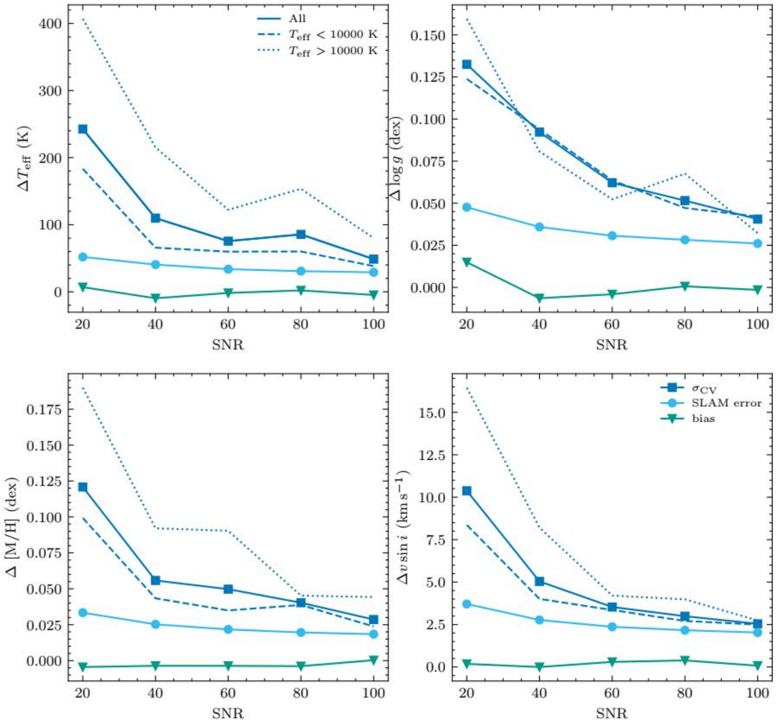
Li et al. 2020, ApJS

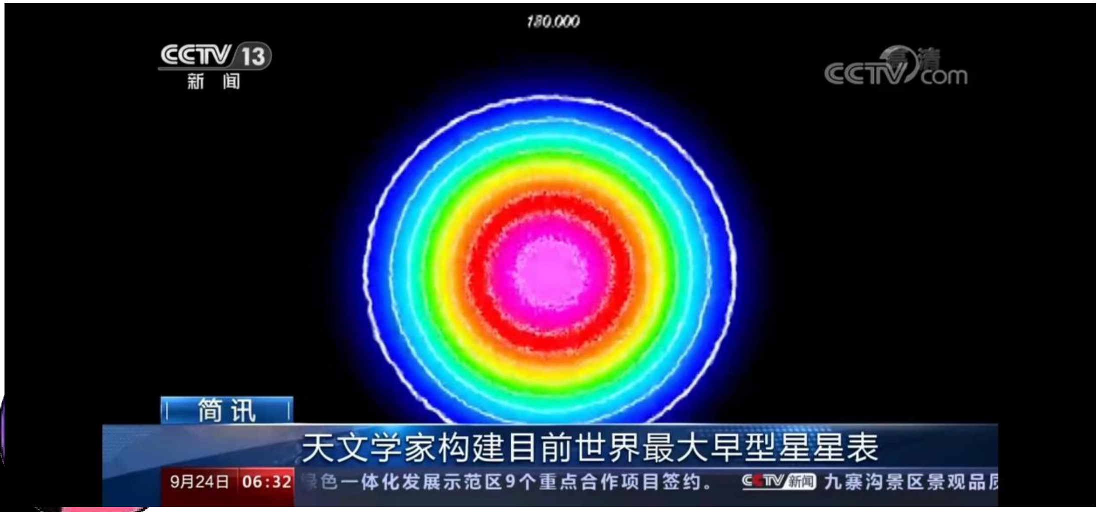
Early-type stars

- 40,034 early-type stars

with vsini,Teff, log g, [M/H]

Medium resolution observed by LAMOST





Sun et al. 2021 ApJS

发现有异常特性的红巨星

- 红巨星是一类处于演化晚期、明亮的恒星；
- 处于双星系统中的红巨星物质转移很难被观测到；
- 发现40颗具有异常特性的红巨星：
  - ü 质量偏小（0.5-0.7太阳质量）:超过了宇宙的演化年龄，有物质转移
  - ü 亮度偏暗：中心核质量偏小

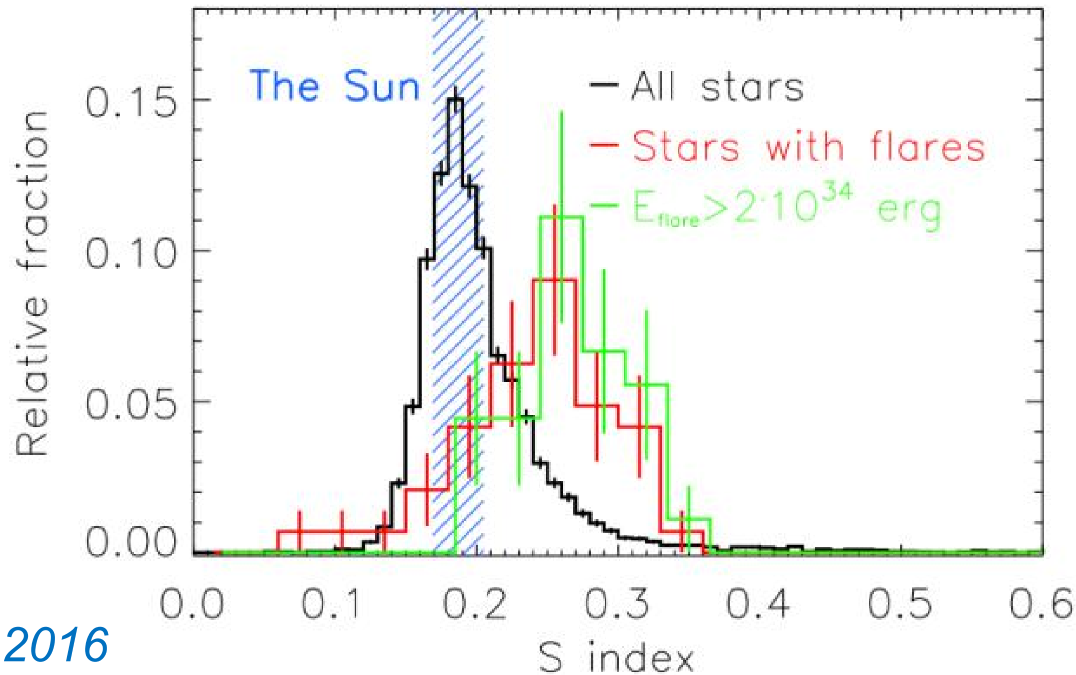
Li et al. 2022, Nature Astronomy, 6, 673

Superflare stars characterised by enhanced magnetic activity

•5648 solar-like stars
•48 superflare stars.

Superflare stars are generally characterised by larger chromospheric emissions than other stars, including the Sun.

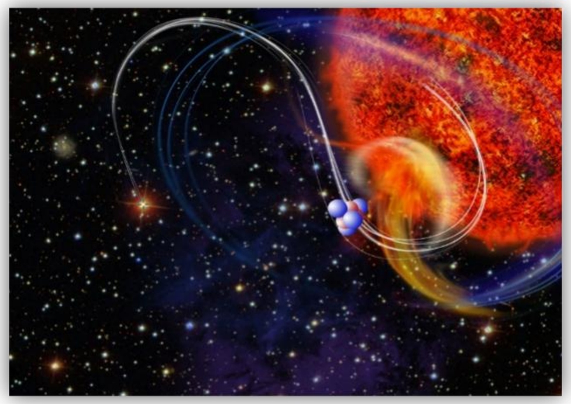
1-6 orders higher than solar flares



Karoff et al. Nature Comm. *2016*

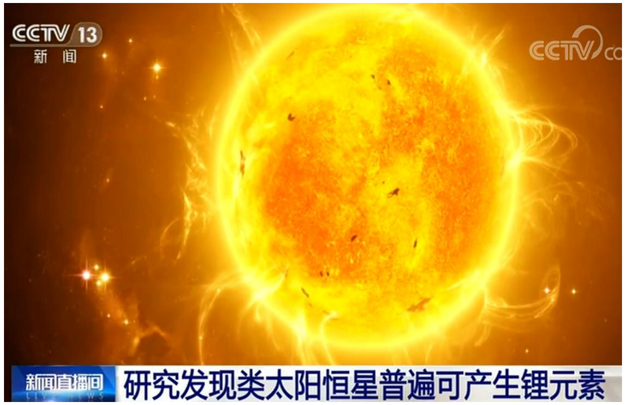
Highest Li abundance in the Li-rich giants

Highest Li abundance in the Li-rich giants



Yan et al. 2018, Nature Astronmy

Li produced by solar-like stars



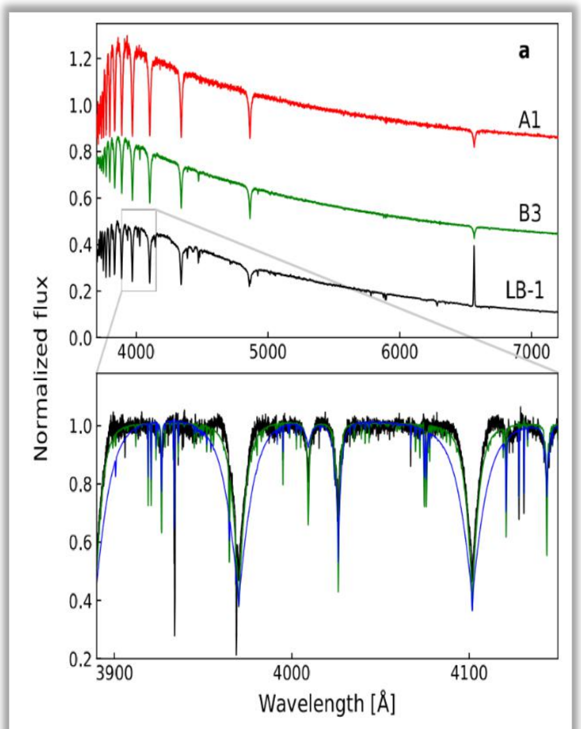
Kumar et al. 2020, Nature Astronmy

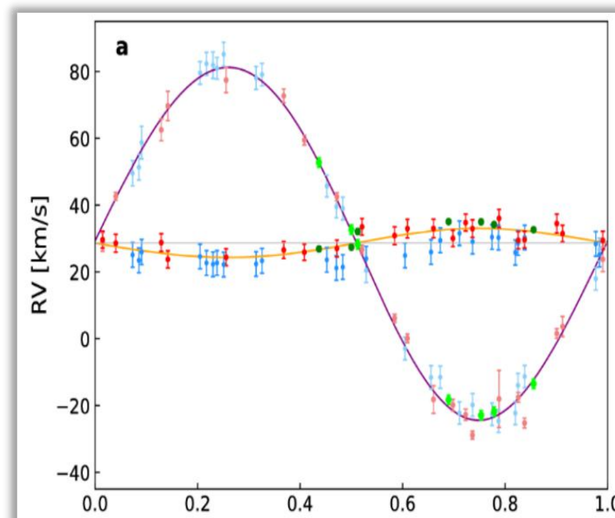
Li-rich in red clump stars, not in red giants

Yan et al. 2021, Nature Astronmy

Discovery of stellar-mass black hole

- **70 M black hole**
- **New method to discover black holes**



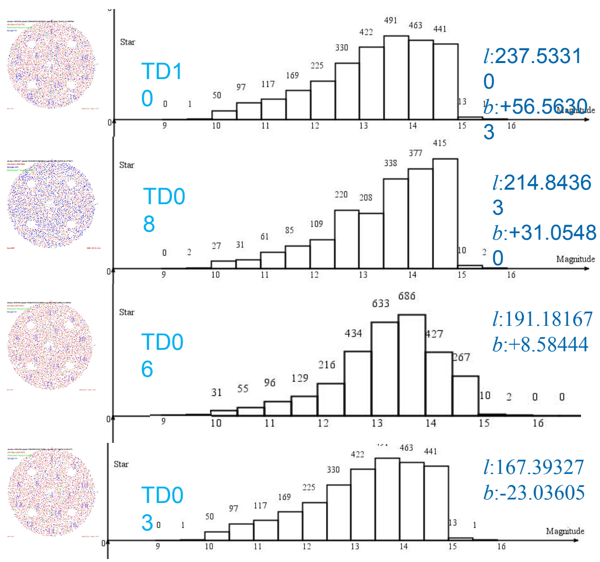


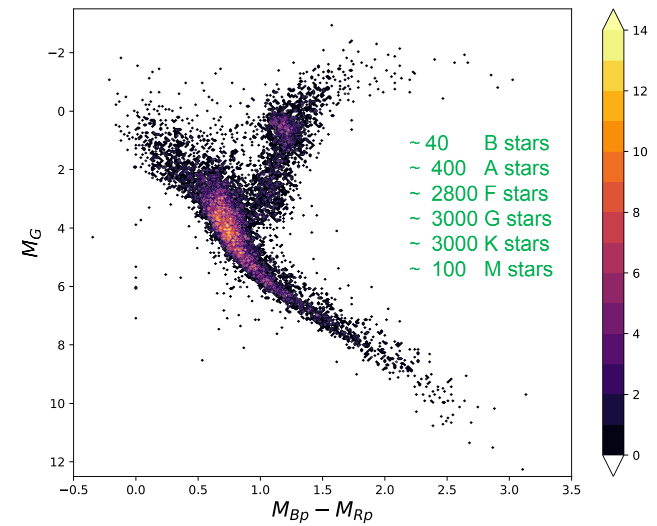
Liu et al. 2019, Nature

“Black-hole hunter”

黑洞猎手计划

Four plates of LAMOST





Wang et al. 2020b

发现宁静态的中子星

- 发现一颗宁静态的中子星，它与一颗红矮星组成了旋转的双星系统；

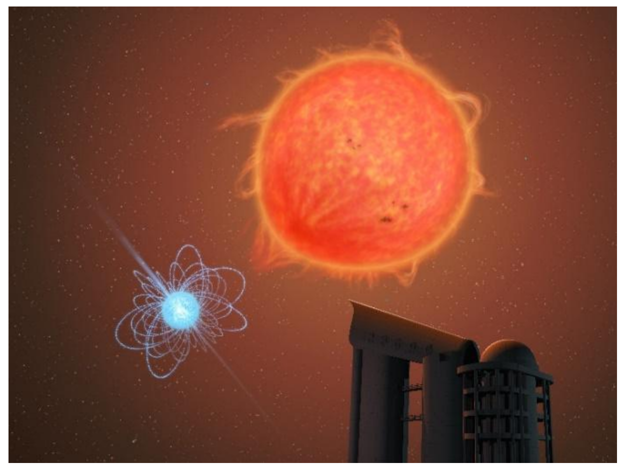
Yi et al. 2022, Nature Astronmy

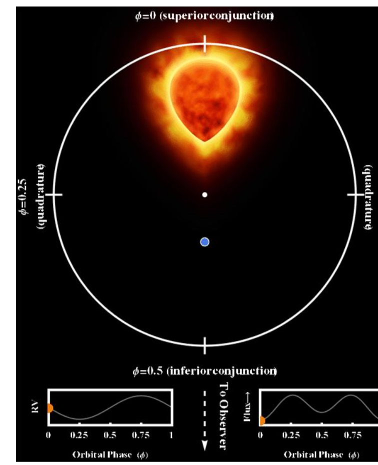
- 以色列天文学家也发现一个包括宁静态的中子星的双星系统；

Tsevi et al. 2022, MNRAS, Accepted

- 还有约十个可能包含中子星或者黑洞的双星系统等待证认

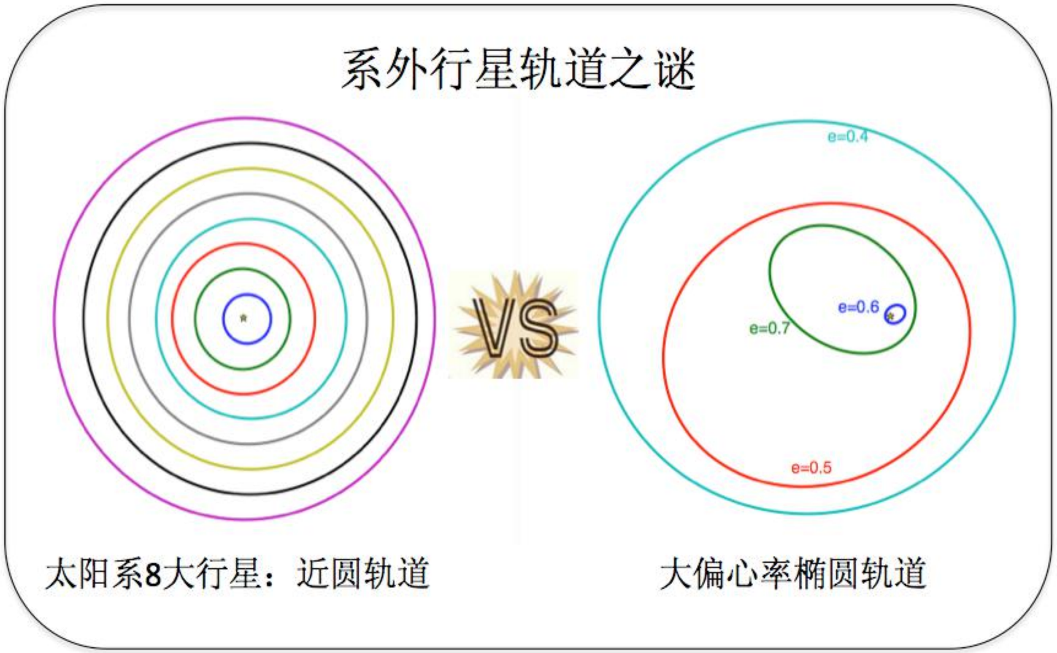
Yuan et al. 2022, ApJ, Accepted



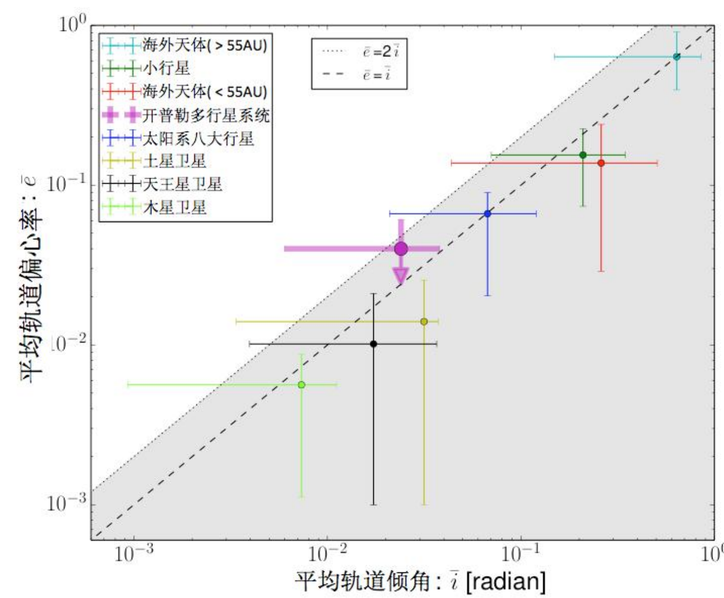


为发现处于双星系统中的宁静态致密天体开创了新途径

Puzzle of Exoplanet Orbits



The eccentricity distributions for a large (698) and homogeneous Kepler planet sample with transit duration statistics.



The prevalence of circular orbits and the common relation may imply that the solar system as well as its formation is not so atypical in the Galaxy after all.

Xie, et al. 2016, PNAS

New type of exoplanets: Hoptunes

Proceedings of the National Academy of Sciences of the United States of America www.pnas.org

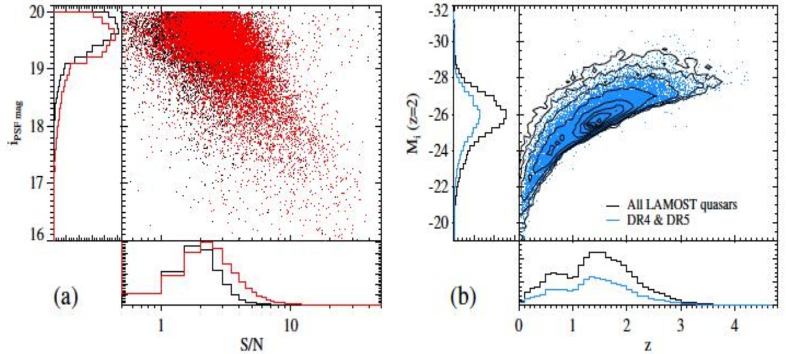
From the Cover

January 9, 2018 | vol. 115 | no. 2

Dong & Xie et al., 2018, PNAS,115, 266–271

LAMOST Quasar Survey

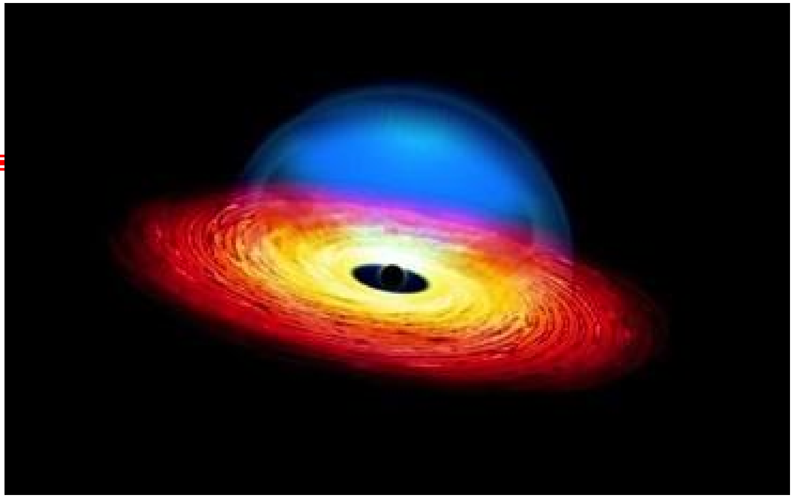
- Identified 56000 quasars
  - 28000 independently discovered
  - 22500 new discovered

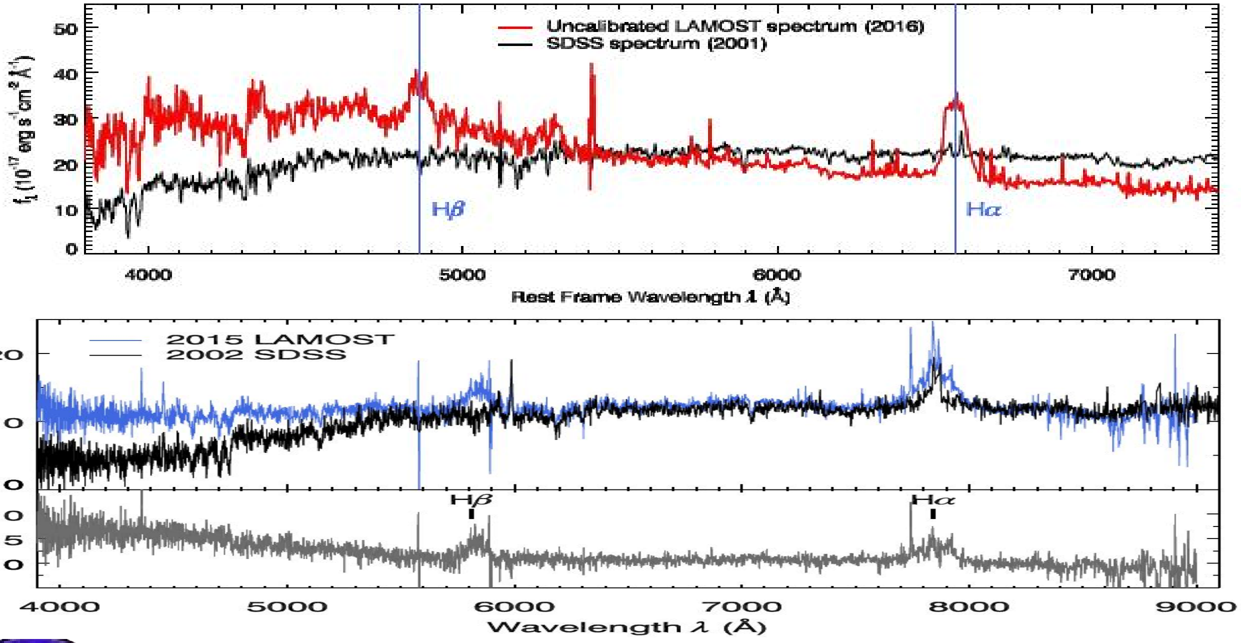


- DR1: Ai, Wu, Yang, et al., 2016, AJ, 151, 24
  - 3921 quasars identified, 1180 new
- DR2/DR3: Dong, Wu, Ai, et al., 2018, AJ, 155, 189
  - 19935 identified, 12126 independent, 8100 new
- DR4/DR5: Yao, Wu, Ai, et al., 2019, ApJS, 240, 6
  - 19246 identified, 11446 independent, 8149 new
- DR6-DR8: Jin, Wu, Fu, et al., 2021,
  - 12761 identified, 7071 independent, 5380 new

- LAMOST quasar survey has become one of the top 2 quasar surveys, after SDSS

- # 21 “face-change” QSOs

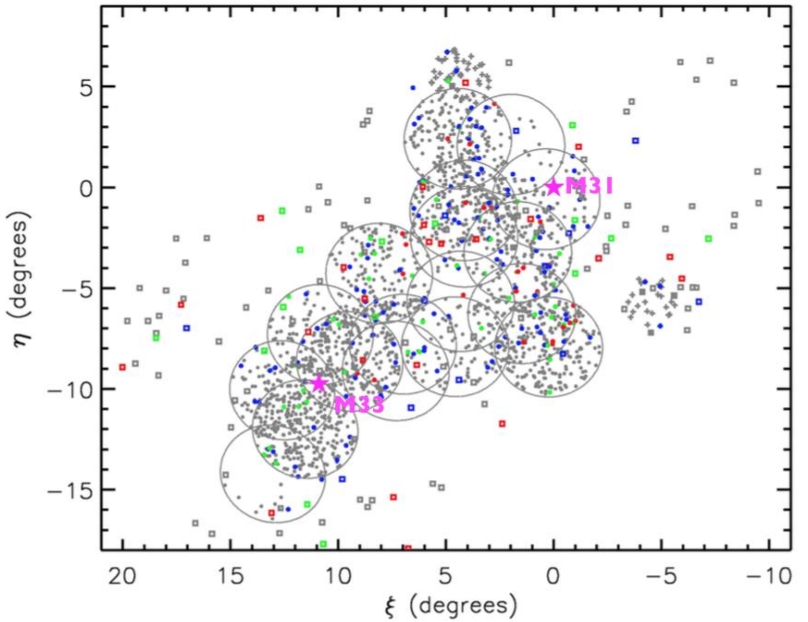




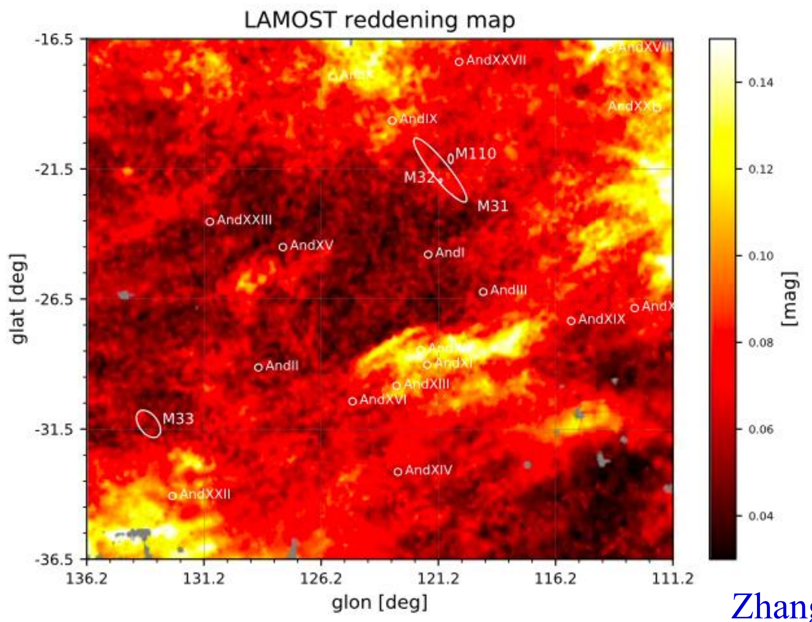
Yang et al. 2018

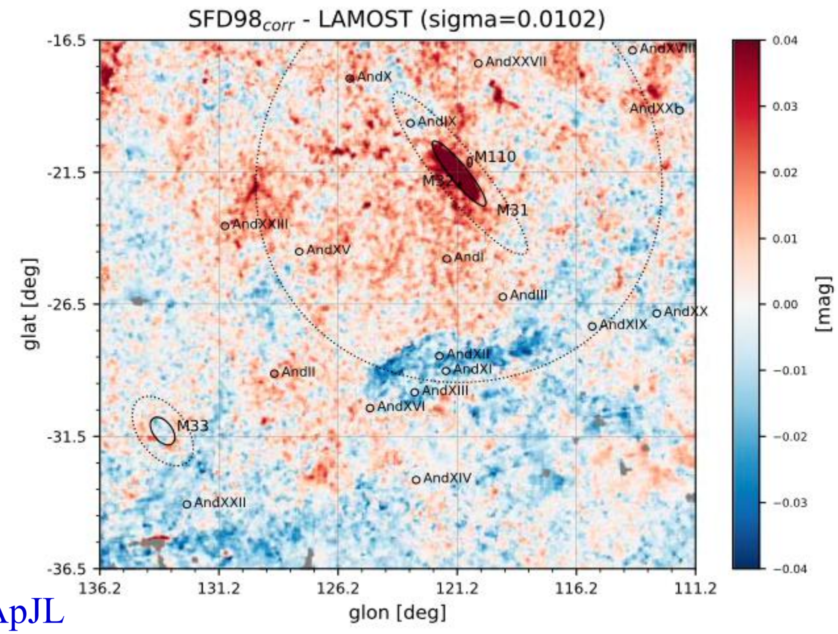
M31/M33

Background QSOs
in the vicinity fields of M31/M33
~4000 QSOs
~100 PNs



Dust distribution of M31/M33 (LAMOST + Gaia, 190,000 stars)

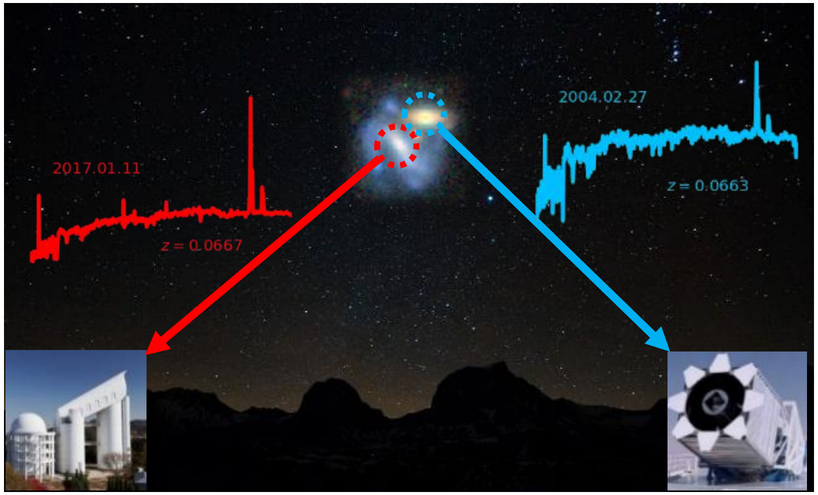




Zhang+2020 ApJL

Pair of galaxies

- **LAMOST + SDSS**



Mass function of pairs

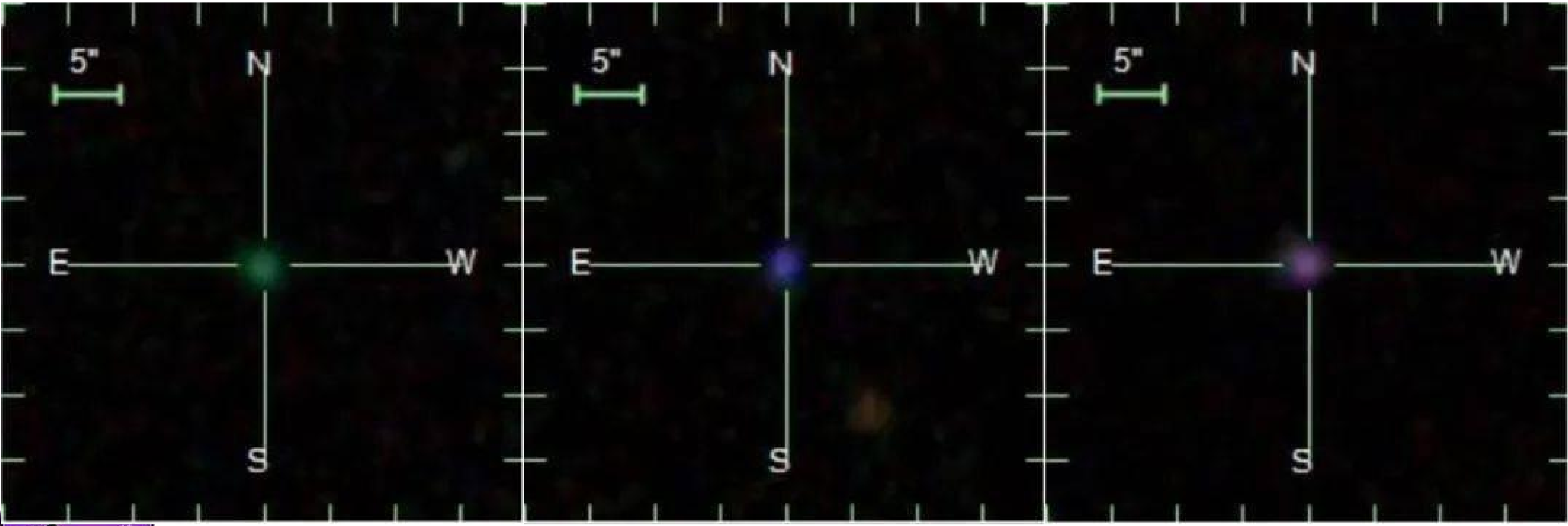
Interaction of galaxies: 150 kpc

Feng et al. 2019, ApJ

Compact galaxies:
“extragalctic fruit & vegetable garden”

1417 new discovery (800 before)

- **739 green pea**
- **270 blueberry**
- **388 purple grape**



Liu, Luo et al., 2022, ApJ, 927, 57

Review

Overview of the LAMOST survey in the first decade

Hongliang Yan,[1,2] Haining Li,[1] Song Wang,[1] Weikai Zong,[3] Haibo Yuan,[3] Maosheng Xiang,[4] Yang Huang,[5] Jiwei Xie,[6,7] Subo Dong,[8] Hailong Yuan,[1] Shaolan Bi,[3] Yaoquan Chu,[9] Xiangqun Cui,[10,11] Licai Deng,[1] Jianning Fu,[3] Zhanwen Han,[12] Jinliang Hou,[2,13] Guoping Li,[10,11] Chao Liu,[2,14] Jifeng Liu,[1,2,15] Xiaowei Liu,[5] Ali Luo,[1,2] Jianrong Shi,[1,2] Xuebing Wu,[8,16] Haotong Zhang,[1] Gang Zhao,[1,2] and Yongheng Zhao[1,2,*]
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www.the-innovation.org

GRAPHICAL ABSTRACT

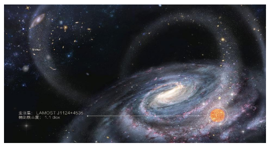
PUBLIC SUMMARY

- LAMOST is an innovative telescope designed with both a large-aperture and a wide-FOV for astronomical spectroscopic survey
- LAMOST observed over 10 million objects in our Galaxy, and constructed the largest spectroscopic dataset
- LAMOST data changed the astrophysical viewpoint in the fields including stars, the Milky Way, exoplanets, and black holes

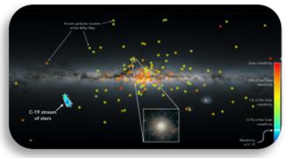
https://arxiv.org/abs/2203.14300

LAMOST典型科研成果

- **银河系形成**

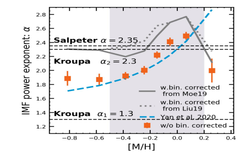


化学追踪“星系际移民”
*Xing et al. 2019, **Nature Astronomy***



宇宙中金属含量最低的球状星团遗迹
*Nicolas et al. 2022, **Nature***

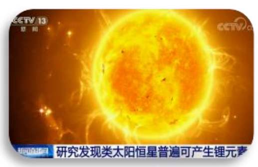
揭示银河系早期形成和演化历史
*Xiang et al. 2022, **Nature***



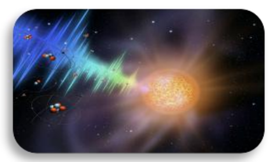
恒星初始质量函数
*Li et al. 2023, **Nature***

- **富锂巨星**

发现锂丰度最高的巨星
*Yan et al. 2018, **Nature Astronomy***



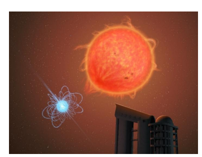
类太阳恒星可以产生锂
*Kumar et al. 2020, **Nature Astronomy***



富锂巨星真身探秘
*Yan et al. 2021, **Nature Astronomy***

- **黑洞与中子星**

发现最大质量恒星级黑洞
*Liu et al. 2019, **Nature***



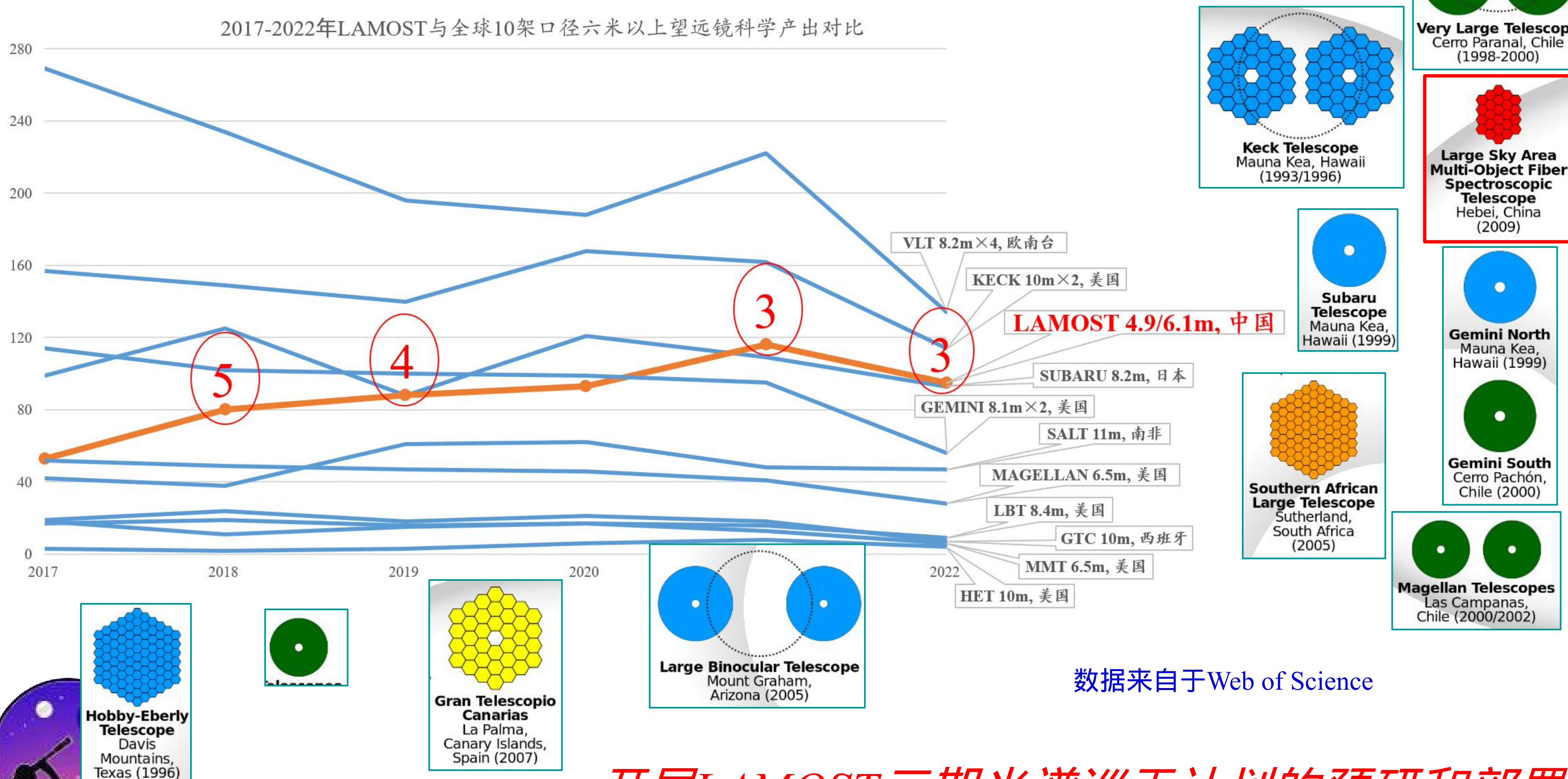
发现宁静态中子星
*Yi et al. 2022, **Nature Astronomy***

预期成果

与国际大型地面光学望远镜产出比较

作为光谱巡天领域的典范，数据被其他望远镜作为比对标准

在全球10个口径六米以上的中大型望远镜中科学产出排名第三



数据来自于Web of Science

开展LAMOST三期光谱巡天计划的预研和部署

Capability of LAMOST: A Ω =247

Existing and planned multi-object spectroscopic projects

Table 1: Existing and planned multi-object spectroscopic capabilities, with defining characteristics. These include wavelength range, field of view, etendue, the number of simultaneous spectra per field, the spectral resolution, the fraction of time the capability is in use, the image quality, and the discovery efficiency (defined in the text)

Telescope/Instrument	D_{M1} (m)	Status	Available	λ (μm)	Ω (deg^2)	$A\Omega$ (m^2 deg^2)	N_{mos}	$\mathcal{R}$	f	IQ	$\log\eta$
Ground-Based											
AAT/AAOmega	3.9	Existing	1996	0.37–1.00	3.14	37.5	392	1000–17000	0.5	1.5	3.5
SDSS	2.5	Existing	2000	0.38–0.92	1.54	7.6	640	1800	1.0	1.4	3.6
Keck/DEIMOS	10.0	Existing	2002	0.41–1.10	0.023	1.8	150	2500–5500	0.4	0.7	2.1
VLT/VIMOS	8.2	Existing	2002	0.37–1.00	0.062	3.3	600	180–2500	0.2	0.8	2.9
VLT/FLAMES	8.2	Existing	2003	0.37–0.95	0.136	7.2	8–130	5600–25000	0.2	0.8	1.3–2.6
MMT/Hectospec	6.5	Existing	2004	0.36–0.92	0.79	26.1	240–300	1000–40000	0.2	1.0	2.6–2.7
WIYN/Hydra	3.5	Existing	2005	0.37–1.00	0.79	7.5	90	800–40000	0.2	0.8	2.4
Magellan/IMACS	6.5	Existing	2008	0.36–1.00	0.16	5.3	400	1100–16000	0.2	0.6	3.3
SDSS/APOGEE	2.5	Existing	2011	1.51–1.70	1.54	7.6	300	27000–31000	0.5	1.4	2.8
Subaru/FMOS	8.2	Existing	2012	0.8–1.8	0.20	10.4	400	600-2200	0.2	0.7	3.3
LAMOST†	4.0	Existing	2012	0.37-0.90	19.6	247	4000	1000–10000	1.0	3.0	5.1
AAT/HERMES	3.9	Existing	2013	4 windows	3.14	37.5	392	28000	0.5	1.5	3.6
Subaru/PFS	8.2	Planned	2017	0.38–1.30	1.1	70	2400	1900-4500	0.3	0.7	5.0
WHT/WEAVE	4.2	Planned	2018	0.37–1.00	3.14	41	∼1000	5000–20000	0.7	0.8	4.8
Mayall/DESI	4.0	Planned	2018	0.36–1.05	7.1	89	5000	3000–4800	0.5	1.5	5.1
VLT/MOONS	8.2	Planned	2018	0.8–1.8	0.14	7.3	1000	4000-20000	0.3	0.8	3.3
VLT/4MOST	4.1	Planned	2019	4 windows	3.0	40	1500	3000-20000	1.0	0.8	5.1
MSE	10.0	Planned	2021	0.37–1.30	1.5	118	3200	2000	1.0	0.7	6.0
				0.37–1.00			3200,800	6500,20000	1.0	0.7	5.4
Space-Based											
Gaia	2×(1.4×0.5)	Existing	2014	0.85–0.87	all sky survey (V < 17)			11500			
Euclid	1.2	Planned	2020	1.10–2.00	0.55	0.62		250			
WFIRST	1.5	Planned	2025:	1.10–2.00	0.5	0.89		75–320			

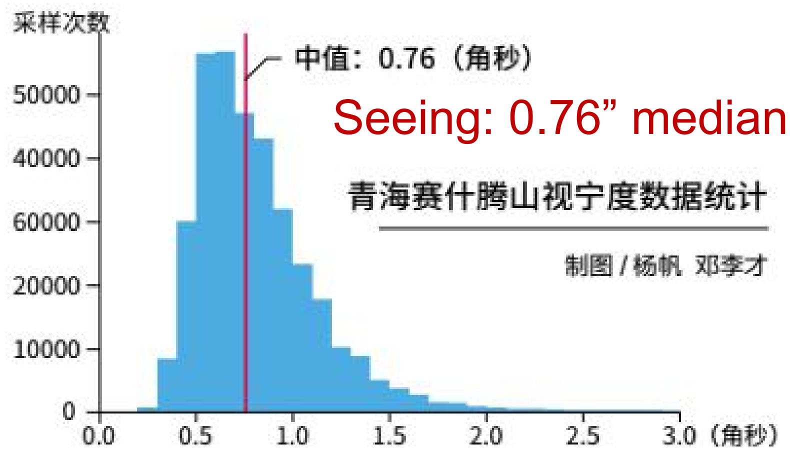
† – *Also known as the Guo Shou Jing Telescope (GSJT).*

A. McConnachie, R.Murowinski, D. Salmon, D.Simons, P.Côté c，2014，SPIE

LAMOST II project

Site: Xinglong → Lenghu

- Mirrors: MA24 + MB37
- Fibers: 4,000 → 12,000
- Survey mag.: 17.8m → 19.8m
- Spectra： 10 M → 100 M




Thank You ！