

# Spatially resolved stellar mass buildup and quenching of star formation in massive disk galaxies over the last 10 Gyrs

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## 論文内容要旨

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氏名	Abdurrouf	提出年	平成 30 年
学位論文の 題目	Spatially resolved stellar mass buildup and quenching of star formation in massive disk galaxies over the last 10 Gyrs (過去 100 億年の大質量円盤銀河の内部での星の集積と星形成の終焉)		

## 論文目次

1. Introduction
  - 1.1. Cosmic star formation history
  - 1.2. Global properties of galaxies
    - 1.2.1. Galaxy bimodality: blue and red sequences
    - 1.2.2. Global star formation main sequence
    - 1.2.3. Downsizing phenomenon
  - 1.3. Spatially resolved view of the galaxy evolution
    - 1.3.1. Distinct structures between star-forming and quiescent galaxies
    - 1.3.2. Indications of the inside-out growth
    - 1.3.3. Indications of the inside-out quenching
  - 1.4. Open questions and aims of this thesis
2. Data sample
  - 2.1. Sample galaxies in the local universe
  - 2.2. Sample galaxies at high redshift
  - 2.3. Imaging data-set
    - 2.3.1. Reasons why using imaging data-set
    - 2.3.2. Imaging data-set from GALEX and SDSS
    - 2.3.3. Imaging data-set from CANDELS and 3D-HST
  - 2.4. Ability of the rest-frame FUV-NIR photometric SED on breaking degeneracies existing in model SEDs
3. Methodology: pixel-to-pixel SED fitting
  - 3.1. Analysis of imaging data-set
  - 3.2. Construction of model SEDs

- 3.3. SED fitting with Bayesian statistics approach
- 3.4. Example of the pixel-to-pixel SED fitting result
4. Spatially resolved distributions of SFR and stellar mass in massive disk galaxies at  $z \sim 0$ 
  - 4.1. Spatially resolved star formation main sequence (SFMS) in massive disk galaxies at  $z \sim 0$
  - 4.2. Spatially resolved SFMS as a function of distance from the global SFMS
  - 4.3. Understanding the scatter of the spatially resolved SFMS
  - 4.4. Radial profiles of stellar mass surface density, SFR surface density, and sSFR
  - 4.5. Spatially resolved SFR and stellar mass in barred- and non-barred galaxies
5. Spatially resolved distributions of SFR and stellar mass in massive disk galaxies at  $z \sim 1$ 
  - 5.1. Spatially resolved SFMS in massive disk galaxies at  $z \sim 1$
  - 5.2. Radial profiles of stellar mass surface density, SFR surface density, and sSFR of massive disk galaxies at  $z \sim 1$
  - 5.3. Investigating galaxies with high possibility being experiencing gas compaction event (i.e. blue nugget phase) which will lead to the onset of inside-out quenching
6. Connecting local and high- $z$  samples: empirical model for the evolution of the surface density radial profiles of massive disk galaxies over the last 10 Gyrs
  - 6.1. Observed evolutionary trend of the spatially resolved SFMS at  $0 < z < 1$
  - 6.2. Connecting the  $z \sim 0$  and  $z \sim 1$  samples: looking for the progenitors and descendants galaxies
  - 6.3. Empirical model for the evolution of the surface density radial profiles at  $0 < z < 1$
  - 6.4. Radial profile of the quenching timescale
  - 6.5. Reproduction of the observed evolutionary trend of the spatially resolved SFMS by the evolutionary empirical model
7. Summary and future prospects
8. Appendix A: Reliability of the pixel-to-pixel SED fitting method
9. Appendix B: Integrated and spatially resolved  $UVJ$  diagram

### Abstract

It has been established that star formation activities in the universe were in their maximum rate about 10 Gyrs ago ( $z \sim 2$ ; an epoch commonly called as the cosmic noon) after which most galaxies undergoing quenching of star formation activity. Despite the decreasing global average of star formation activity over the last 10 Gyrs, stellar mass buildup in the universe were still progressing. About 50% of the current stellar mass density in the universe is built over the last  $\sim 8.7$  Gyrs ago. How galaxies quench their star formation activities and build their stellar masses during the cosmic afternoon epoch (i.e. an epoch after the cosmic noon) is still unclear. In order to understand that and furthermore study the spatially resolved quenching process and stellar mass buildup in galaxies, information on the spatially resolved star formation rate (SFR) and stellar mass ( $M^*$ ) of galaxies over wide redshift range is needed. In this thesis, we study the spatially resolved distributions of SFR and  $M^*$  in massive disk galaxies at  $0.01 < z < 0.02$  and  $0.8 < z < 1.8$  and infer the evolution of surface density radial profiles of massive disk galaxies over the last 10 Gyrs. We derive the spatially resolved SFR and  $M^*$  in a galaxy using our

established spatially resolved spectral energy distribution (SED) fitting method, namely pixel-to-pixel SED fitting. In this method, spatially resolved SEDs of a galaxy are fitted to a set of model SEDs using Bayesian statistics approach to obtain the spatially resolved (at  $\sim 1$  kpc-scale) SFR and  $M^*$  of the galaxy. We construct spatially resolved SEDs, which covers rest-frame far-ultraviolet (FUV) to near-infrared (NIR), of a galaxy at  $0.01 < z < 0.02$  by combining imaging data-set from GALEX and SDSS. For the sample galaxies at  $0.8 < z < 1.8$ , we use imaging data-set from CANDELS and 3D-HST, which gives a similar rest-frame FUV to NIR coverage.

We find a relation between SFR surface density and  $M^*$  surface density at sub-galactic scale ( $\sim 1$  kpc) namely spatially resolved star formation main sequence (SFMS), which is hold at  $z \sim 0$  and  $z \sim 1$ . In massive star-forming disk galaxies at  $0.8 < z < 1.8$  that reside on the global SFMS, this relation is linear over entire  $M^*$  surface density range, while in massive disk galaxies with lower global specific SFR ( $sSFR = SFR/M^*$ ) at both  $0.8 < z < 1.8$  and  $0.01 < z < 0.02$  redshift ranges, the spatially resolved SFMS has a 'flattening' trend at high  $M^*$  surface density end. The spatially resolved SFMS evolves with cosmic time by decreasing  $sSFR$  (SFR surface density/ $M^*$  surface density) over entire  $M^*$  surface density range with systematically larger decrease at high  $M^*$  surface density region compared to that at low  $M^*$  surface density region leading to an increasing prominence of the 'flattening' at high  $M^*$  surface density end. The 'flattening' trend at high  $M^*$  surface density end of the spatially resolved SFMS is consistent with a suppression of  $sSFR$  in the central region as shown in the  $sSFR$  radial profile. The evolutionary trend shown in the spatially resolved SFMS is consistent with the evolutionary trend of the  $sSFR$  radial profile, which shows decreasing  $sSFR$  with cosmic time over entire radii with systematically larger decrease in the central region compared to that in the outskirts, agrees with the 'inside-out' quenching scenario. The above evolutionary trend of  $sSFR$  radial profile combined with an observed tendency of increasing bulge fraction with decreasing global  $sSFR$  suggests a formation and growth of bulge as galaxies undergoing the inside-out quenching. In order to quantitatively examine evolution of the spatially resolved SFR and stellar mass of massive disk galaxies, we construct an empirical model for the evolution of the surface density radial profiles (i.e. SFR surface density radial profile,  $M^*$  surface density radial profile, and  $sSFR$  radial profile). The empirical model could connect between the evolution of the SFR surface density radial profile and resolved stellar mass growth depicted by the evolution of the  $M^*$  surface density. The empirical model suggests that massive disk galaxies undergoing steady stellar mass buildup and quenching of star formation that proceed in 'inside-to-outside' manner.

## 別 紙

### 論文審査の結果の要旨

Abdurrouf 氏の博士論文は、過去 100 億年前から現在の宇宙に渡る大質量円盤銀河の内部での星形成史と星質量の集積史を明らかにし、現在の宇宙に見られる円盤銀河の内部構造が宇宙の歴史の中でどのように確立してきたのかを調べることを目的としている。2 本の査読付き出版論文に基づき博士論文を取りまとめている。現在の宇宙の銀河については GALEX 衛星とスローンデジタルスカイサーベイの紫外線から可視の波長域に渡る撮像データを用い、100 億年前の銀河についてはハッブル宇宙望遠鏡の紫外線から赤外線波長域に渡る撮像データを用いて解析を行っている。これらの撮像データはそれぞれの時代の銀河のスペクトルを静止波長で同じ波長領域を同程度の波長分解能でサンプルしており、また空間スケールでのサンプリングもそれぞれの宇宙で 1-2kpc 程度と似通った値になっている。

銀河内部の構造を分解した撮像データを用いて、銀河の場所ごとのスペクトルエネルギー分布を求める上で、情報を失うことなく高い信号ノイズ比で議論をするために、スペクトルが似た近い領域のみをビンニングするという新しい手法が導入された。また広帯域撮像データによるスペクトルエネルギー分布に対してベイズ統計の手法を用いて、星質量と星形成率という観測量により比較的つよく制限される推定量に絞って推定を行う新しい独自の手法を導入している。

この解析の結果、大質量円盤銀河の内部では全体として星形成率が下がる方向に進化していること、また特に中心から外側に向かって星形成の停止が伝搬していること、を発見した。さらに定量的な解析から、100 億年前から現在に向かって見られている星形成による各半径での星質量の増加は、この期間の円盤内部での星集積の様子とコンシステントなものであることが発見された。これは星が形成された後に動径方向に大きな移動を起こすことのないモデルで円盤銀河の構造の進化を説明することが出来ることを示している。

このように、大質量銀河の円盤内部の星形成と星質量の集積の様子を明らかにし、大質量円盤銀河の構造の進化の様子を描き出したことは大きな研究成果であると認める。このような研究を遂行し、2 本の査読論文として出版した上で、博士論文としてまとめたことは、自立して研究活動を行うに必要な高度の研究能力と学識を有することを示している。したがって、Abdurrouf 氏が提出した博士論文は、博士（理学）の学位論文として合格と認める。