

# Magnetic Structure of Milky Way Galaxy Derived from Observation of Variable Stars

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Master's program 2nd year  
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GRADUATE  
SCHOOL OF  
FACULTY OF **SCIENCE**  
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# Outline

## 473 Miras in 20'×30' (50pc ×75pc @ 8kpc)

Galactic Center (d ~ 8kpc) objects: approximately 300

- Position Angle(PA) peaks ~ 16 degree  
<=> Galactic Plane 31.04 degree

Closer (d ~ 6kpc) objects: 28

- PA : distributed widely
- Average ~ 22.52degree (wide 14.11degree)

**First discussion about kpc-scale magnetic structure**

## 21 Classical Cepheids in 4×20deg

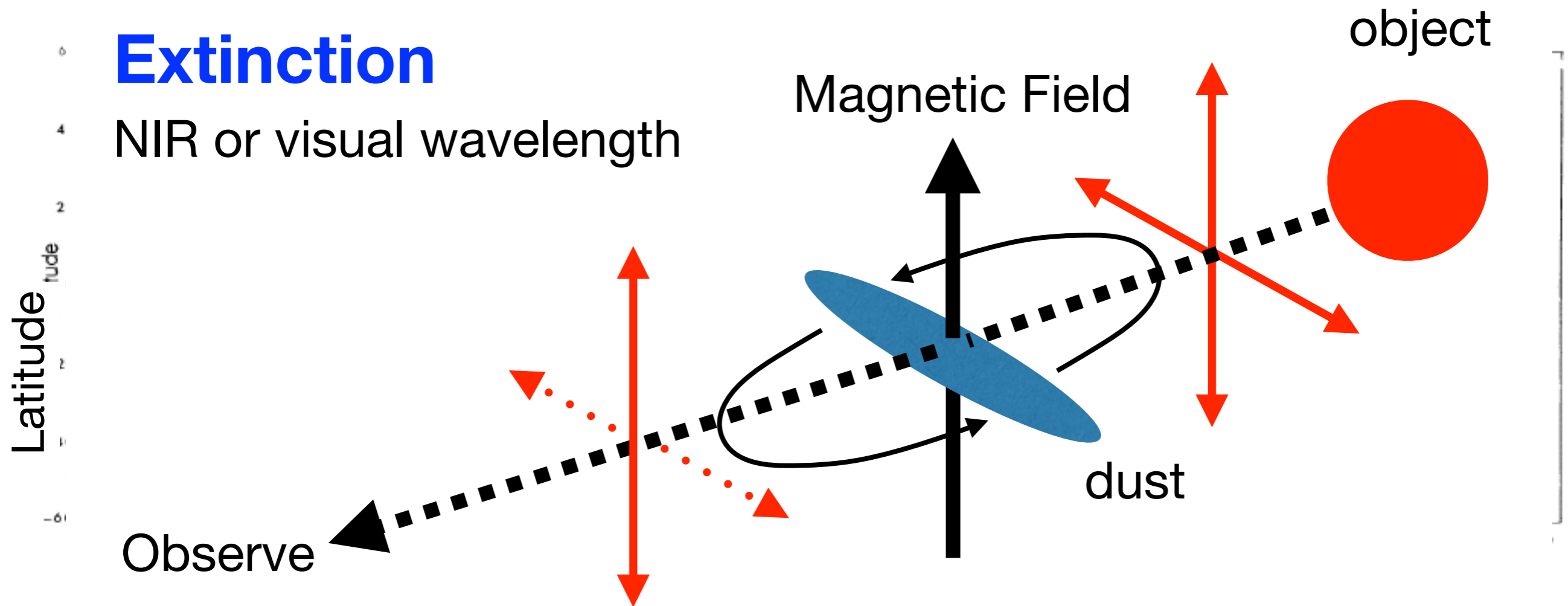
*New!!*

- 16 Cepheids show the polarization ( $P/\sigma > 2.5$ )
- One area objects( $-6.7^\circ \leq l \leq -9.3^\circ$ ): Position Angle shows large inclination to the Galactic Plane

# Introduction

## Extinction

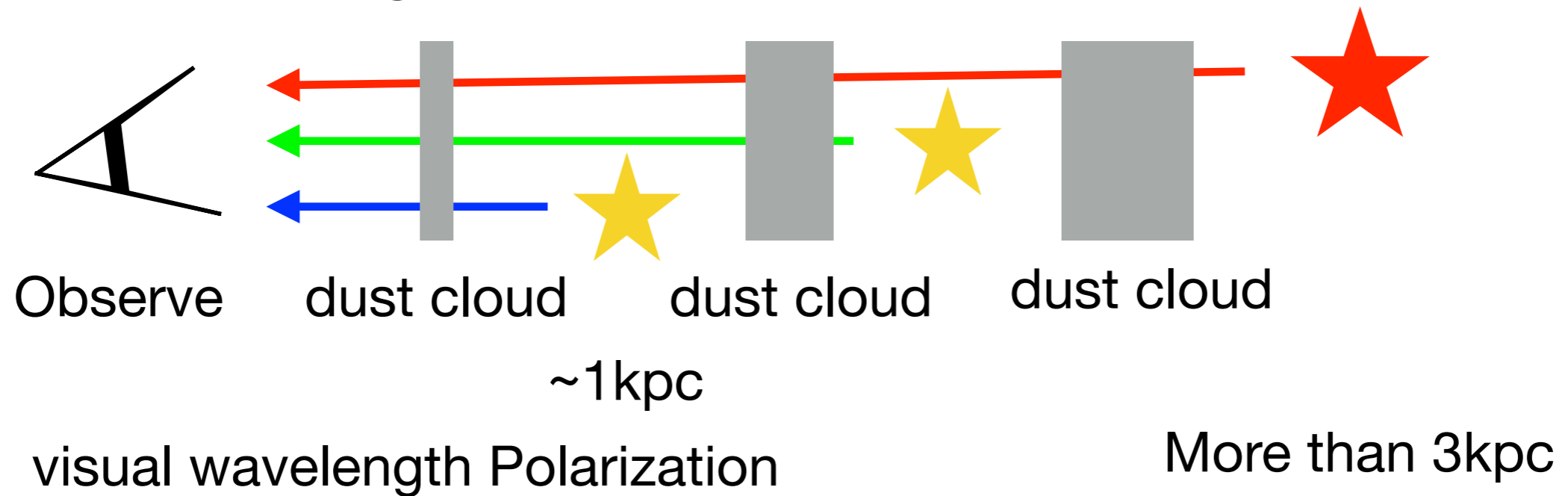
NIR or visual wavelength



Polarization parallel to the Galactic Plane@visual wavelength

Davis-Greenstein or Radiation Torque, or ...

Interstellar Polarization results as **INTEGRAL**  
of the line of sight



**Where do magnetic field change ?**

We need distance information

**How can we measure the distance?**

Difficult near Galactic Center(GC:d~8kpc)

# Changing Magnetic Field with distance?

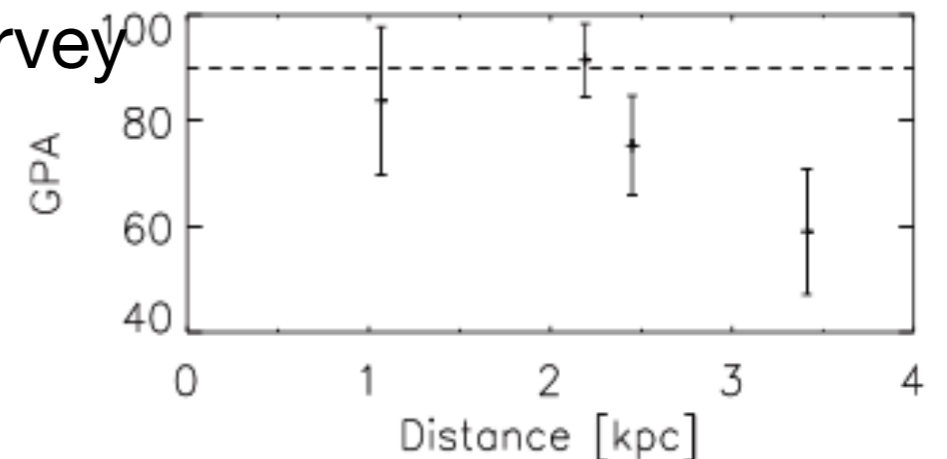
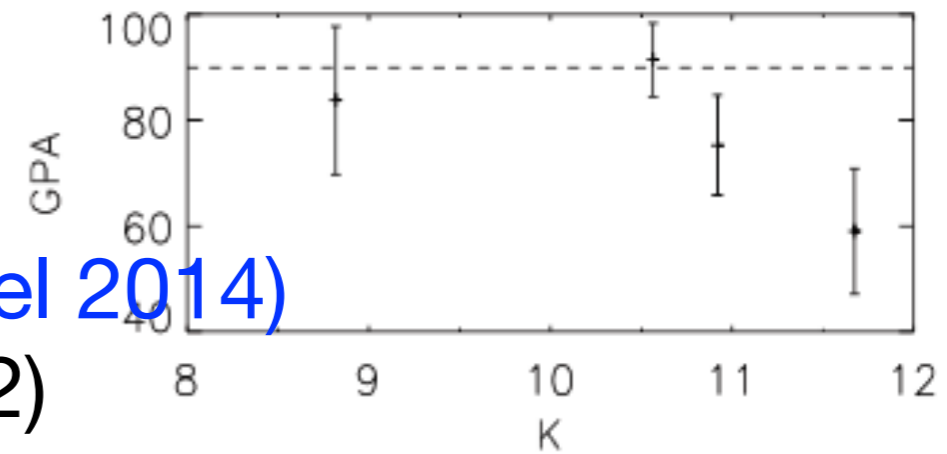
A few attempts in literature

## Polarimetry of Red Clump Stars (Pavel 2014)

- Catalog: 2MASS & GPIPS (Clemens+2012)

GPIPS: Galactic Plane Infrared Polarization Survey

“Position Angle change with Distance??”



$(l, b) = (19.49^\circ, 0.56^\circ)$

## Color Excess as proxy of distance

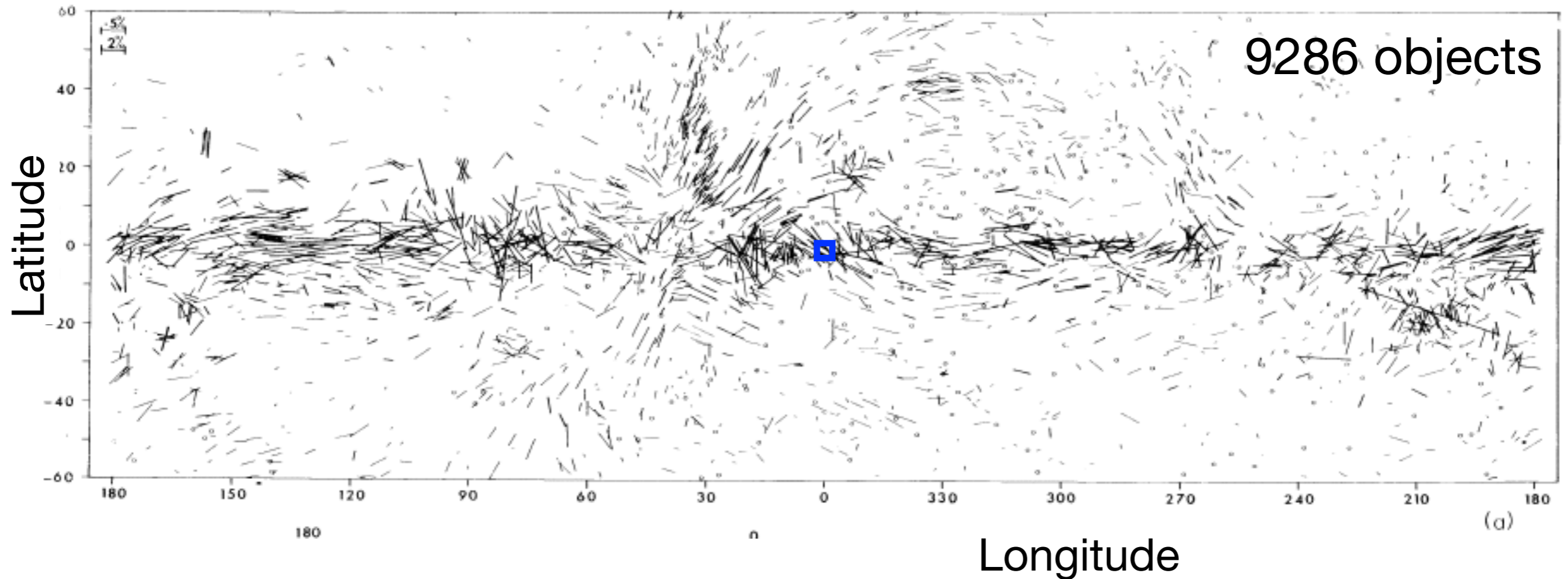
(Hatano+2013, Nishiyama+2009, Kobayashi+1983)

- H-K color toward the Galactic center
- blue H-K color = foreground, red H-K color = background

# Compare NIR and visual wavelengths

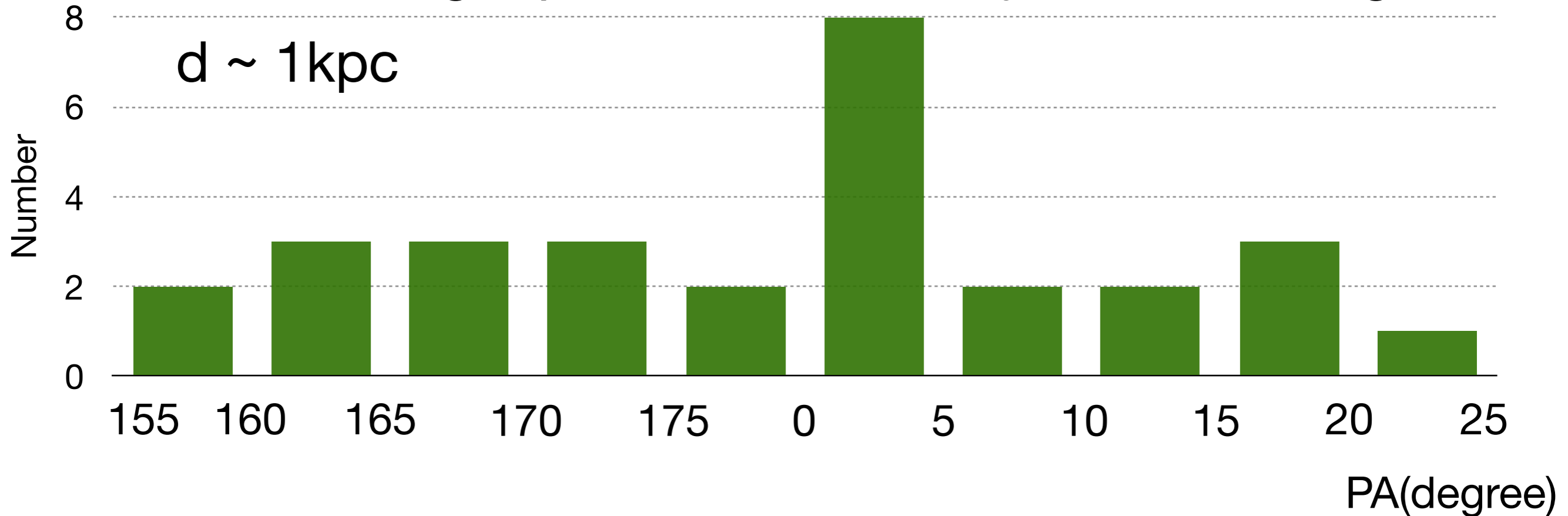
Blue square:  $3^\circ \times 3^\circ$

Mathewson & Ford (1970), Heiles (2000)



## Heiles(2000)

visual wavelength polarization: 29 objects @ 3×3deg GC

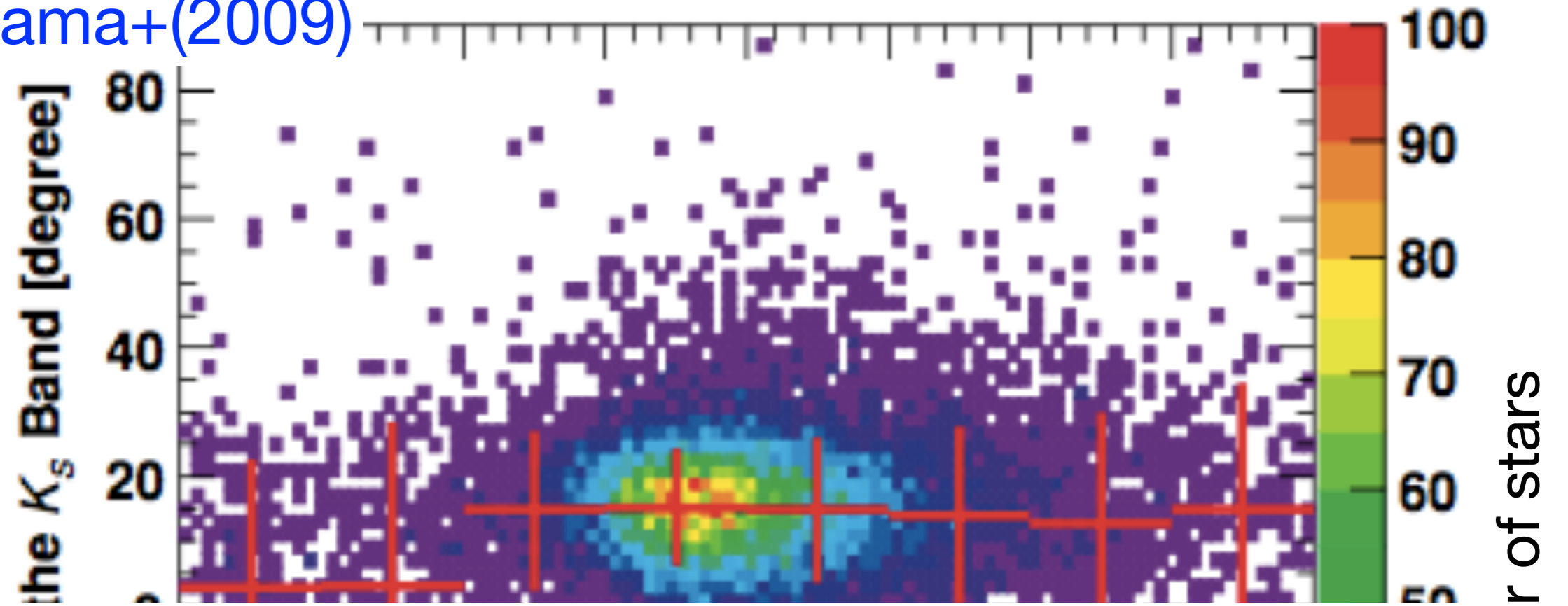


However...

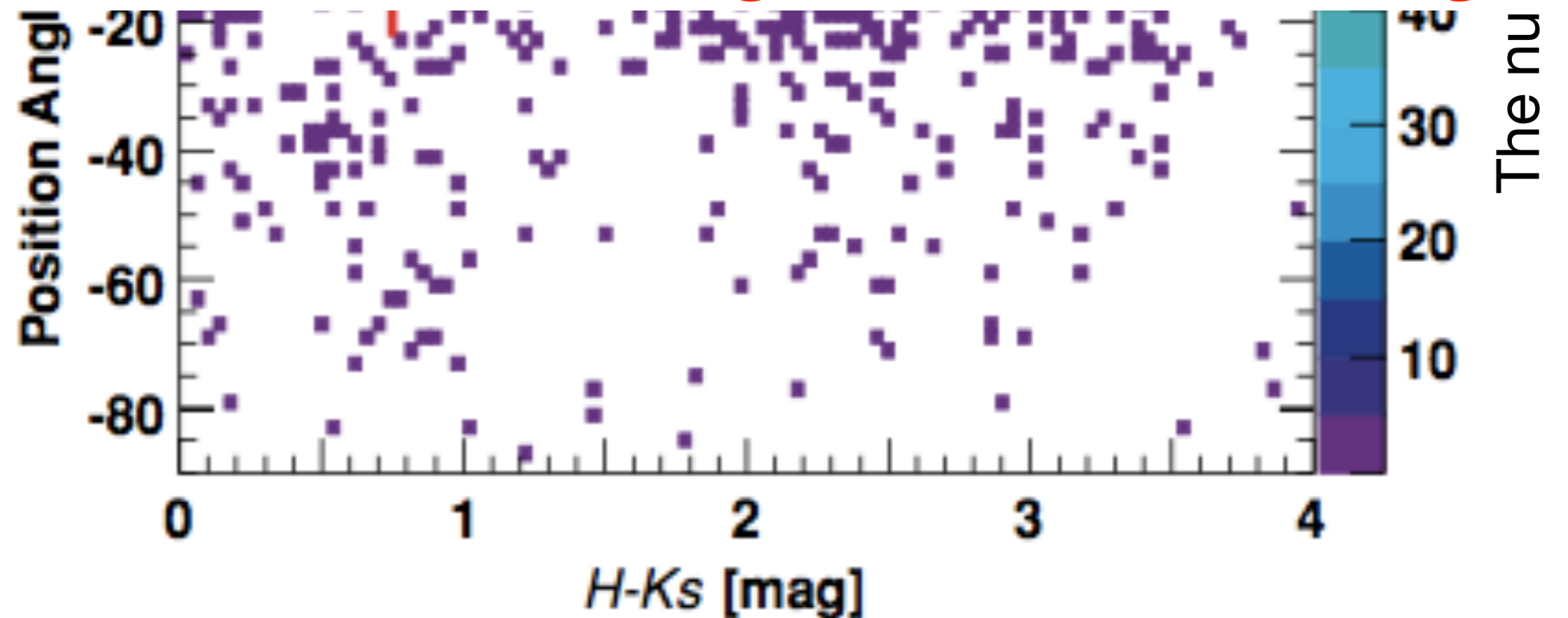
NIR polarization ~ **16degree** (average)

(Kobayashi+ 1983, Nishiyama+ 2009, Hatano+ 2013)

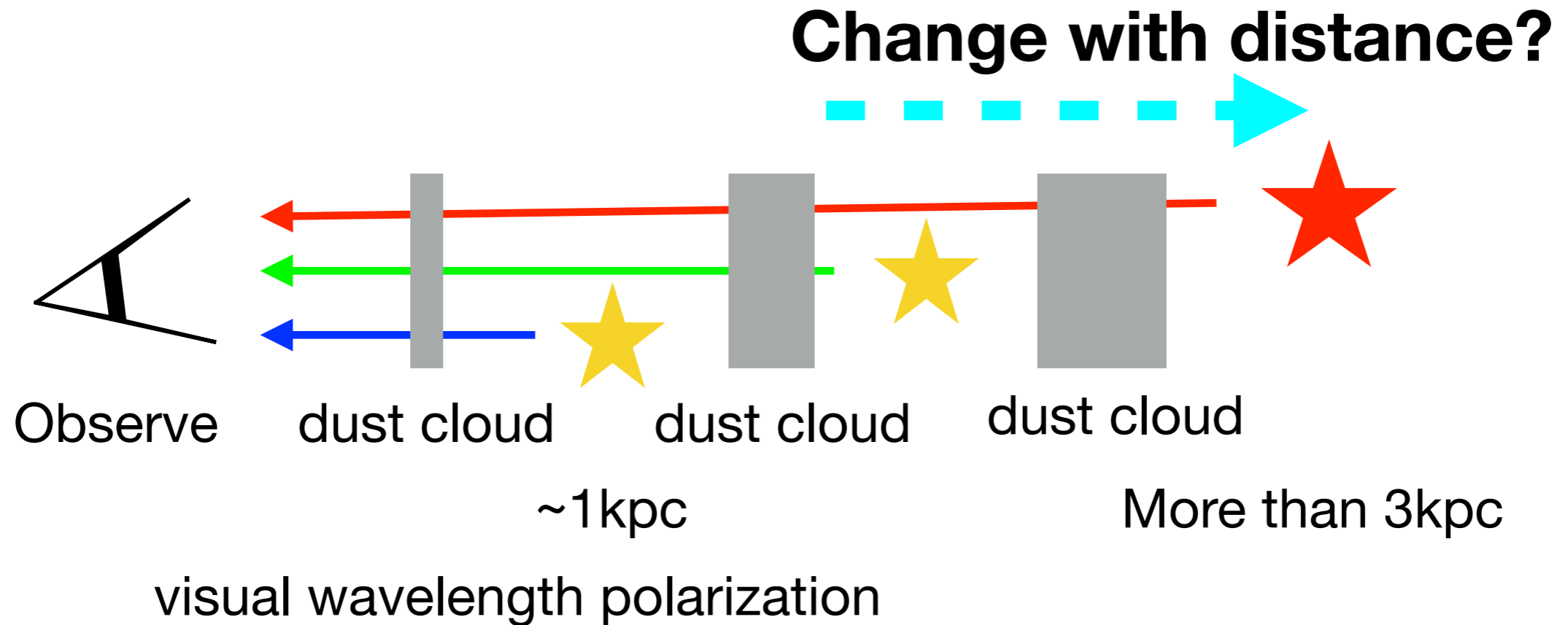
Nishiyama+(2009)



Where does the magnetic field change?







## This work

### **NIR Polarization of variable stars**

Pulsating Variable Stars : Period-Luminosity Relation

=> distance determination

# Data analysis

## IRSF:SIRPOL,SIRIUS

1024pixel×1024pixel HAWAII array

J,H,Ks simultaneous observation

## Polarimetry [Hatano+ 2013](#)

2006-2009

limiting magnitude( $\delta p < 1\%$ )

J  $\sim$  14.0mag

H  $\sim$  13.4mag

Ks  $\sim$  12.5mag

## Variability Observation

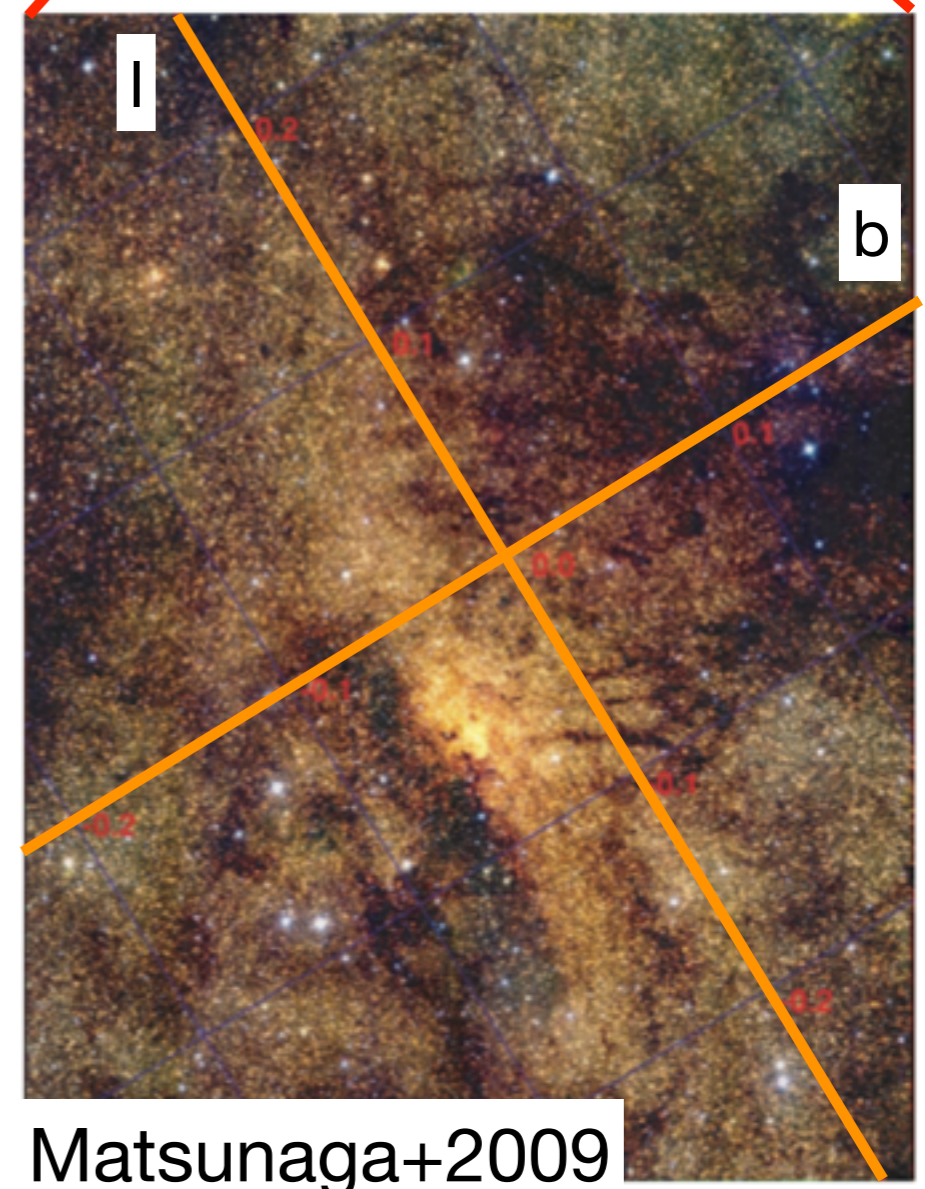
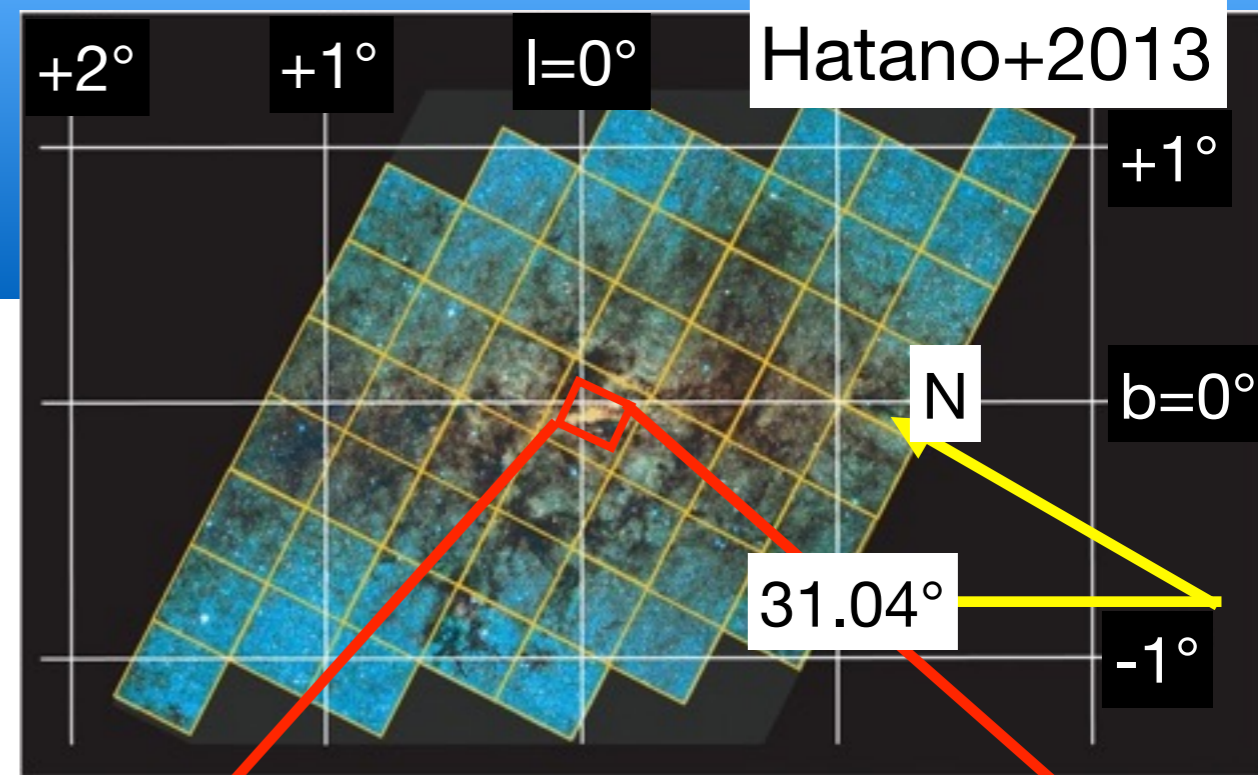
2001-2008

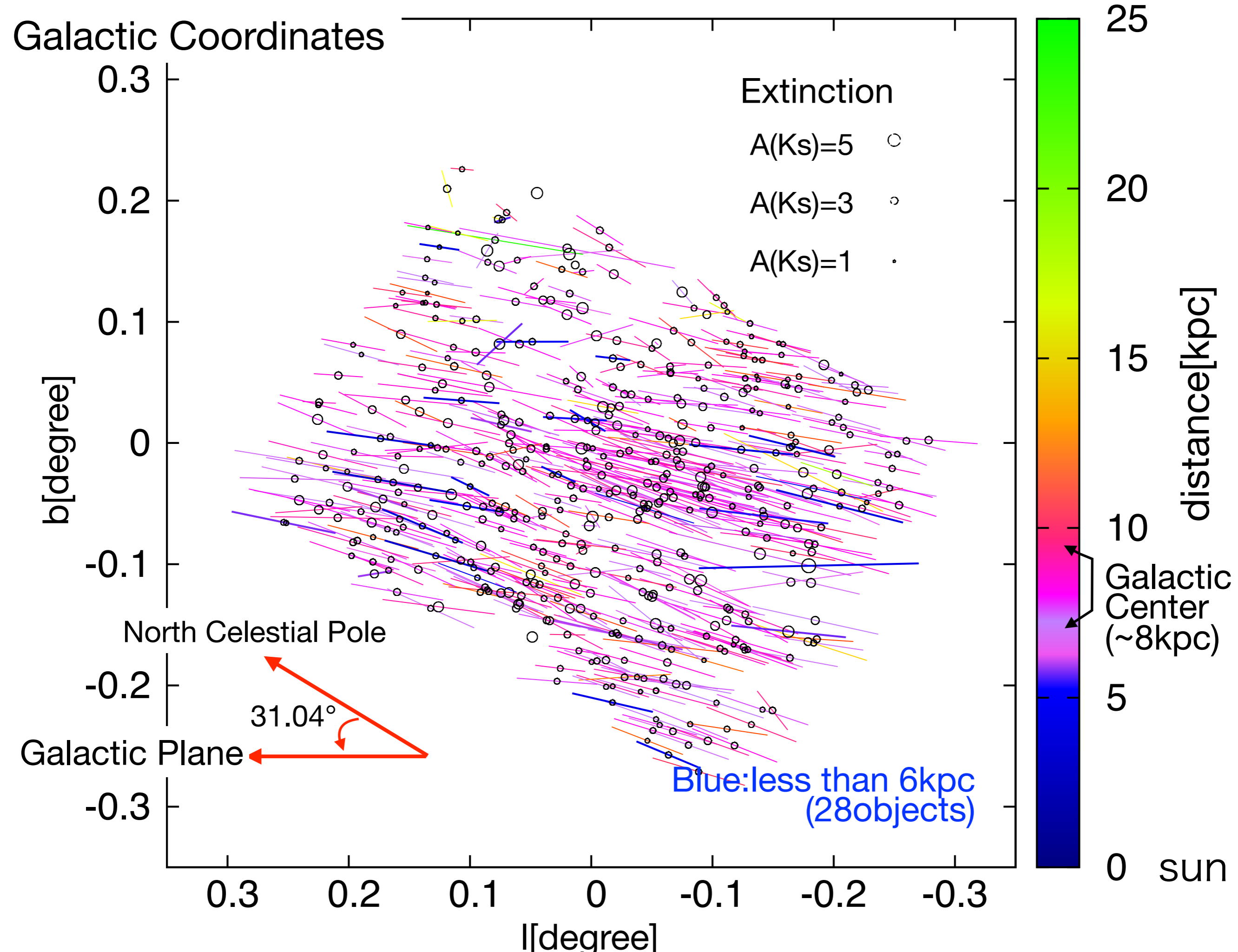
[Matsunaga+ 2009](#)

20'×30'(corresponds to 50×75pc@8kpc)

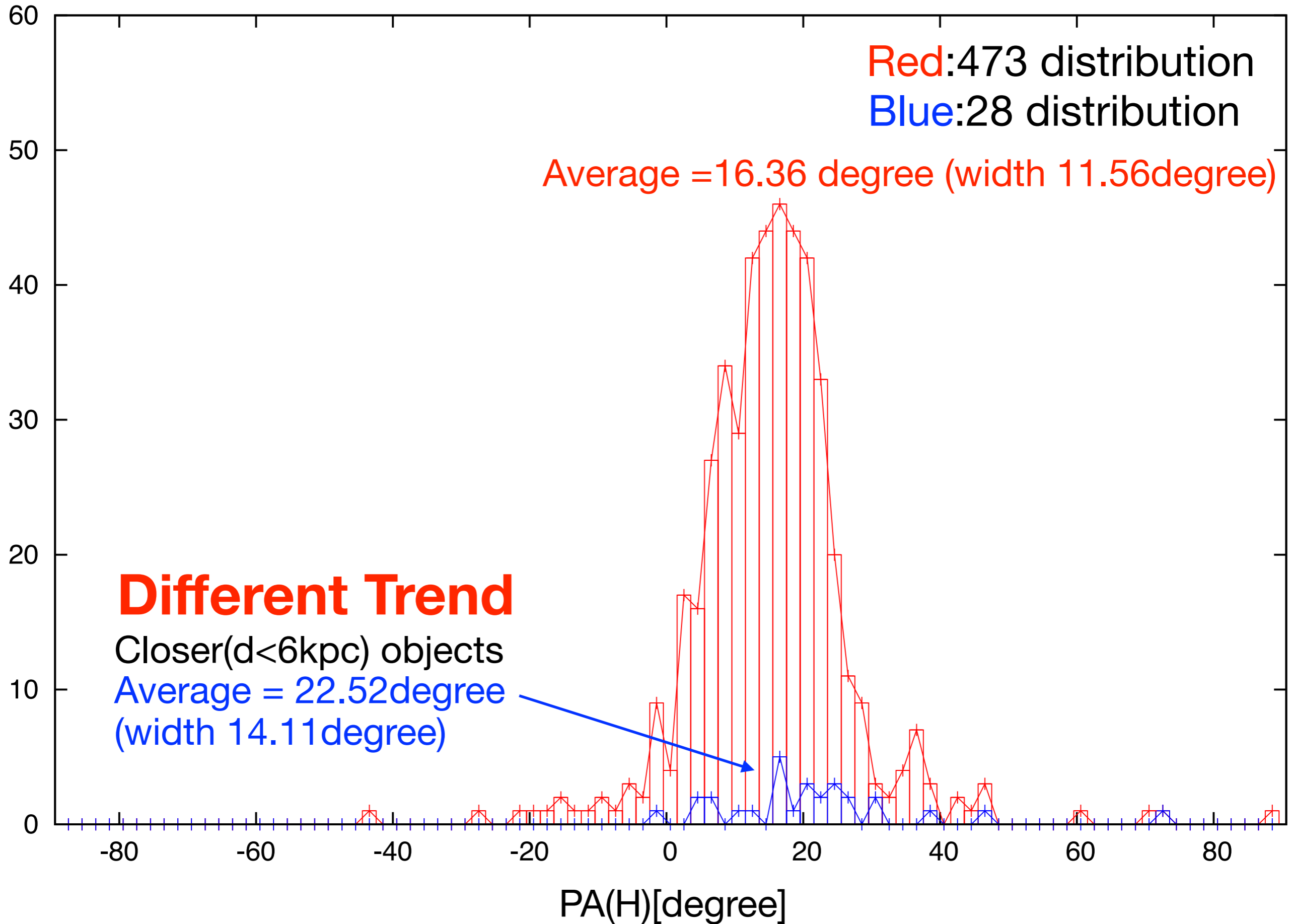
549 Miras => 545 Polarimetry observation

473 Miras (Hband)





# Position Angle all 473 Miras & 28 Miras ( $d < 6\text{kpc}$ )



# Point

- Most of Mira : PA  $\sim$  16degree
- Closer ( $d < 6\text{kpc}$ ) Objects have different trend

**We need the polarimetric observation with distance**

## How does the magnetic field change with distance?

- Area ( $20' \times 30'$ )
- Closer ( $d < 6\text{kpc}$ ) objects are a few  
=>Other area show the same trend?

But...

- No large Polarization survey(IR) in the Galactic Center
- Few variable star survey (IR)

~~=>Other area show the same trend?~~

**The dependence of Polarization with longitude**

# Observation

## Classical Cepheids

(Dékány+ 2015)

VISTA Variables in the Vía Láctea (VVV) 2010~2014

Range:  $-10.5^\circ \leq l \leq 10^\circ$ ,  $-1.7^\circ \leq b \leq 2^\circ$

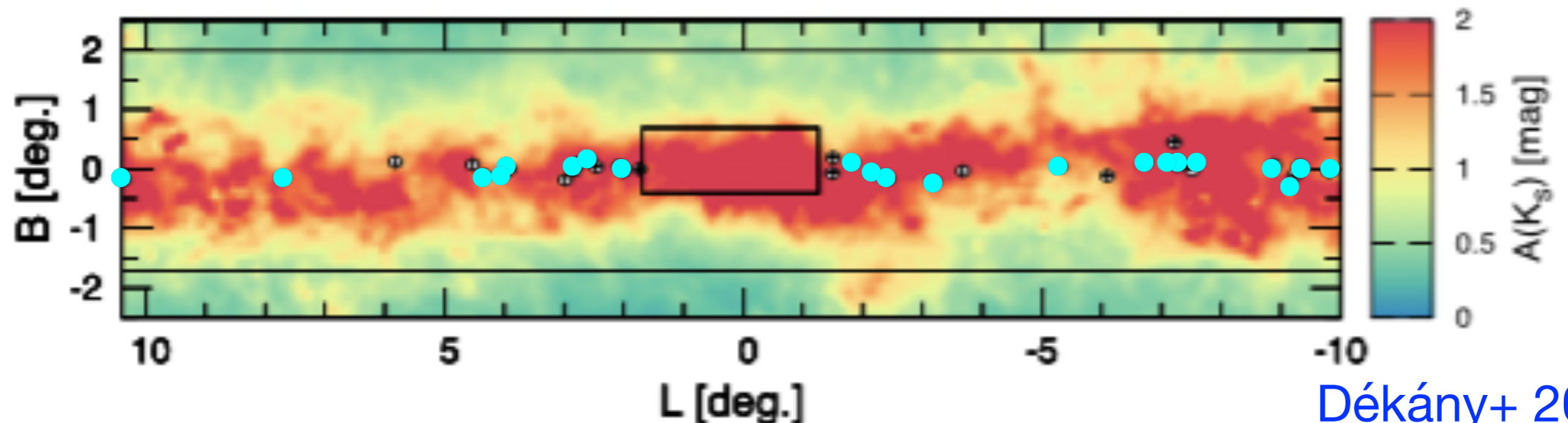
Ks-band multi epoch    Z,Y,J,H-band single epoch

## Polarimetry observation by IRSF

2016/6/25~7/5 (only 5 nights observation)

seeing : 1.2 ~ 2.9 arc second @ Ks (strong wind & bad weather)

21 Classical Cepheids (blue circle)



Dékány+ 2015

VVVCepheid28 P\_T=18.239day NCP=34.02degree

1  
D  
N

7'.7x7'.7

Plane

!!M!!

b[degree]

b[degree]

-1

0

1

2

3

4

0.2

0.15

0.1

0.05

0

-7.45

-7.5

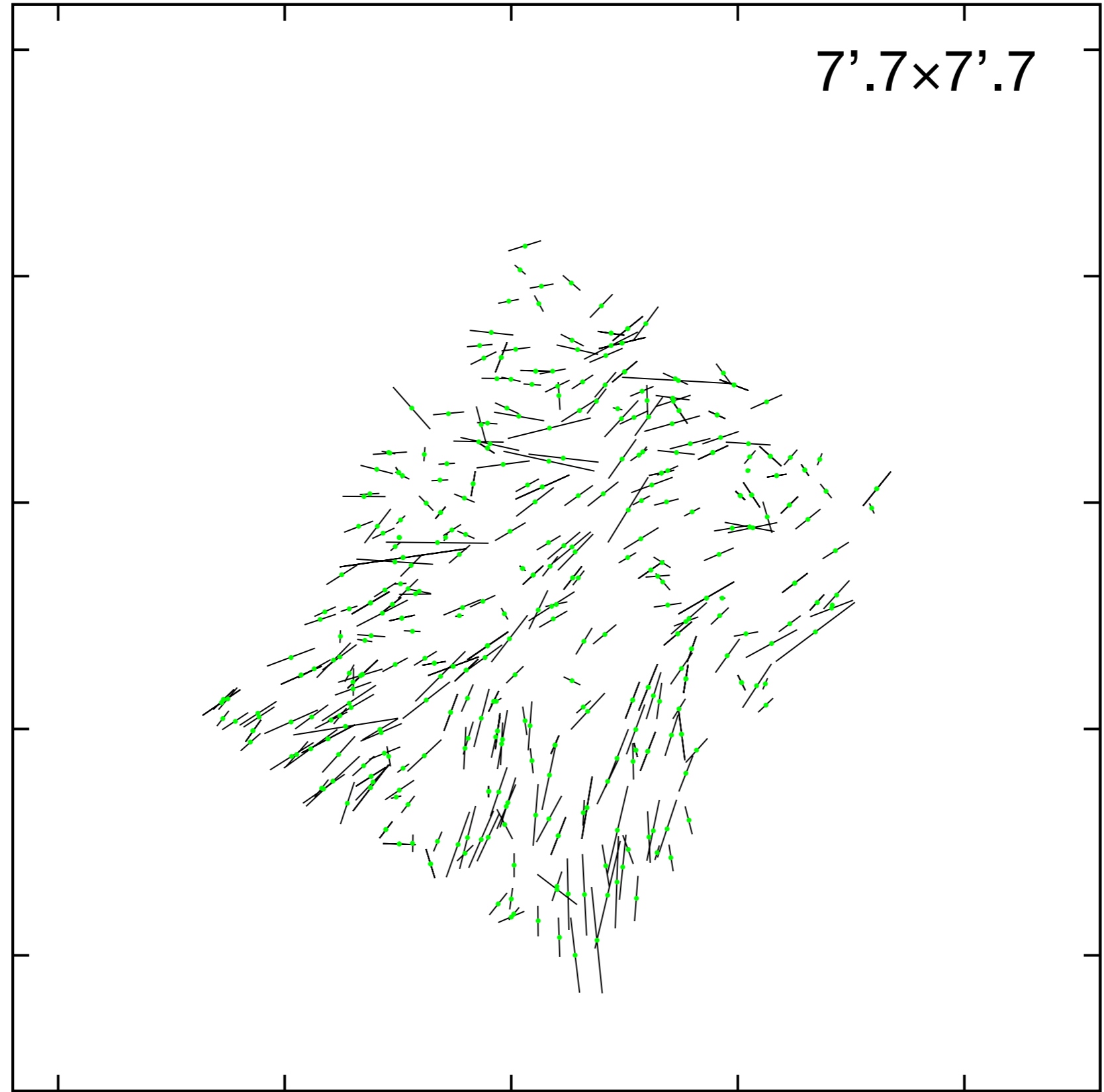
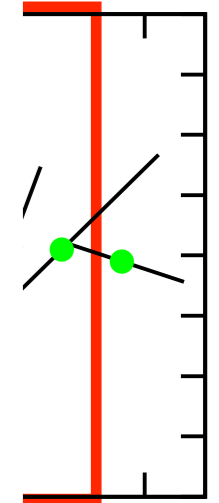
-7.55

-7.6

-7.65

l[degree]

-10



# Conclusion

## 473 Miras (Hband) 50x75pc@~8kpc

- 28 Miras ( $d < 6\text{kpc}$ )
- Most of Mira : PA  $\sim 16\text{degree}$  @  $\sim 8\text{kpc}$   
 $\Leftrightarrow$ Galactic Plane  $31.04\text{ degree}$

less than 6kpc...

- Closer ( $d < 6\text{kpc}$ ) objects have different trend

## First discussion about kpc-scale magnetic structure

## 21 Classical Cepheids (Ks band)

- 16 Cepheids show the polarization ( $P/\sigma > 2.5$ )
- $-6.7^\circ \leq l \leq -9.3^\circ$  : PA shows large inclination to the Galactic Plane
- Other objects: PA is approximately parallel to the Galactic Plane

## Different Magnetic Structure ( $-6.7^\circ \leq l \leq -9.3^\circ$ )