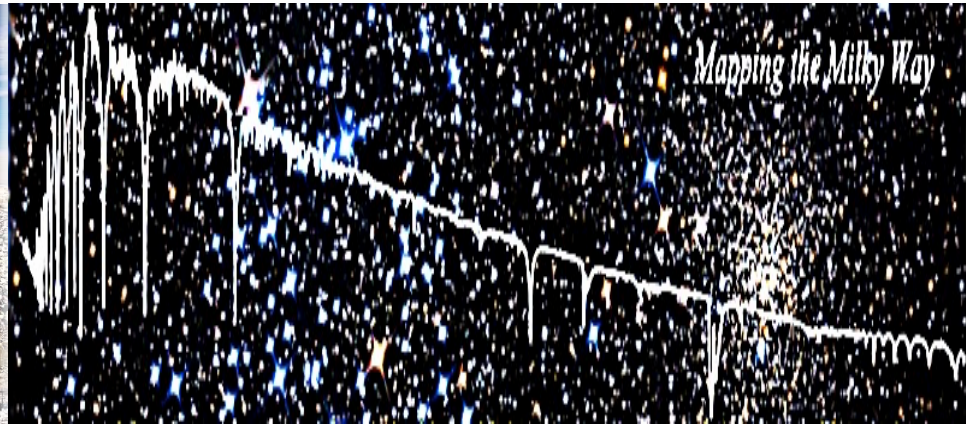
中国科学院国家天文台
NATIONAL ASTRONOMICAL OBSERVATORIES ,CHINESE ACADEMY OF SCIENCES



The Spatial structures of the Galactic outer disk

with LAMOST DR3 K giant stars

Haifeng Wang(hfwang@bao.ac.cn)

Co-authors: LiuChao, Licai Deng et al.

2017.2.18-Kunming-LAMOST 973 annual meeting

Outline

1. Introduction & Motivation

2. LAMOST K giants & Selection corrections

3. Milky Way Model & Non-parametric Results

4. Discussions & Conclusions

Why is the outer disk intriguing ?

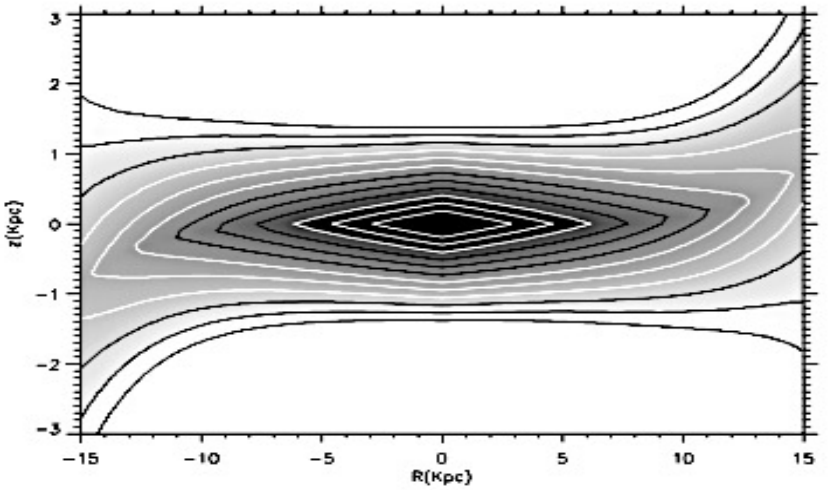
1.Based on radial profiles, disk can be divided into three categories(Pohlen+2006):Type I, classical single exponential (10%); Type II, down-bending joint exponential (60%); Type III, up-bending joint exponential (30%).

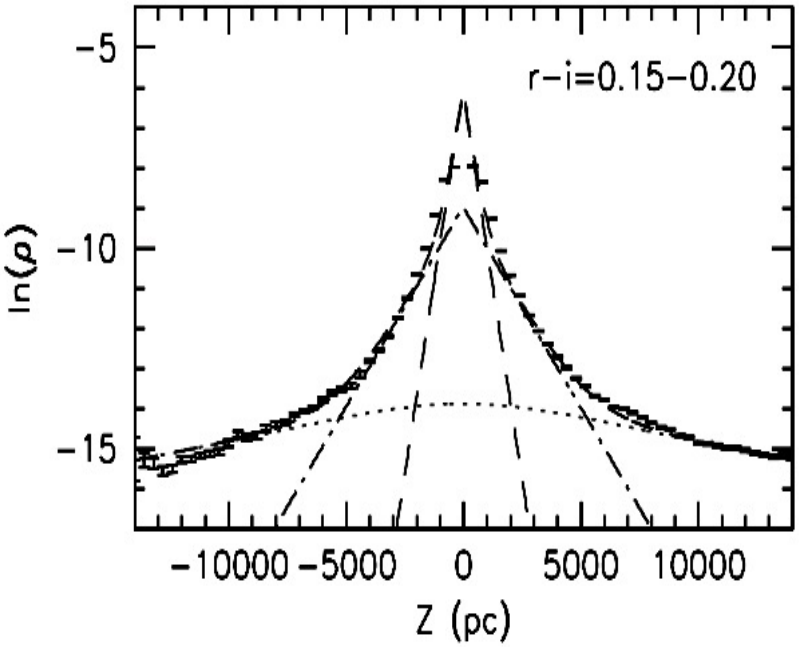
2.Milky Way is the benchmark for the research of the disk Galaxy formation and evolution! And there might be multiple formation mechanisms for the observed outer stellar disk. (Rix&Bovy+2013;Hayden+2015;Zheng+2015).

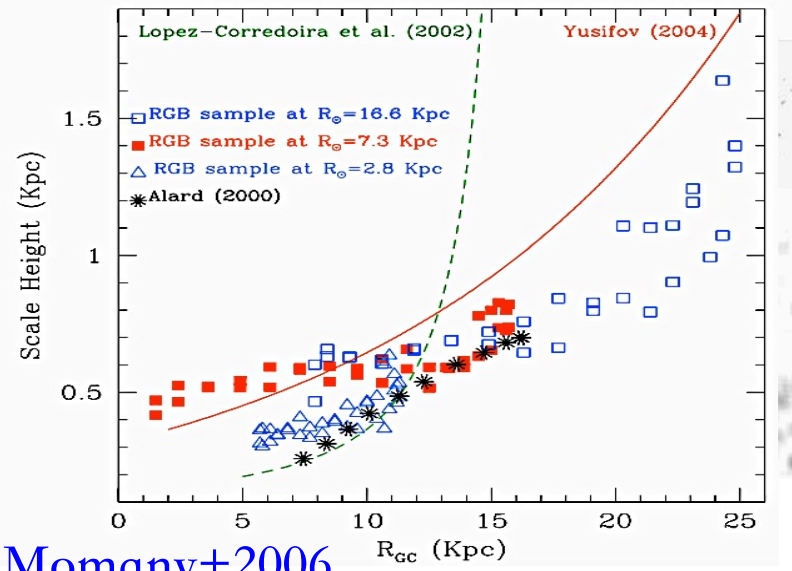
3.The outer disks of galaxies present a unique laboratory for studying the process of disk formation and it can provide us with a direct view of disk assembly in progress(Roskar+2008).

Current status I: Juric+2008;SDSS ,Stellar density structures

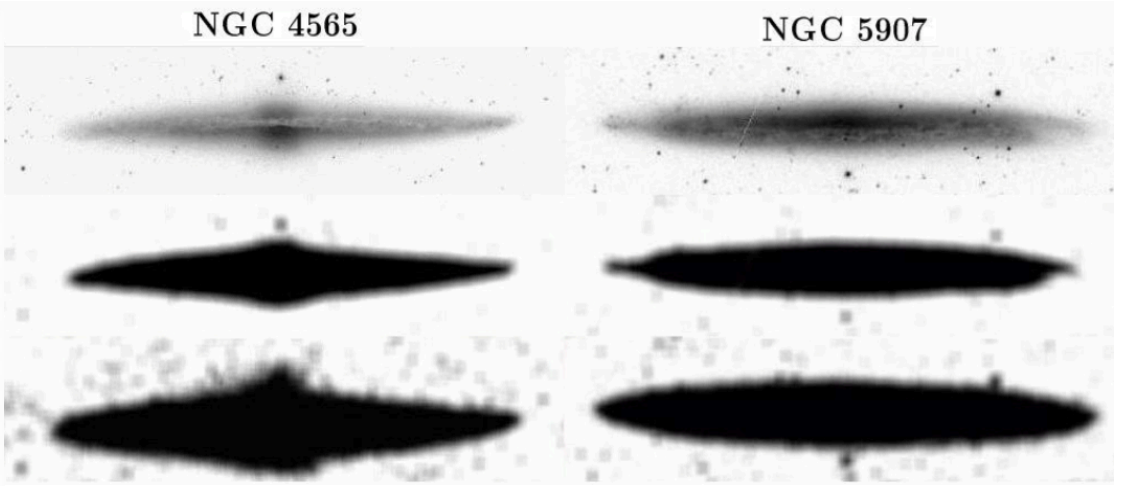
Lopez-corredoira+2002,2MASS ;RCG







Momany+2006



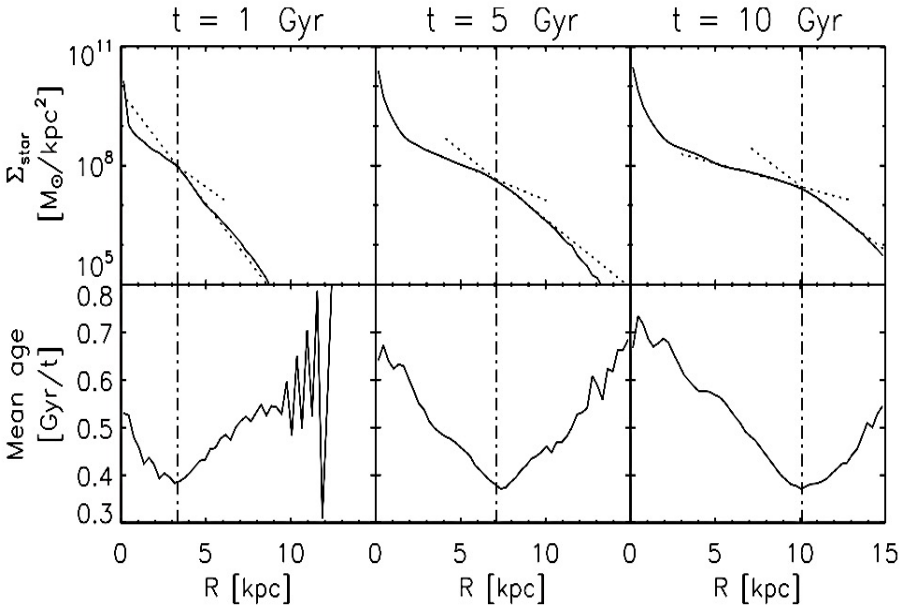
Truncation in stellar disk? Observation and Model? van der Kruit+2011

Current status II:

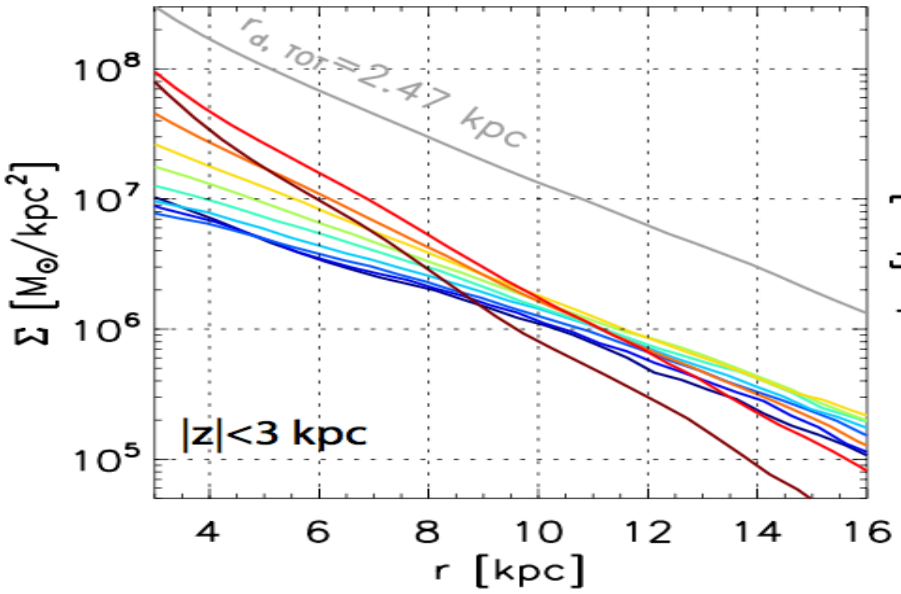
Current deficiencies:

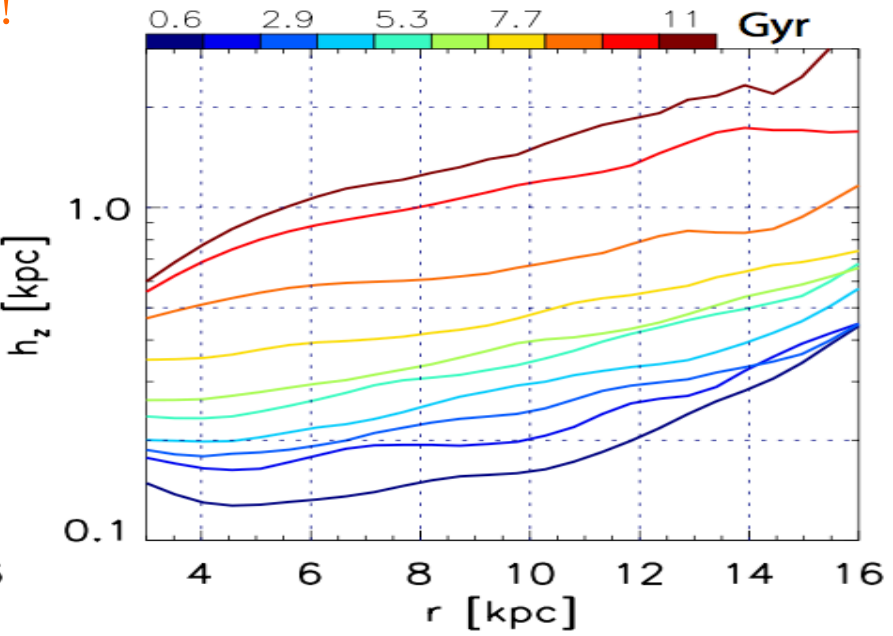
1. Photometric sample?
2. Galactic Anti-Center and low latitude(LAMOST)?
3. Solar neighborhood(systematic)?
4. cut-off at ~15kpc?

Roskar+2008: N-body simulation; migration clues for outer disk



Minchev+2016 : Chemical-Dynamical simulation: Inside-out; Flare in all age bins!





Motivation(Big questions)

1. What about spatial-chemical-dynamical properties of the outer disk?

2. What is the nature and mechanism of the Monoceros Ring(or Tri-And, CMa) , flare, warp,truncation?

3. Is there a thick disk and what is the origin?

4. How do the disk and spiral arms/bars or dark matter halo interact with each other ?

Data:70000 K giants

1.LAMOST DR3 >5700000 stars

2.Selection Criteria:

1)stellar parameters is not empty & similar with Liu+2014

2)Exclude Wan+2015 Red clump stars;

3)Mk(Carlin+2015) =-4 ~ -2(mag) & K>14.3mag

4)New distance>0.5 kpc

(extinction is Zasowski+2013)

Selection functions (Liu+2017, Submitted)

as:

$$P_{ph}(D|C,l,b,c,m) = \frac{P_{ph}(C|D,l,b,c,m)P_{ph}(D|l,b,c,m)}{P_{ph}(C|l,b,c,m)}$$

$$\nu_{ph}(D|C,l,b,c,m) = \nu_{sp}(D|C,l,b,c,m)S^{-1}(l,b,c,m) \quad (2)$$

where $S^{-1}(l,b,c,m)$ can be derived from:

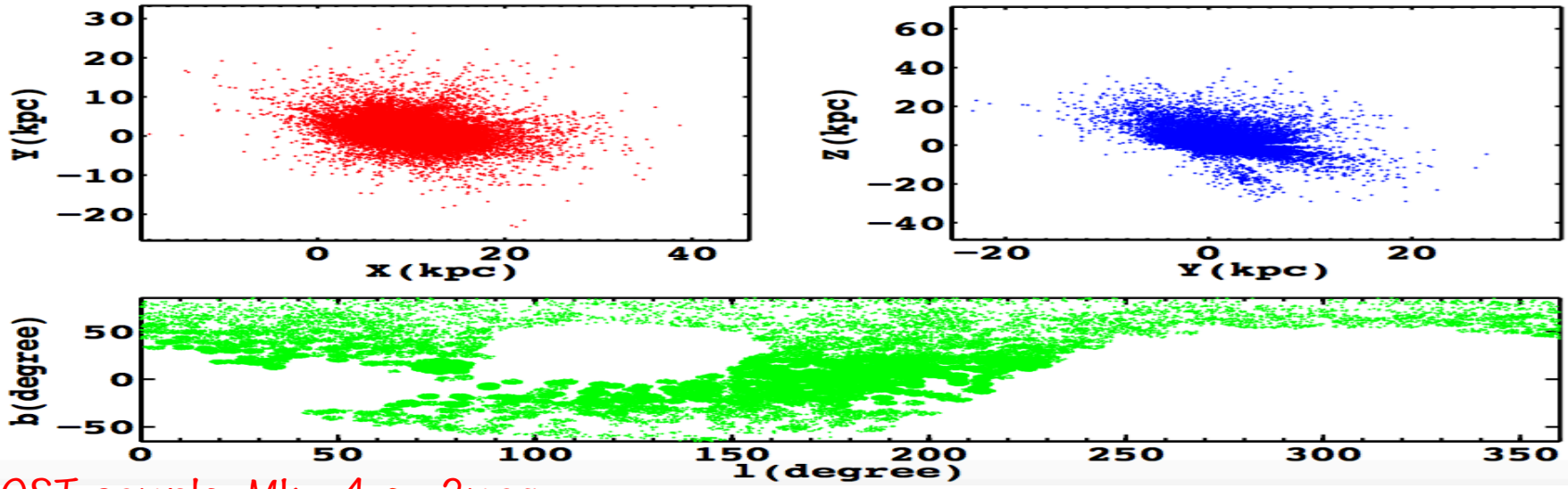
$$S(l,b,c,m) = \frac{n_{spec}(l,b,c,m)}{n_{ph}(l,b,c,m)} \quad (3)$$

Model:5 free Parameters of disk

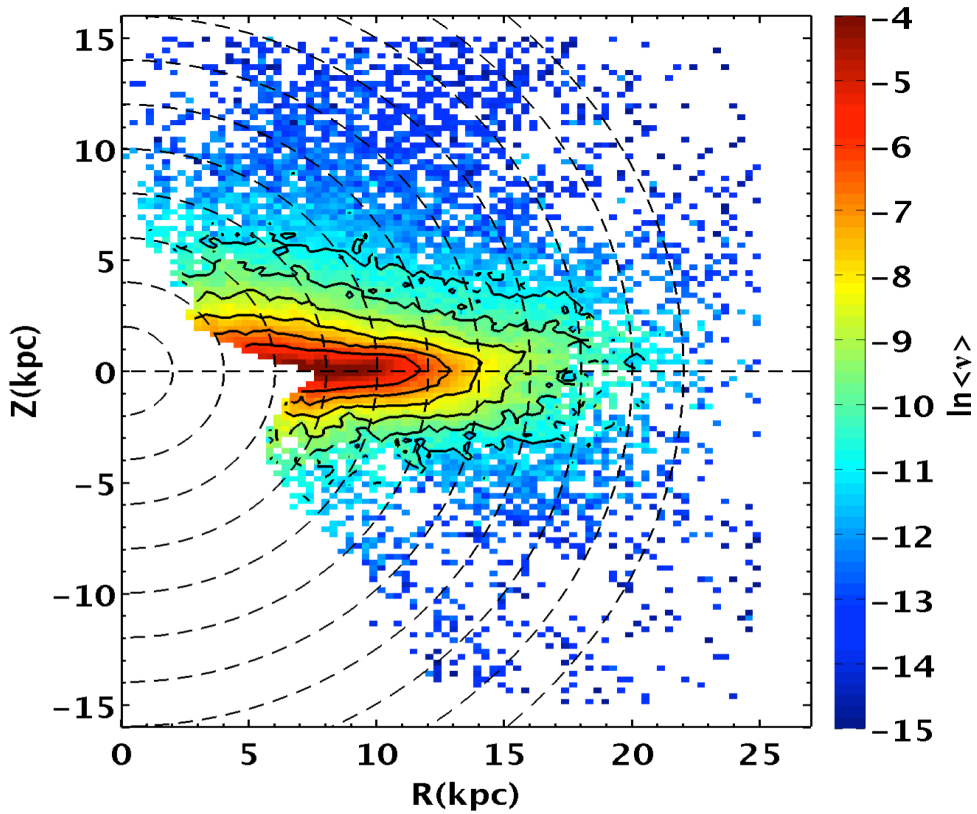
Our final model is as follows:

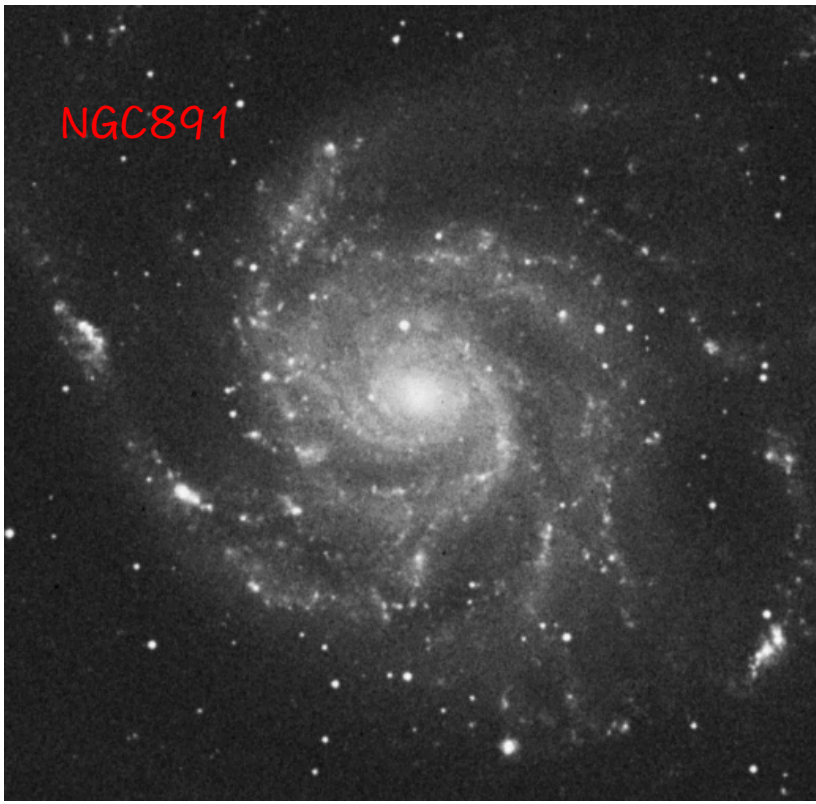
$$\nu_{MW}(R,Z) = \nu_0\left(\mathrm{sech}^2\left(\frac{nZ}{2h_{z1}}\right) + f_t\mathrm{sech}^2\left(\frac{nZ}{2h_{z2}}\right)\right) + \nu_0 f_h\left(\frac{R_\odot}{\sqrt{R^2+(Z/q_H)^2}}\right)^{n_H}. \quad (10)$$

ρ_0 ?
h_{z1} ?
h_{z2} ?
f_t ?
f_h ?

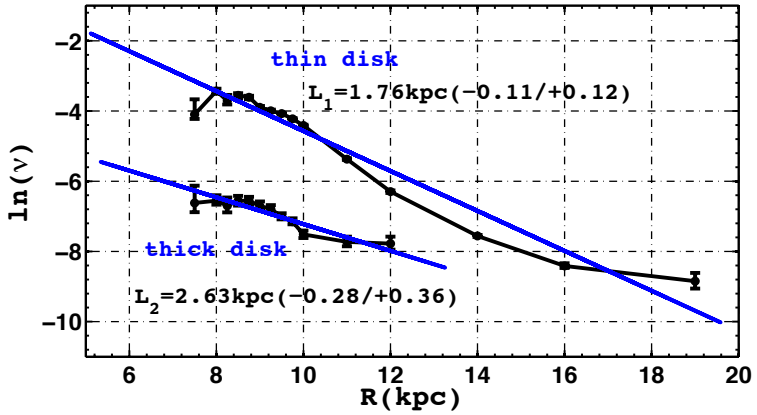


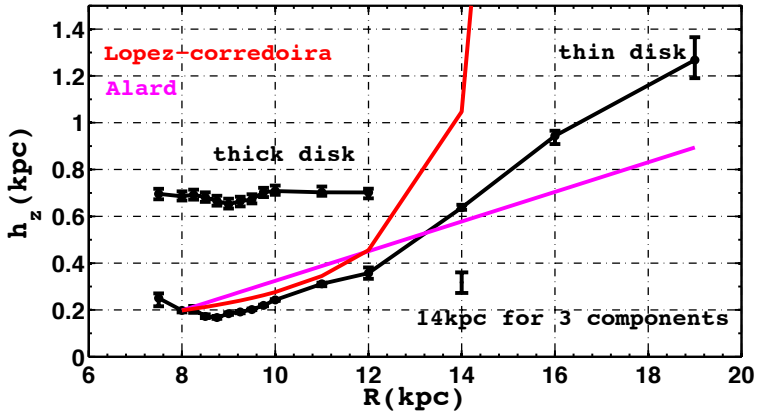
LAMOST sample: Mk=-4 ~-2mag

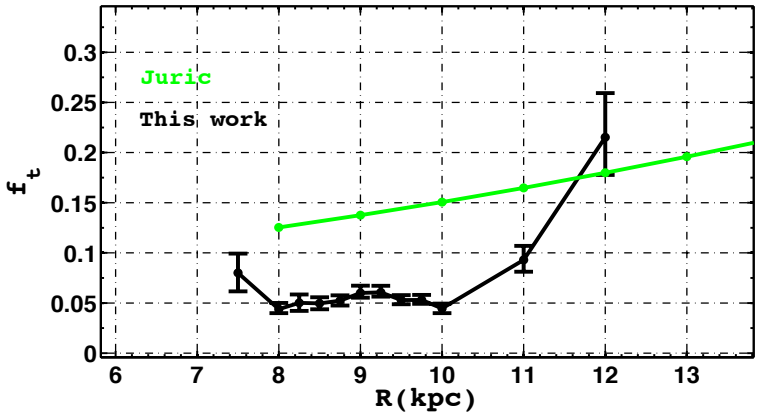


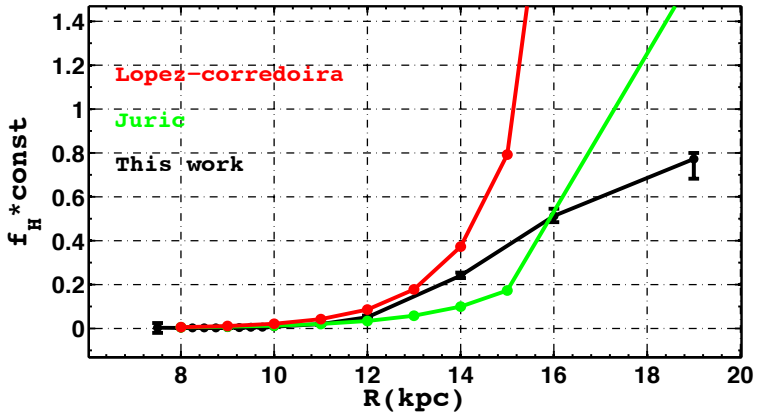


Radial Non-parametric method revealing the our disk structures





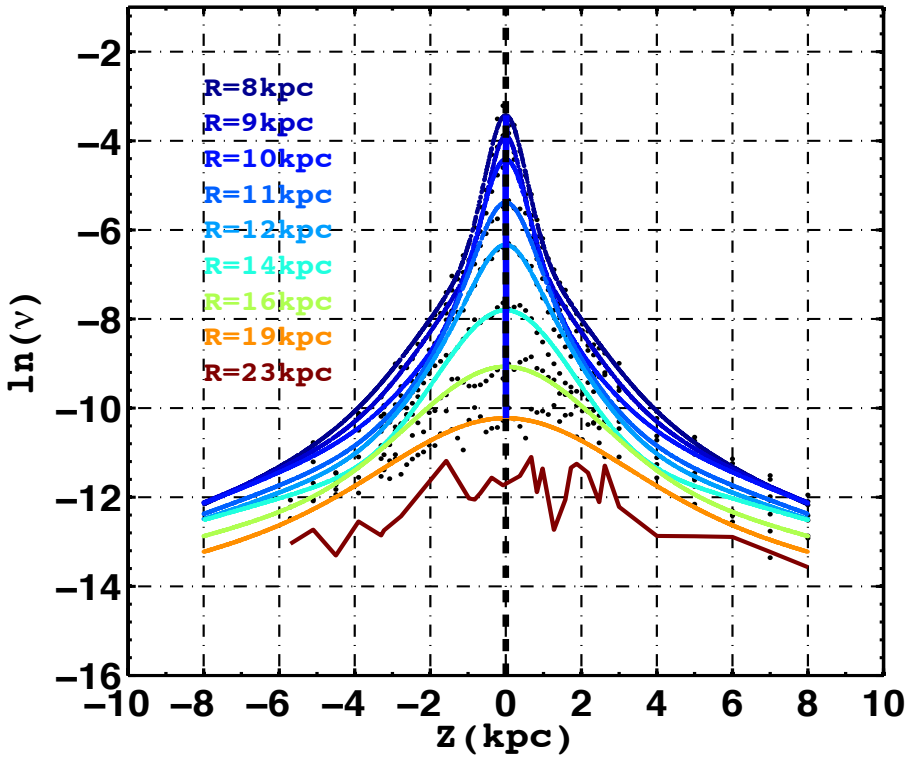


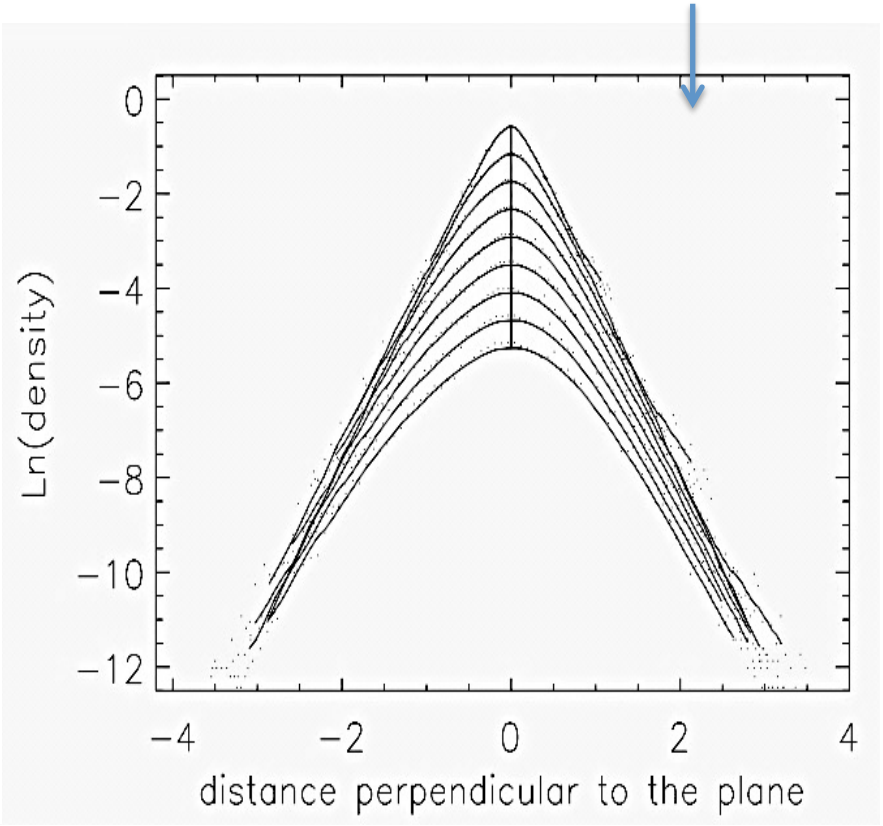


See Bovy+2012,2016; Juric+2008;Lopez-Corredoira+2002;Momany+2006;Minchev+2014;

The flattening of the density profile

The vertical density profile at R=8,9,10,11,12,14,16,19,23kpc. Similar with the Alard!





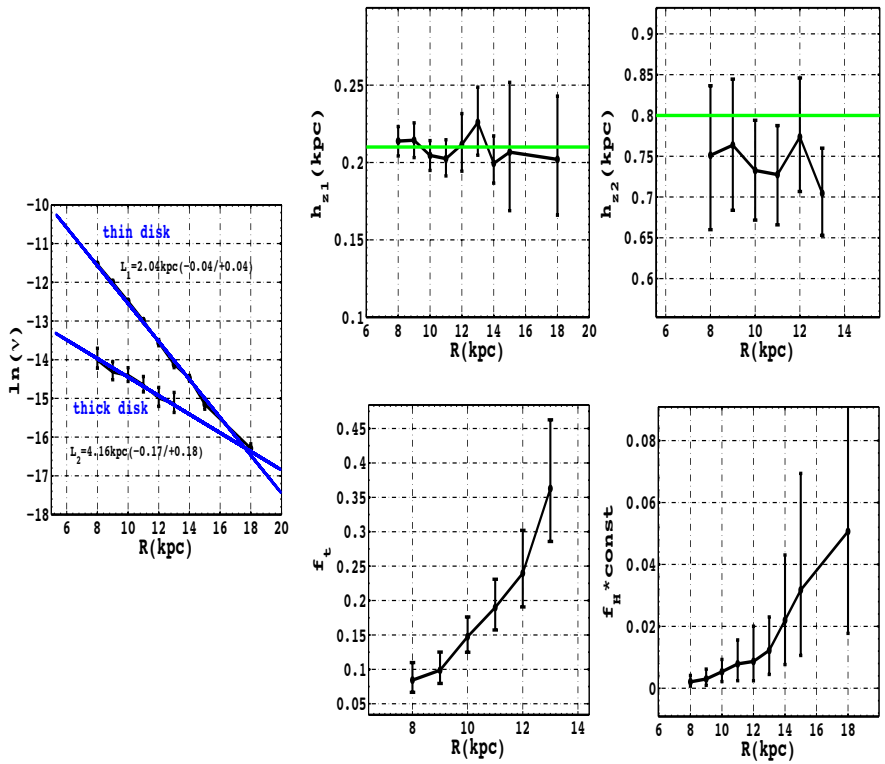
1.The flattening trend of the vetical density profile.

2. It is a real effect ,see (Alard +2002);warp may not be present !

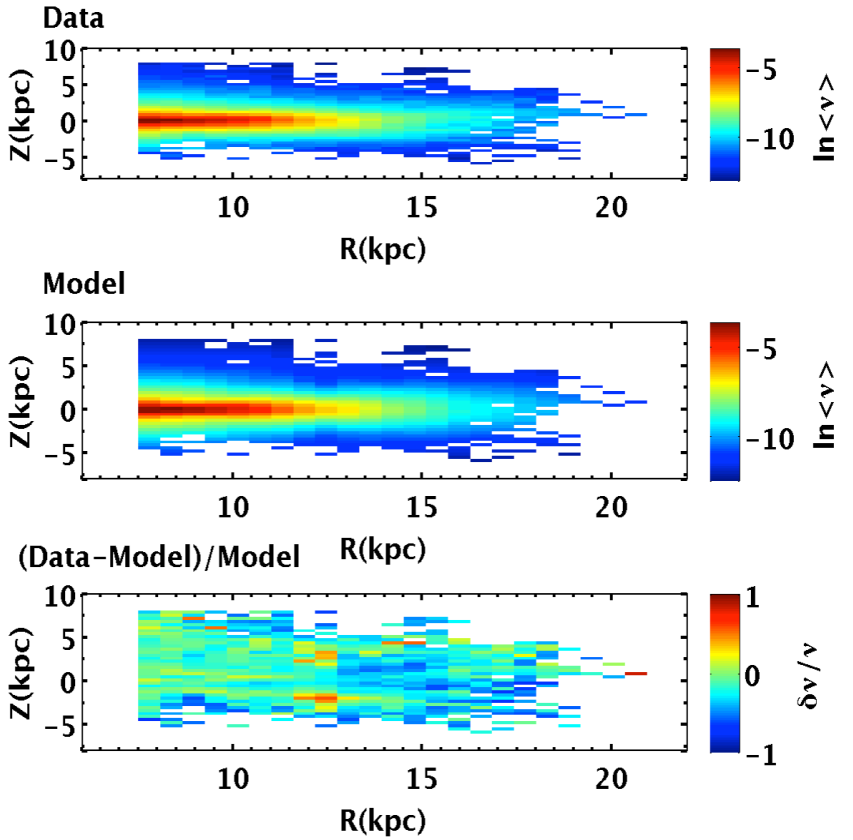
3. The thickening of the disk is a flaring process(Alard:no thick disk! other scenarios or details of the thickening disk?)

Validations &Robustness

hz1=0.21kpc;hz2=0.8kpcL1=2kpc;
L2=4kpc; fH=0.0041;ft=0.08;



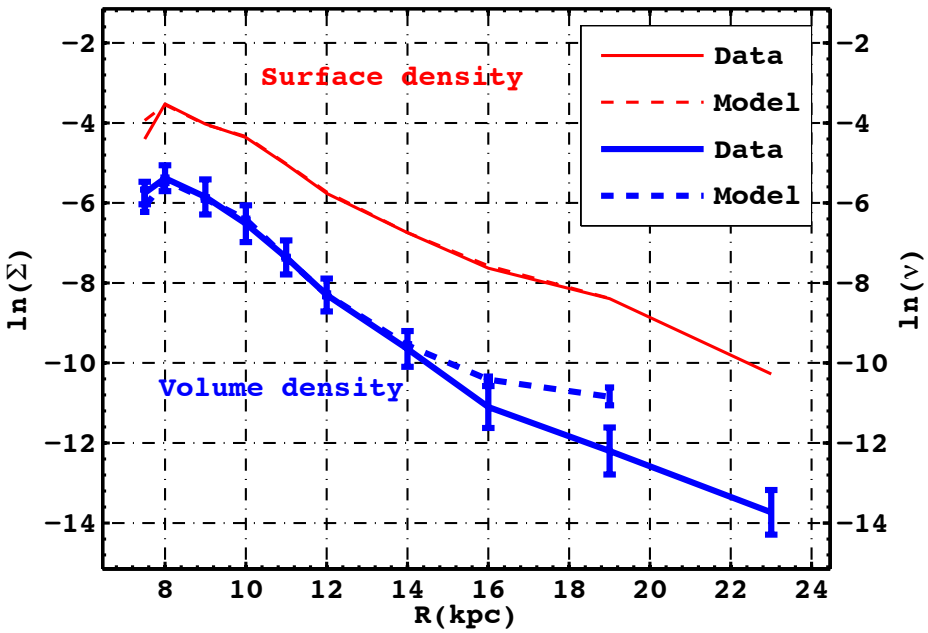
Relative difference
of Data and Model



(No large systematic bias and no Mri overdensity)

Mock data to test hz1,hz2(~3%,7%);

Discussions(1): Disk truncation beyond 20kpc?



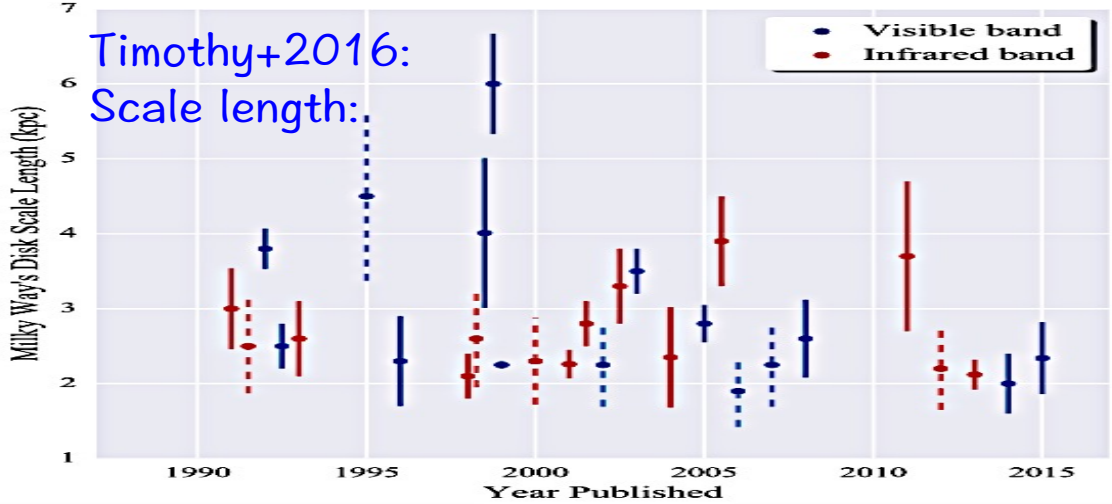
1.Extinction?(10%)(Green 2015,Liu+2017)

2.High α stars in the outer disk?(Carlin+2015)

3.2MASS completeness?

Discussions(2): Disk Flaring mechanism is uncertain! (comparison with others)

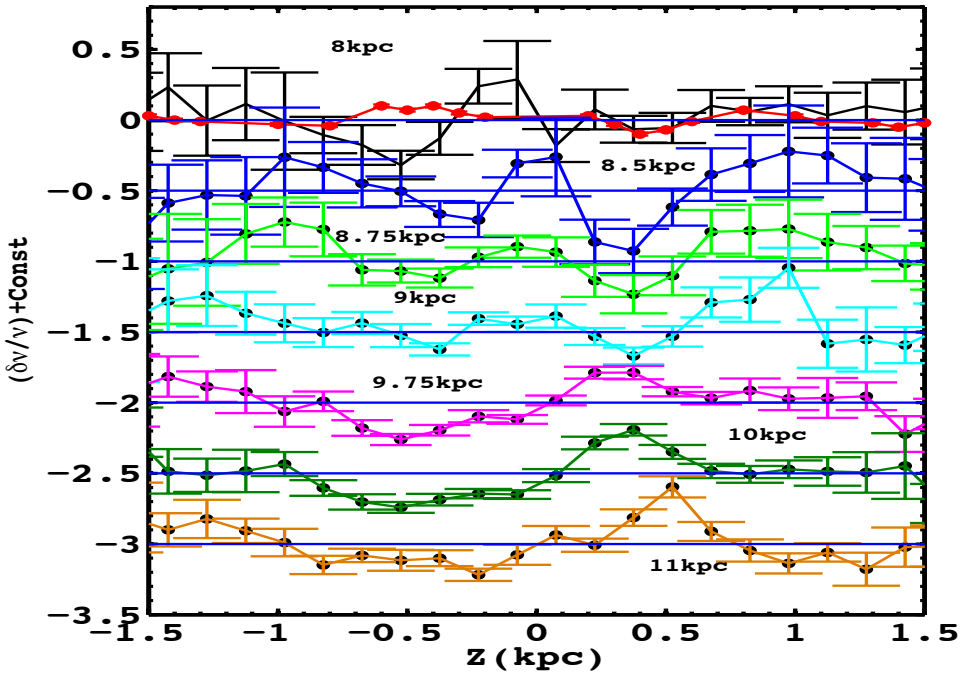
LAMOST Results is different from others?

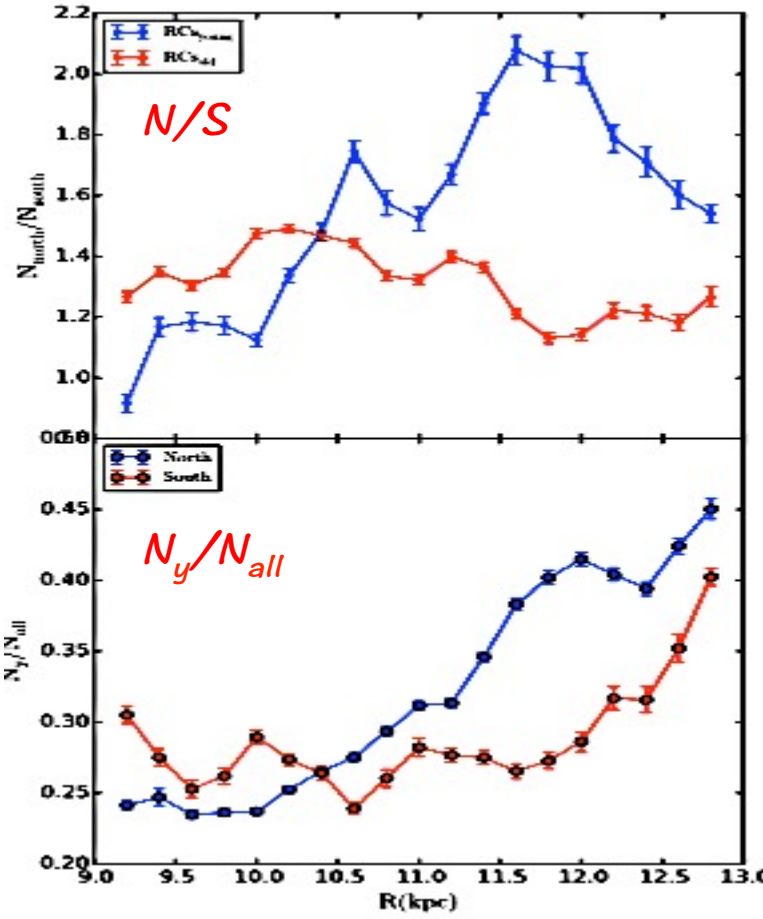


1.This work: L_1=1.76kpc? L_2=2.63kpc?

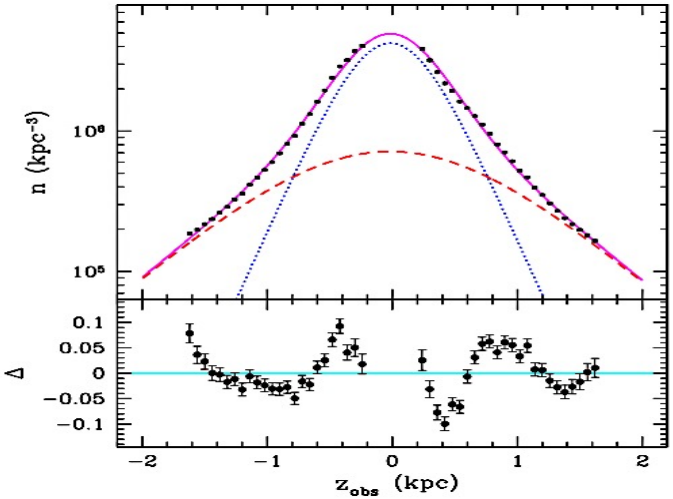
2.Flaring features?

3.Other parameters? (Mentioned above)





Widrow+2012(l=100-160,b=54-68)
Solar neighborhood :SDSS



Wan+2017 (submitted; lamost Red clumps [z= -1—1 kpc], old results)

Discussions(3):GALACTOSEISMOLOGY

1.Oscillations

2.asymmetry

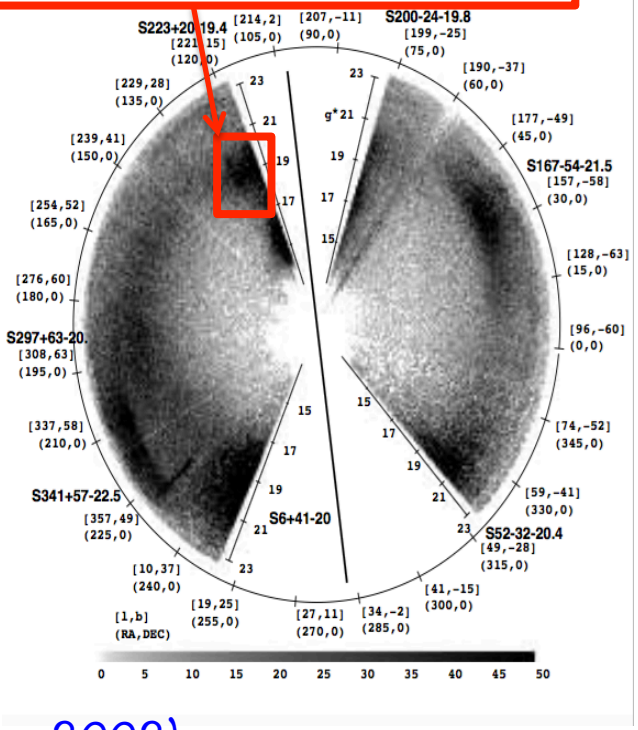
The Mri formation scenarios and details are uncertain:

(1) tidal tails from an accreting dwarf galaxy? (Martin et al. 2004);

(2) misidentification of normal Galactic warp/flare profiles (Momany et al. 2004)

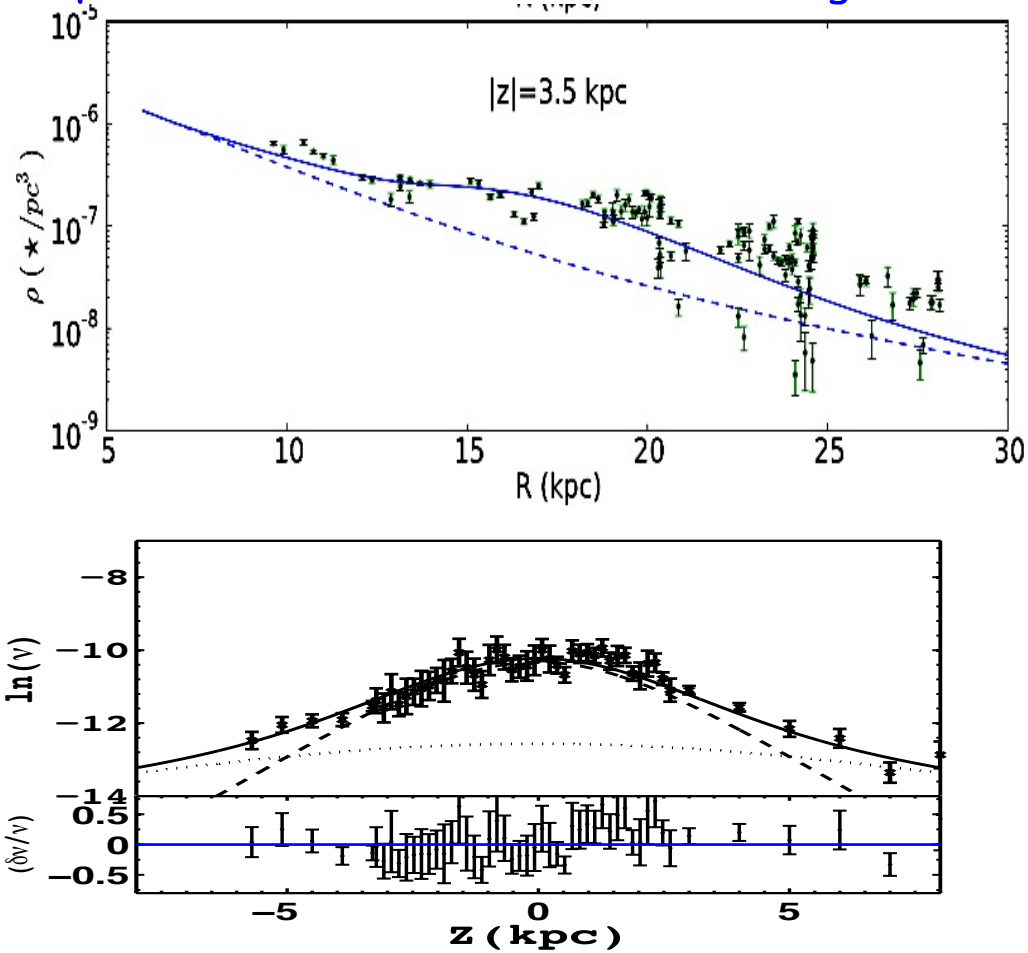
(3) interaction between a dark matter satellite and disk to induce its formation (Gomez et al. 2012)

Monoceros overdensity/stream(?)



(Newberg+2002)

Lopez-corredoira+2011,Hammersly+2014



Discussion(4):

Why do not we see the over-density corresponding to Mri?

---We consider flaring disk carefully!(see Momany+2004)

Summary:

1.We detect the disk maybe truncate beyond 20kpc in the Anti-Center direction !

2. We real the more detailed oscillating and asymmetric structures than previous works !

3. The thickening and flattening disk are obviously displayed in a broader range(Z= -6~8kpc)! The flaring features are re-confirmed but details have much difference with others!

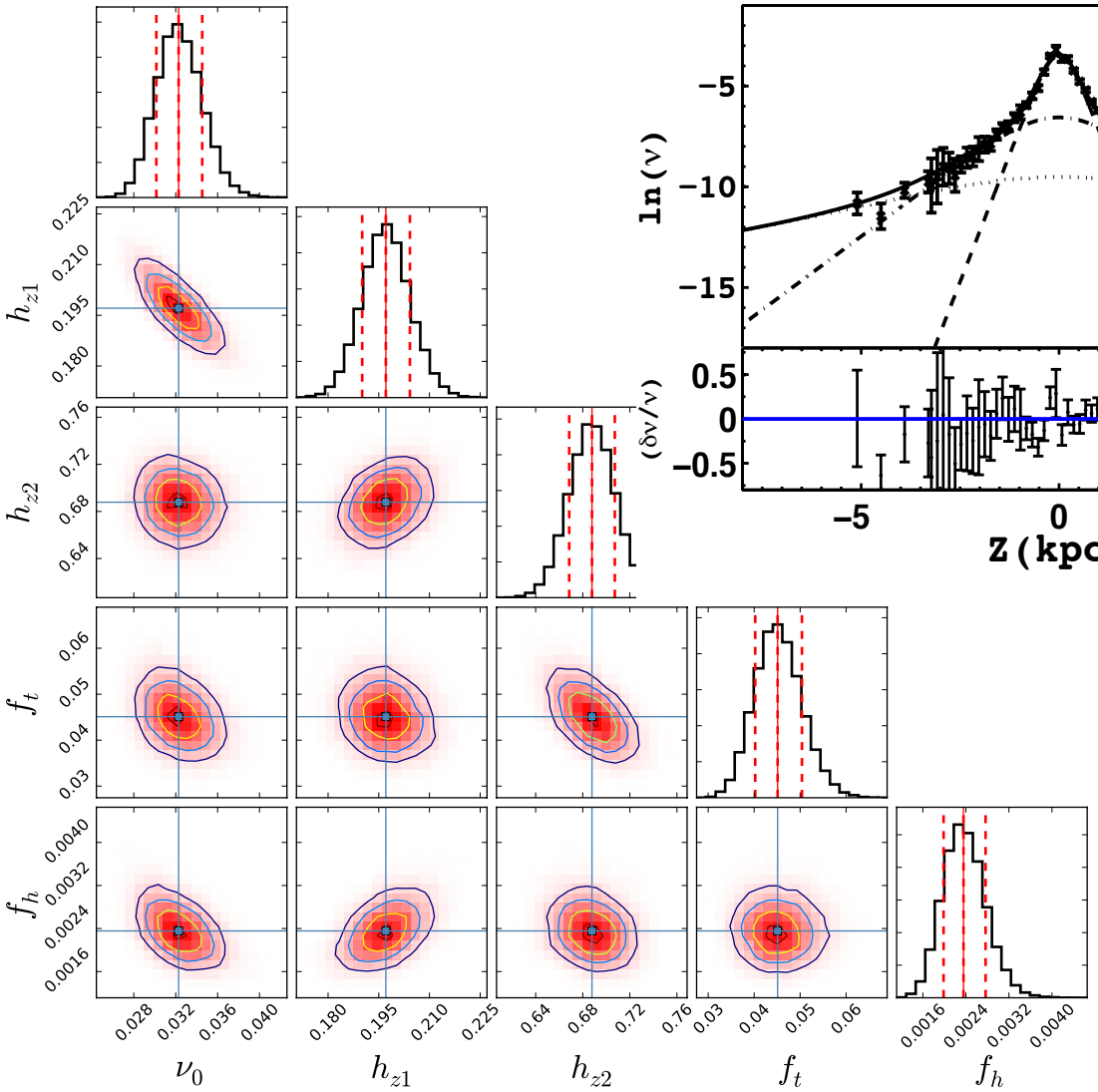
4. We don't detect over-density corresponding to Monoceros Ring, It might be originated from disk flaring and warp!

5. Detailed spatial structural variation of the outer disk(7-20kpc) are displayed with non-parametric method as the first attempt!

6. Do our results probably imply the different SFH/SHE/Dynamics/ Mass distribution of the different disk locations?

Thank you(any comments or suggestions are welcome)!

Appendix(8kpc): other locations is similar: 7.5,8,8.25,8.5,8.75,9,9..25,9.75,10,11,12,14,16, 19kpc(Haifeng Wang +2017, to be submitted)



MCMC:
Non-parametric method;
2D ----1D technology
RJCE extinction