

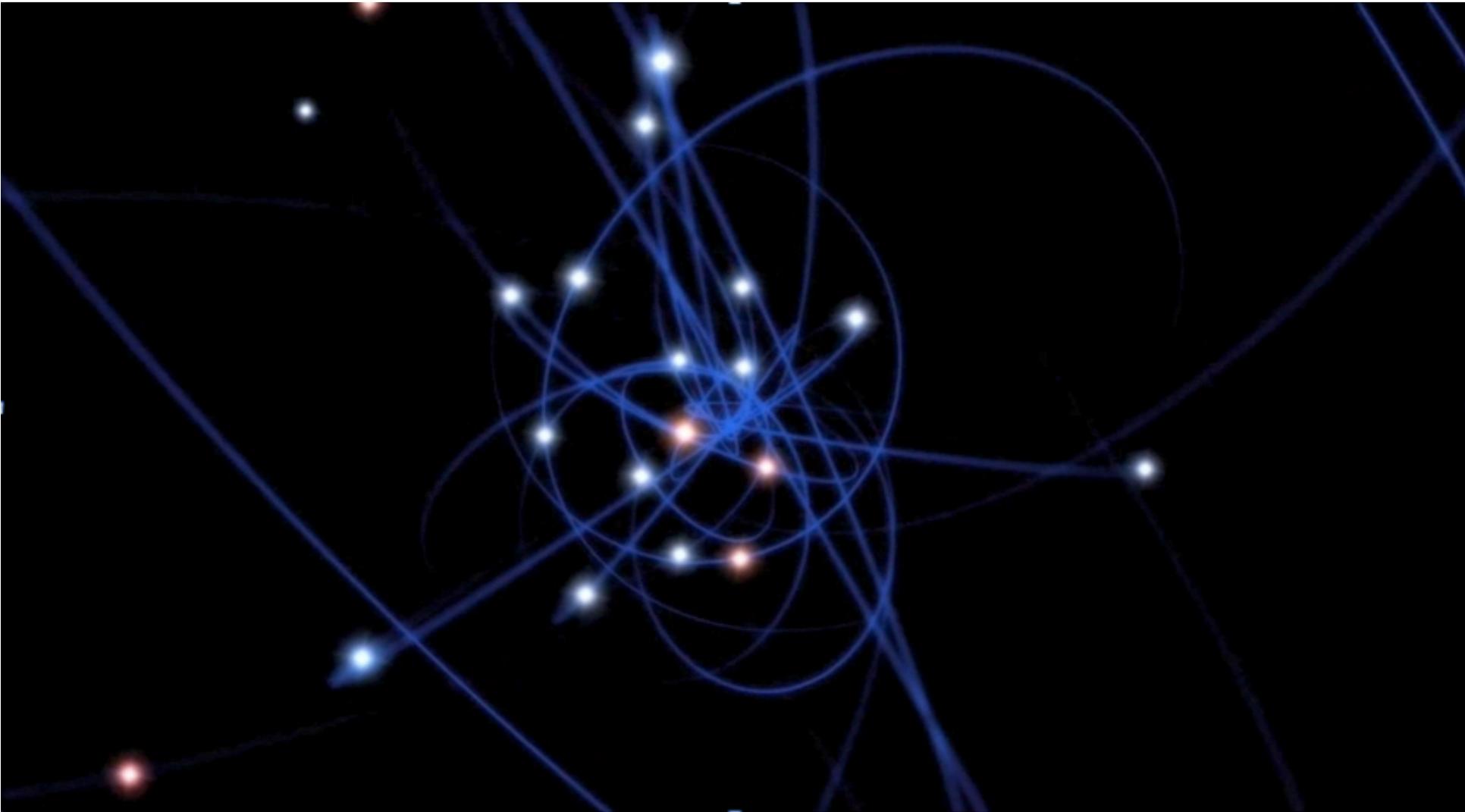
*Astrometry  
at the Galactic center  
with Subaru/GLAO*

西山正吾 (国立天文台)



# Astrometry at Galactic Center

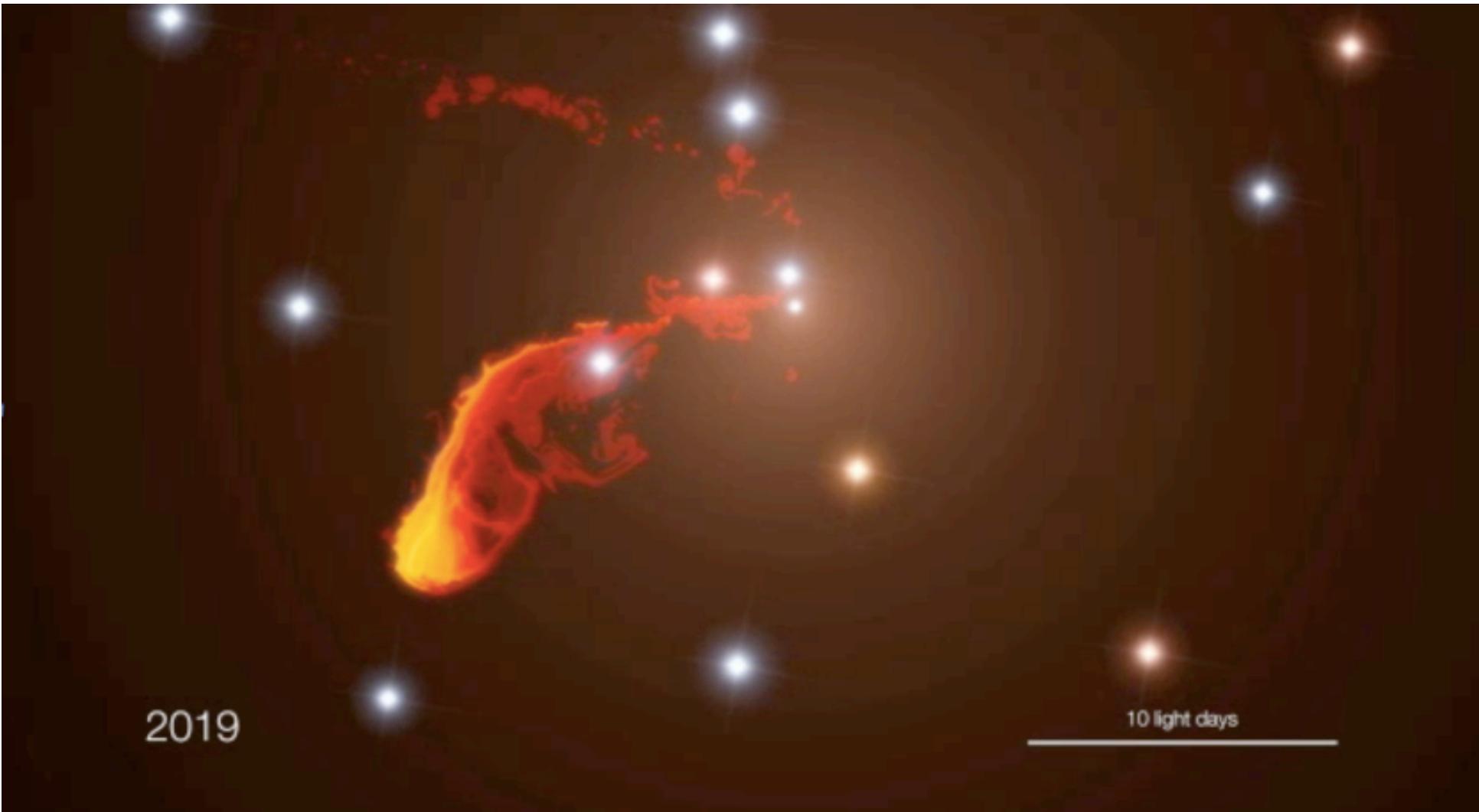
2/23



# Astrometry at Galactic Center

3/23

Sgr A\* へ落ち込む gas cloud (Gillessen+ 12)



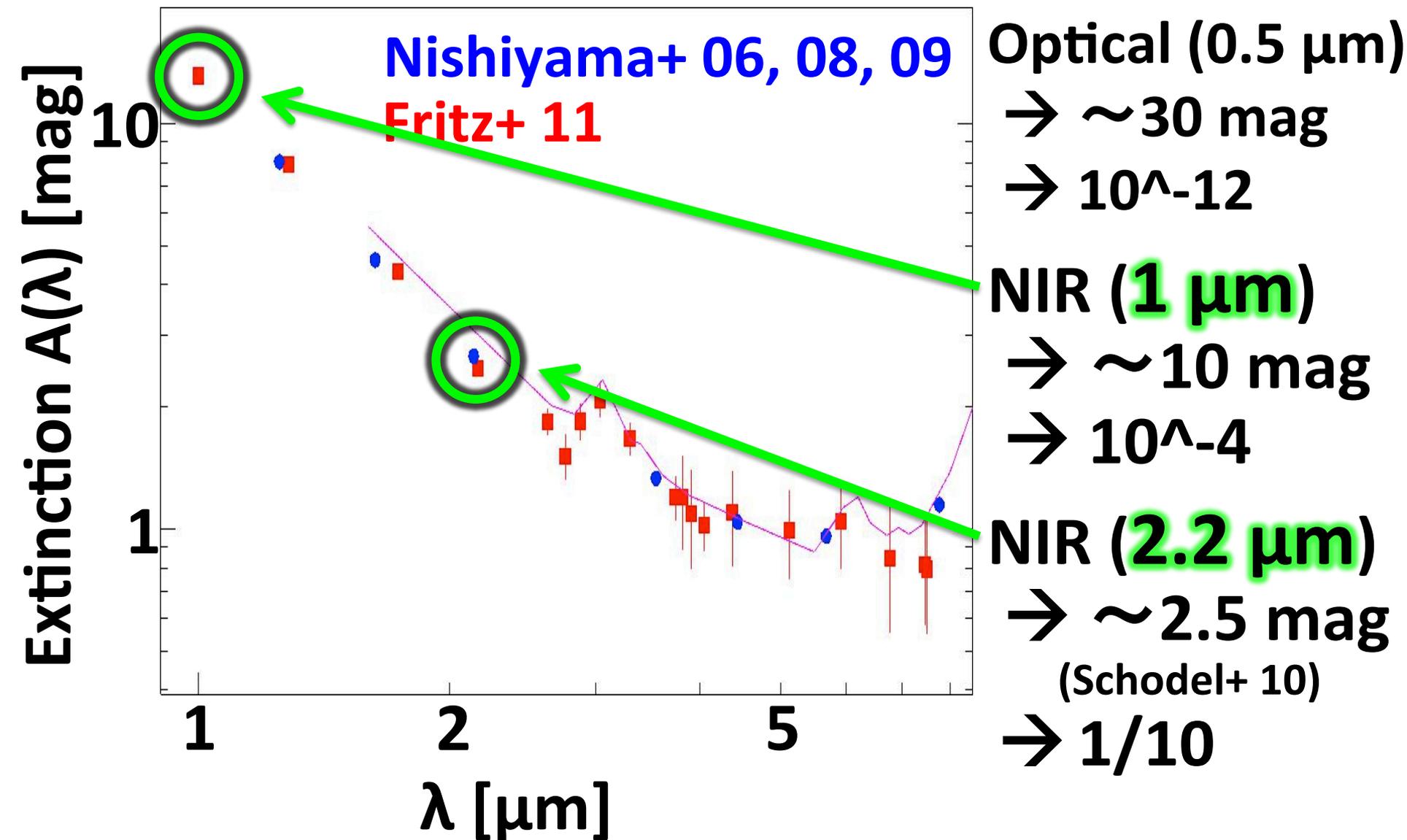
(たぶん Burkert+ 2012)

©ESO/MPE/M.Schartmann

# **Astrometry** at the Galactic center with wide-field NIR camera & GLAO

1. Why NIR & AO & Astrometry?
2. Science cases
  1. Hypervelocity stars (HVS)
  2. Nuclear stellar cluster (NSC)
  3. Hidden cluster in/around NSC

## Severe Interstellar Extinction

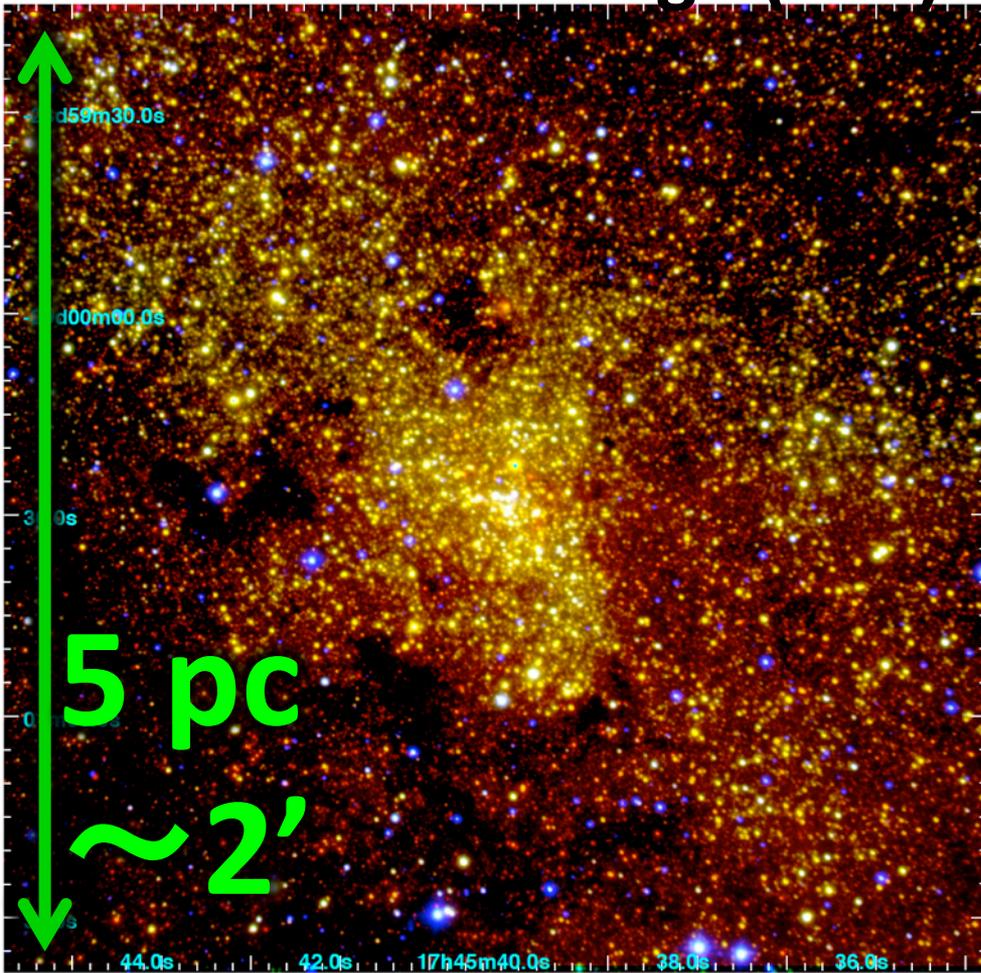


# Observation of Galactic Center

6/26

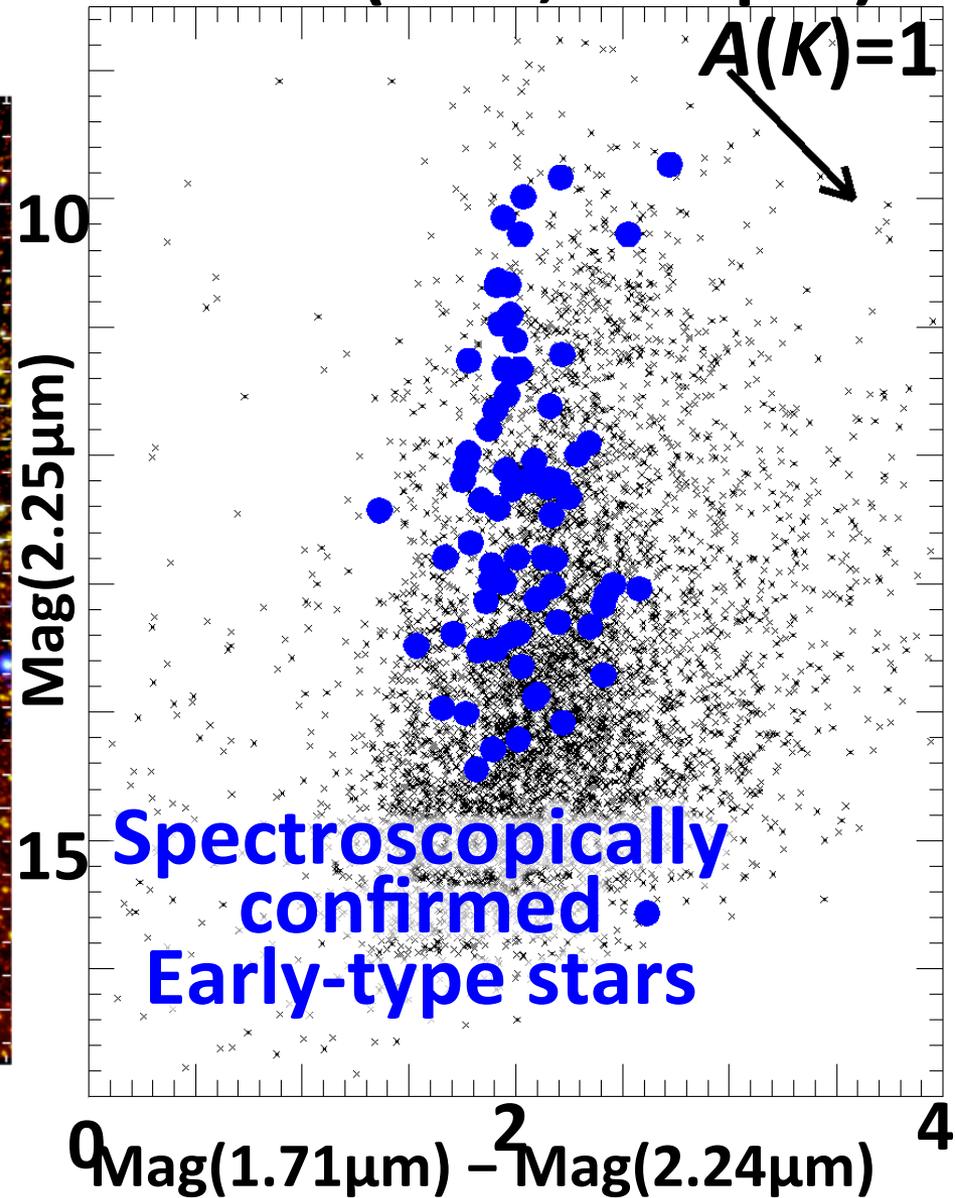
## Patchy Extinction

NIR 3-color Image (JHK)



(Nishiyama & Schodel 2012,  
A&A, submitted)

CMD (1.71, 2.25 $\mu$ m)



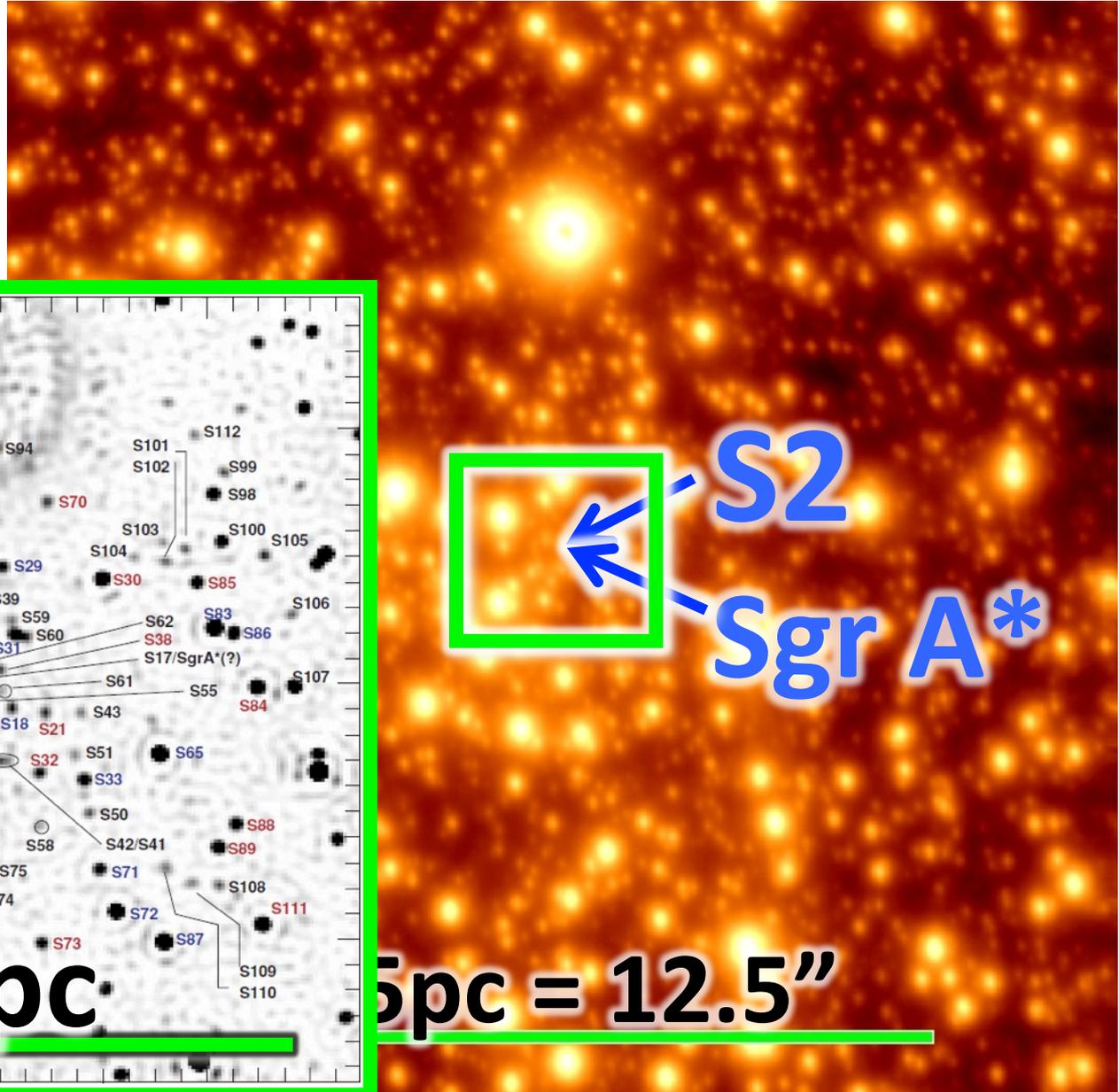
# Observation of Galactic Center

7/23

## Confusion

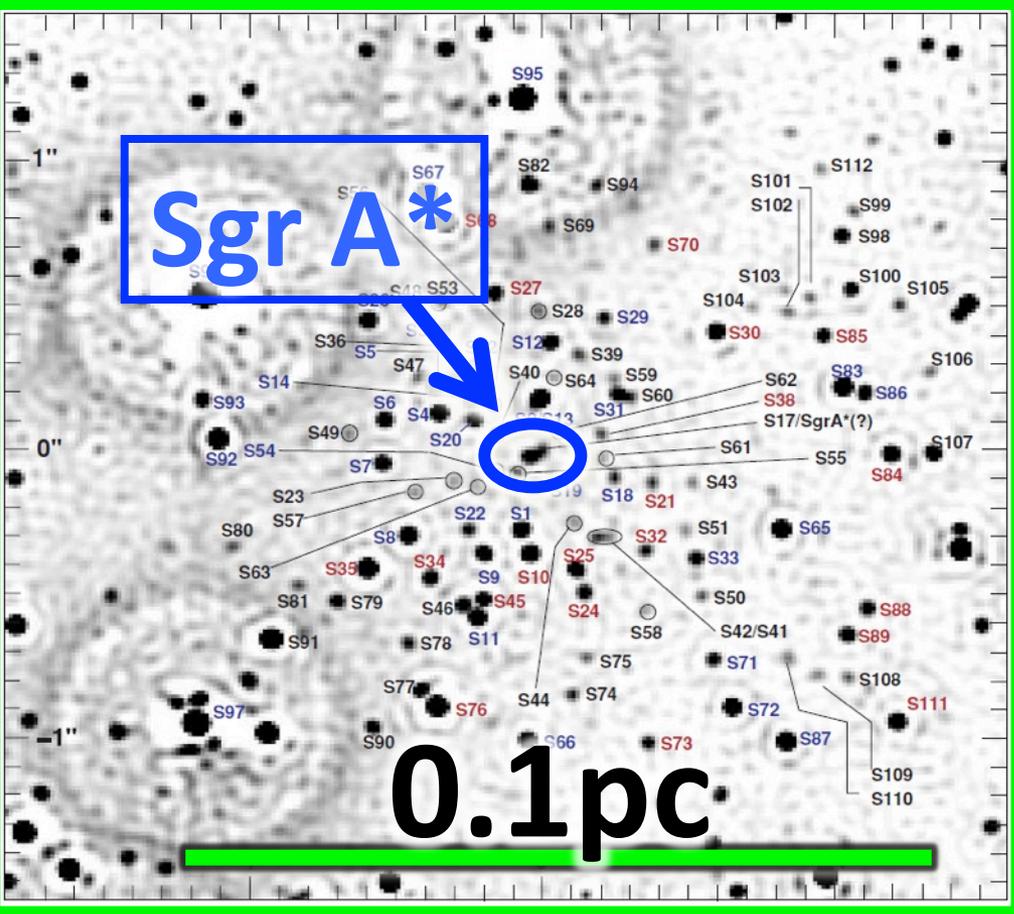
## Subaru

## CIAO/A036



S2  
Sgr A\*

5pc = 12.5"



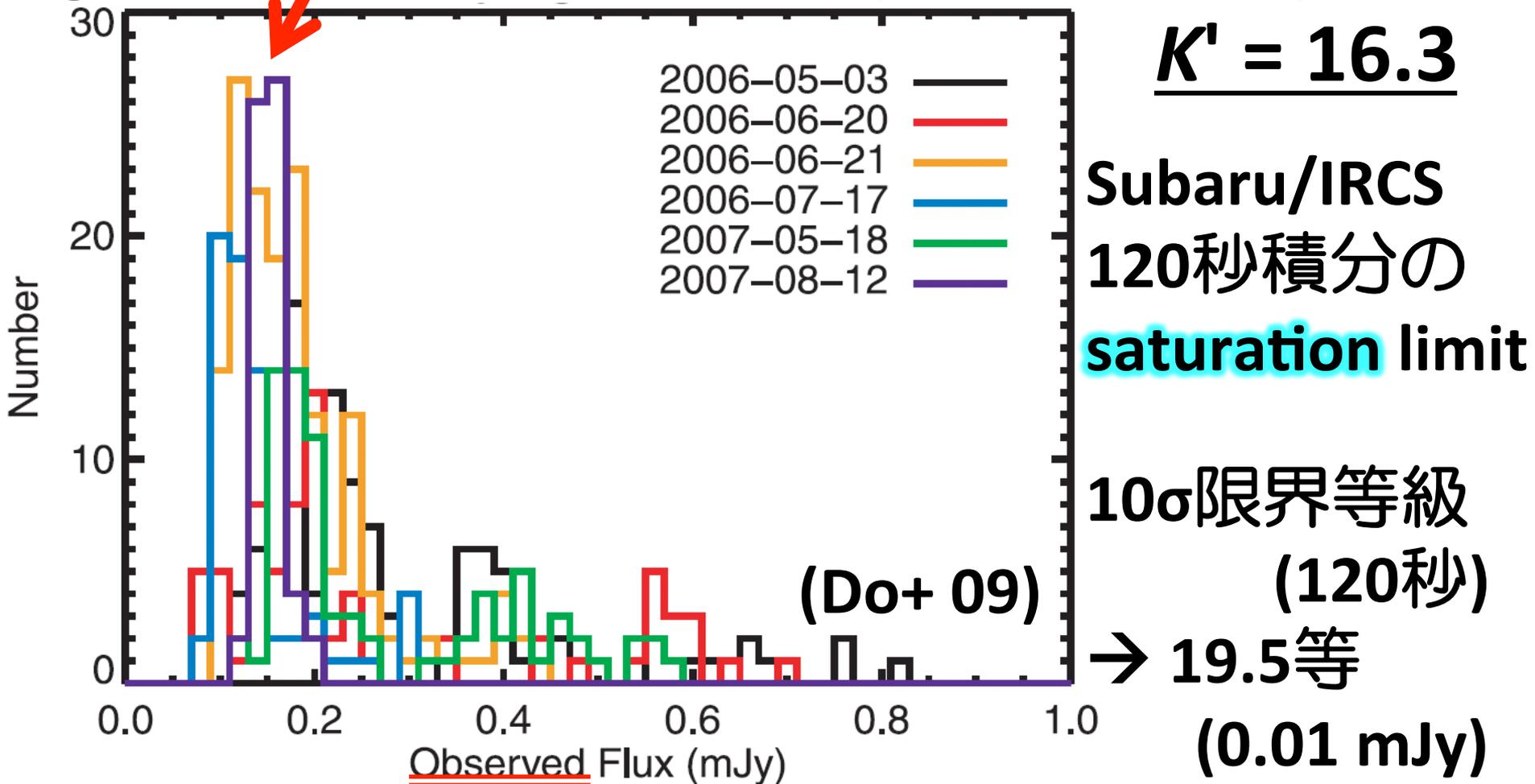
Sgr A\*

# Observation of Galactic Center

8/23

**median: 0.19 mJy (2.2 $\mu$ m)**

Sgr A\*のフラックス分布 (Keck/LGSAO)



**Astrometry** at the Galactic center  
with wide-field NIR camera & GLAO

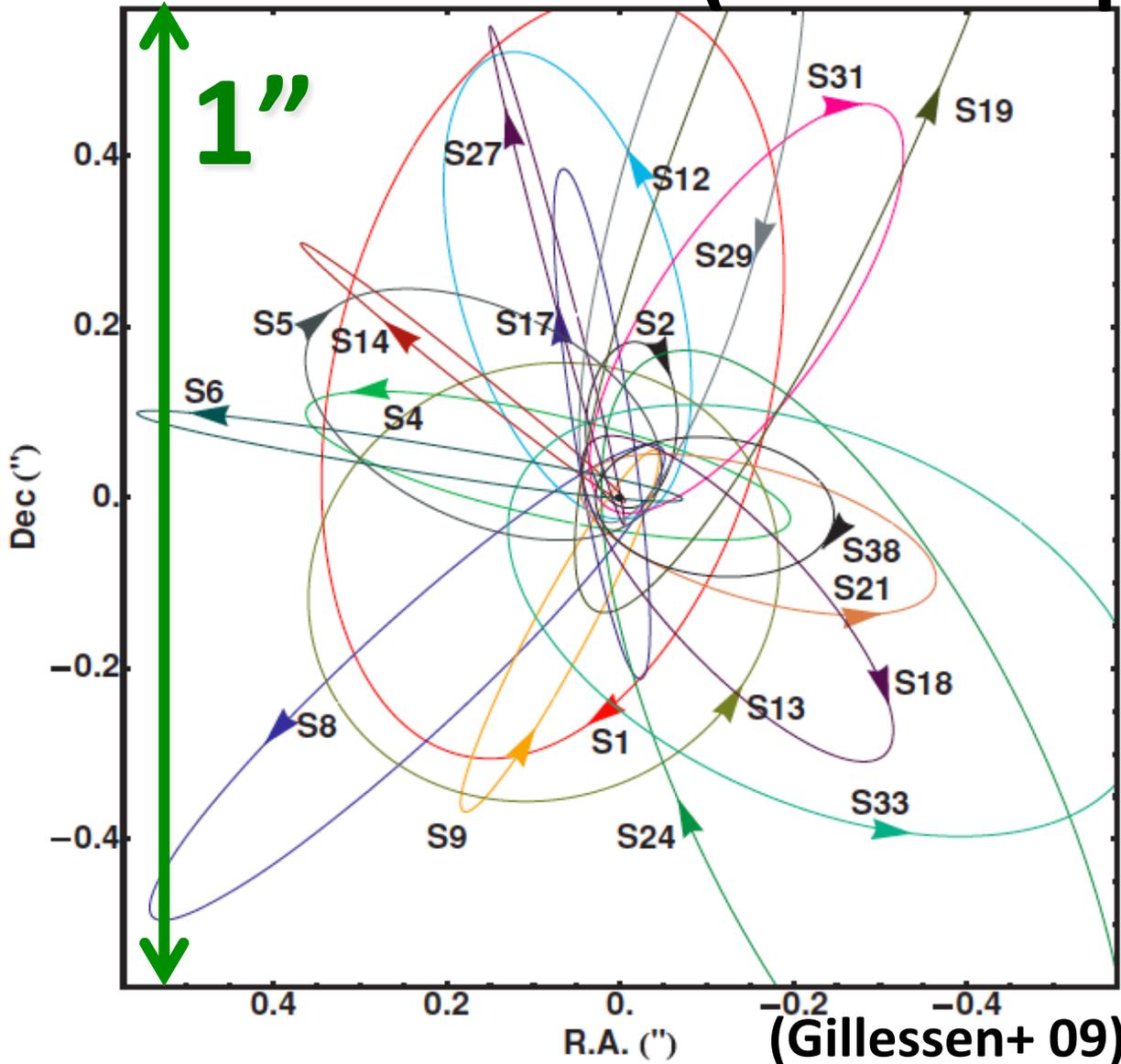
1. Why NIR & AO & Astrometry?
2. Science cases

1. Hypervelocity stars (HVS)

2. Nuclear stellar cluster (NSC)

3. Hidden cluster in/around NSC

## Orbits of S-Stars ( $<1''=0.04\text{pc}$ )



**S-stars (BV)**



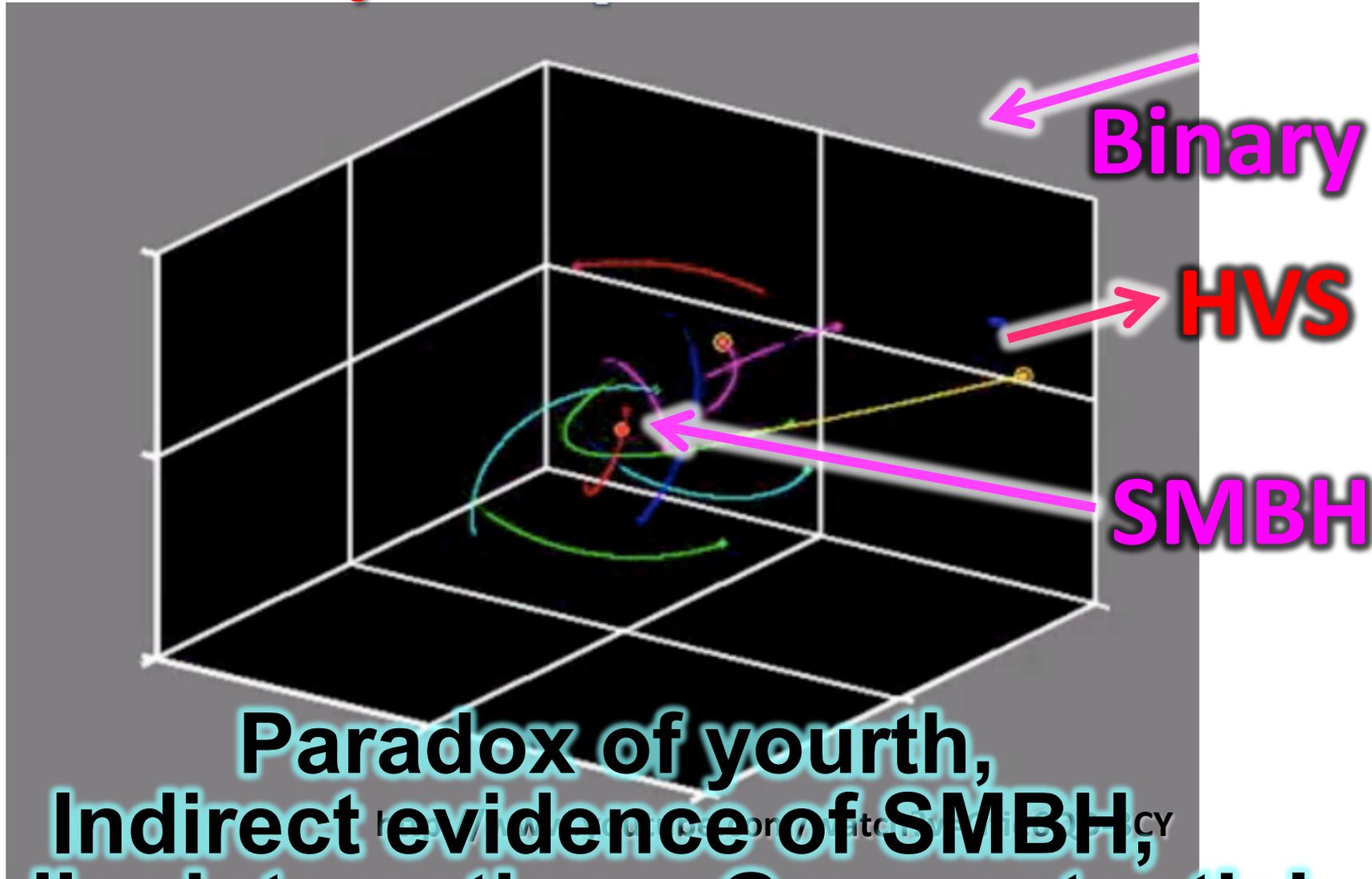
- **SMBH mass**
- **distance**
- **density**

**paradox  
of  
youth**

# Hypervelocity Stars

11/23

**Hypervelocity stars (HVS; Brown+05, 06, 07, 09)**



**Paradox of youth,  
Indirect evidence of SMBH,  
Stellar interactions, Grav. potential**

**Astrometry** at the Galactic center  
with wide-field NIR camera & GLAO

1. Why NIR & AO & Astrometry?

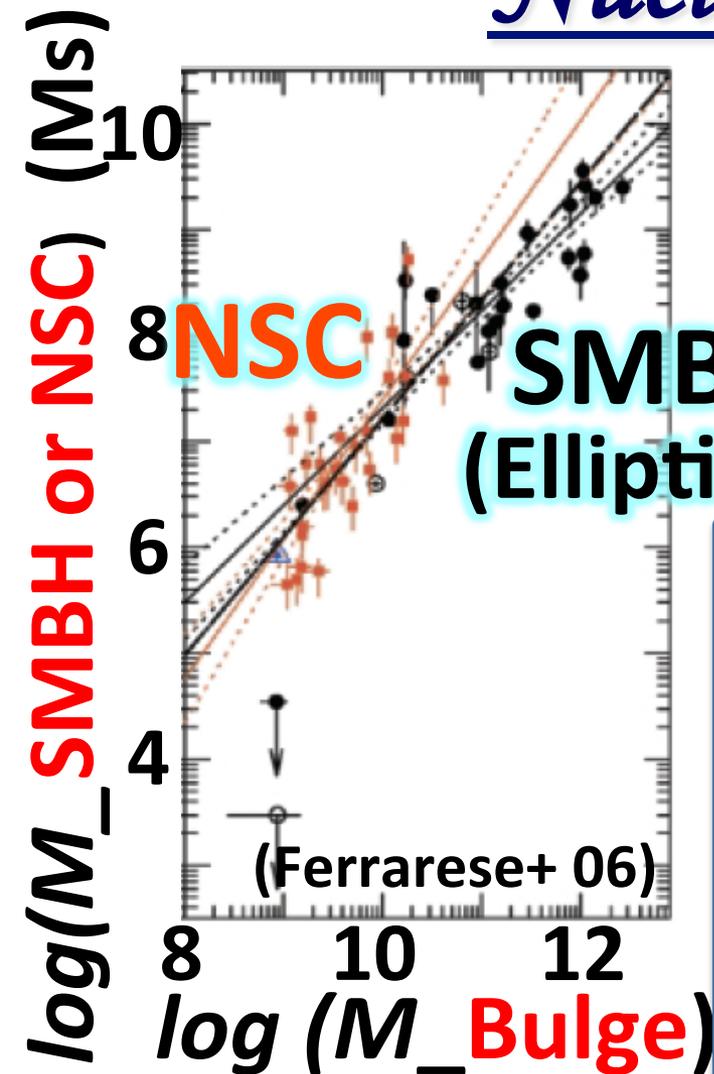
2. Science cases

1. Hypervelocity stars (HVS)

2. Nuclear stellar cluster (NSC)

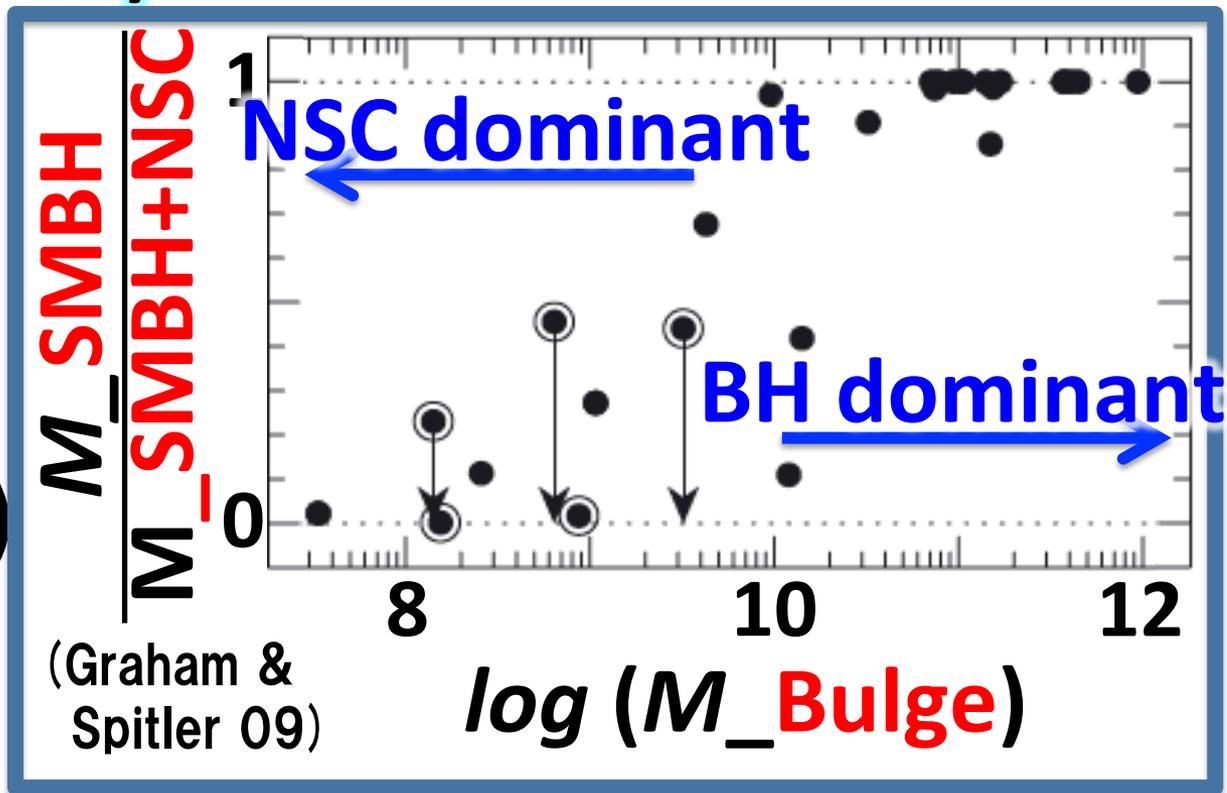
3. Hidden cluster in/around NSC

# Nuclear Star Cluster

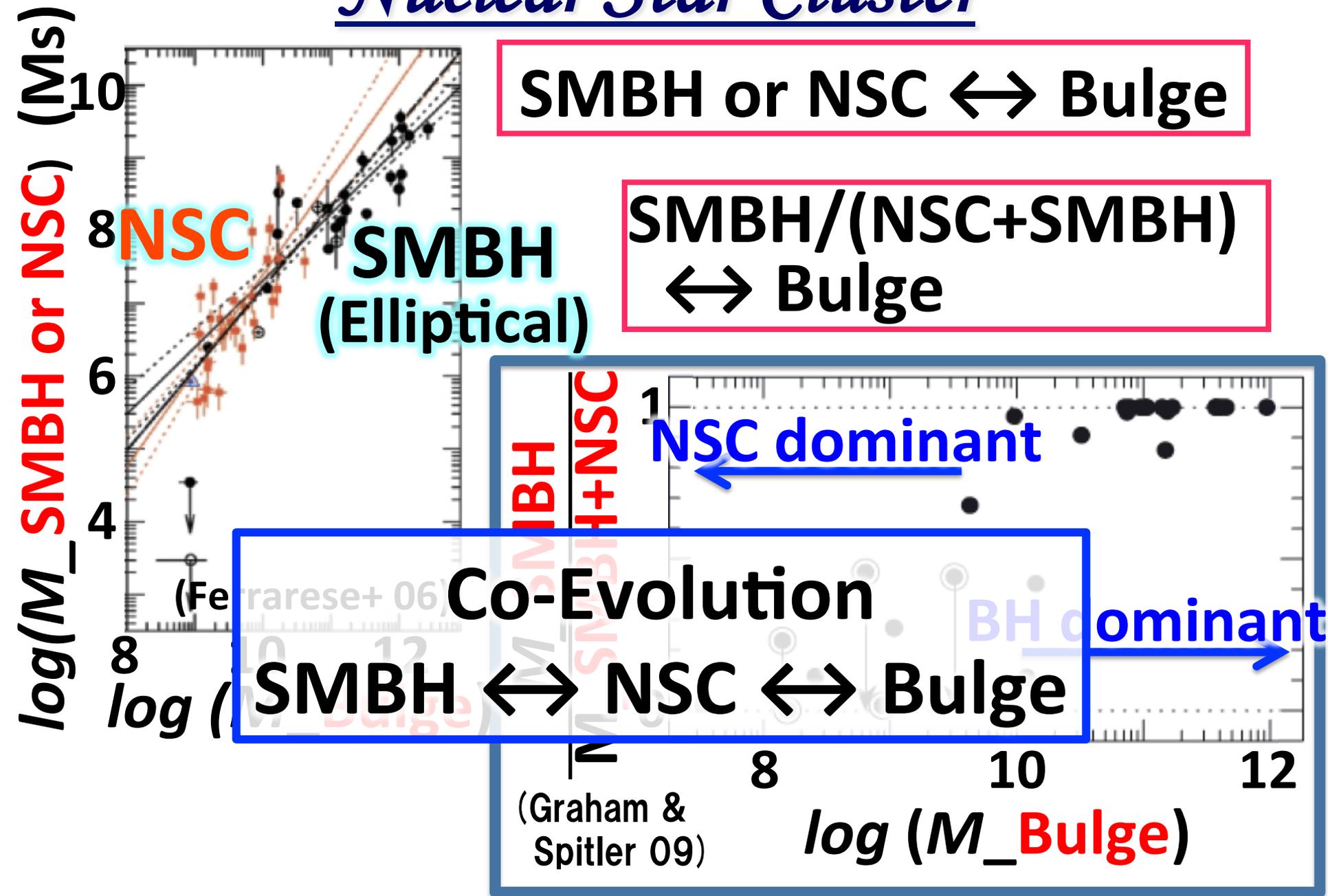


SMBH or NSC  $\leftrightarrow$  Bulge

SMBH/(NSC+SMBH)  $\leftrightarrow$  Bulge

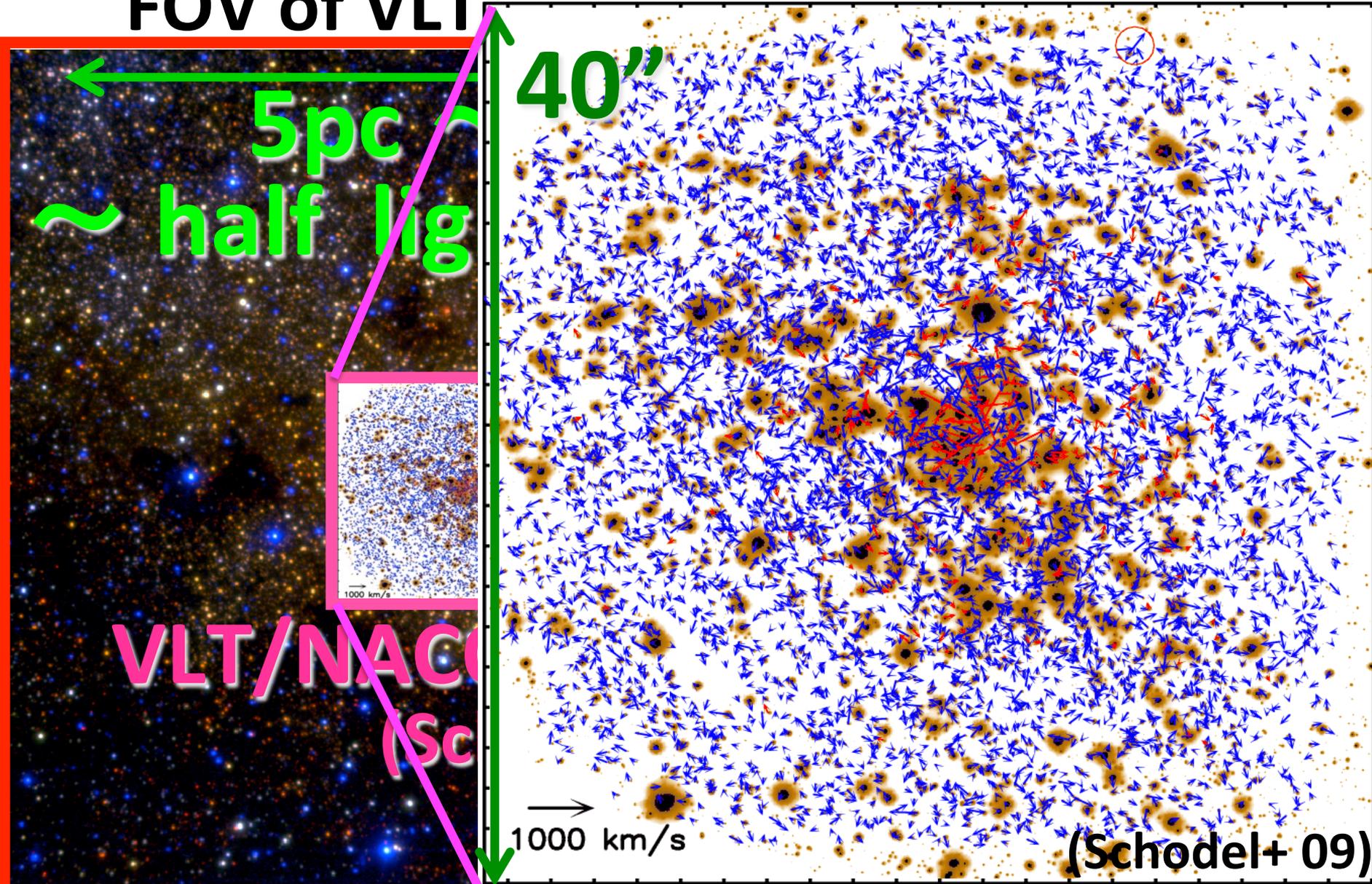


# Nuclear Star Cluster



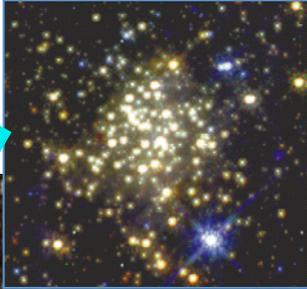
# Nuclear Star Cluster

FOV of VLT/NACO



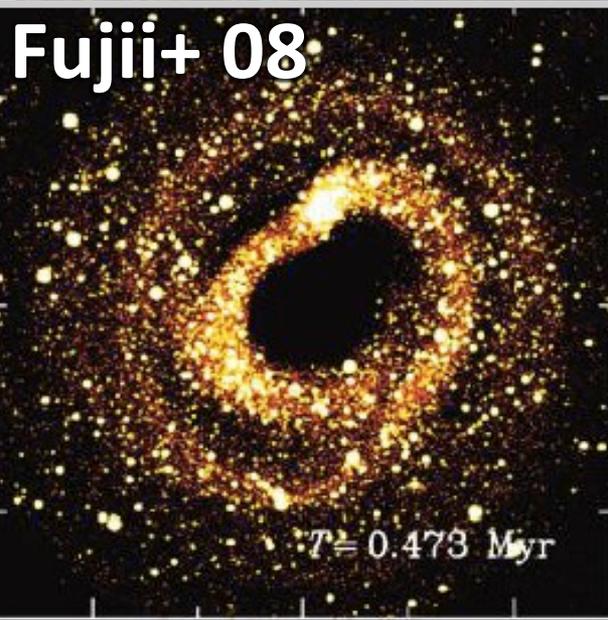
# Hidden Clusters

## Arches Cluster



**SF rate (last a few  $\times 10$  Myr)**  
 $\sim 0.075 \text{ Msun/yr}$   
 (Matsunaga, Kawadu, Nishiyama+ 11)  
 $\rightarrow$  a few  $\times 10$  clusters  
 (several % of  $M_{\text{NSC}}$ )

**Fujii+ 08**



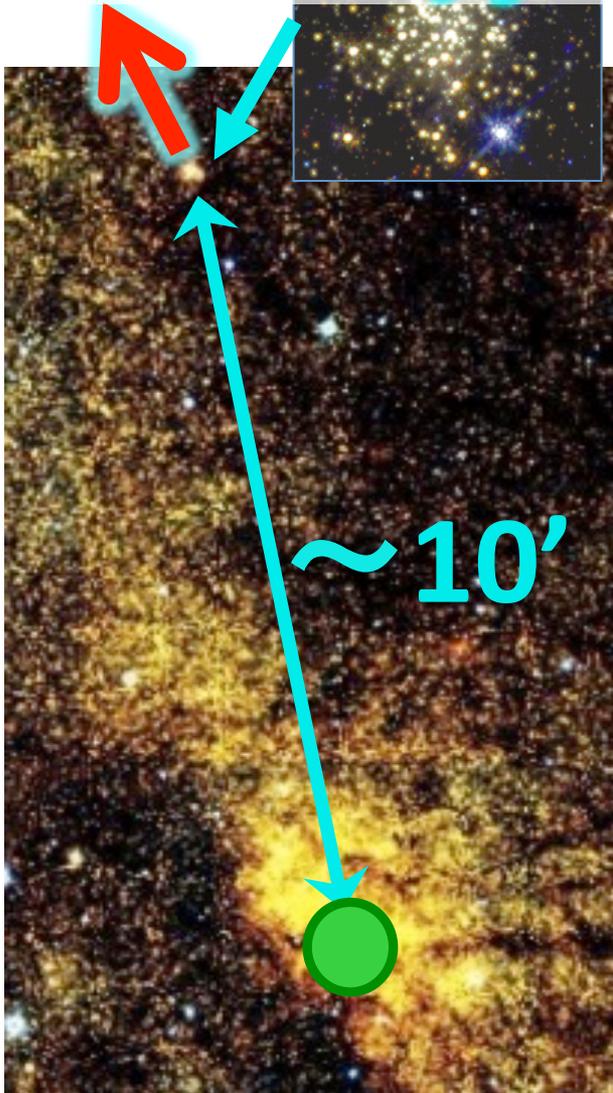
**Only 2 clusters found**

$\rightarrow$  Many cluster remnant  
 age  $<$  a few Myr: undetectable  
 (Portegies Zwart+ 02)

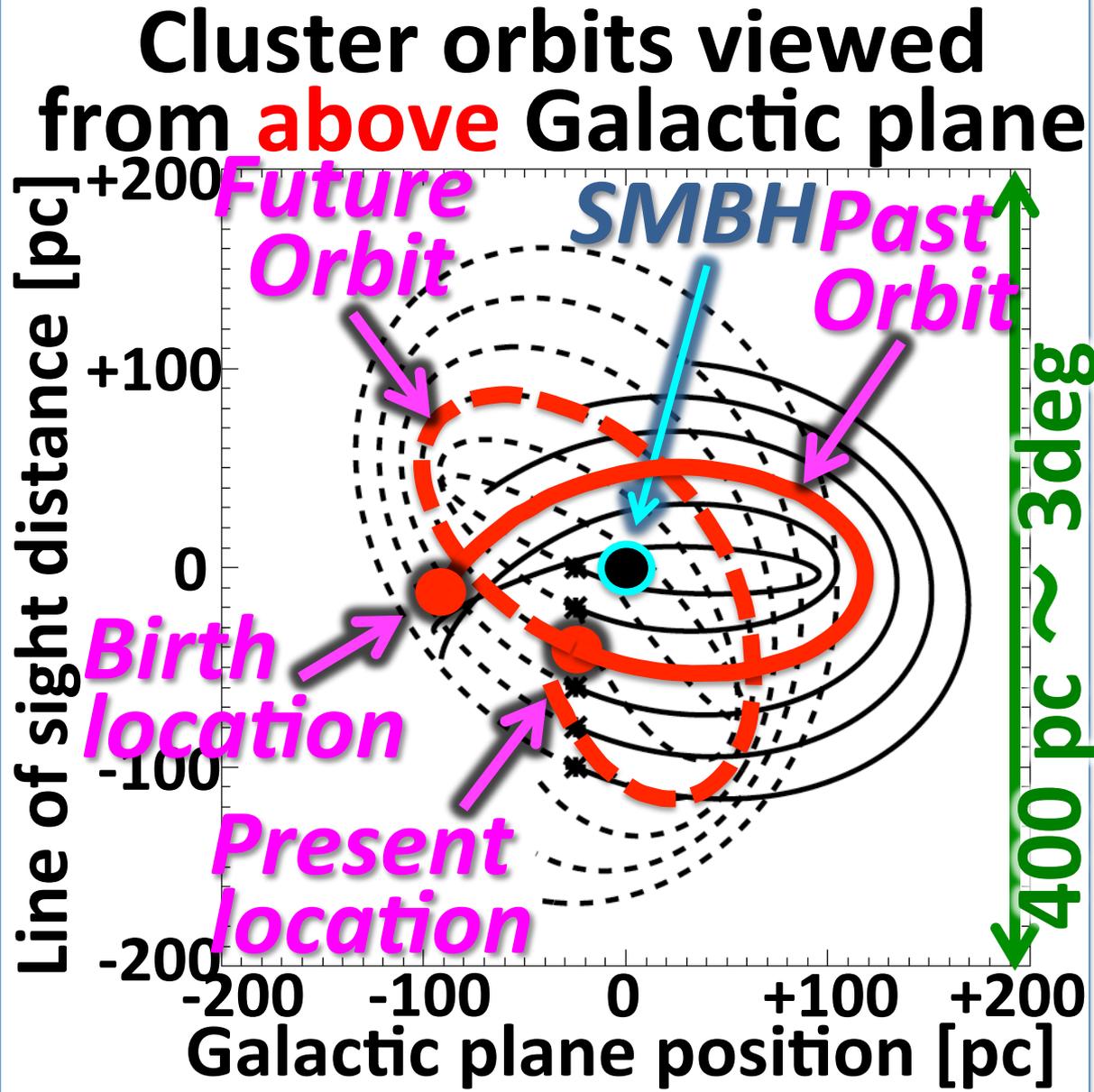
# Hidden Clusters

## Arches Cluster

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



$\sim 10'$



# Expected Performance with LGAO<sup>18/23</sup>

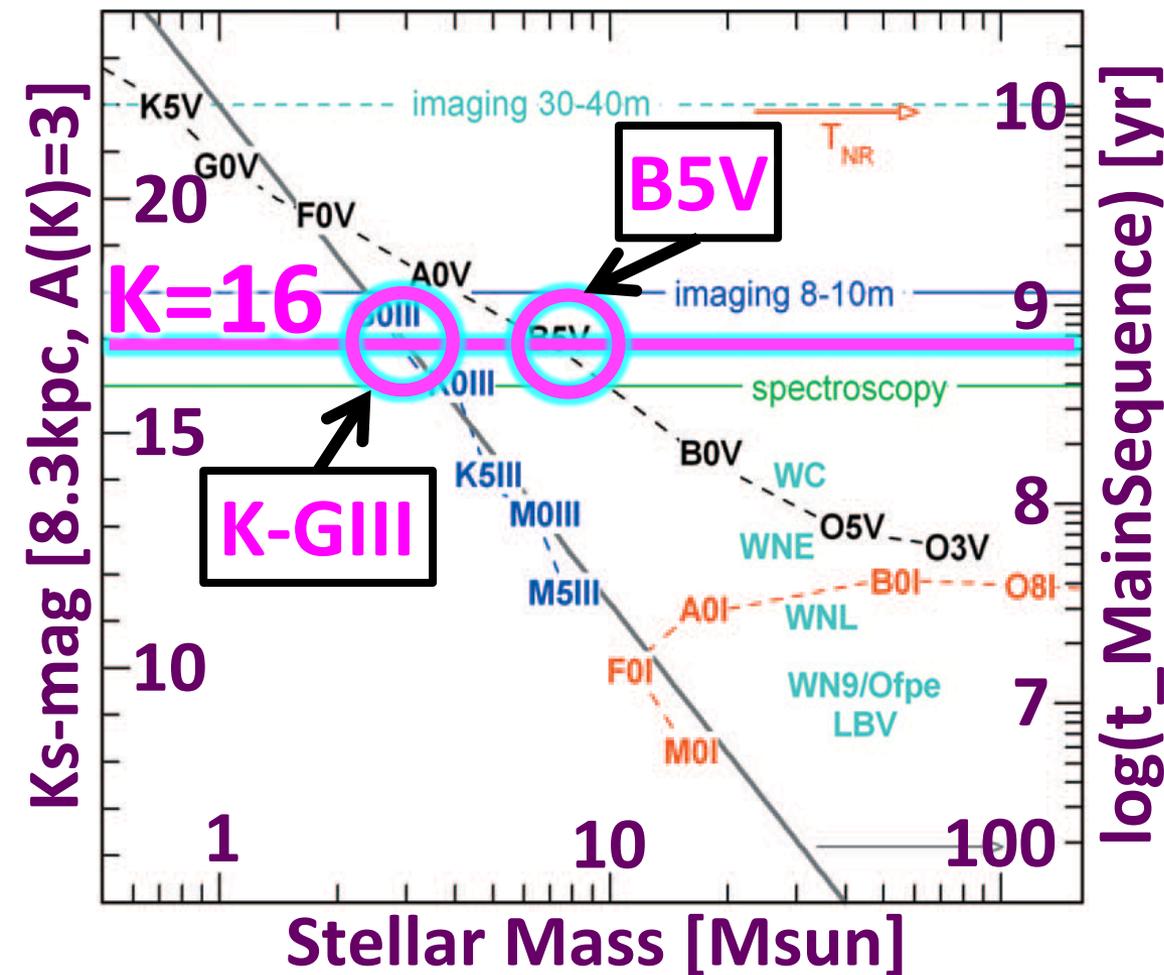
Proper motion detection  
with  $> 5\sigma$  in 5 year observations

Objects	Required accuracy [mas]
HVS	$\sim 10$
Clusters	$\sim 5$
NSC	$< 1 - 2$

HST/NICMOS/NB  
(Dong+ 11)  
FWHM:  
 $\sim 200\text{mas}@1.9\mu\text{m}$   
SN=20:  $\sim 16\text{ mag}$   
 $\delta p \sim 40\text{ mas}$   
100 observations  
(accuracy  $\propto \sqrt{N}$ )  
 $\rightarrow \sim 4\text{ mas}$

# Expected Performance with LGAO<sup>19/23</sup>

Proper motion detection  
with  $> 5\sigma$  in 5 year observations



HST/NICMOS/NB  
(Dong+ 11)  
FWHM:  
~200mas@1.9 $\mu$ m  
SN=20: ~16 mag  
 $\delta p \sim 40$  mas  
100 observations  
(accuracy  $\propto \sqrt{N}$ )  
 $\rightarrow \sim 4$  mas

$t(\text{B5V, MS}) \sim 100$  Myr  
early-KIII: red clump

# Expected Performance with LGAO<sup>20/23</sup>

Proper motion detection  
with  $> 5\sigma$  in 5 year observations

Objects	Required accuracy [mas]	GLAO Moderate (200 mas)	HST/NICMOS/NB (Dong+ 11) FWHM: $\sim 200\text{mas}@1.9\mu\text{m}$ SN=20: $\sim 16\text{ mag}$ $\delta p \sim 40\text{ mas}$ 100 observations (accuracy $\propto \sqrt{N}$ ) $\rightarrow \sim 4\text{ mas}$
HVS	10	○	
Clusters	$\sim 5$	○	
NSC	$< 1 - 2$	△	

$t(\text{B5V, MS}) \sim 100\text{ Myr}$   
early-KIII: red clump

# Expected Performance with LGAO<sup>21/23</sup>

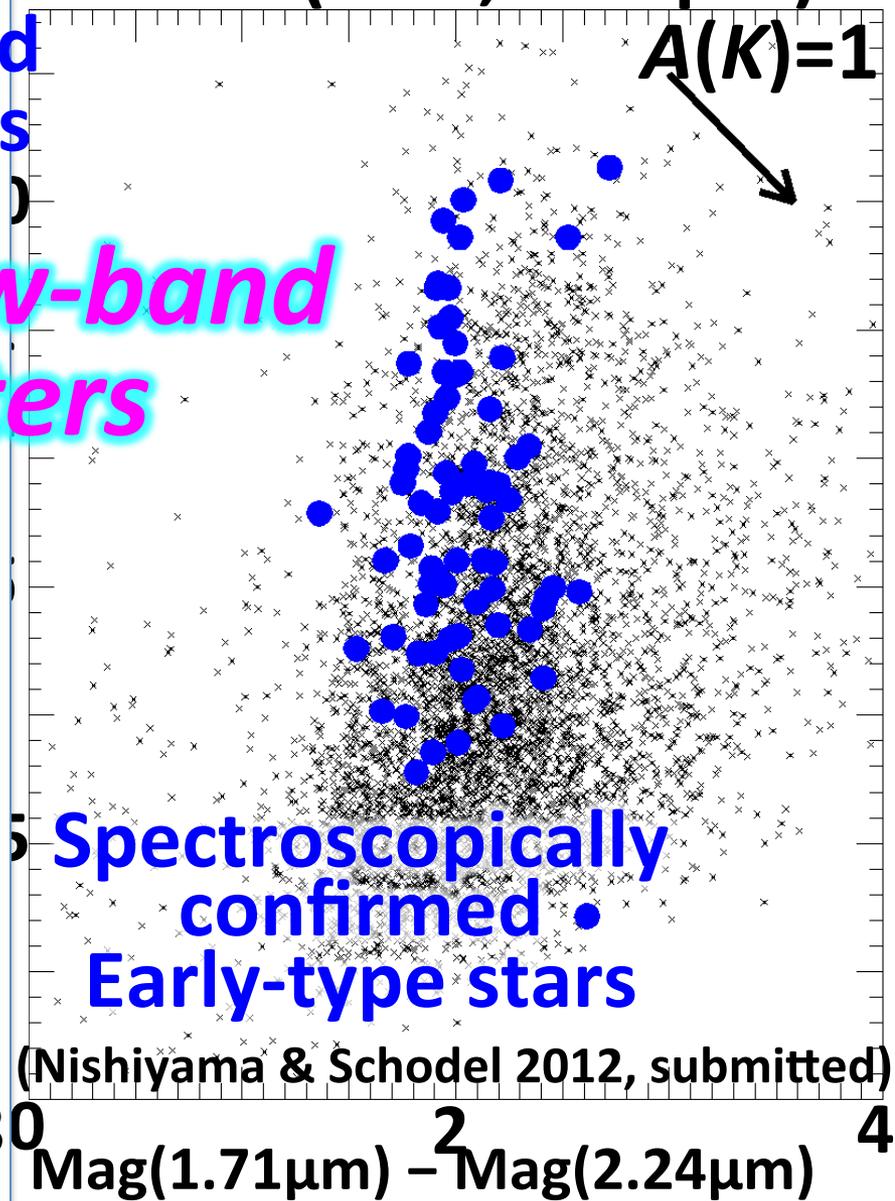
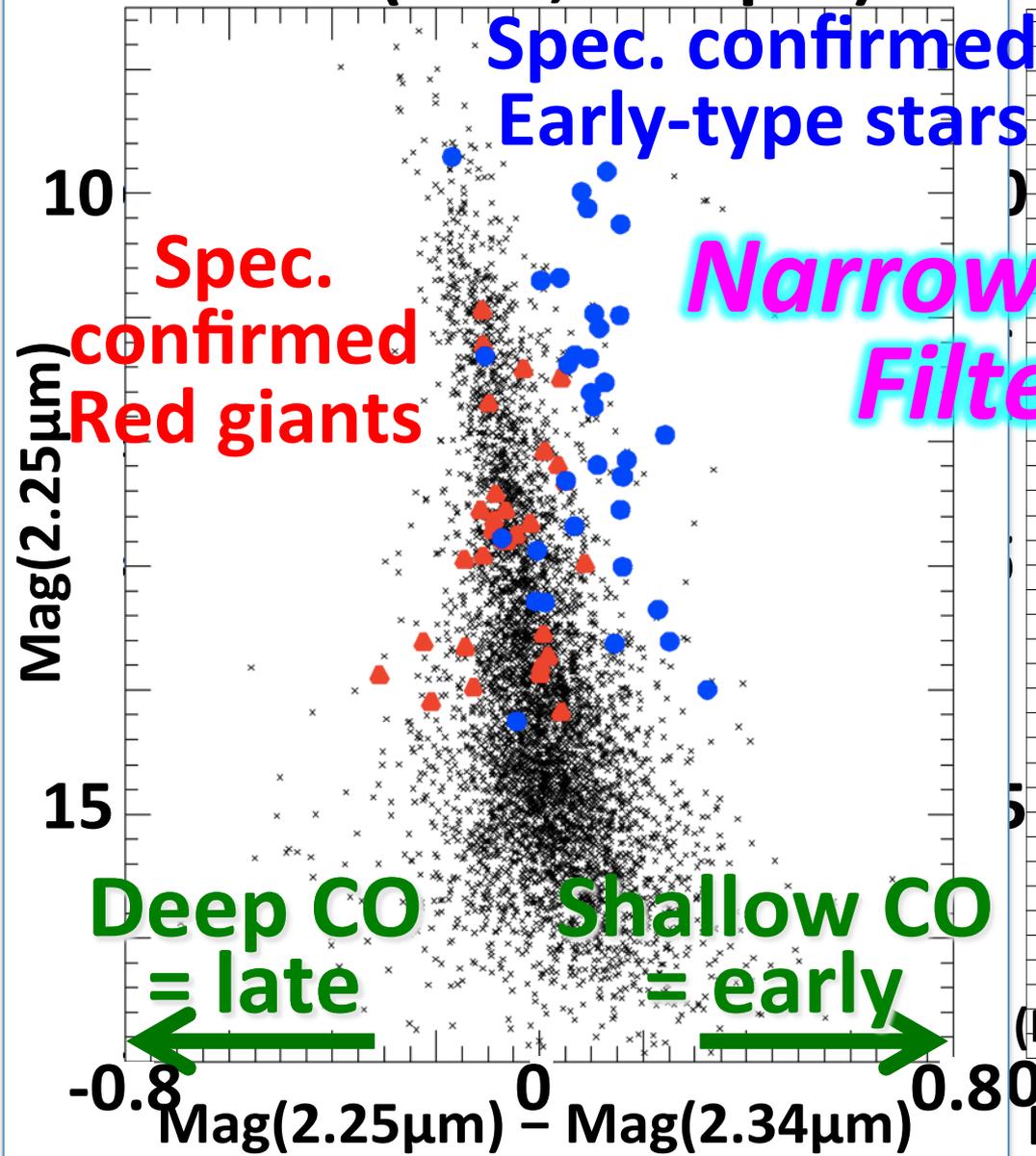
**Proper motion detection  
with  $> 5\sigma$  in 5 year observations**

<b>Objects</b>	<b>Required accuracy [mas]</b>	<b>GLAO Moderate (200 mas)</b>	<b>1-min <math>\times</math> 100obs <math>\times</math> 3<math>\times</math>3 FoV = 15h <math>\rightarrow</math> 4 nights</b>
<b>HVS</b>	<b>10</b>	<b>○</b>	<b>Wide-Field survey <math>10^{-5}</math> – <math>10^{-4}</math> yr (Yu &amp; Tremaine 03) <math>\rightarrow</math> 0.8 – 8 HVSs @40' <math>\times</math> 40' (3<math>\times</math>3FoV)</b>
<b>Clusters</b>	<b><math>\sim 5</math></b>	<b>○</b>	
<b>NSC</b>	<b>&lt; 1 - 2</b>	<b>△</b>	

# Narrow Band Filter Observation<sup>22/23</sup>

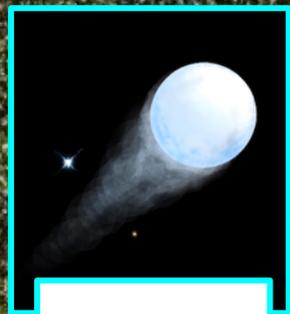
CMD (2.25, 2.34 $\mu$ m)

CMD (1.71, 2.25 $\mu$ m)





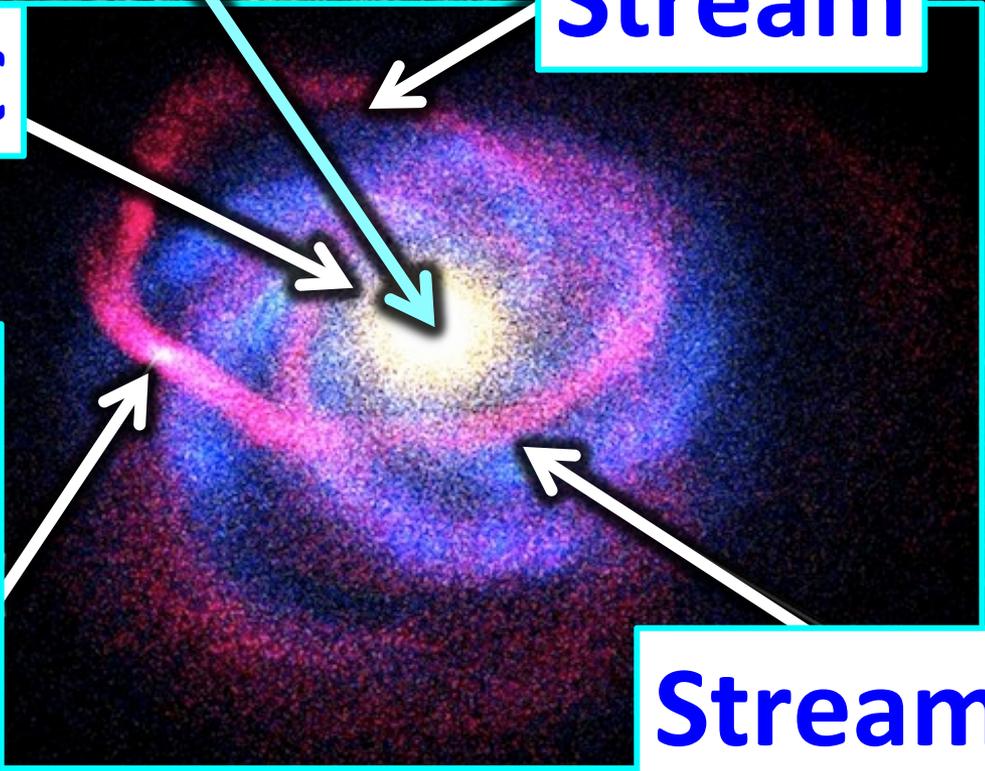
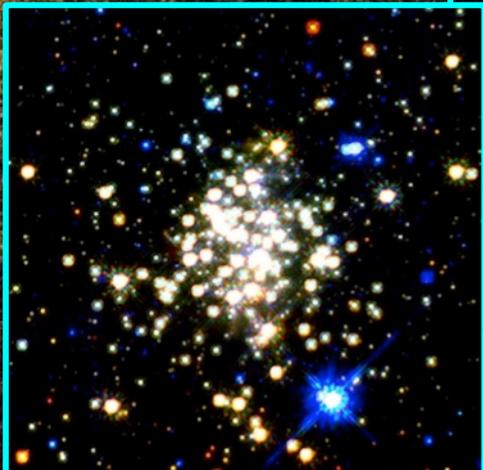
**SMBH**



**HVS**

**NSC**

**Stream**



**Stream**