Identifying the Ongoing Nuclear Star-Formation in Elliptical/S0 Galaxies
การค้นหาดาราจักรแบบทรงรี/เอสศูนย์ที่มีการก่อกำเนิดดาวฤกษ์บริเวณใจกลาง

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ABSTRACT

We presenta sample elliptical/S0 galaxies with blue core (BlueCore Elliptical/S0, BCE) selected fromthe Sloan Digital Sky Survey (SDSS)Data Release 9and the NASA-Sloan Atlas. Our selection technique makes use of the difference betweenthe synthesized color within the SDSS' spectroscopic fiber positioned at thecore and the global, galaxy-wide color from photometric data. This methodallows a large number of galaxies to be searched for the presence of blue coresefficiently. We limit our redshift range to $0.01 < z < 0.02$ to ensure that coreof the galaxy is well-resolved. The result from color-magnitude suggest that a majority of BCE is located on blue cloud galaxy populations. Furthermore, the BCE have star formation ratehigher thanelliptical/S0 galaxies with red core. Thus, our results show that the BCE have characteristics similar to spiral galaxies despite beingmorphologically similar to the elliptical galaxies.

บทคัดย่อ

งานวิจัยนี้นำเสนอตัวอย่างดาราจักรแบบทรงรีและเอสศูนย์ที่มีใจกลางสีฟ้า ซึ่งค้นหาจากฐานข้อมูล Sloan Digital Sky Survey (SDSS)Data Release 9 และ NASA-Sloan Atlas การคัดเลือกดาราจักรลักษณะดังกล่าวในงานวิจัยนี้ใช้เทคนิคการเปรียบสีในสองบริเวณ คือ สีบริเวณใจกลางที่บันทึกโดยเส้นใยนำแสงจากการถ่ายสเปกตรัมของกล้อง SDSS และสีโดยรวมของดาราจักรที่ได้จากการคำนวณทางโฟโตเมตรี ซึ่งวิธีดังกล่าว สามารถนำไปใช้ในการค้นหาดาราจักรจำนวนมากที่แสดงลักษณะใจกลางสีฟ้าได้อย่างประสิทธิภาพ ผู้วิจัยได้กำหนดค่าการเลื่อนทางแดง ให้อยู่ในช่วงระหว่าง 0.01 ถึง 0.02 ผลลัพธ์ที่ได้จากแผนภาพความสัมพันธ์ระหว่างดัชนีสีและแมกนิจูดชี้ให้เห็นว่า ดาราจักรแบบทรงรีและเอสศูนย์ที่มีใจกลางสีฟ้าส่วนใหญ่อยู่บนปริภูมิดัชนีสี-แมกนิจูดเดียวกับประชากรดาราจักรสีฟ้า นอกจากนี้อัตราการเกิดดาวฤกษ์ของดาราจักรแบบทรงรีและเอสศูนย์ที่มีใจกลางสีฟ้ามีค่าสูงกว่าดาราจักรแบบทรงรีทั่วไป ดังนั้น ผลที่ได้จากงานวิจัยนี้แสดงให้เห็นว่า ดาราจักรแบบทรงรีและเอสศูนย์ที่มีใจกลางสีฟ้า มีคุณสมบัติใกล้เคียงกับดาราจักรแบบกังหัน แม้จะมีรูปร่างความคล้ายคลึงกับดาราจักรแบบทรงรีก็ตาม

Key Words: BlueCore Elliptical/S0, Color magnitude diagram (CMD), Star formation rate (SFR)
คำสำคัญ: ดาราจักรแบบทรงรีและเอสศูนย์ที่มีใจกลางสีฟ้า แผนภาพความสัมพันธ์ระหว่างดัชนีสีและแมกนิจูด อัตราการเกิดดาวฤกษ์

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Introduction

The star formation rate (SFR) of the universe has declined by an order ofmagnitude since z $\sim$ 1 (Madau et al., 1996; Hopkins, 2004; Hopkins &Beakom, 2006). As the star formation (SF) in galaxies ceased, galaxy evolved passively from the blue cloud (BC) to the red sequence (RS). The exactmechanism(s) is still an open question.But a few passively evolving elliptical/S0galaxies harbor nuclear SF thought to be the residue of declining SF (Suh et al., 2010) in dyinggalaxies and thus could represent a population of galaxy in transition from BC to RS. These galaxies can be identified by blue nuclear emissions in an otherwisered galaxy. These blue core elliptical/S0 (BCE) galaxies presents a potentiallyimportant population to study the mechanisms that suppress SF in the universe.

This work explores a criteria to efficiently select blue core galaxies from the SDSS Data Release 9 (SDSS DR9; Ahn et al., 2012) and the NASA-Sloan Atlas(NSA; Blanton et al., 2011).

Selection of Blue Core Elliptical/S0 Galaxies

- We begin with volume-limited sample of 12,940 primary galaxy samples from NSA at 0.01 < z < 0.02 with absolute magnitude in SDSS' r band, k-corrected (Blanton &Roweis, 2007) to z=0.1 ,M_r< 17.5
- The elliptical/S0 galaxies are selected from primary galaxy samples with parameter Sersic index (see appendix A) between 4.0 to 5.9 and stellar mass (M_s) must have $\log\left(M_s/h^{-2}M_\odot\right) > 9.0$
- To remove contaminated galaxies such as spiral or dwarf galaxies, we reject by EW $(H\alpha)>0$, which is equivalence width (EW) of hydrogen emission lines in the Balmer series.
- BCE are selected from this sample by requiring the nuclear color i.e. color from the central region observed by SDSS spectroscopic fiber or fiber color)to be bluer than color of the entire galaxy define by Petrosian color (see appendixB for more details). We define

$$\Delta_{(g\text{-}r)} \equiv (g^*\text{-}r^*)_{fiber} - (g^*\text{-}r^*)_{Petrosian}$$

- Quantitatively, we require blue core sample to have $\Delta_{(g\text{-}r)} < -0.05$
- Visually inspect the result. At this step, we have removed three galaxies with spiral morphology and blue color, which are outside the scope of this work.
- The final blue core elliptical/S0 sample contains 11 galaxies

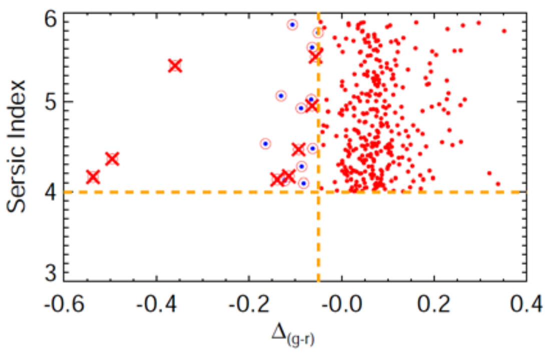

Fig 1 The correlation between Sersic index and $\Delta_{(g\text{-}r)}$.

The diagram in Fig 1 shown the correlation between Sersic index and $\Delta_{(g\text{-}r)}$ is a new tool that suggest that all galaxies resided on left hand side of vertical dashed line are BCE, while the red dots represent red core E/S0 galaxies (RCE).

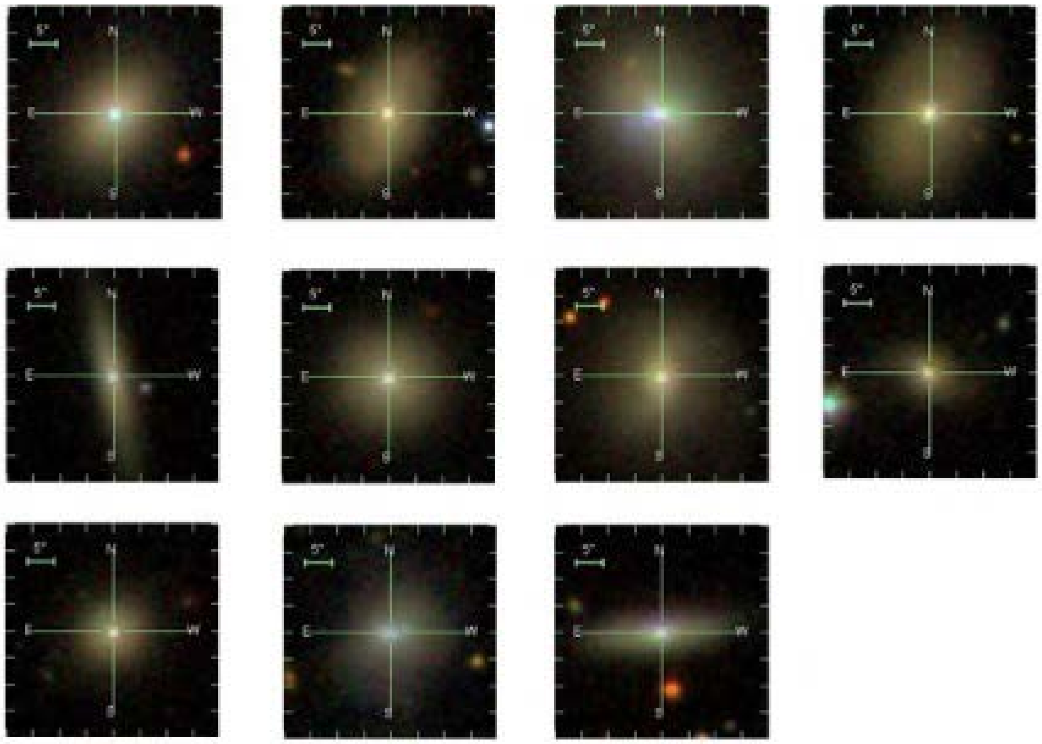

Fig 2 The optical SDSS image of 11 BCE samples.

For red cross symbols are galaxies which remove by visual inspection and both of the dash lines are empirical thresholds in this work. We show all BCE images taken from SDSS image archive.

Results

The color-magnitude diagram(Fig 3) of blue cloud and red sequence galaxies, both populations are represented by the grey shades and the 11 BCE(purple dots) with shows a majority of BCE falls in the blue cloud despite their morphologybeing elliptical/S0, suggesting that their optical emission is dominated by starformation.

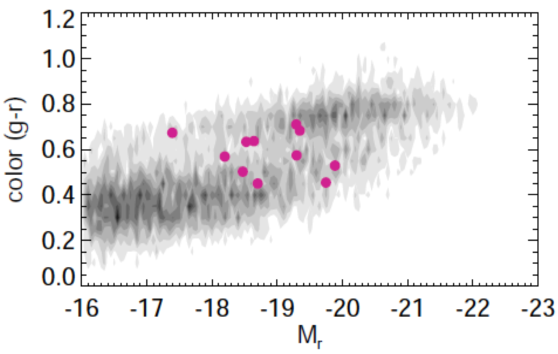

Fig 3 The color-magnitude diagram.

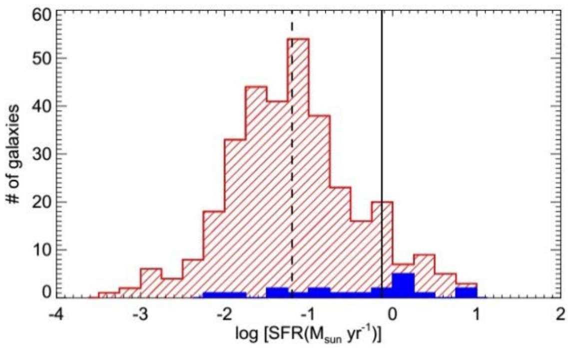

Fig 4 The comparison of SFR of BCE and RCE derived from $H\alpha$ emission lines.

The star formation rate of the BCE using Hα emission from SDSS measurement according to the Kennicutt (1988) formalism. In the Fig 4, we compare the SFR of BCE (blue histogram) and RCE (red histogram) and found to have significantly higher SFR despite being morphologically similar to the red sequence galaxies.

Conclusions

A method to select Blue Core Elliptical/S0 galaxies (BCE) is presented along with a sample of 11 BCE. It shows that nuclear region of the BCE are dominated SF despite being morphologically similar to RS galaxies. The resulting of BCE also show SFR higher than RCE.

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Appendix

A. The brightness profile of galaxy

In describe light distribution of galaxies, we use **Sersic profile**, which is defined as

$$I(r) \propto \exp\left[-\left(\frac{r}{r_e}\right)^{1/n}\right]$$

where I(r) is surface brightness at r radius, r_e is an effective radius (half-light radius r_{50}) and n is defined as the ***Sersic index***. The best fitting of Sersic profile varied range between n=0.5 and n=10. When taking n =1 the Sersic profile will be called that Exponential light profile. Conversely, setting n=4 we call the de Vaucouleurs profile (Graham & Driver, 2007). The spiral/disk galaxies are better described by exponential light profile. But the elliptical/S0 galaxies are the de Vaucouleurs profile.

B. The Petrosian Magnitude

For galaxy photometry, measuring flux is more difficult than stars because a brightness profile of galaxy at same radius is not constant. So we measure a constant fraction of total brightness called Petrosian ratio (R_p)(Blanton et al., 2001; Yosuda et al., 2001), which is defined as

$$R_p(r) \equiv \frac{\int_{0.8r}^{1.25r} dr' 2\pi r' I(r') / [\pi(1.25^2 - 0.8^2) r^2]}{\int_0^r dr' 2\pi r' I(r') / \pi r^2}$$

where I(r) is surface brightness at r radius. For Petrosian radius is defined as radius at which Petrosian ratio (R_p)equal to 0.2 in SDSS case. The Petrosian flux(F_p) is defined as the flux within 2 times of Petrosian ratio (R_p)

$$F_p \equiv \int_0^{2r_p} 2\pi r' dr' I(r')$$

The Petrosian magnitude $(m_{Petrosian})$ is

$$m_{Petrosian} = -2.5 \log(F_p) + C$$

where the C is a constant value.

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