An Introduction to LAMOST

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Outline

- Introduction to LAMOST
  - Telescope
  - Fiber positioning
  - Ma and Mb
  - Active optics technique
- LAMOST survey
  - Exoplanet measurement
  - High-velocity stars
  - Local dark matter density
  - Disrupted Satellite

Introduction

- The Large Sky Area Multi-Object Fibre Spectroscopic Telescope (LAMOST), also known as the Guo Shoujing Telescope after the 13th-century Chinese astronomer, is a meridian reflecting Schmidt telescope
- located in Xinglong Station, Hebei Province, China

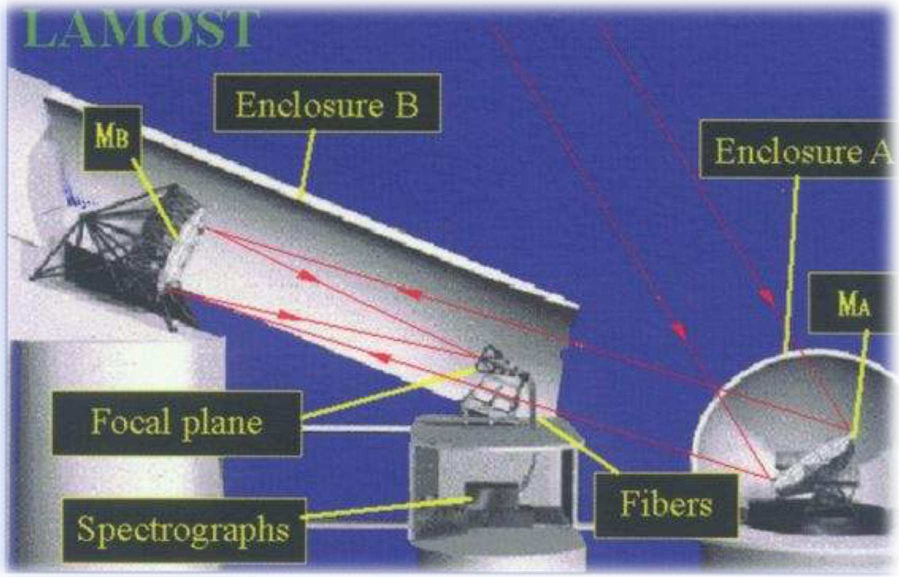
LAMOST

History

- 1996.7, was incorporated into the plan
- 2001.9, the construction of LAMOST was started and completed in 2008.10
- 2009, began to test
- 2012.6, the pilot survey was successfully completed
- 2010.4.17, LAMOST was officially named "Guo Shoujing Telescope"
- 2012.9, the official survey started

Telescope

- Ma： 5.72m×4.4m
- Mb： 6.67m×6.05m
- Field of view： 5°
- Number of fibers： 4000
- Spectral ranges： 370-900nm
- Limit magnitude： 20.5m (1.5h exposure in R=500 mode)
- Spectral resolution： 1/0.25nm
- Observable sky： -10°to +90° Declination



The structure of LAMOST

Fiber positioning

- All of 4000 fibers are required to be positioned on 5 degrees focus surface precisely and quickly to right positions.

  - The 2-D positioning error of any among the 4000 fibers is less than 0.4arcsec in focal surface
  - The time needed for positioning all the 4000 fibers once is shorter than 10 minutes.
  - During observation, errors can be compensated.

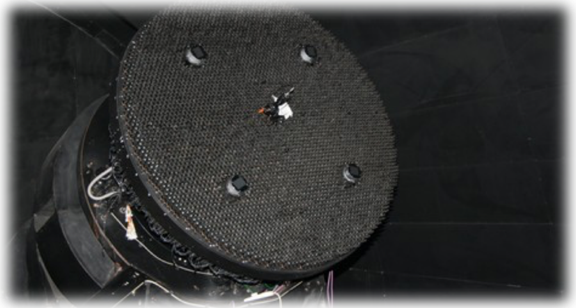


Figure1 shows the focal plane with 4000 fiber positioning units

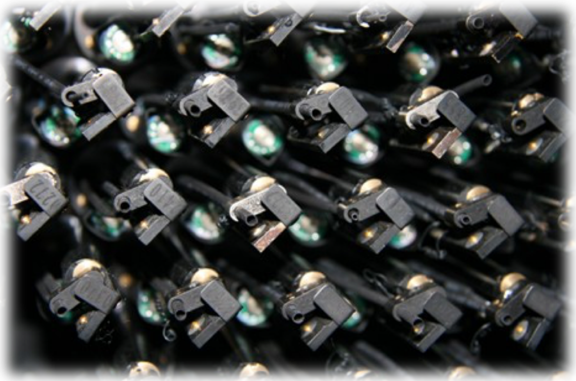


Figure 2 shows the fiber positioning units

Active optics technique

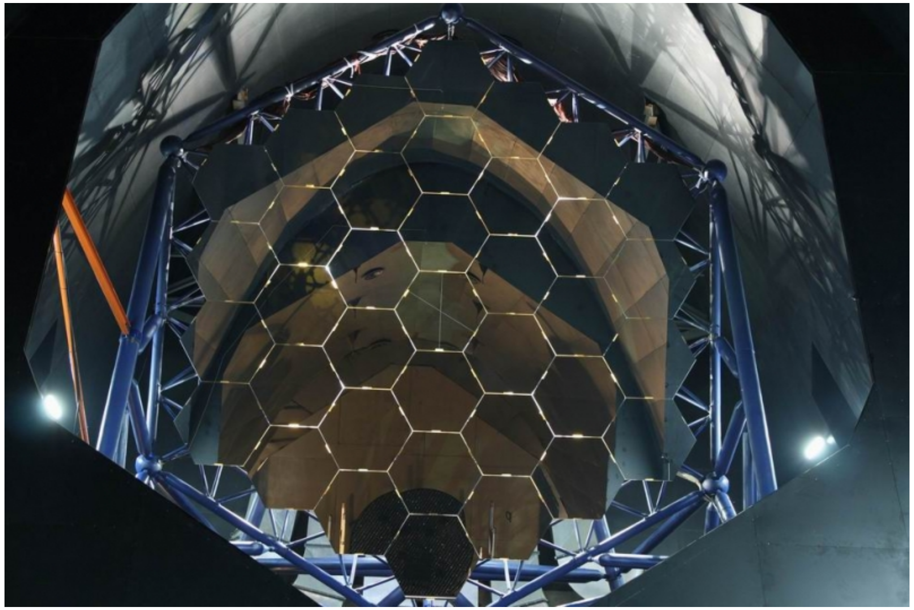
- 4000 Fiber positioning devices Produce a lot of heat

- During the observation, the dome should reduce the influence of the wind on the MA, and the temperature in the path is uniform, without deteriorating the atmospheric visibility.

LAMOST

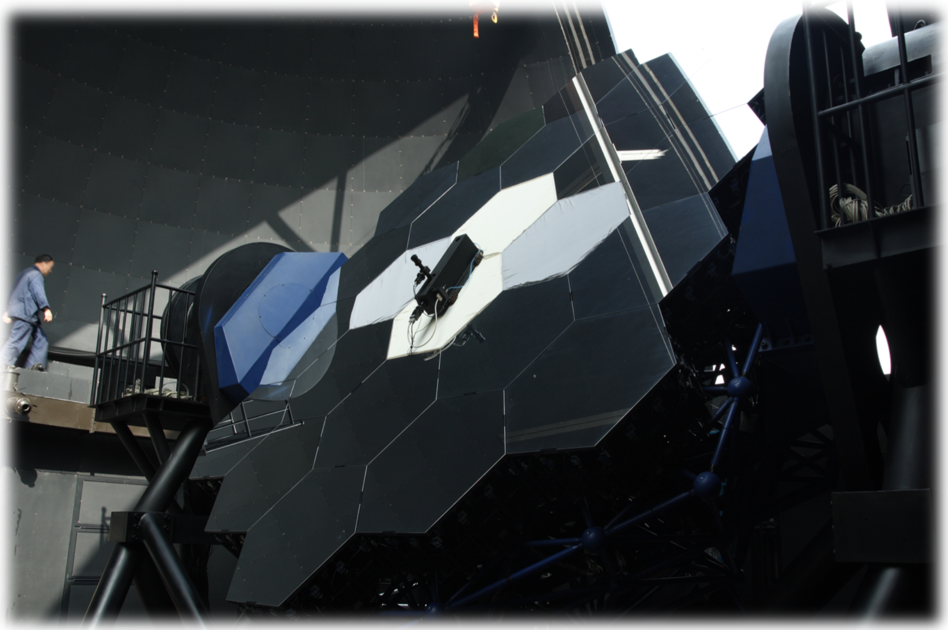
Reflecting Schmidt Ma and spherical primary mirror Mb

- Ma:
  - 5.72m×4.40m
  - 24 hexagonal plane sub-mirrors
  - each has a diagonal diameter of 1.1m
  - thickness :25 mm
- Mb:
  - 6.67m×6.05m
  - 37 hexagonal spherical sub-mirrors
  - each diagonal diameter of 1.1m
  - thickness :75mm.


primary mirror Mb

Active optics technique

- LAMOST use active optics technique to control its reflecting corrector
- which makes it a unique astronomical instrument in combining large aperture with wide field of view.



Reflecting Schmidt Ma

LAMOST Main Survey

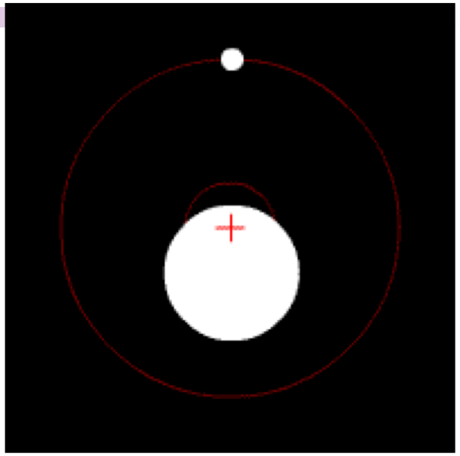
- the LAMOST ExtraGAlactic Survey (LEGAS)
- the LAMOST Experiment for Galactic Understanding and Exploration (LEGUE) survey of Milky Way stellar structure

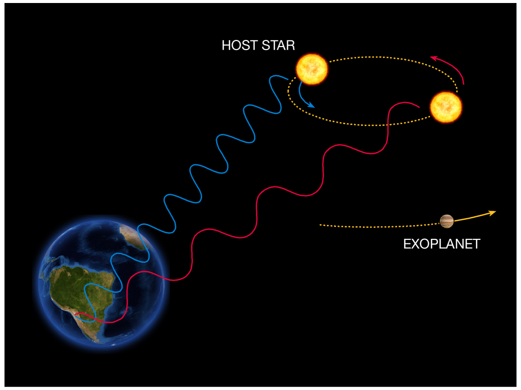
Exoplanet measurement

- The first several hundred extrasolar planets discovered using the radial velocity technique are commonly on eccentric orbits (e" ≈ 0.3).
- This raises a fundamental question: Are the solar system and its formation special?

Exoplanet measurement

- radial-velocity method(Doppler spectroscopy)
- systems meeting special conditions:
    - giant planets with high eccentricities
    - precisely characterized host stars from asteroseismology
    - highly compact and dynamically rich systems exhibiting transit timing variations
    - …… …



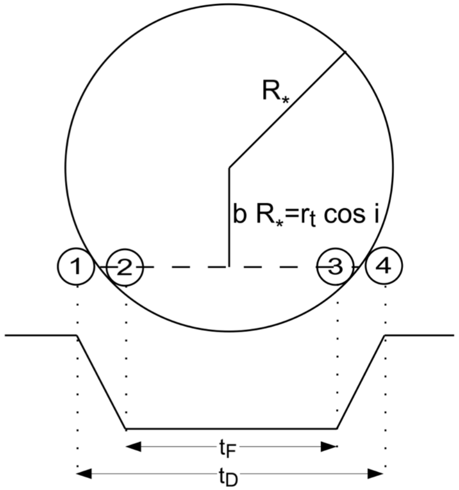


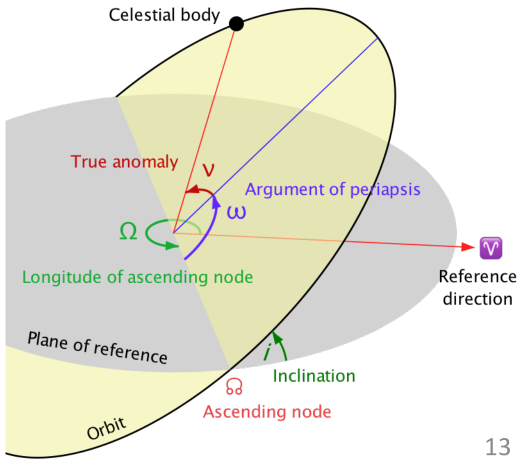
The Radial Velocity Method

ESO Press Photo 22e/07 (25 April 2007)

Exoplanet measurement

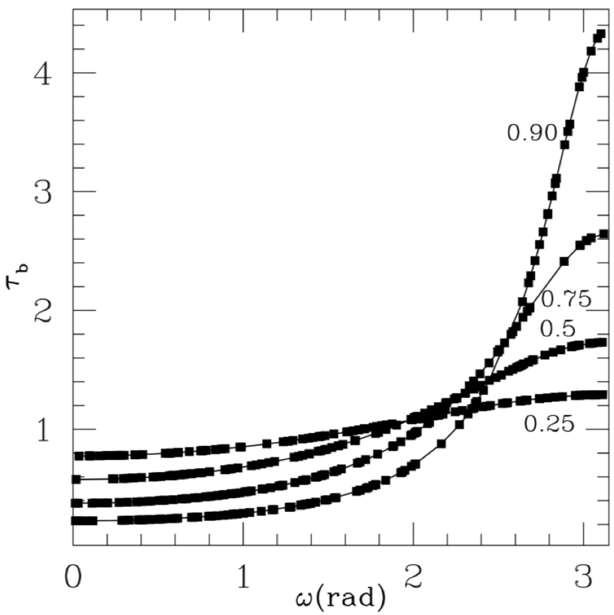
- A robust general method based on the statistics of transit duration
  - Circular: T_0 is uniquely determined by
    - the orbital period P,
    - the planet-to-star radius ratio r $=R_p/R\star$,
    - stellar density
  - eccentric and inclined orbit:T also depends on
    - the eccentricity e
    - orientation of the orbit
    - Argument of periapsis ω



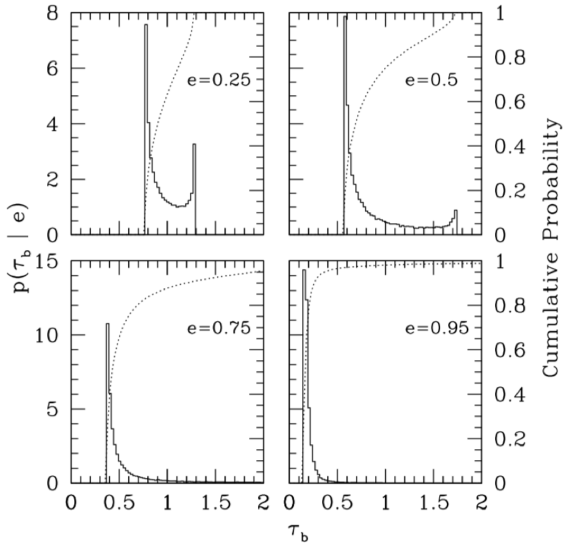


Exoplanet measurement

- degeneracy



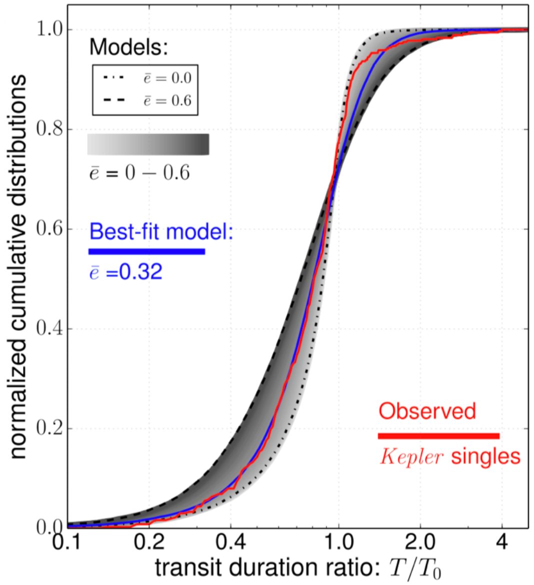
Transit duration as a function of eccentricity (e) and argument of periastron (ω)



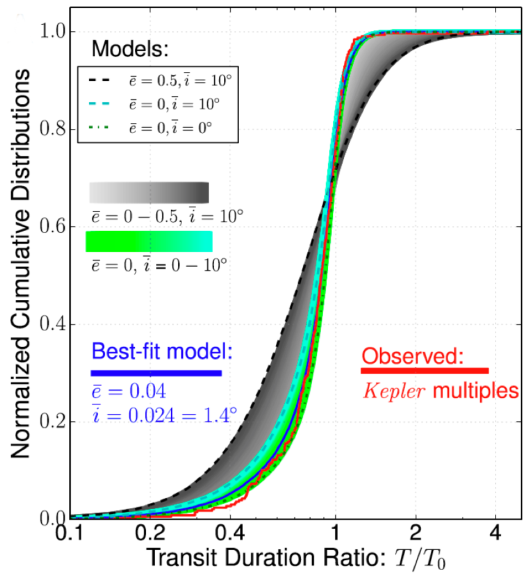
Probability distribution for transit duration at a given eccentricity (e)

Exoplanet measurement

- Xie J W 2016 measured the eccentricity distributions for a large (698) and homogeneous Kepler planet sample with transit duration statistics.



Transit duration ratio statistics of Kepler single transiting planets



Transit duration ratio statistics of Kepler multiples transiting planets

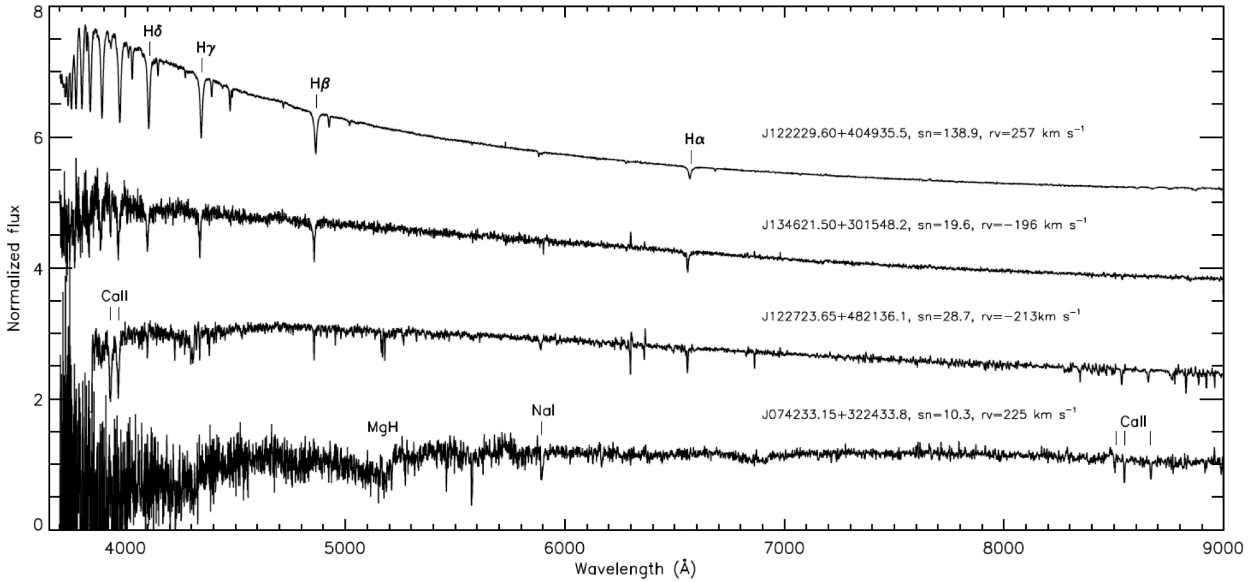
High-velocity stars

- High-velocity stars (HVSs) move sufficiently fast so that they can escape from the Galaxy’s gravitational pull
- The orbits of High-velocity stars can provide useful information about the environments in which they are produced.

High-velocity stars

- Chen L,et al 2014,reports the discovery of 28 candidate high-velocity stars (HVSs) at heliocentric distances of less than 3 kpc

- discovering statistically large numbers of HVSs of different spectral types in LAMOST survey data



Typical spectral sequence representative of the HVS candidates.

Local dark matter density

- Anchor the total dark matter mass of the Galactic halo
- Gives strong constraints in the search for dark matter particles in ground-based laboratories

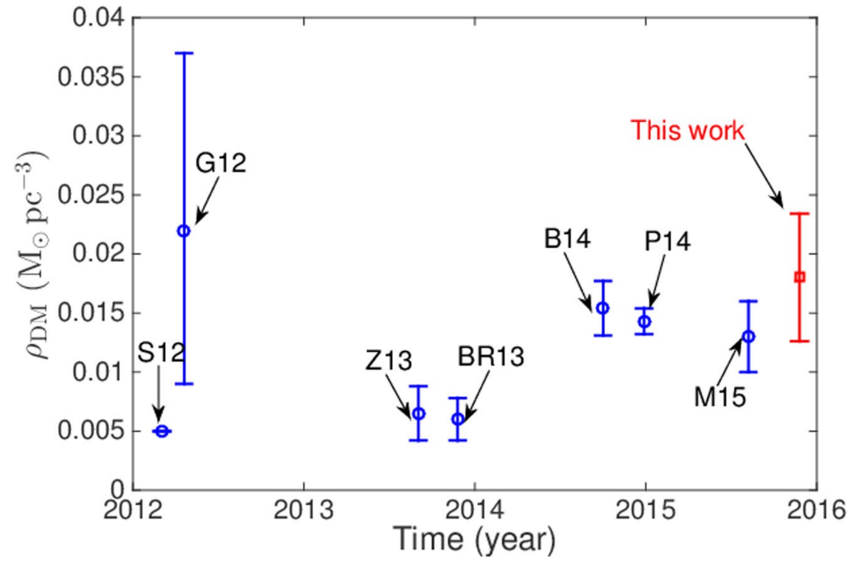
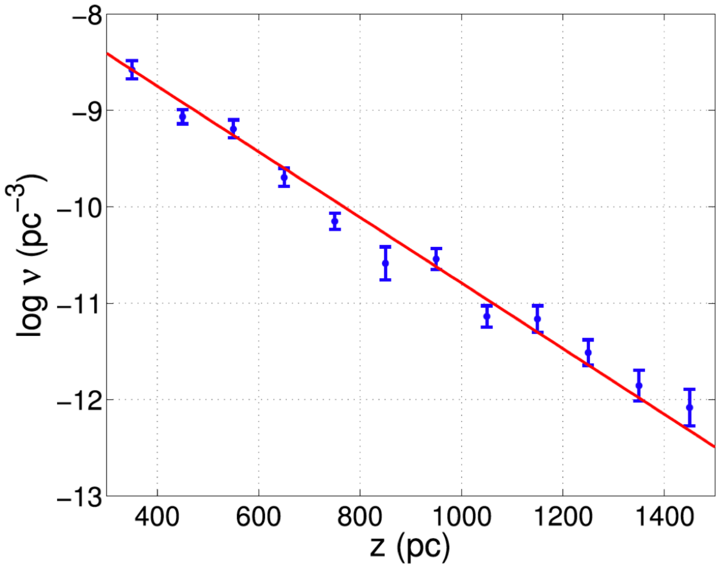


Figure1. Comparison of the measurements of the local dark matter density in the past three years. The points are from Smith et al. (2012; S12), Garbari et al. (2012; G12), Zhang et al. (2013; Z13), Bovy & Rix (2013; BR13), Piffl et al. (2014; P14), Bienaymé et al. (2014; B14), and McKee et al. (2015; M15).Q Xia et al 2015 is shown as the red square with error bar.

Local dark matter density

- LAMOST large data set covers the solar neighbourhood well and thus provides an ideal data base for the selection of the data sample for the measurement of the local dark matter density.



The dots with error bars are the vertical stellar density profile for the observational sample.The red solid line is the best-fitting exponential density profile model.

Local dark matter density

- Vertical jeans equation

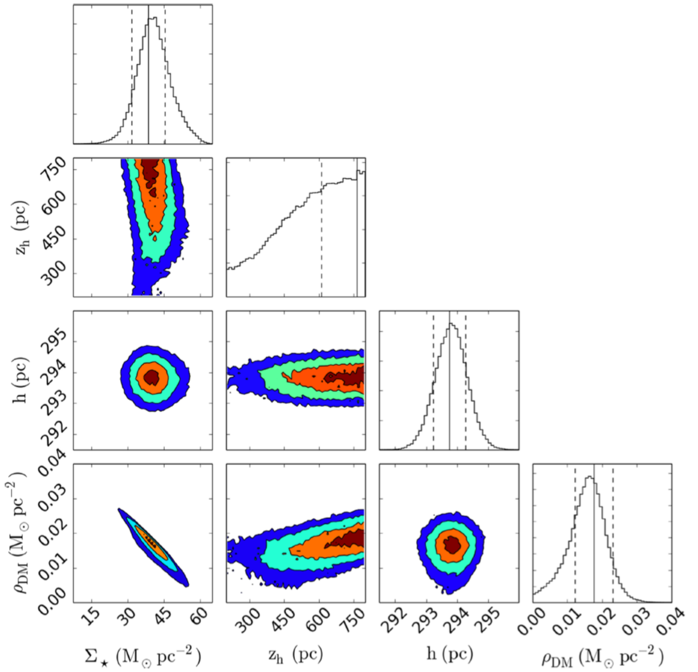
$$\frac{\partial}{\partial z}(\nu\sigma_{zz}^2) + \frac{1}{R}\frac{\partial}{\partial R}(R\nu\sigma_{Rz}^2) = -\nu\frac{\partial\Phi}{\partial z},$$

- 1D Poisson equation

$$4\pi G\rho_{\rm tot}(z)|_{R_0} = \left.\frac{{\rm d}^2\Phi(z)}{{\rm d}^2 z}\right|_{R_0}.$$

- The best-fitting parameters:
  ρ_{DM} ($M_\odot$ pc^{-3}) = 0.018±0.0054

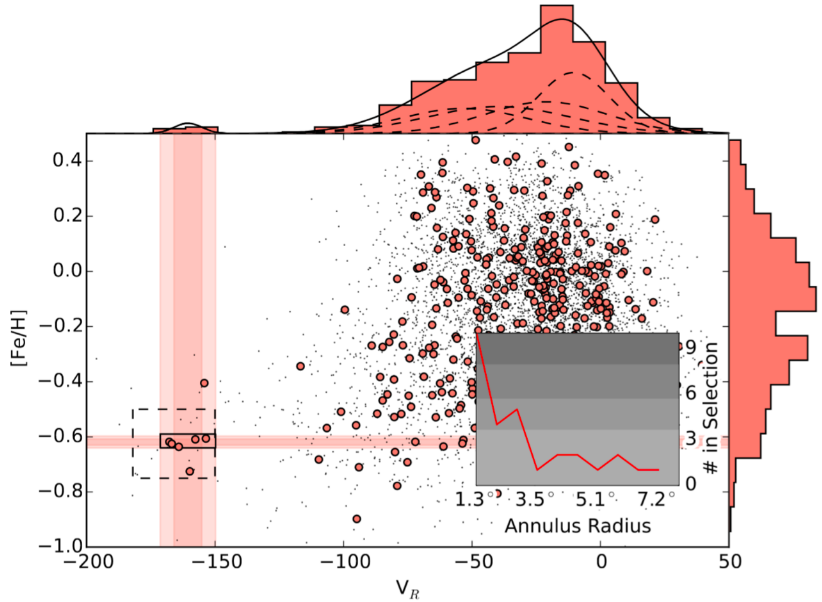
- MCMC



The MCMC result of the model parameters

Disrupted Satellite

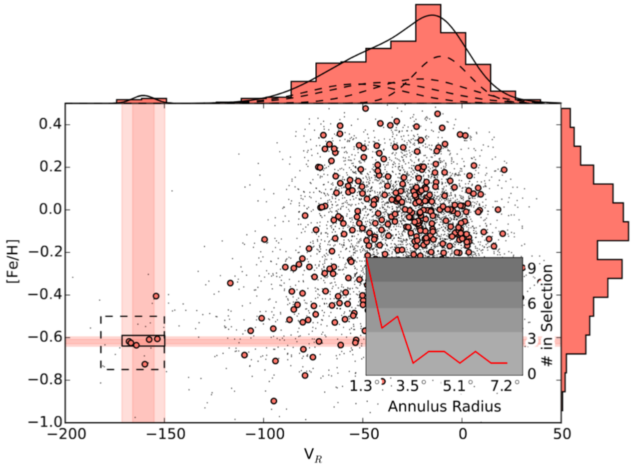
- Using LAMOST spectroscopic data, finds a strong signal of a comoving group of stars in the constellation of Draco.



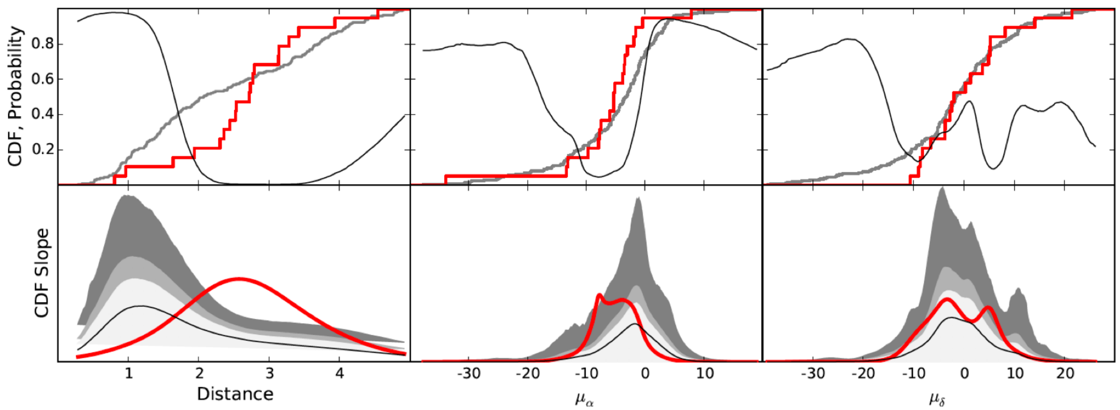
Radial velocity and metallicity of LAMOST stars

Disrupted Satellite

- Significance of Overdensity
  - 24/204
  - P = P([Fe=H],ν_r) · P(μ_α) · P(μ_δ) · P($dist$)≈ 0.012×0.005×0.05×0.09 ≈3.0×10e-7
  - 204/22798 ≈ 1×10e-2



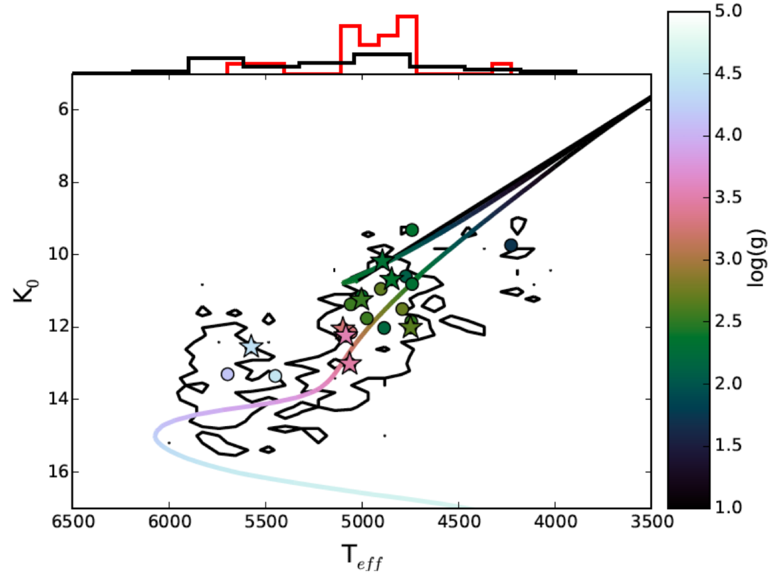
Radial velocity and metallicity of LAMOST stars



The significance of distance and proper motion detections

Disrupted Satellite

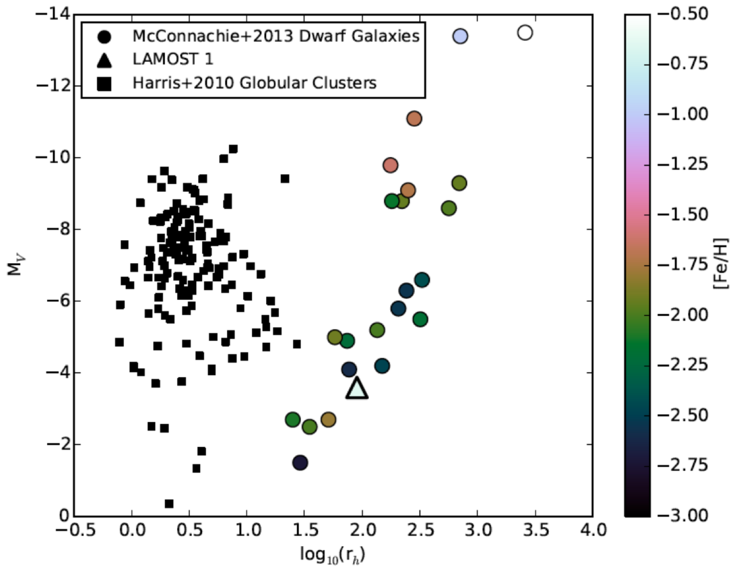
- Age and Distance
  - best fitting isochrone
    - 11 Gyr
    - 2.6 kpc
- An overdensity of giants in the target selected stars can be noticed.



Best fit Padova isochrone for the objects falling within 5° of (l, b) = (80.6, 26.1) and in the dashed selection box (circles) or solid selection box (stars). This isochrone is 11 Gyr at a distance of 2.6 kpc.

Disrupted Satellite

- High metallicity,Dwarf galaxies?
- No strong spatially coherent structures
- May be disrupted globular cluster



Integrated V band magnitude as a function of half light radius for globular clusters from the catalog of Harris (1996),2010 edition, and dwarf galaxies from the catalog of McConnachie(2012)

Reference

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- [4]Xia Q, Liu C, Mao S, et al. Determining the local dark matter density with LAMOST data[J]. Monthly Notices of the Royal Astronomical Society, 2015, 458(4).
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Summary

- Two key technologies
  - Segmented mirrors
  - Active optics technique
- LAMOST survey
  - Exoplanet measurement
  - High-velocity stars
  - Local dark matter density
  - Disrupted Satellite