B02 Subaru spectroscopy
status report of FY2021

Masahiro Takada
(Kavli IPMU)

KAVLI IPMU INSTITUTE FOR THE PHYSICS AND MATHEMATICS OF THE UNIVERSE

東京大学 THE UNIVERSITY OF TOKYO

wpi

Dark matter search with Subaru

ν e p bacteria Human Earth Sun

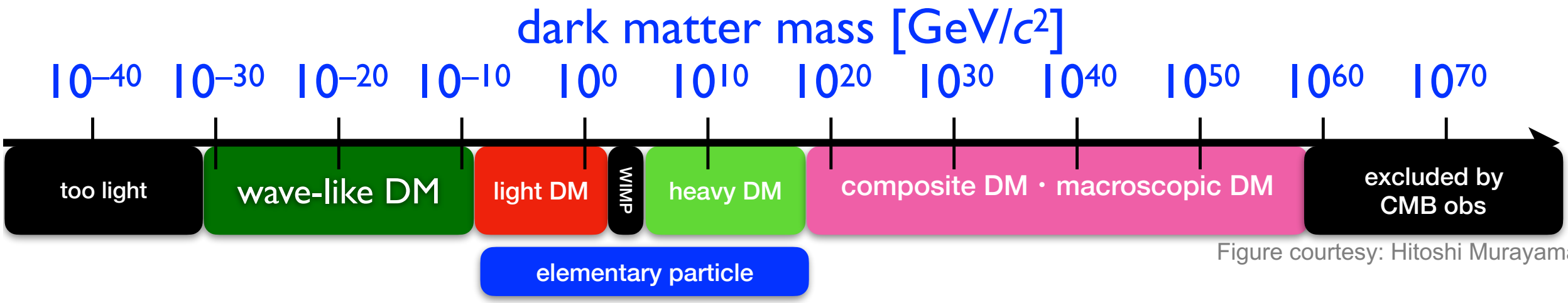

Figure courtesy: Hitoshi Murayama

Subaru spectroscopy
(axions, FDM, SIDM, WIMP; dSphs, MW streams …)
see Jowett, Ando-san, Horigome-san, Chiba-san, Hayashi-san's … talks!

Subaru microlensing
(axion stars, PBHs, …)

1 Subaru PFS night = ~50 Keck nights (even $10B JWST can't do it)

Unique capabilities of PFS

- A natural path forward after HSC (imaging)
- Very expensive, international projects, being led by Kavli IPMU (NAOJ, Princeton, Caltech, JHU, MPA/MPE, ASIAA, Brazil, LAM, China) (see Naoyuki's talk)
- Unique capabilities! (large aperture + wide field-of-view + high multiplexity + ideal site); game changer
- Our survey will start in 2024, finally since the initial start of 2007!
- Mentioned in several places of Astro2020 (PFS is only the Japan-led experiment/project mentioned, except for TMT, KAGRA, Hyper-Kamiokande, …)

Decadal Survey on Astronomy and Astrophysics 2020 (Astro2020)

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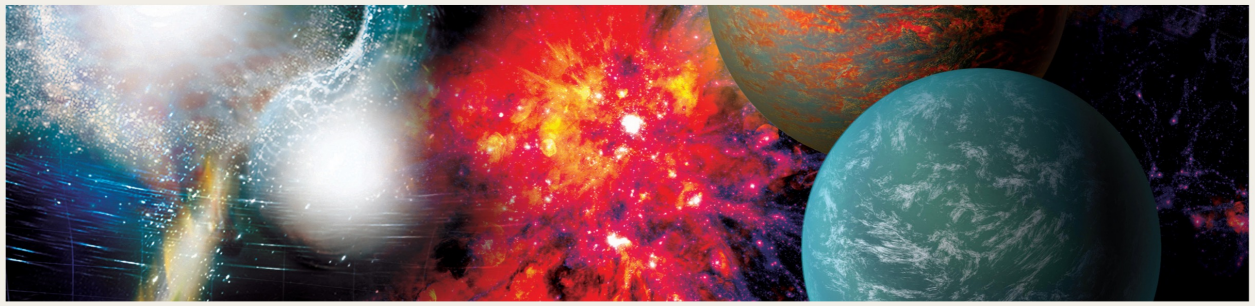
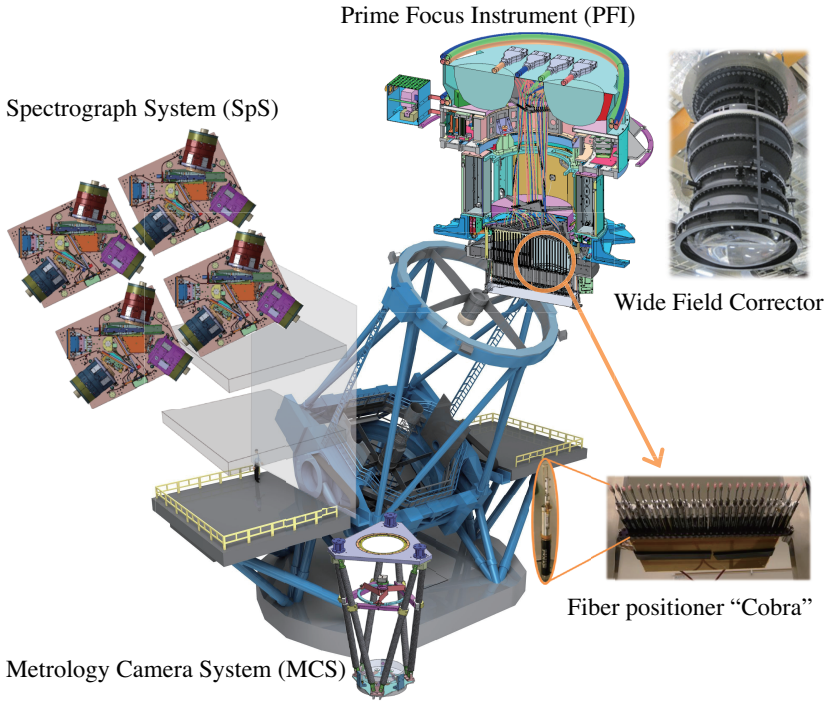




Instrument/Tel	Collecting area [m²]	FoV [deg²]	Multiplex
Subaru/PFS	**52.8**	**1.25**	**2400**
Keck DEIMOS	76.0	0.015	150
VLT/MOONS	52.8	0.14	500/1000
Mayall 4m/DESI	11.4	7.08	5000
VISTA/4MOST	10.7	4.00	1400
WHT/WEAVE	13.0	3.14	1000

8m-class telescopes

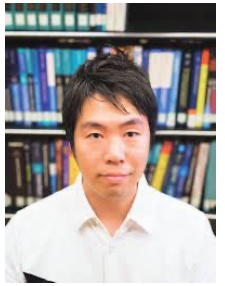
4m

"multiplex"=capability of simultaneous spectroscopic obs at one time

Team members

- Masahiro Takada (Kavli IPMU: PFS Science WG co-chair)
- Naoyuki Tamura (Kavli IPMU: PFS Project Manager/System Engineer)
- Collaborator: Kiyoto Yabe (Kavli IPMU: Survey planning coordinator)
- Collaborator: Yuki Moritani (IPMU⇒NAOJ: Commissioning observation coordinator)
- Tomomi Sunayama (Nagoya U.: PFS Cosmology WG co-chair)
- Ryuichi Takahashi (Hirosaki U.: Cosmological simulations)
- Miho Ishigaki (NAOJ: PFS Galactic Archaeology)
- Sakurako Okamoto (NAOJ: PFS Galactic Archaeology)
- New faculty members at Kavli IPMU: Collaborators,
  Jia Liu (neutrino mass), Elisa Ferreira (fuzzy DM)
- New postdoc at Kavli IPMU (from April 2022): Yue Nan (Cosmology)
- Collaborators: Youngsoo Park, Jingjing Shi, …
- Students: Sunao Sugiyama, Toshiki Kurita, Tian Qiu, Akira Tokiwa, Takahiro Taniguchi, Ryo Terasawa, …
- Colleagues in PFS collaboration including Chiba-san, Hayashi-san, … colleagues at Princeton, JHU, Caltech, ASIAA, …


N.Tamura (IPMU)


K. Yabe (IPMU)


Y. Moritani
(IPMU⇒NAOJ)

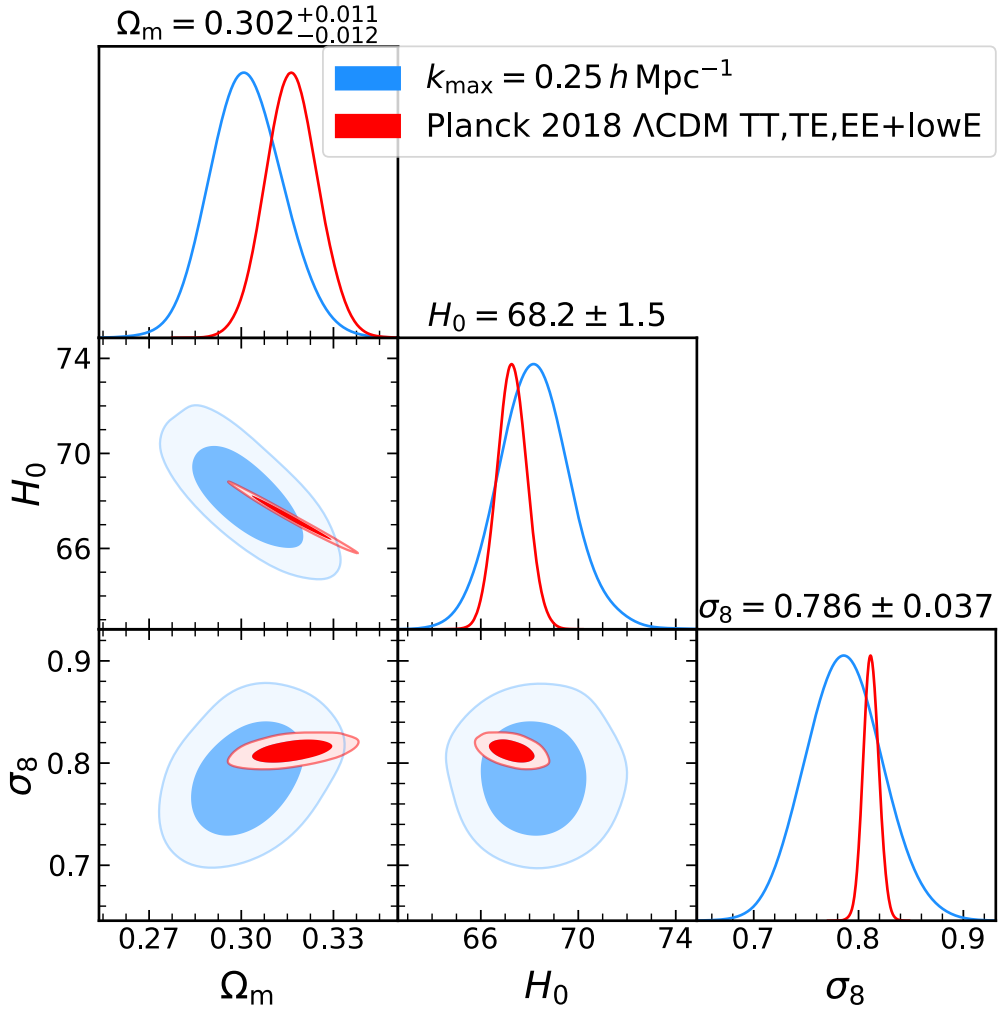

E. Ferreira (IPMU)


Y. Nan
(Hiroshima U. ⇒ IPMU)

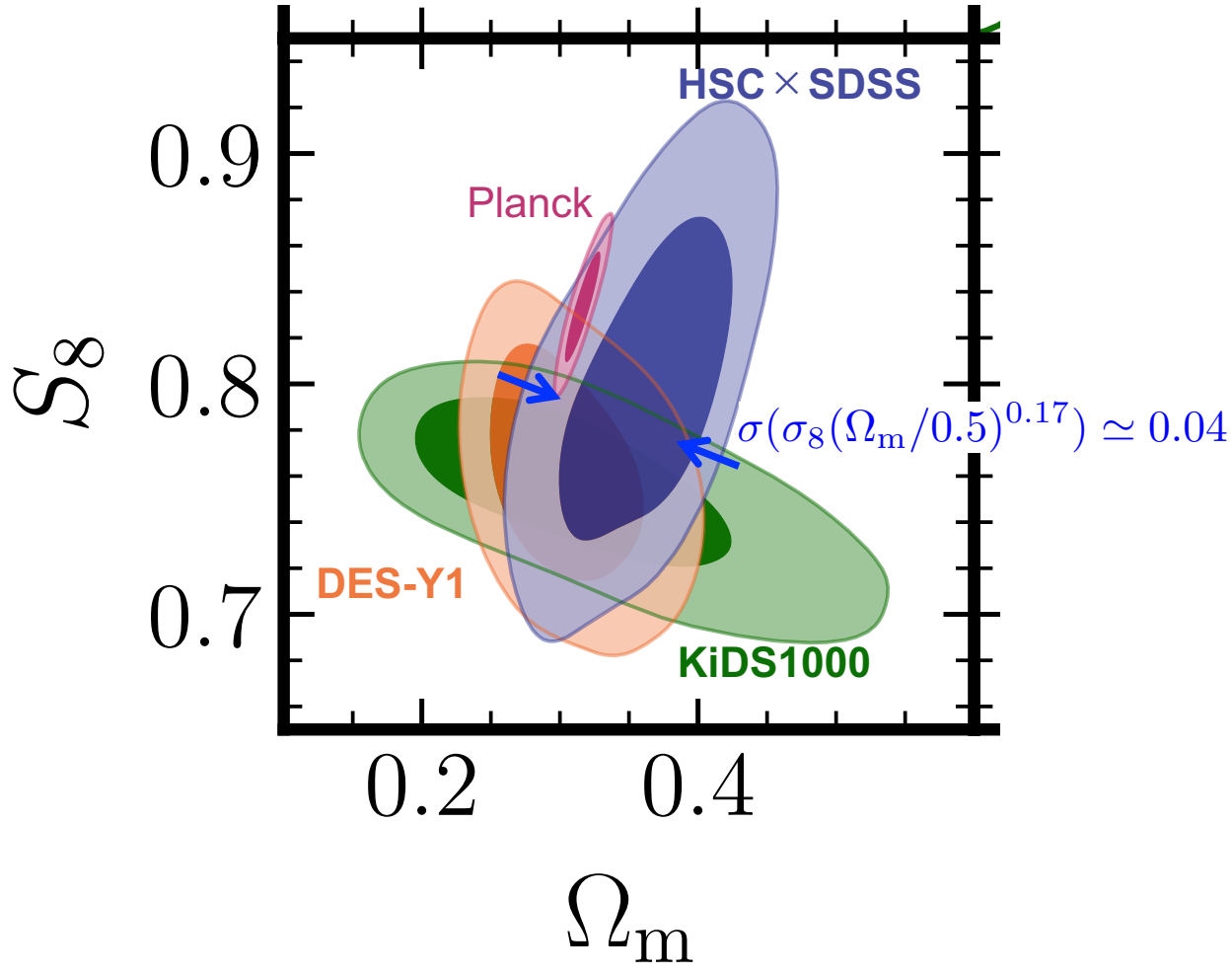
Publications in FY2021

- We are very active: ~22 published papers in FY2021
- Stringent tests of ΛCDM model, with Subaru HSC and SDSS datasets ⇒ S8, sigma8 tension?

Kobayashi, Nishimichi (C02), MT+ PRD in press



Miyatake, Sugiyama, MT+ HSC collaboration



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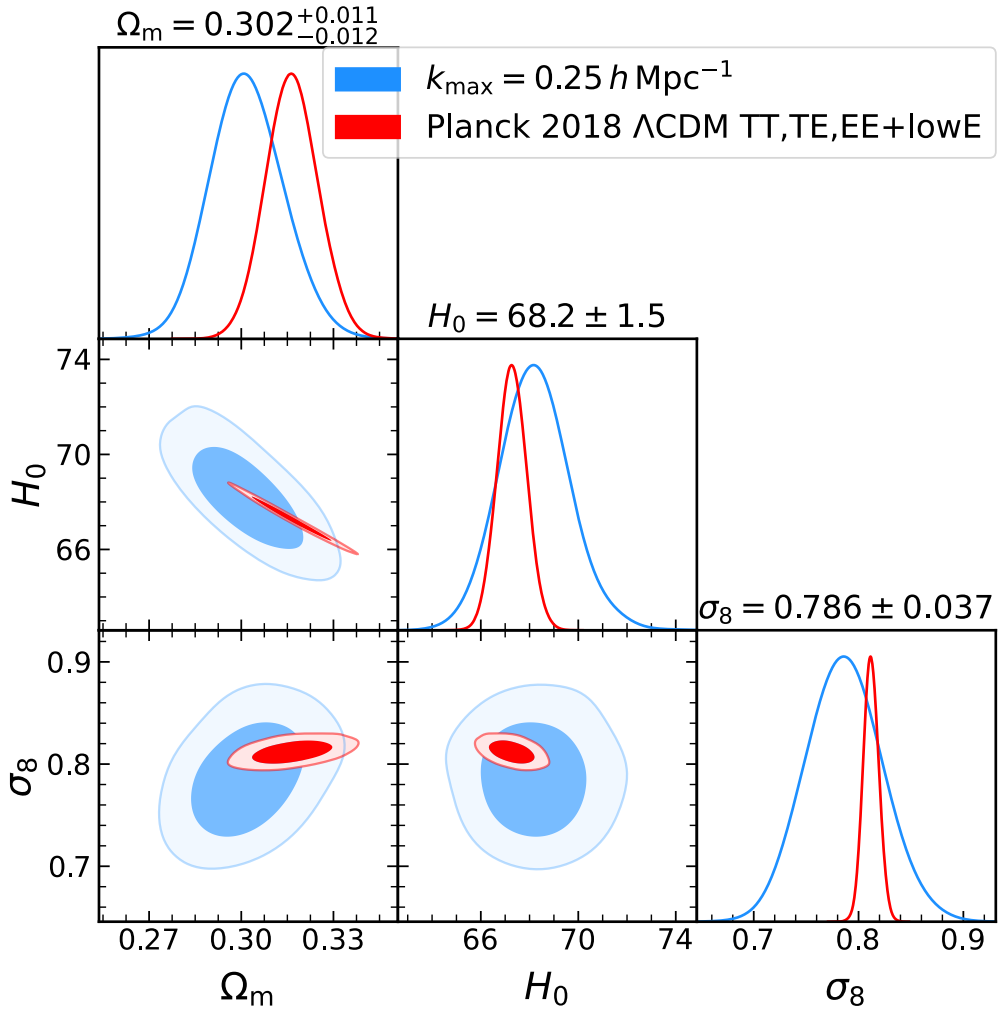
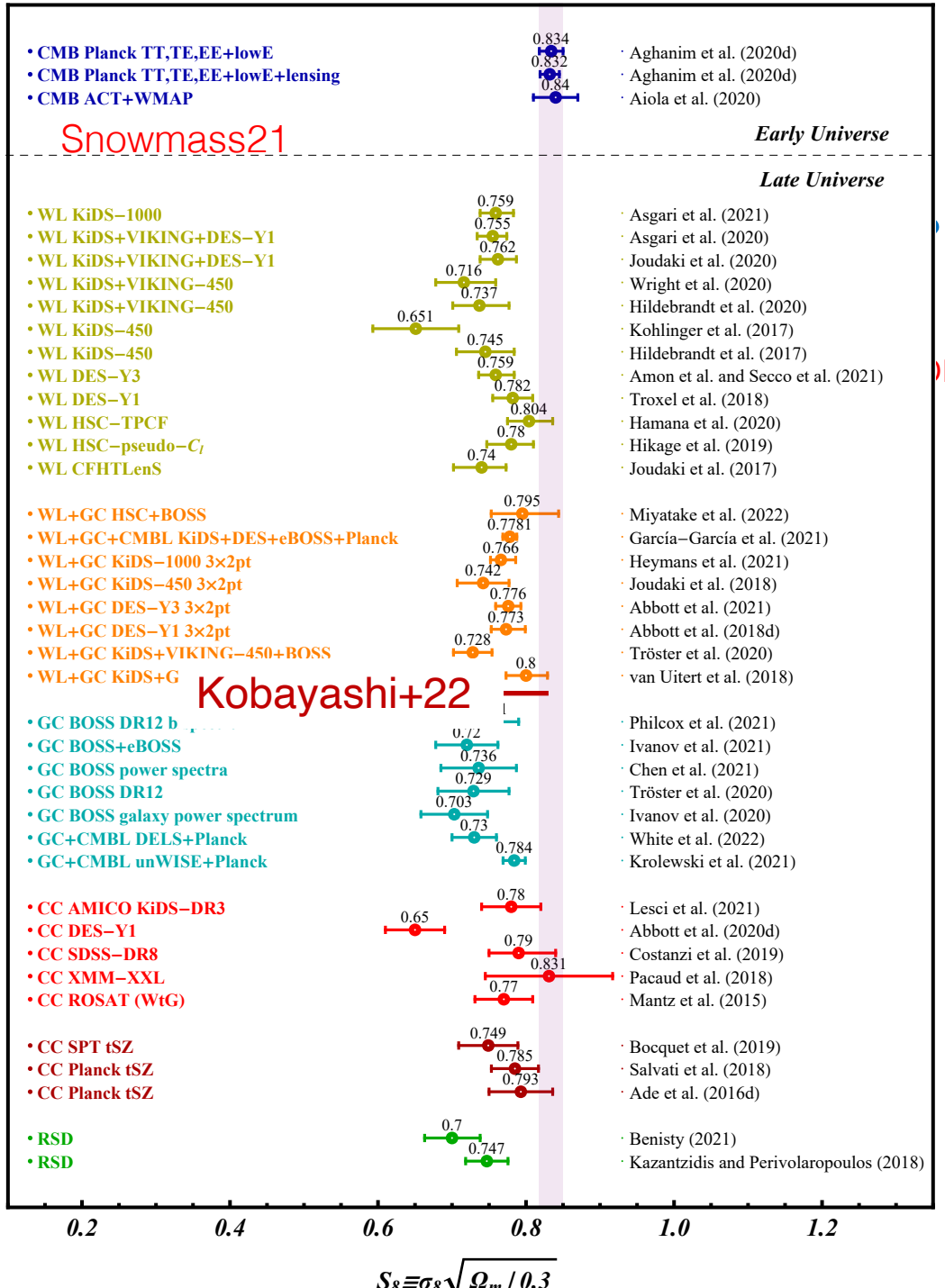




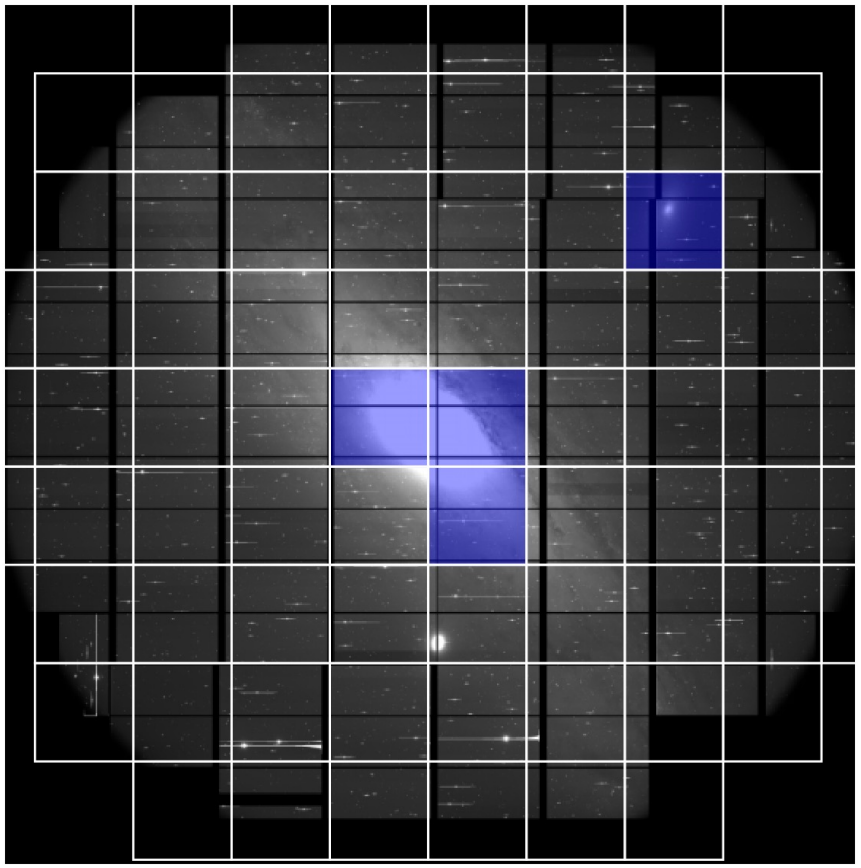
Workshops

- Online meetings are crucial, during the pandemic
- 4 online collaboration meetings during FY2021:
  all-hands collaboration meeting in March 2022; ~180 participants (~100 from abroad)

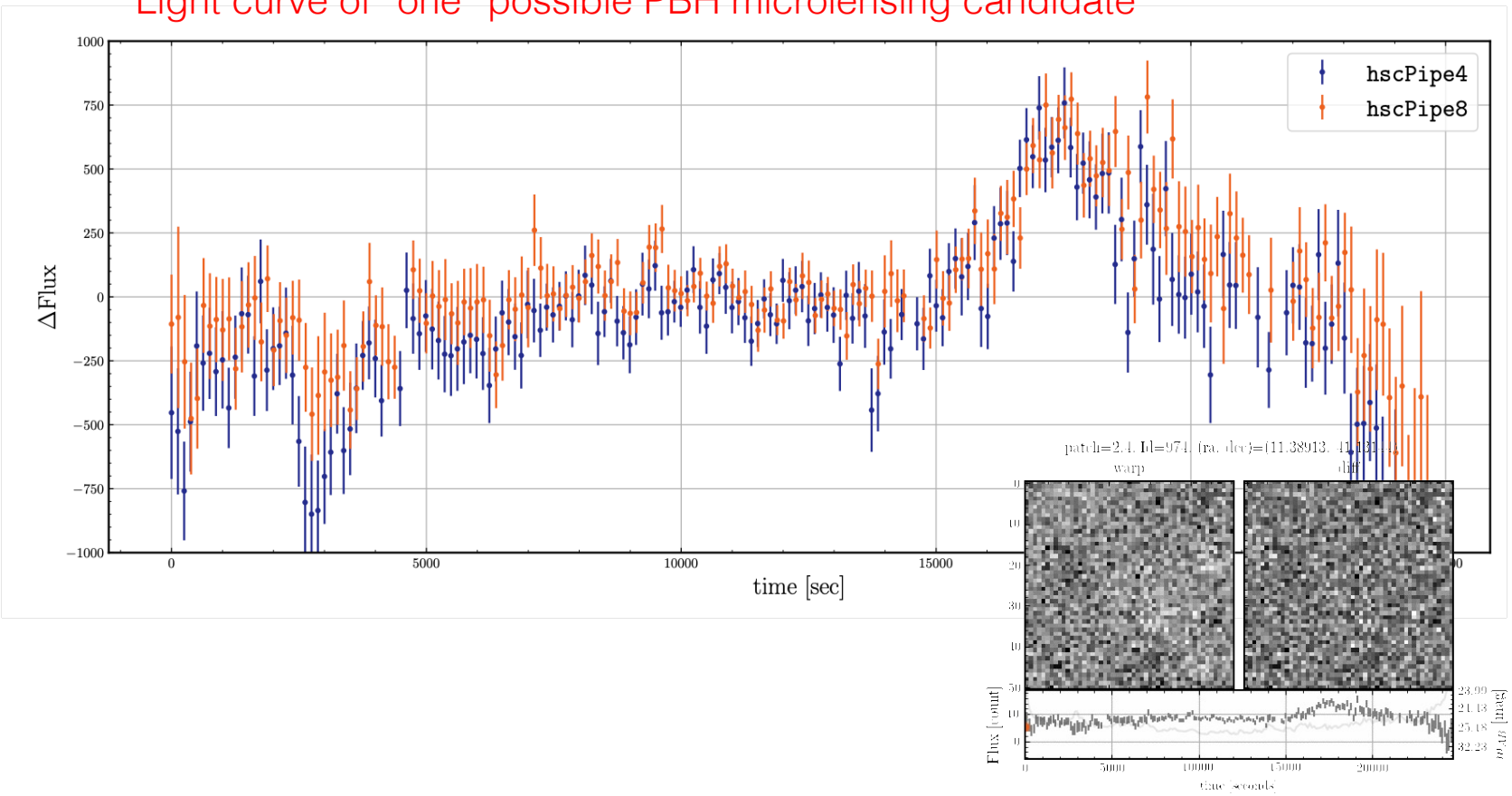
Update on HSC M31 microlensing search of PBHs

- HSC is so powerful! (Niikura + Nature Astronomy, 2019)
- Sunao is leading this project; used the latest HSC pipeline (**`hscPipe8`**) to analyze the HSC data, in collaboration with N. Yasuda (IPMU), T. Ohgami (NAOJ), N. Tominaga (NAOJ), V. Takhistov (IPMU), A. Kusenko (UCLA/IPMU), …

Sunao Sugiyama
(D2, Kavli IPMU)

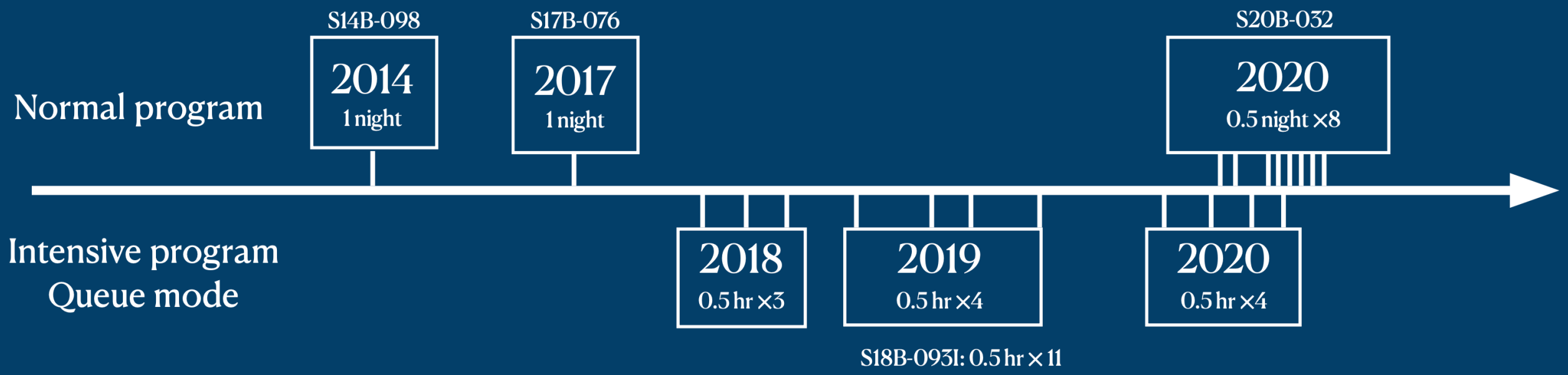


Light curve of “one” possible PBH microlensing candidate



PBH search with new HSC datasets

Sunao Sugiyama
(D2, Kavli IPMU)

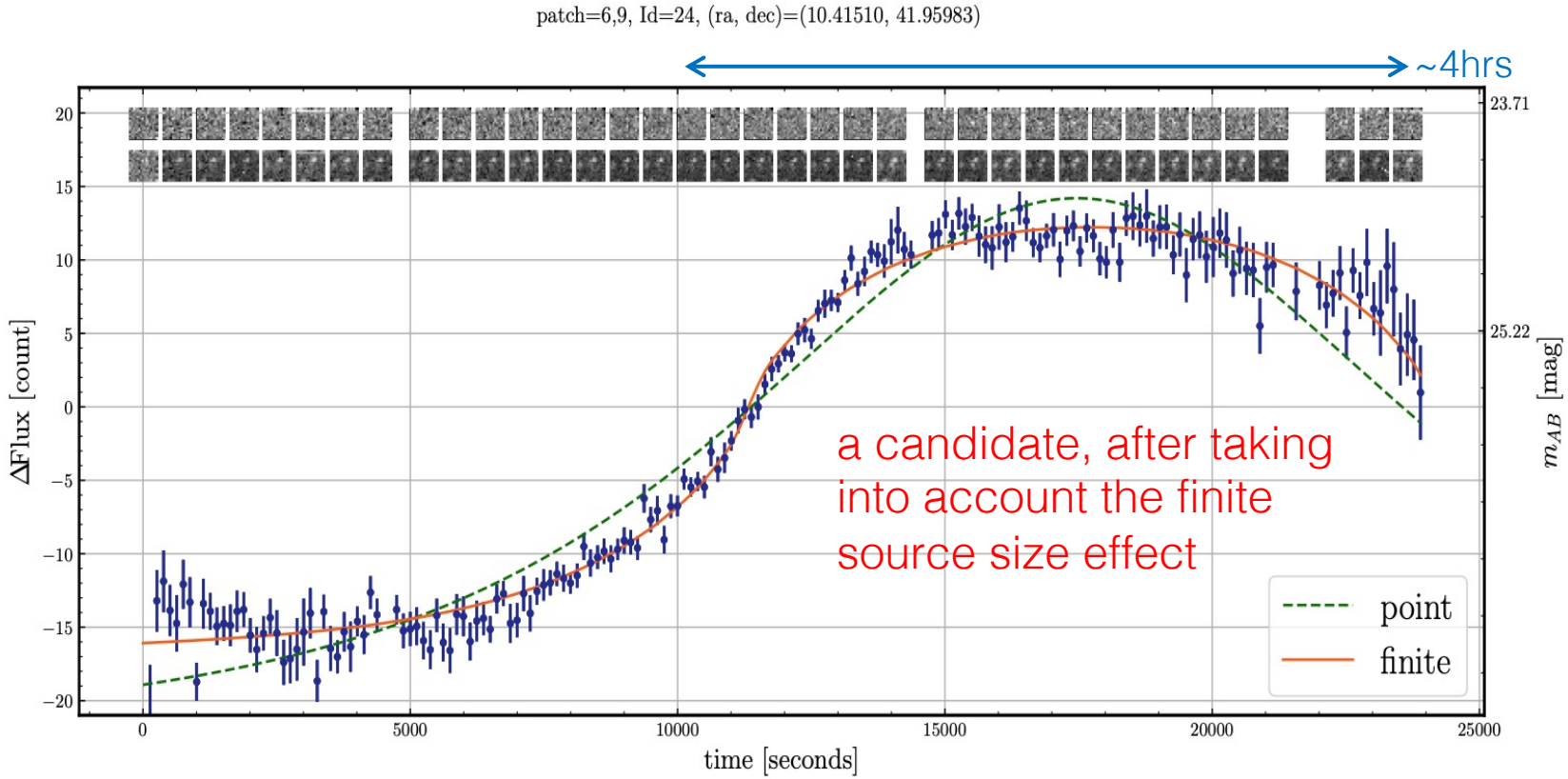


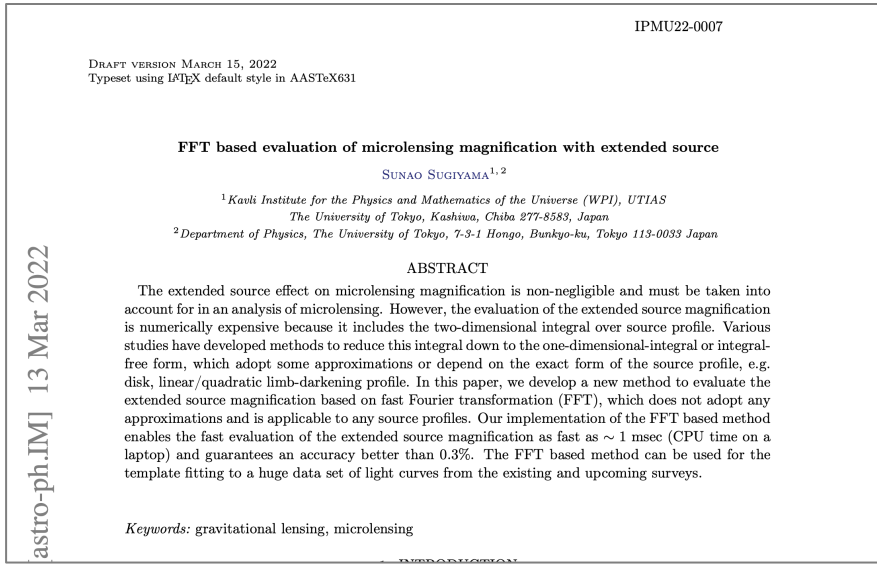
- Sunao has been analyzing these new datasets that can probe PBH over a wide range of mass scales (from Moon to ~10Msun), with the latest pipeline "`hscPipe8`"
- Stay tuned! (Sugiyama et al. in prep.)

PBH search with new HSC data (cont'd)

- Sunao developed the new, very fast (~msec) code/method to compute the effect of finite source size on microlensing light curve, applying the FFT method (**`FFTlog`**), often used in cosmology
- Submitted a "single-authored" paper (Sugiyama, arXiv:2203.06637)

Sunao Sugiyama
(D2, Kavli IPMU)





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FFT based evaluation of microlensing magnification with extended source

Sunao Sugiyama[1,2]

[1]*Kavli Institute for the Physics and Mathematics of the Universe (WPI), UTIAS The University of Tokyo, Kashiwa, Chiba 277-8583, Japan*
[2]*Department of Physics, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033 Japan*

ABSTRACT

The extended source effect on microlensing magnification is non-negligible and must be taken into account for in an analysis of microlensing. However, the evaluation of the extended source magnification is numerically expensive because it includes the two-dimensional integral over source profile. Various studies have developed methods to reduce this integral down to the one-dimensional-integral or integral-free form, which adopt some approximations or depend on the exact form of the source profile, e.g. disk, linear/quadratic limb-darkening profile. In this paper, we develop a new method to evaluate the extended source magnification based on fast Fourier transformation (FFT), which does not adopt any approximations and is applicable to any source profiles. Our implementation of the FFT based method enables the fast evaluation of the extended source magnification as fast as ∼ 1 msec (CPU time on a laptop) and guarantees an accuracy better than 0.3%. The FFT based method can be used for the template fitting to a huge data set of light curves from the existing and upcoming surveys.

Keywords: gravitational lensing, microlensing