

The distance measurement to M31 from detached eclipsing binaries with HSC

HSC を用いた分離食連星法によるアンドロメダ銀河の距離決定

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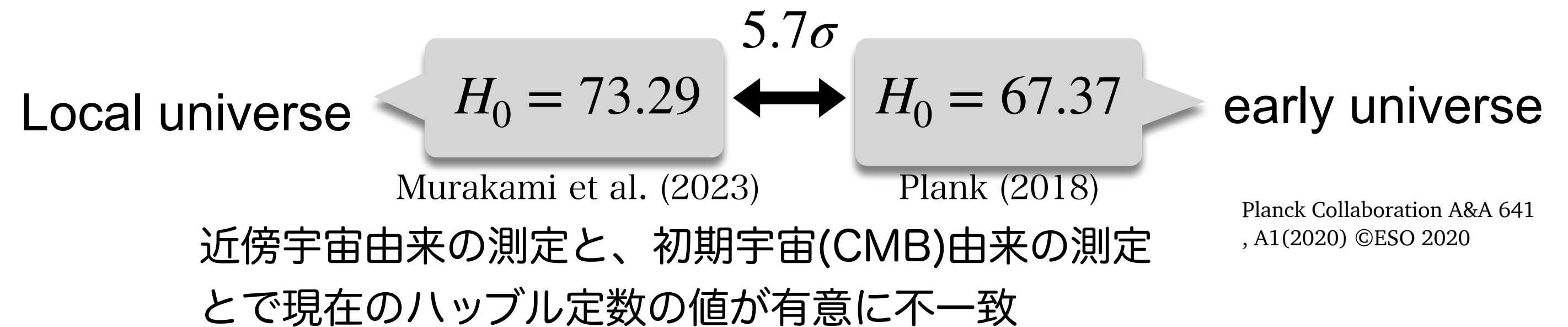
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with K. Hotokezaka [1], K. Masuda [2], S. Sugiyama [3], M. Takada [1], K. Wong [1],
N. Yasuda [1], R. Lupton [4], K. Kashiya [5], Y. Shiraishi [1]

[1] UTokyo [2] Osaka Univ. [3] Univ. of Pensilvenia [4] Princeton Univ. [5] Tohoku Univ.

🎲 Hubble tension ハッブル定数問題

- discrepancy of H_0 (the present Hubble constant)
Local universe vs early universe (CMB)
- New physics ? 標準モデルの綻びか?
beyond Λ CDM, standard particle physics ?
- Systematics ? それとも系統誤差か?
ex) Cepheid problem ?
- Local distance ladder 近傍距離はしご
only 3 galaxies accesible for calibration



🎲 This project

- We aim to add M31 as a new calibrator.
- We have to determine the absolute distance to M31.
- Subaru/HSC is an unique facility for this end.

すばる望遠鏡でアンドロメダ銀河までの絶対距離を
高精度に測定し、4つ目のアンカー銀河へ！



Image Credit : Kiso Observatory, UTokyo (東京大学木曽観測所)

- There are diverse distance indicators

Cepheids (セファイド型変光星) TRGB (Tip of Red Giant Branch)

Ia supernova (Ia型超新星) redshift (赤方偏移)

We need to calibrate zero point for these indicators

- Local distance ladder

- The first rung

geometry => Cepheids

第一段：幾何(絶対)距離 => セファイド等

- The second rung

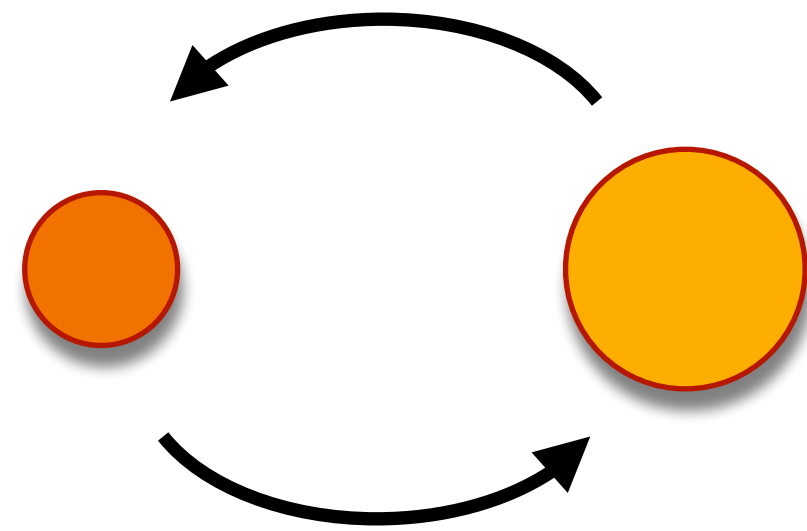
Cepheids => Type Ia supernova

第二段：セファイド等 => Ia型超新星

- The third rung

Type Ia supernova

第三段：Ia型超新星



Detached Eclipsing Binary (分離食連星)

- ① light curve (光度曲線)
- ② colour-surface brightness relation
(色-表面輝度)
- ③ radial velocity (視線速度)

$$d^2 = \frac{1}{4\pi^2} \frac{F}{F^{\text{obs}}} \left(\frac{R}{a} \right)^2 P^2 v^2$$

- d : geometric distance (絶対距離)
 F : absolute flux (絶対フラックス)
 F^{obs} : apparent flux (観測フラックス)
 R : star radius (天体半径)
 a : semi major axis (軌道長半径)
 P : Period (周期)
 v : radial velocity (視線速度)

We need to use enough short period ($\lesssim 5$ days) eclipsing binaries.

- we can measure radial velocities with enough precision

視線速度を十分な精度で測るには、5日以内くらいの周期が必要

If using brighter stars, not many main sequence.

- Eclipsing binaries of red giants with short period are not detached.

巨星で短い周期だと分離食連星にならない。

We need deep time-series data.

- We want to measure ~ 22 mag stars.
- 90 secs for 1 exposure.

深い時系列データが必要 (90秒露光で22等くらいまで見たい)。

We also need wide field of view covering M31.

M31 をカバーする広い視野が必要。

Only Subaru can do that.

- ✓ located in the northern hemisphere => We can see M31
- ✓ wide field of view => We can cover M31 using HSC
- ✓ 8 m class telescope => We can reach 22 mag.

北天を見渡せ、アンドロメダをカバーする広い視野と
8m鏡による深い撮像能力を併せ持つ、すばる望遠鏡なら可能である



M31 DEBs with Subaru

S24B-069

Naokawa et al.

7 half nights (3.5 nights) allocated

Good quality in 6 half nights

7半夜中 6半夜で品質の良いデータを取得

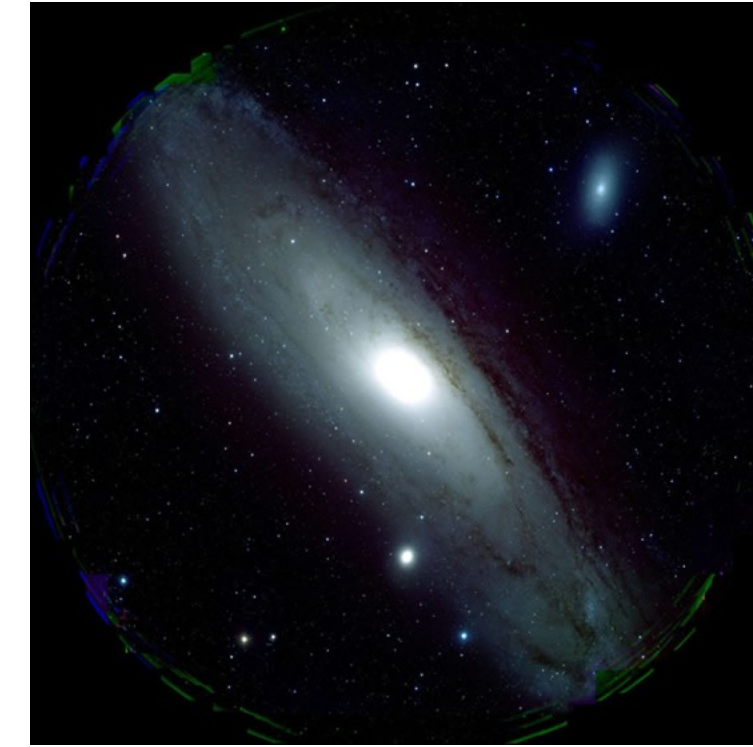
2024

2025

Under reduction 解析中

- new ~100 DEBs in M31 ?

HSC

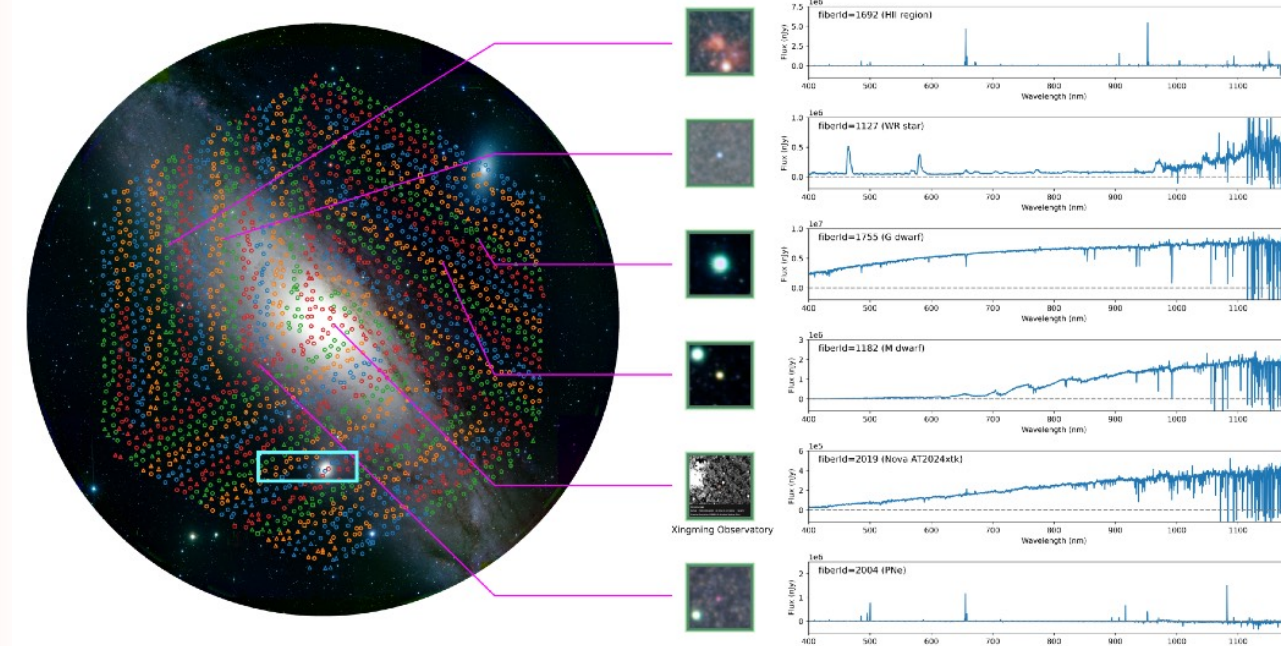


Credit : HSC Project/国立天文台

- a few more surveys ?
for more samples
for longer light curves

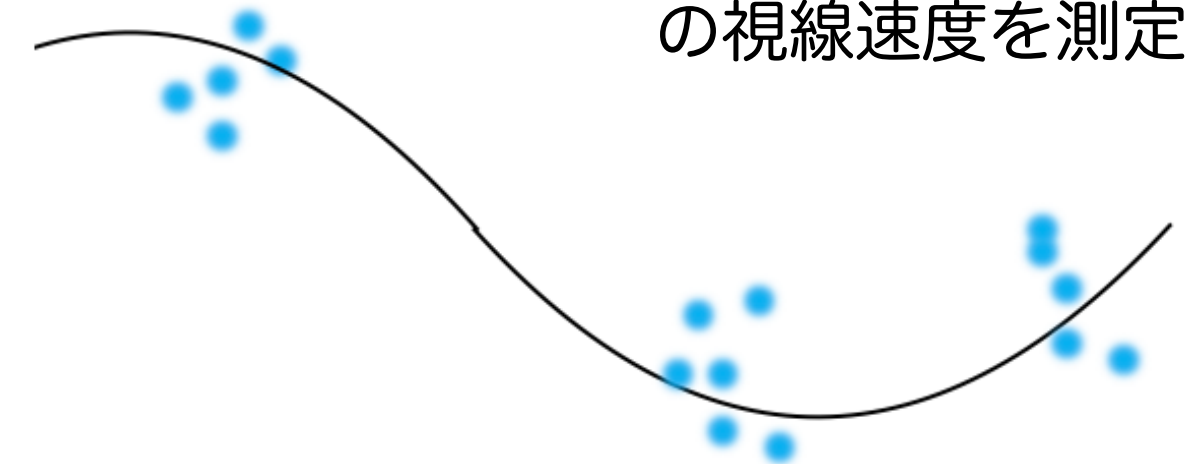
分離食連星のサンプル数と
光度曲線のデータを増やすため
に、あと何度かHSCサーベイ？

PFS



Credit: PFS Project/Kavli IPMU/NAOJ

- PFS observations for radial velocities ?
PFS を用いて M31 の分離食連星(数百個)
の視線速度を測定？



Requests to community : Cadenced observation option

Queue : no cadance (time critical) option

Classical : unit is a half night (we need multiple separated ~45 min exposures.)

45分ほどの露光を間隔を開けて何度も行ふことが必要だが、現行の共同利用枠には
そのような観測が可能な選択肢がない。

Summary

- Hubble tension & local distance ladder
 - Singal of new physics or a systematics ?
 - Establishing robust distance ladder is quite important.
 - Only 3 galaxies are used for anchors.
 - M31 has a potential to be an additional anchor.

Mahalo nui loa !

Thank you !

近傍の距離はしごの信頼性を向上させ、ハッブル定数問題等に挑むため、アンドロメダ銀河の幾何距離測定が極めて重要

- This project
 - Search hundreds of Detached Eclipsing Binaries (DEBs) in M31 with Subaru.
 - Measure the absolute distance to M31 via the DEBs
 - We did the first survey with HSC in 2024B.
 - A few more survey with HSC and follow-up with PFS ?

すばる望遠鏡で M31 の分離食連星を搜索して、幾何距離を測定する！

Request !!

Cadence mode for PFS
Shorter unit for Classical
PFS でケーデンス観測を可能に
(クラシカルを半夜単位から1/4夜
や1/8夜単位へ等)

