Science brought by JASMINE data

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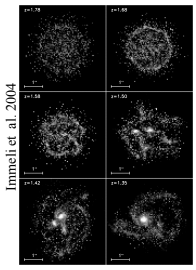
ABSTRACT

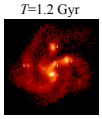
The planned astrometric space mission *JASMINE* will provide the exact positions, distances, and proper motions of the bulge stars. The data brought by *JASMINE* will certainly reveal the origin and evolution of the Galactic bulge. In fact, the formation process of the bulge is still veiled. The Galactic bulge has a bar, and kinematics of the bulge stars implies a secular formation of the bulge. On the other hand, the color-magnitude diagram as well as chemical abundances support a rapid formation of the bulge, that is consistent with the merger-built bulge in the framework of hierarchical galaxy formation. Thus, the major goals that we aim for are (i) the construction of precise color-magnitude diagram by a removal of disk stars in terms of their kinematics and distances, and (ii) determination of detailed kinematics of the bulge stars, including the change in rotation velocity along a minor axis, both of which will lead to the complete understanding of the origin of the Galactic bulge.

I. *Enigma of bulge formation in the context of galaxy formation*



"Spheroids": 50-70% of stellar mass in local Universe

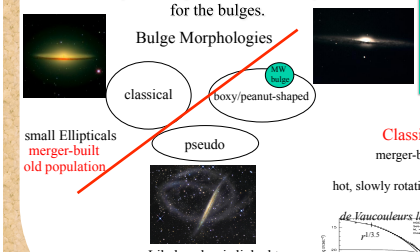
In the hierarchical galaxy formation scenario based on the cold dark matter Universe, the bulges are inevitably formed in the central region of galaxies at a very early stage.



Its fossil record is imprinted in stars.

- ✓ Age: old
- ✓ kinematics: e.g., V/σ small
- ✓ density profile: $r^{1/4}$ law

There are plural origins and formation processes for the bulges.

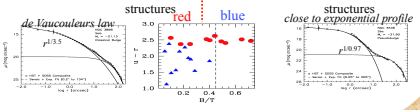


Likely, a bar is linked to the formation process.
secular evolution likely, not so old

Cold dark matter Universe predicts classical bulge.
But, classical : pseudo = 1 : 2
In real Universe, pseudobulges are dominant.
How do we make a pseudobulge through secular evolution without making a merger-built classical bulge ??

Two types of bulges

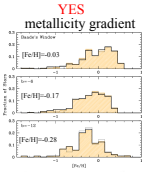
Classical bulges	vs.	Pseudobulges
merger-built bulges		central, high-density products of disk secular evolution
hot, slowly rotating E-like structures		cold, rapidly rotating disky structures
red		blue
de Vaucouleurs law		*close to exponential profile*



II. *The origin of the Galactic bulge*

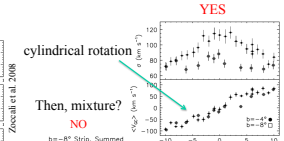
merger-built?

YES
metallicity gradient

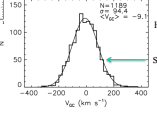


bar-induced?

YES
cylindrical rotation

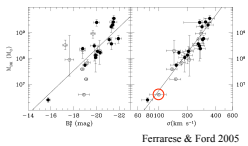


Then, mixture?
NO



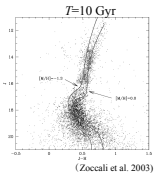
single population

The Galactic bulge also obeys M_{BH} - σ relation.
$M_{BH} = 4 \times 10^6\ M_{sun}$
$\sigma = 100$ km/s



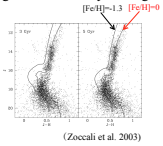
Unravel the origin from a star formation history

~color-magnitude diagram~



I. We don't have a precise CMD for the bulge at the moment.
The difficulty in the removal of disk stars

II. Age and metallicity are degenerated.



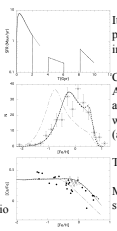
Secular evolution is not supported.

~chemical evolution~

input
SFH

outcomes
ADF

evolution of elemental ratio



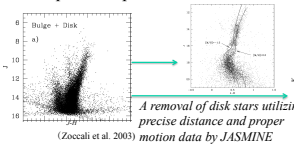
It is implied that a large part of stars are formed in a short timescale.

Concretely,
At least 70-80 % stars are likely to be formed within the first 2Gyrs (age>10 Gyr).

Then,
Merger-built origin is supported ??

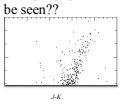
III. *Goals of JASMINE*

1. acquire the precise CMD: star formation history



A removal of disk stars utilizing precise distance and proper motion data by JASMINE

multiple populations will be seen??



ten thousands of stars will be plotted

2. V_ϕ, σ gradient, distribution: the origin of the Galactic bulge

merger-built? or bar-induced?
identify a mixture of two origins
classical component will be detected??

International collaboration

radial velocity, chemical composition are the critical supplementary information

complete kinematics

- ✓ metallicity could be an age indicator
- ✓ CMD = *f*(age, metallicity)
- ✓ kinematics-metallicity correlation gives an insight into the formation process

JASMINE needs to collaborate with ongoing projects.

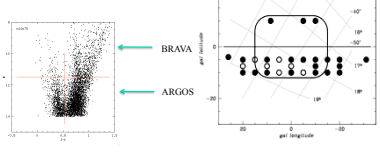
strategy
1. science with a huge data (only *JASMINE*)
2. the number is small (~a few hundreds), but complete information

IV. *Tie up with ongoing bulge survey projects*

1. ARGOS project

PI: K. Freeman (ANU)
J. Bland-Hawthorn (Usyd), M. Asplund (MPA), L. Wylie (ANU), M. Ness, G. Lewis (Usyd), D. Yong (ANU), R. Ibata (CNRS), L. Kiss, R. Lane (Usyd), E. Athanassoula (LAM)

observations starting from 2008
measurements of radial velocities, metallicities, and α-abundances
spectrograph called AAOmega at AAT 4m
~1000 stars/field
spectra in Ca triplet region (R~11000, S/N~50)
~23000 stars up to date
completion (~28000) in June 2010

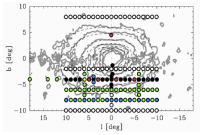


2. BRAVA project

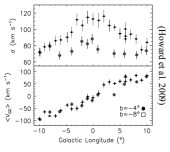
The Bulge Radial Velocity Assay

PI: R. Michael Rich (UCLA)
C. Howard, D. Reitzel, A. Koch (UCLA), H. Zhao (St. Andrews), R. De Propris (CTIO), A. McWilliam (Carnegie), J. Fulbright (JHU), L. Origlia (Bologna)

observations starting from 2005
Hydra fiber spectrograph at CTIO Blanco 4m
Cross correlation from 7000-9000A (include Ca IR triplet)
~100 M giants/field with R ~4000
~8000 stars until 2008



discovery of cylindrical rotation



Abundances from either future IR studies or from modeling of optical spectra