Observations of the Galactic center with Subaru/GLAO

Shogo Nishiyama (NAOJ)
Introduction

Milky Way

dwarf galaxy

stellar tidal stream

Milky Way Bulge

dwarf galaxy

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Central 500 pc of our Galaxy

Introduction

SMBH

Nuclear star cluster (NSC)

Massive cluster

Stream

Cluster remnant
Introduction

What I want to understand
1. How the NSC and SMBH are related
2. How the NSC evolved

Why GLAO+Subaru?
Strong Extinction and Confusion

What I want to do
Search for young/intermediate age stars

How to find them
(1) Astrometry
(2) Narrow-band Photometry
Nuclear Star Clusters

SMBH or NSC ↔ Bulge

SMBH ↔ Bulge

NSC ↔ (whole) Galaxy

(Ferrarese+ 06, but see also Graham+ 12)

(Erwin & Gadotti 12)
The Galactic NSC

How NSC and SMBH related?

- Top Heavy
  - IMF Slope in NSC
    - Normal
    - Heavy (e.g., Lu+13, Bartko+10, Paumard+06)

- Strong Tidal Shear from SMBH (e.g., Lu+13, Bartko+10, Paumard+06)

- Smaller SMBH mass?
  - NSC & SMBH did not co-exist?

- Look back time
  - 5Myr (e.g., Lu+13, Bartko+10, Paumard+06)
  - 1Gyr
  - 5
  - 10

(Pfuhl+13)
How NSC and SMBH related?

The Galactic NSC

How NSC and SMBH related?

Strong Tidal Shear from SMBH?

Top Heavy IMF in NSC

Normal IMF in NSC

IMF Slope in NSC

5 Myr

1 Gyr

Look back time

Strong Tidal Shear from SMBH?

HRD for (part of) NSC

50 Myr

1 Gyr

w/o AO

Narrow but large FoV

w/ AO

Deep but small FoV

GLAO target

Teff [K]

M bol

5000

2500

Pfuhl+13

Lu+13,

Bartko+10,

Paumard+06

50 Myr

1 Gyr

GLAO target

w/o AO

Shallow but large FoV

w/ AO

Deep but small FoV

(Pfuhl+13)
The Galactic NSC

How NSC evolved?

Star formation rate
\sim 0.075 \text{ Msun/yr}

@ central 400 pc

(Yusef-Zadeh+ 09, Matsunaga+ 11)

\rightarrow dozens clusters

(several % of $M_{\text{NSC}}$)

but

2 clusters known

\rightarrow as yet unknown

cluster remnants

& tidal streams
**The Galactic NSC**

What I want to do:

Search for young/intermediate age population (a few Myr - \(~1\) Gyr)

![HRD diagram](image)

- **HRD for (part of) NSC**
  - **Teff [K]**
  - **Mbol**
  - 50 Myr
  - 1 Gyr
  - w/o AO: shallow but large FoV
  - w/ AO: deep but small FoV

**GLAO target**

Fujii+ 08

- $T = 0.473$ Myr
Observations of the GC

Why GLAO? Interstellar Extinction

Nishiyama+ 06, 08, 09
Fritz+ 11

Optical (0.5 µm)
→ ~30 mag
→ 10^-12

NIR (1 µm)
→ ~10 mag
→ 10^-4

NIR (2.2 µm)
→ ~2.5 mag
(Schodel+ 10)
→ 1/10
Observations of the GC

Why GLAO? Confusion

K-band w/ IRCS/AO188

0.5 pc ~

500 pc ~ 3.5°
Observations

What I want to do

Search for young/intermediate age population
(a few Myr - ~1 Gyr)

HRD for (part of) NSC

50Myr
1Gyr

w/o AO

shallow but
large FoV

w/ AO

deep but
small FoV

GLAO target

Fujii+ 08

Teff[K]

5000
2500

Mbol

-6
+2

50Myr
1Gyr

Fujii+ 08

T= 0.473 Myr
Observations: Narrow-band

How to find them? (1) Narrow-band phot.

- B0 dwarf
- K4.5 giant

Narrow-band observations:
- 20 candidates

(Nishiyama & Schödel 13)
Observations: Narrow-band

How to find them? (1) Narrow-band phot.

80% (16/20): < 1 Gyr • 20 candidates

\[
\text{M}_\text{bol} \quad 3000 \quad 5000 \quad -3 \quad -6
\]

\[
\text{T}_{\text{eff}} [K] \quad 3000 \quad 5000
\]

50 Myr 1 Gyr

(Oishiyma & Schödel 13)
Observations: Narrow-band

How to find them? (1) Narrow-band phot.

80% (16/20): < 1 Gyr

- Diagram showing HRD and CMD for (part of) NSC
  - 50 Myr and 1 Gyr markers
  - Labels for CMD with and without AO
  - GLAO target

- Observations: Narrow-band 15/21
Observations: Astrometry

How to find them? (2) Astrometry

Relaxation timescale $> 1 - 10\text{Gyr}$ (Alexander 05)

$<1\text{Gyr}$ stars $\leftrightarrow$ not dyn. relaxed

Stellar Proper motion

$4\text{mas/yr}$

Cluster member (2 Myr)

$\sim 5\text{mas/yr}$

Field stars

$\sim 10'$
Observations: Astrometry

How to find them?

Relaxation timescales $> 1 - 10 \text{ Gyr}$

Alexander 05

$< 1 \text{ Gyr}$ stars

$\beta \leftarrow \beta \leftarrow$ not dyn. relaxed

$\sim 10'$

SMBH

$+100 \quad +200 \quad -200 \quad -100 \quad 0$

Line of sight distance [pc]

Galactic plane position [pc]

Cluster orbits viewed from above Galactic plane

Present location

Future Orbit

Past Orbit

Birth location

Present location

Fujii+ 08

$T = 0.473 \text{ Myr}$

400 pc $\sim 3\text{ deg}$
**Observations: Astrometry**

How to find them? (2) Astrometry

Relaxation timescale $> 1 - 10$ Gyr (Alexander 05)

$<1$ Gyr stars $\leftrightarrow$ not dyn. relaxed

\[
\begin{align*}
HST/NICMOS/NB \\
(Dong+ 11) \\
\text{FWHM:} & \sim 200 \text{mas}@1.9 \mu\text{m} \\
\text{SN}=20: & \sim 16 \text{ mag} \\
\delta p & \sim 40 \text{ mas} \\
\text{100 observations} \\
\text{(accuracy} & \propto \sqrt{N}) \\
\rightarrow & \sim 4 \text{ mas} \\
> 5\sigma \text{ for 4 yrs}
\end{align*}
\]

Stellar Proper motion

\[
4 \text{ mas/yr}
\]

\[
\sim 5 \text{ mas/yr}
\]
**Observations: Astrometry**

How to find them? (2) Astrometry

Relaxation timescale \( > 1 - 10 \text{Gyr} \) (Alexander 05)

\(<1\text{Gyr stars} \iff \text{not dyn. relaxed}\)

HST/NICMOS/NB (Dong+ 11)

FWHM:
\( \sim 200 \text{mas}@1.9\mu\text{m} \)

SN=20: \( \sim 16 \text{ mag} \)

\( \delta \rho \sim 40 \text{ mas} \)

100 observations
(accuracy \( \propto \sqrt{N} \))

\( \rightarrow \sim 4 \text{ mas} \)

\( > 5\sigma \text{ for 4 yrs} \)

100 x 100 pc (40’)

1-min \( \times 100\text{obs} \)

\( \times 3\times3 \text{ FoV} = 15\text{h} \)

\( \rightarrow 8 \text{ (-half) nights/yr} \)

(50% efficiency)
Summary 1/2

Q1. Wide-field imager + Narrow-band filters + fast readout mode may be helpful for astrometry
Q2. Optimized (finer than 0.1”/pix) plate scale preferred, but our object is GC... → TAO!
Q3, Q6. TMT targets:
1. groups of Young/intermediate (Y/I) age population ← hidden cluster remnants
2. other Y/I-age populations ← tidal stream? isolated star formation?
Q4. JWST: small FoV
   Euclid: no K-band, large pixel scale
   WISH: FWHM may be better? must be stable
      but long (> 6yr) operation will be required
Q5. ~8(-half) nights/yr for astrometry
    ~2 - 3 nights for narrow-band photometry
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