# Mira variable stars survey in Galactic halo
# 銀河系ハロー領域における ミラ型変光星サーベイ

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# Our project

We understand
formation and evolution
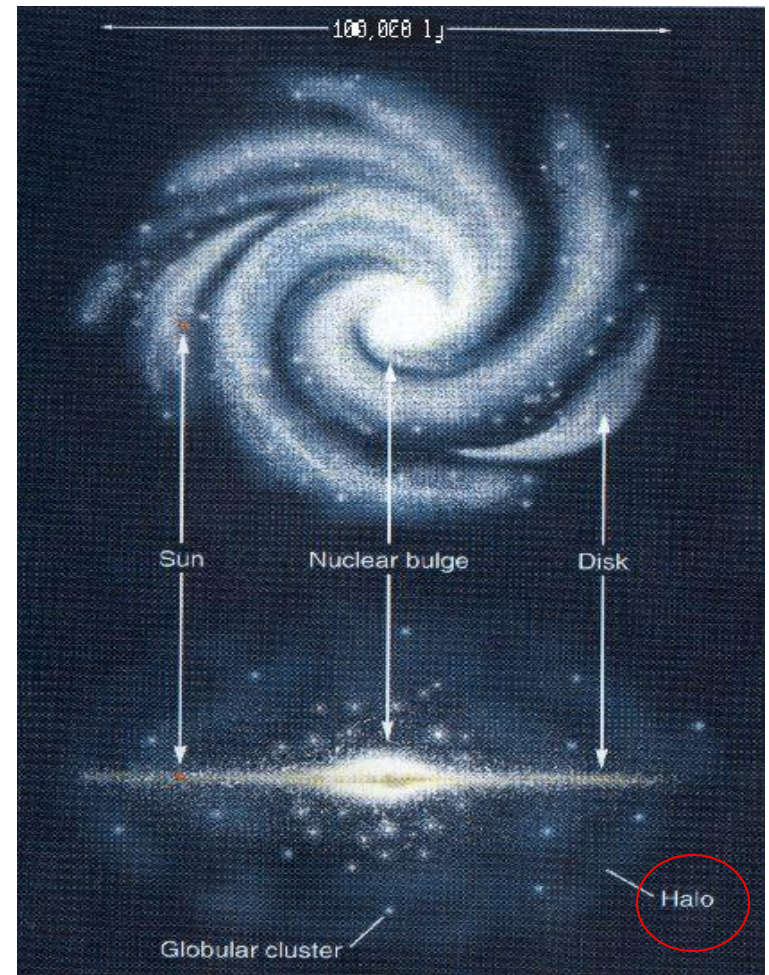of Galactic halo
by using Mira variable stars

Galactic halo
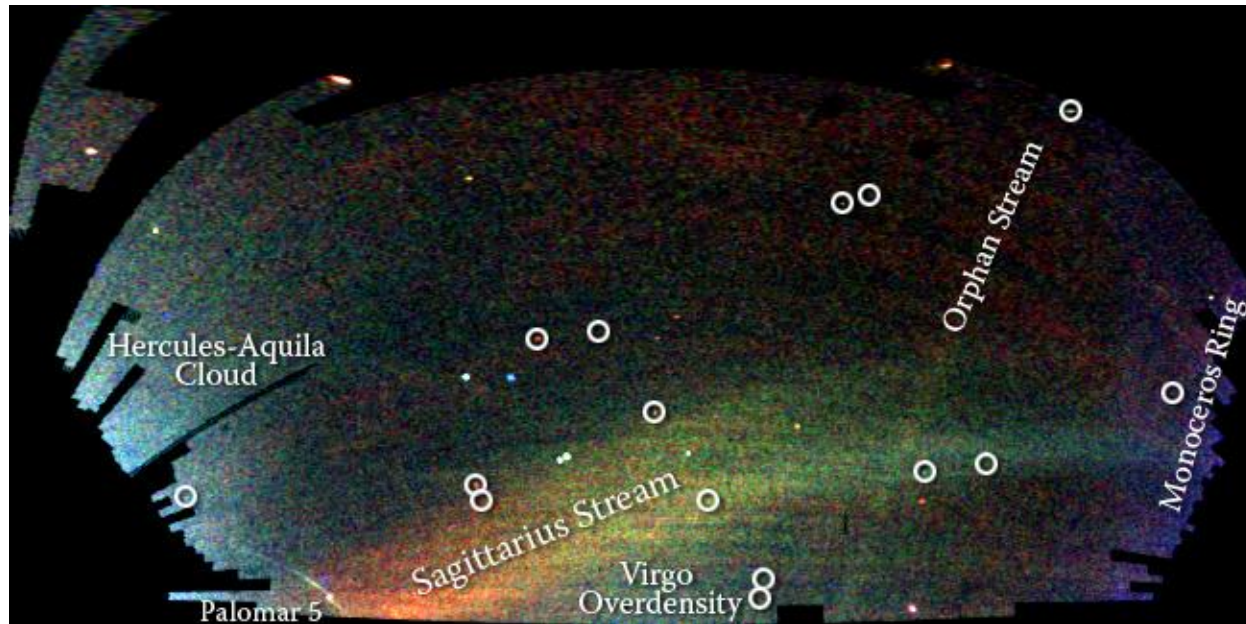  -dominated by old stars (~13 Gyr)
Mira variable stars
  -intermediate-age(0.5-10 Gyr)
  -discovered in Galactic disk/bulge

# SDSS discovered large stellar streams in Galactic halo

- Sloan Digital Sky Survey found large stellar streams up to 100kpc by old stars. Belokurov et al. (2008)



- Galactic halo was partly formed via recent accretion of dwarf galaxies.

# Previous works on stellar streams in Galactic halo

- Previous works focused on old stars (e.g., HB stars)
- Intemediate-age stars(e.g.,C-rich AGB stars, RC,RGB) were also detected.

However, the sample of intemediate-age stars have

- large uncertanty in distance (C-rich stars,RGB stars)
- relatively large contamination
- strongly biased to the age and chemical abundance  of Sgr dSph RC/RGB stars

⇒ ・Their spatial distribution still remains unclear.

・Star formation history and chemical evolution of the progenitor of the stream still remains unclear.

# Mira variable stars

- Very luminous

- Age of 0.5-10 Gyr

- Period-luminosity relation provides accurate distances.

- Period distribution are good probes of the age and metallicities (the younger and more metal-rich, the longer the period is).

- No wide-area survey in Galactic halo

We explore Mira variable stars over wide area of Galactic halo, and understand its formation and evolution.

# Phase-I (2KCCD,2009-2011): monitor the very red stars

- We monitor only the very red stars in Galactic halo, and explore the spatial distribution of intermediate-age stars by detecting Mira variable stars

- 2009-2011  105cm telescope+2KCCD

- Observation in I-band once a month

- Observations in narrow-band filters (777,813nm) for Mira variable stars with no spectra->C-rich/O-rich classification

- Our targets

RA=0-3h,8h-16.5h,21h-24h,b>30°

2MASS J-H>0.7,H-K>0.3,K<13.5

SDSS g'-r'>0.8,r'-i'>0,i'<18.5

The sample is spatially unbiased over the sky the SDSS covers
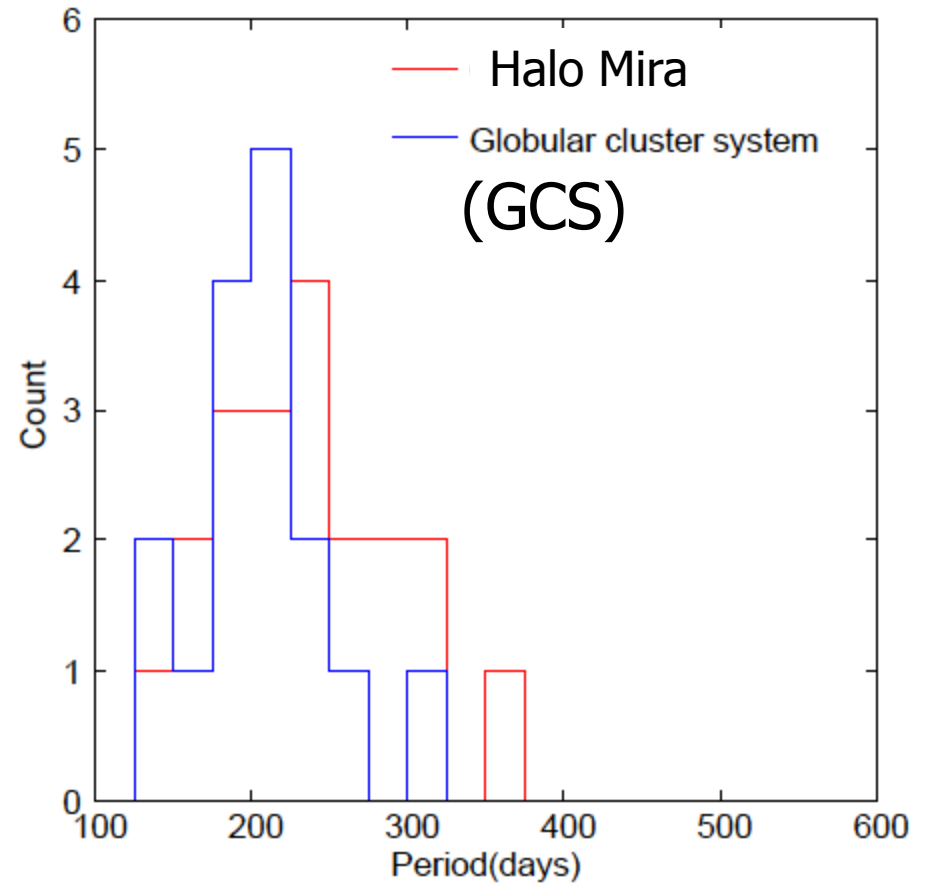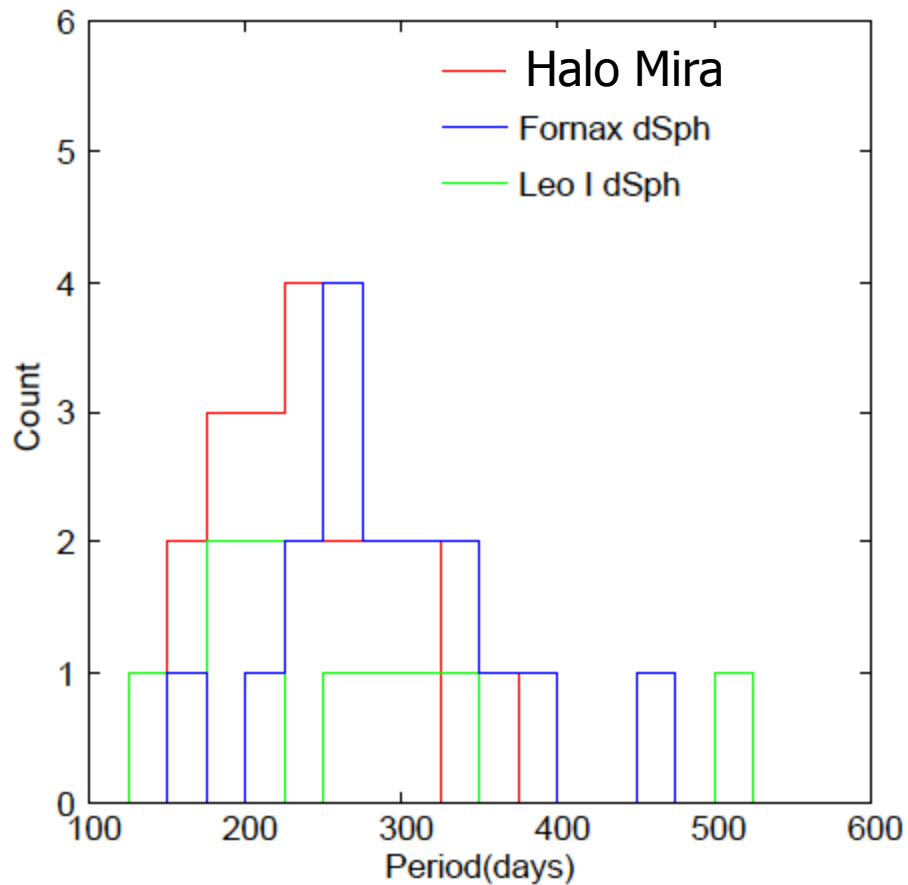
# Period distribution

- 16 Miras (P>100 days,ΔI>1mag) are discovered
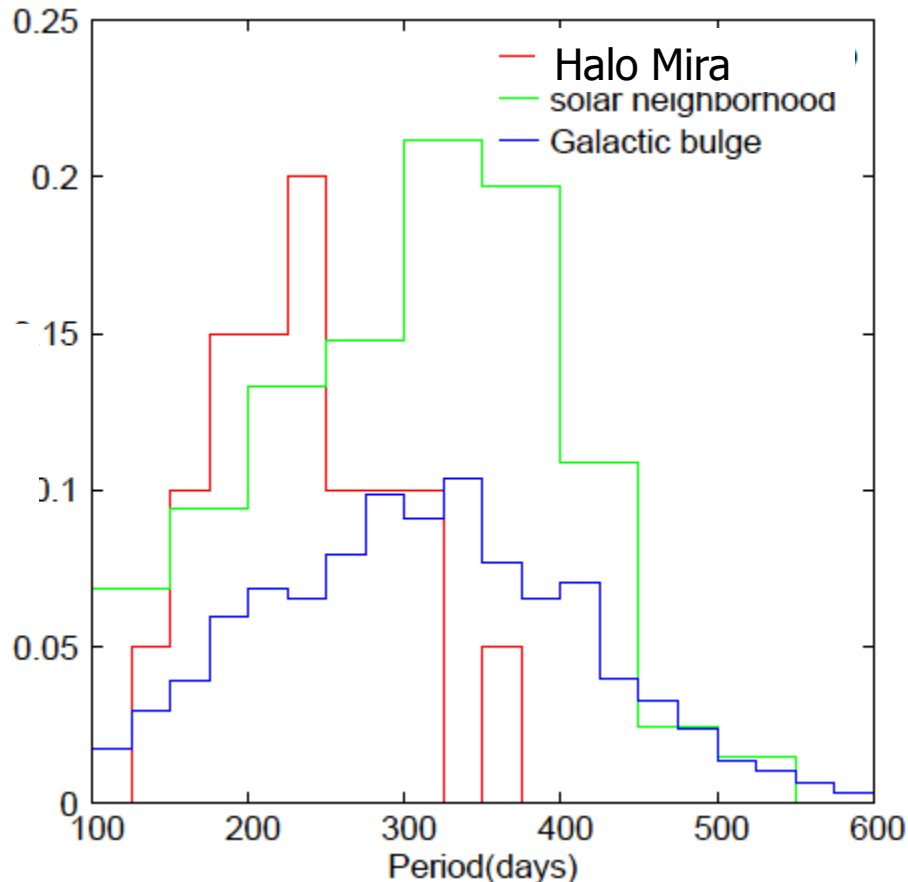


Halo Miras have shorter periods than solar-neighborhood and bulge Miras does.

The intermediate-age stars in the halo is older and/or metal-poor than those in the disk and bulge.

# Period distribution



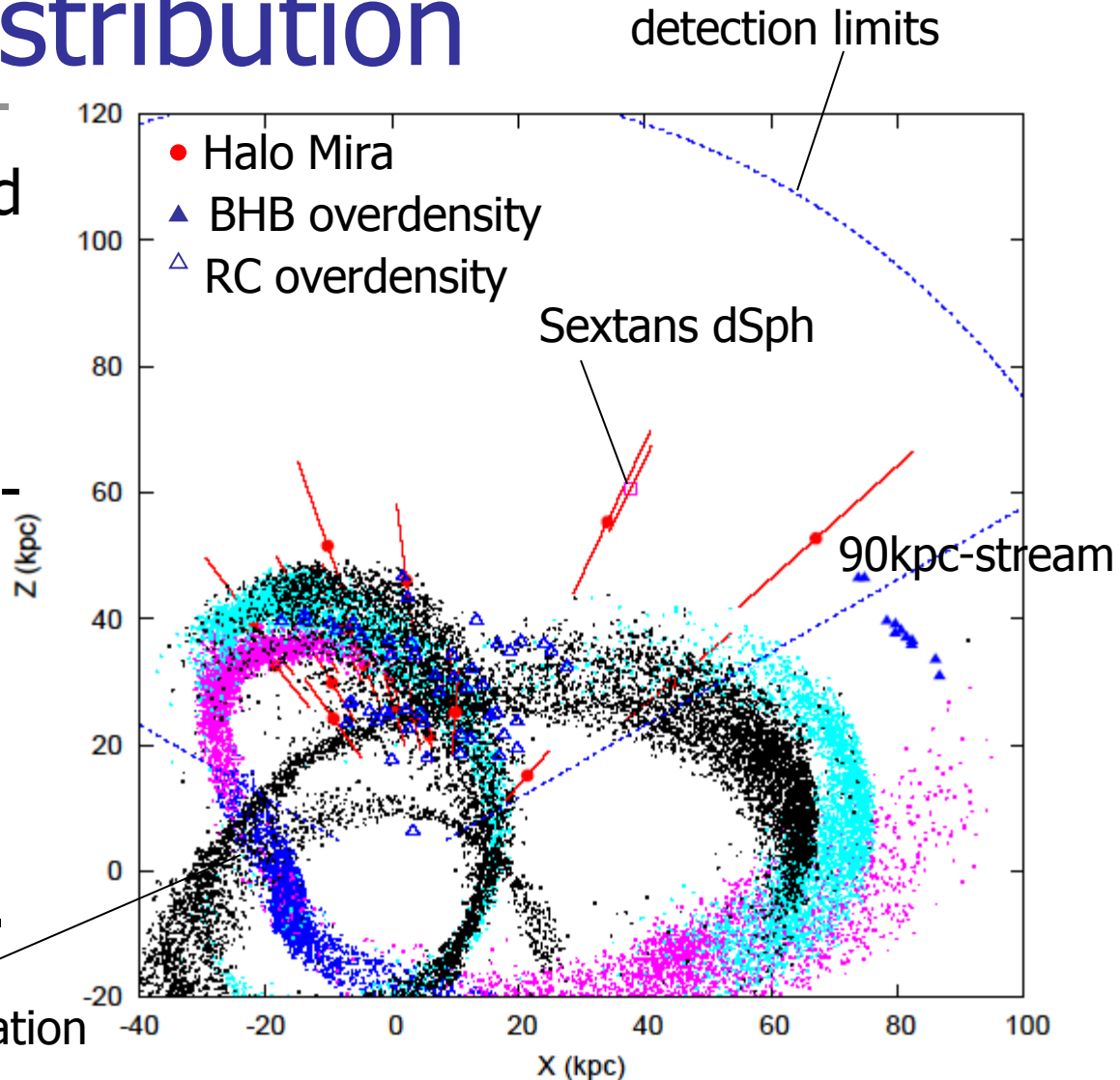Halo Miras are similar to Galactic-dSph and GCS Miras.

# Spatial distribution

- Many Miras are located near 30-40kpc.
- Distant Mira (d~ 90 kpc) is discovered.

  The progenitor of 90kpc-stream have long star formation history.

- A Mira is probably associated with Sextans dSph (Mv=-9.5(faint), [Fe/H]~-2).

detection limits

- Halo Mira
- BHB overdensity
- RC overdensity

Sextans dSph

90kpc-stream

Sgr-stream simulation (Law et al. 2008)

Z (kpc)

X (kpc)

# Spatial distribution near Sgr-stream region

- Miras are located at the overdensity of the RC stars at X<10kpc.

- Miras are located on only Sgr streams, although our sample is unbiased to the region of Sgr stream.

- Intermediate-age stars in the halo were formed only by recently accretion of massive dwarf galaxy.

Sgr-stream simulation (Law et al. 2008)



- Halo Mira
- RC overdensity
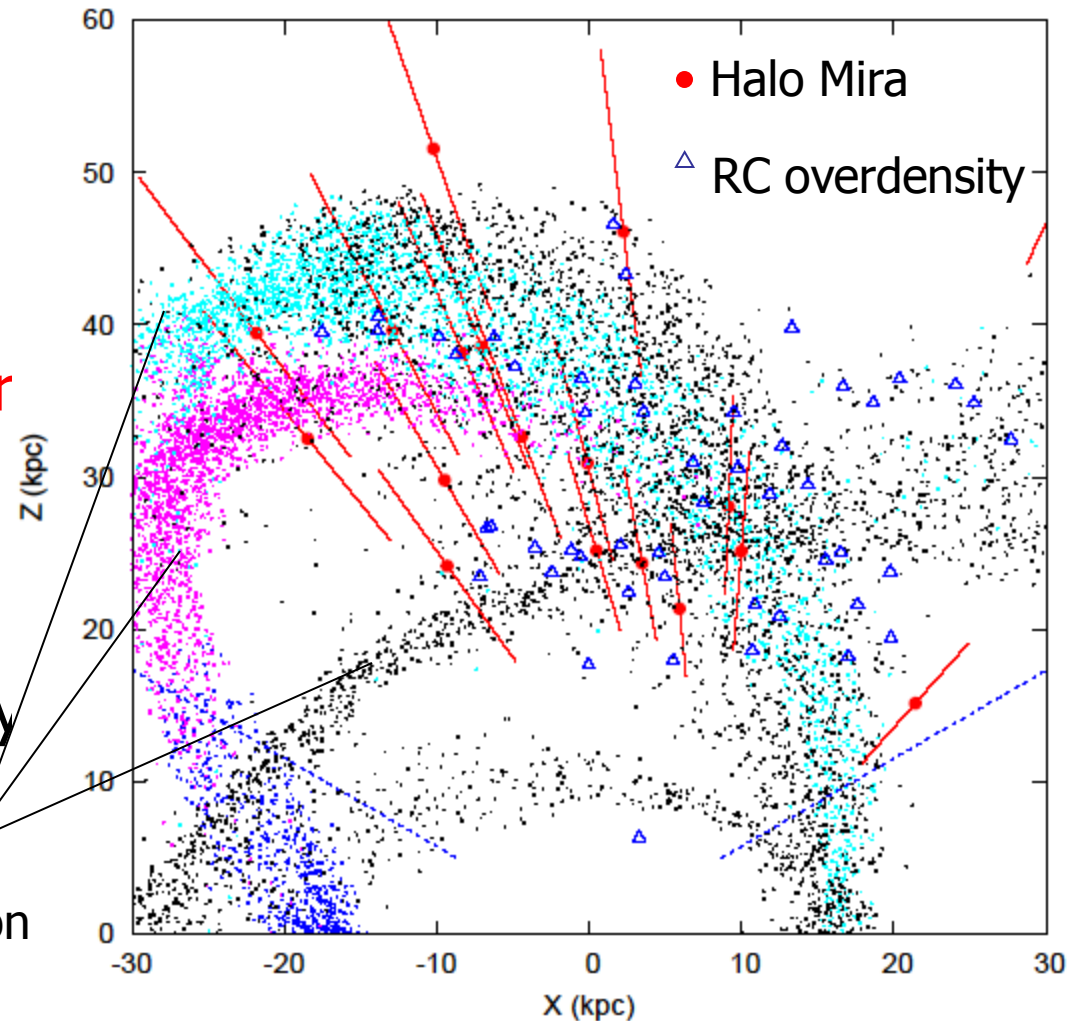
# Summary and future work

- 2KCCDで銀河系ハローを広域にわたってミラ型変光星を探査した
- 16個のミラを発見した
- 周期は銀河系バルジや太陽近傍ミラよりも
  短く、近傍矮小銀河や球状星団系ミラに似る
- 比較的近傍(<40kpc)ミラは全てSgr streamに付随している。90kpc付近と非常に遠方でもミラを発見
- KWFCでもさらにサーベイを進めたい

# Phase-II (KWFC): halo-Mira stars "survey"

- 青いミラはカバーされていない
  これらはより進化の進んでいない星
  比較的古い。
    矮小銀河のデブリ（既にストーリム
  としては残っていない）をトレース
  →早期に(5-10 Gyr)降着した矮小銀河
  の降着率や星形成史に制限
  観測
- 2色図だけではRGBとの区別困難
  ->銀河系ハロー広域サーベイ(月に1度のモニタリングx3年)
- I<18.5 ->うす雲時の観測もok.