# Progress report:
# Constraining ~10Msun primordial black holes with HSC microlensing search of M31 stars
# (S18B-093I)

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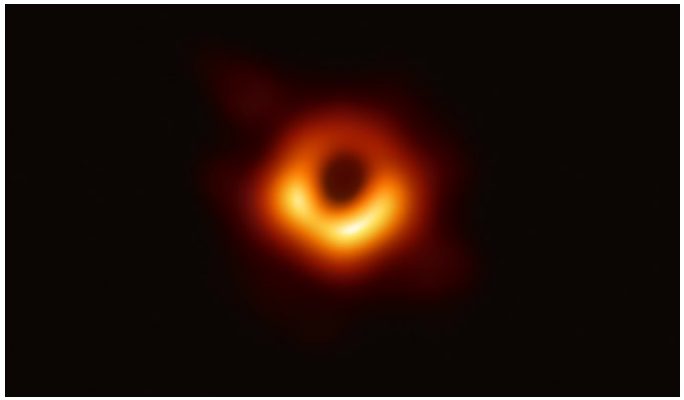
# Primordial black hole (PBH)

black hole



dark matter

PBH

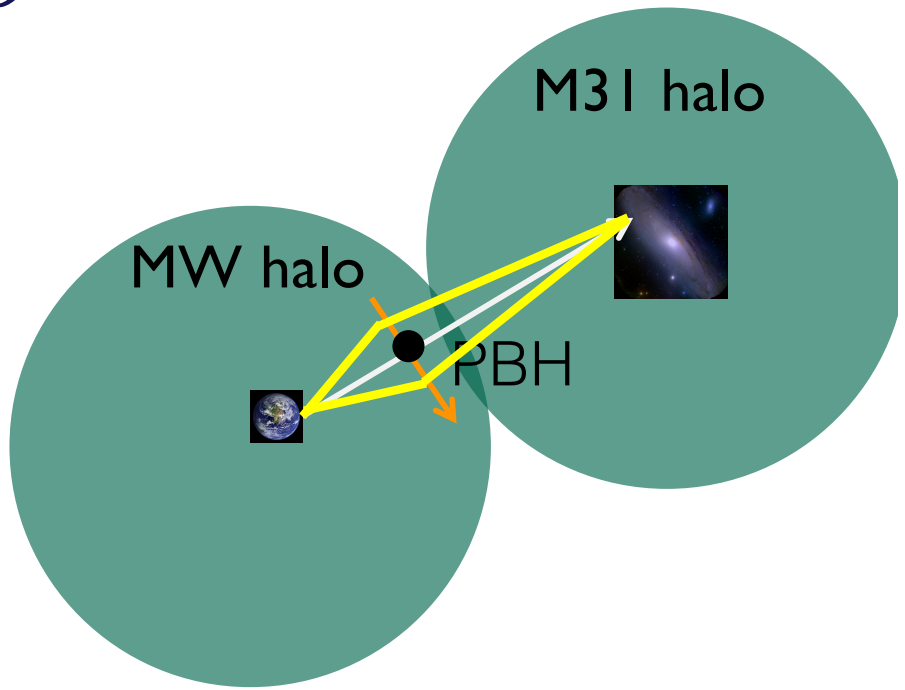
H. Niikura
(PhD 2019)

Sunao Sugiyama
(3rd year student @IPMU)

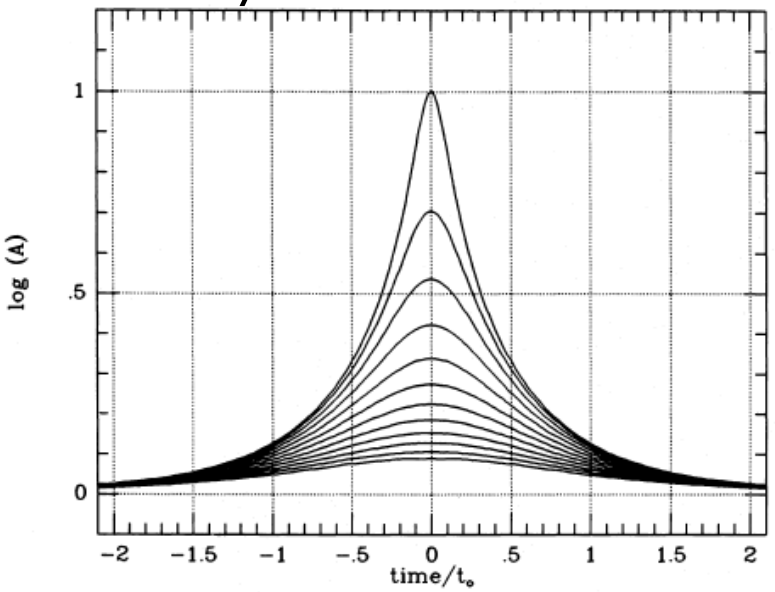
- Black holes can be formed in the early universe (Hawking)
- PBH, if formed, acts as a collision-less dark matter (so is a viable candidate of dark matter)
- If we find any black hole with ~1Msun or smaller, it is a direct evidence of PBH!
- HSC microlensing is very powerful to search for PBHs (already ~250 citations of Niikura et al. 2019)

# PBH microlensing on M31 star

- PBH = a viable dark matter candidate
- Lensed images can't be resolved with optical resolution (~$10^{-8}$ arcsec) ⇒ only light curve is a signal
- Huge volume
- MW/M31 halo ~ $10^{12}$Msun (we assumed NFW models)
- PBH has a peculiar velocity of ~200km/s
- Need to monitor brightness of the same star as a function of "time" (time domain astronomy)




Paczynski 86

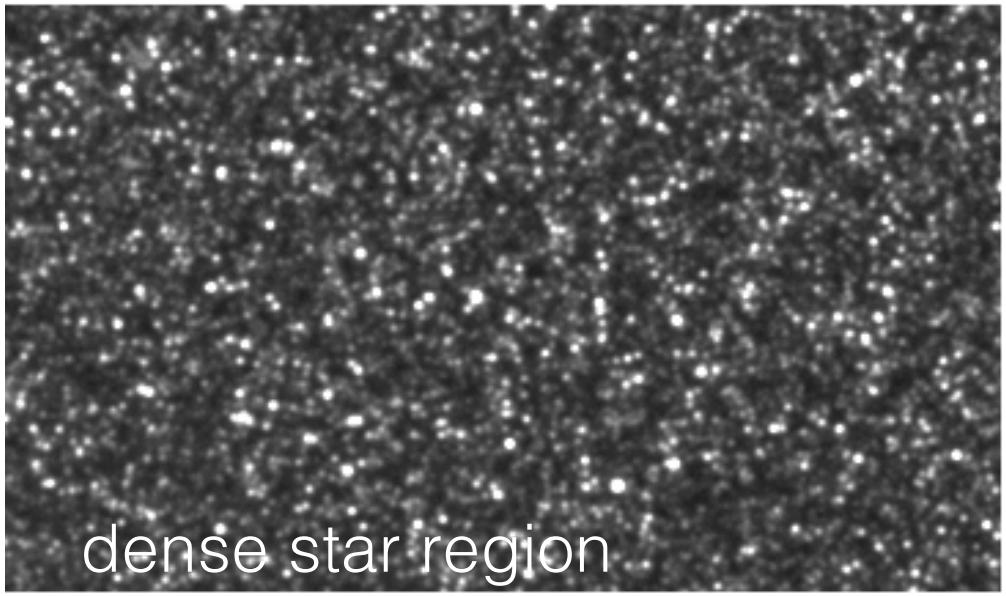


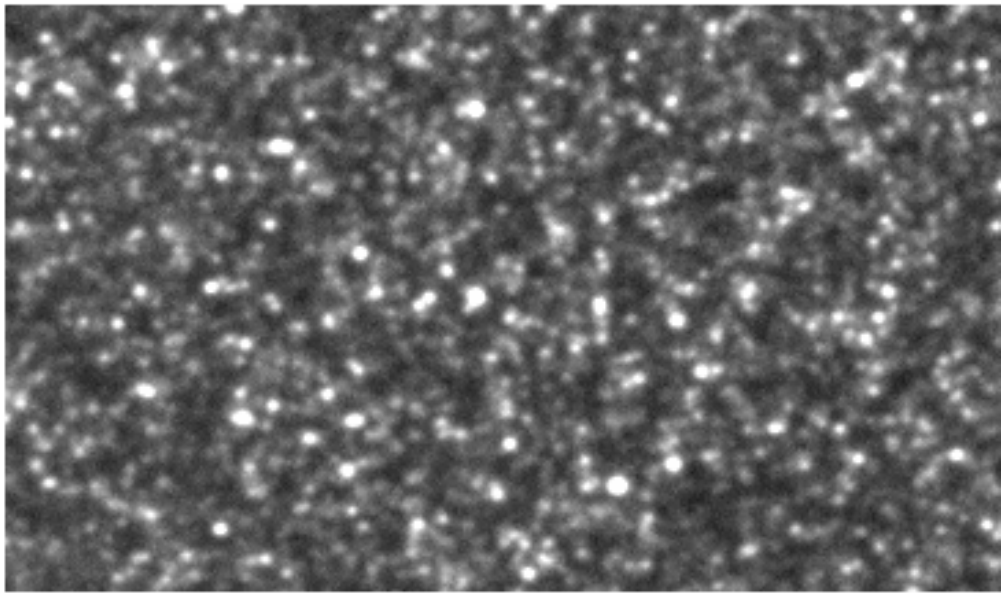

$$R_E = \sqrt{\frac{4\pi G M_{\rm PBH} d(1-d/d_s)}{c^2}}$$

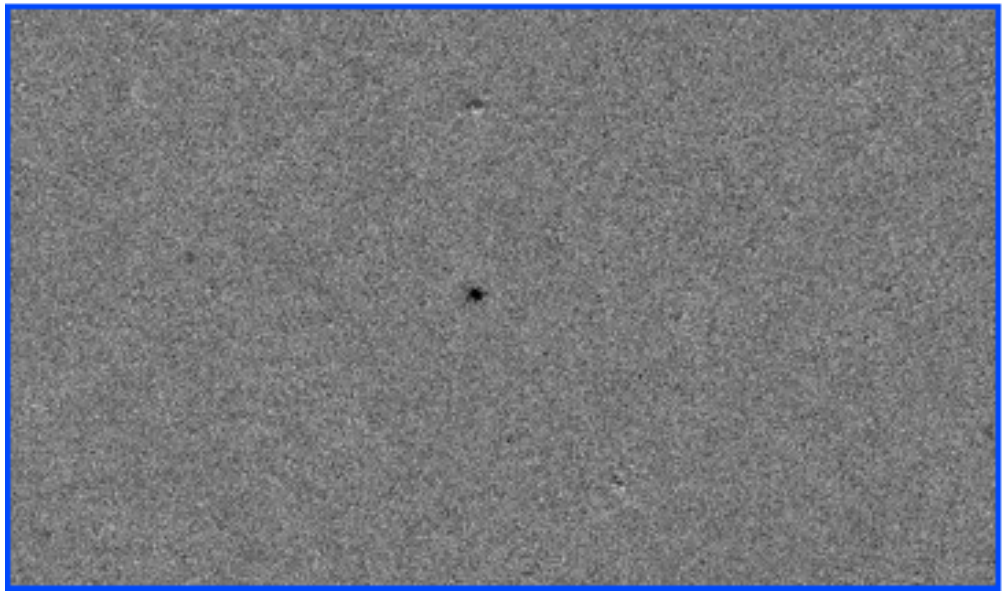
# Pixel lensing: analysis pipeline already developed

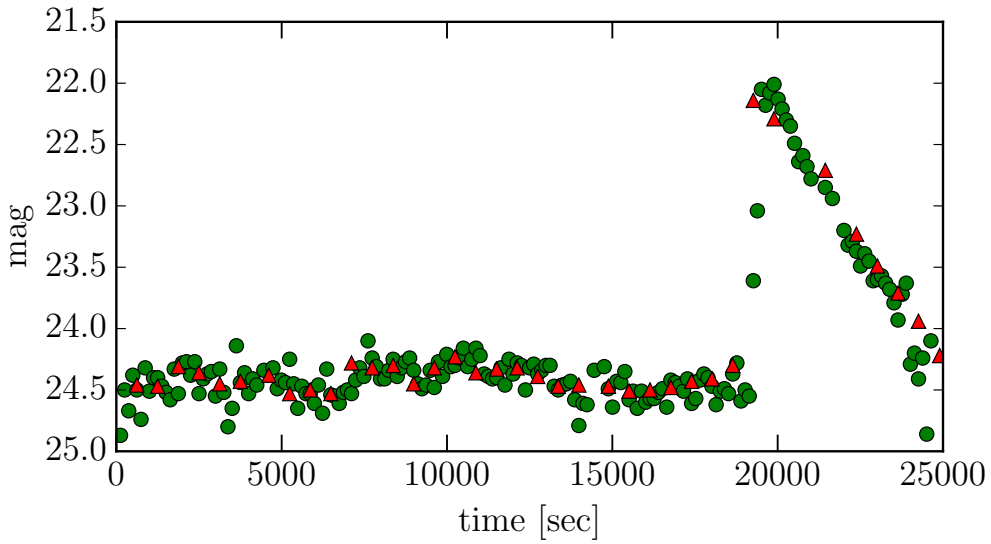
Niikura + 19

Fluxes from multiple stars are overlapped at each position

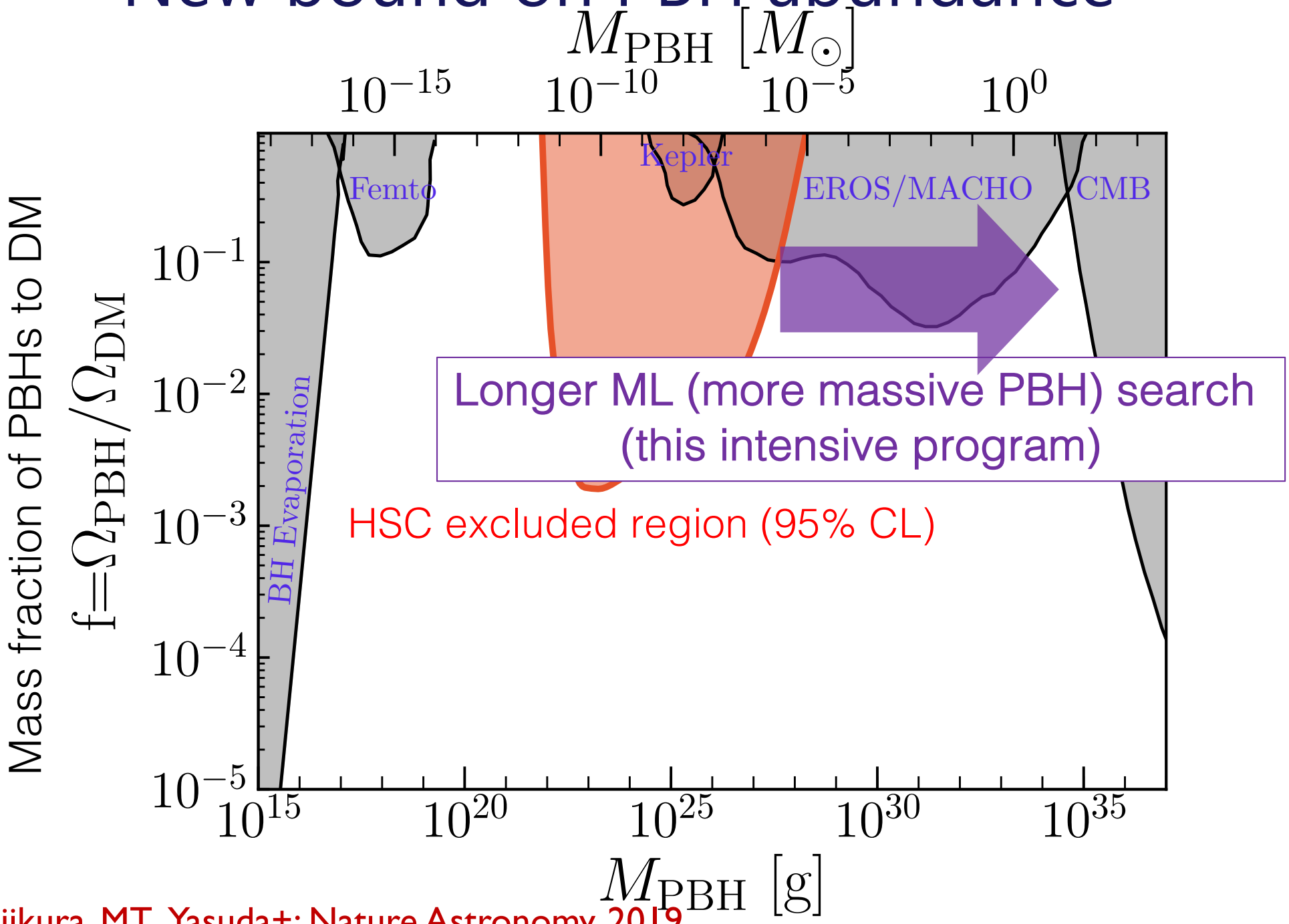






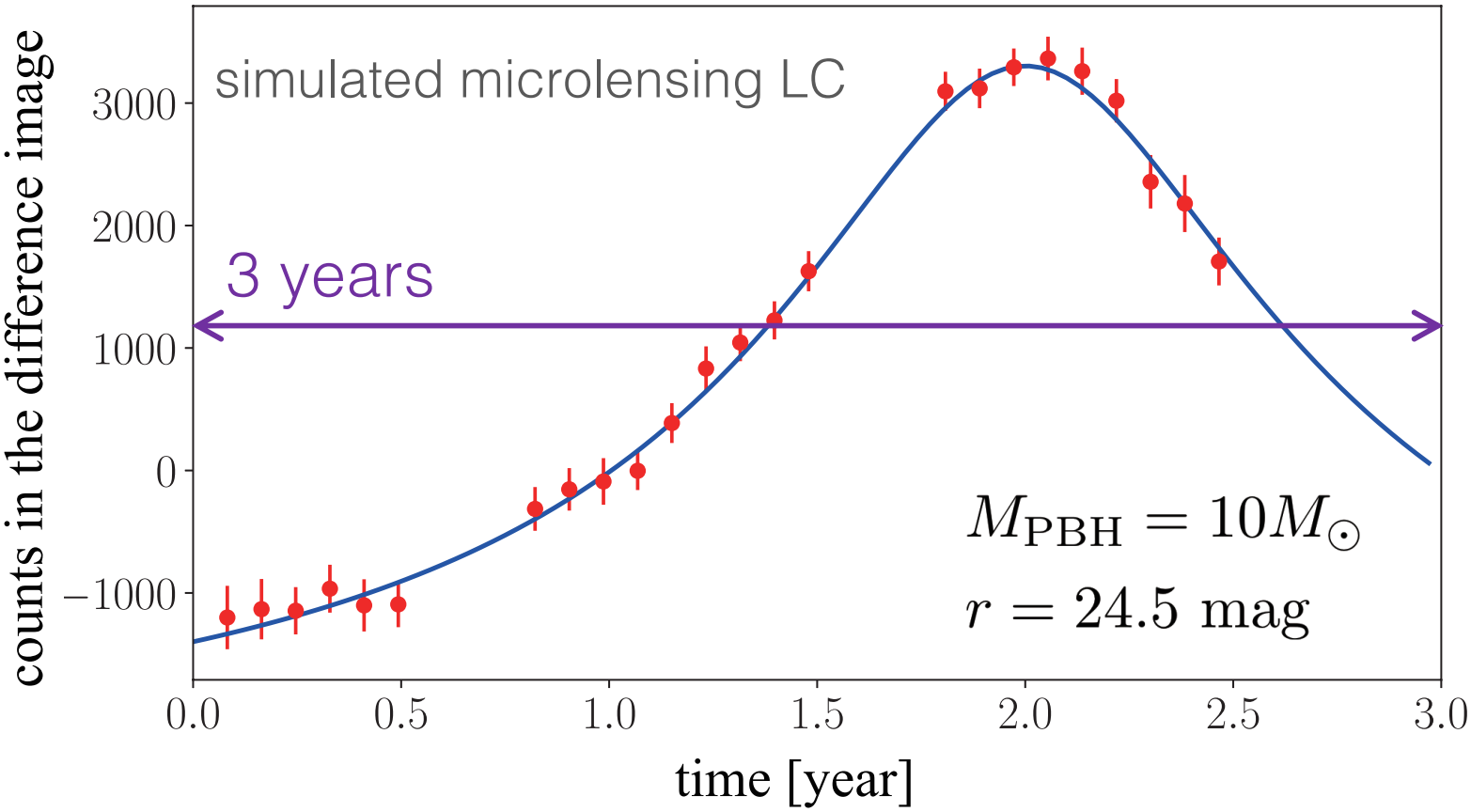
# New bound on PBH abundance

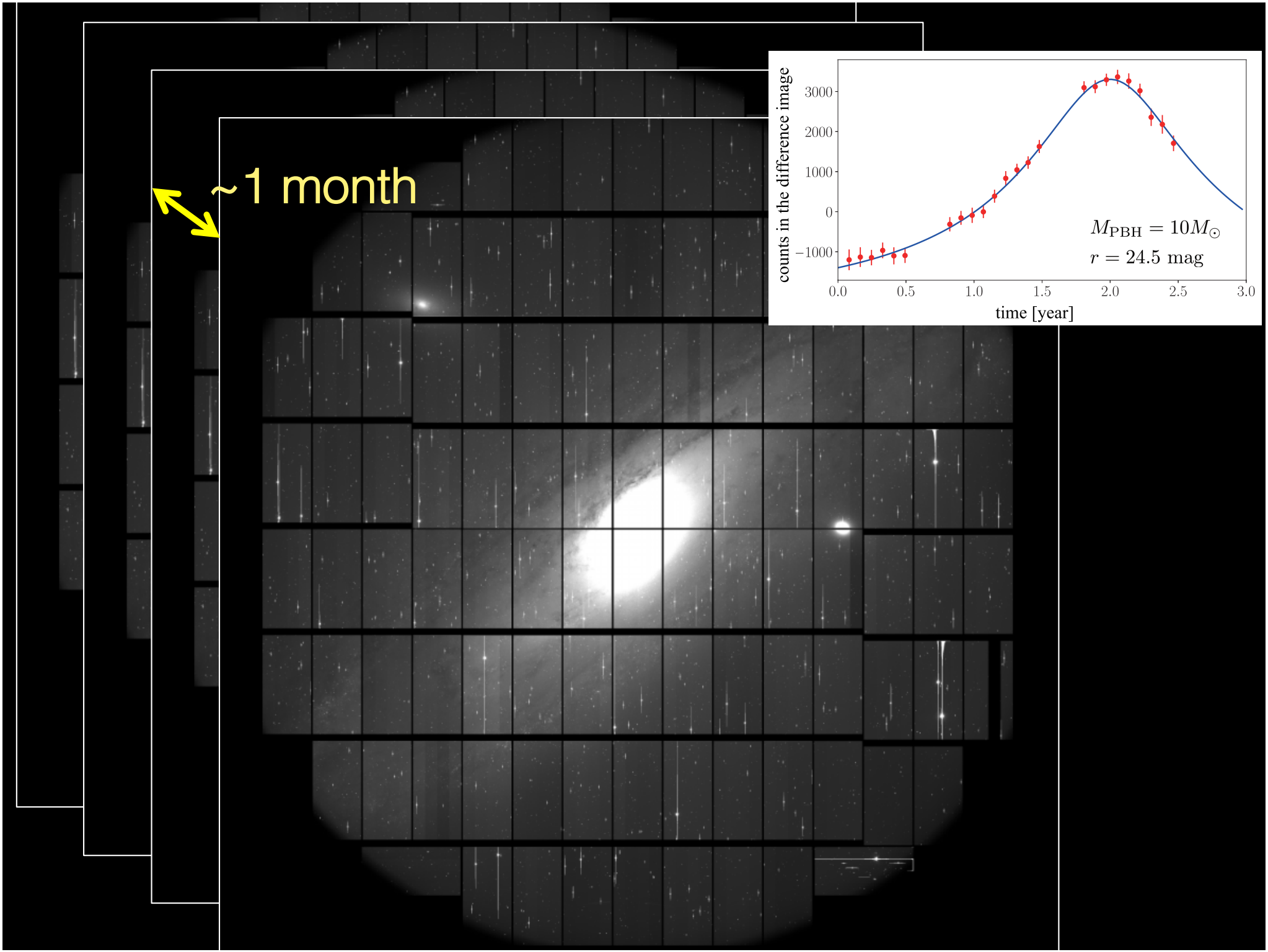



Niikura, MT, Yasuda+; Nature Astronomy, 2019

# S18-093I: Observation strategy

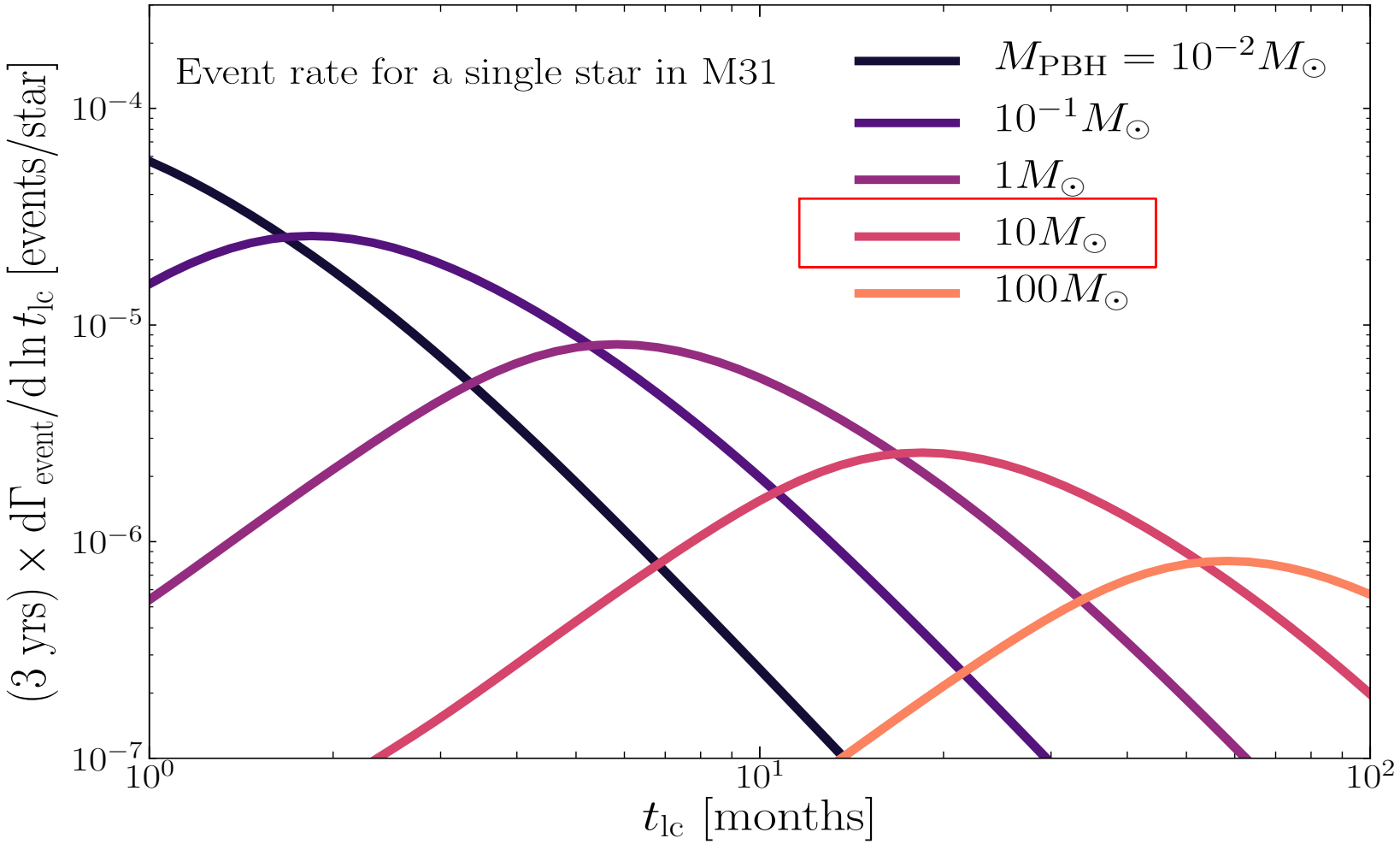
- ~5 × 90 sec exposures in each HSC run of June – Feb each year, both g and r bands (g, r bands needed for testing achromatic nature of microlensing)
- Monitoring HSC obs. of M31 over 3 years (lost some months in S18B semester due to the earthquake/power outage)
- 0.5 nights allocated (S18B – S20B)




~1 month
counts in the difference image
3000
2000
1000
0
−1000
0.0
0.5
1.0
1.5
2.0
2.5
3.0
time [year]
$M_{\rm PBH} = 10 M_\odot$
$r = 24.5$ mag

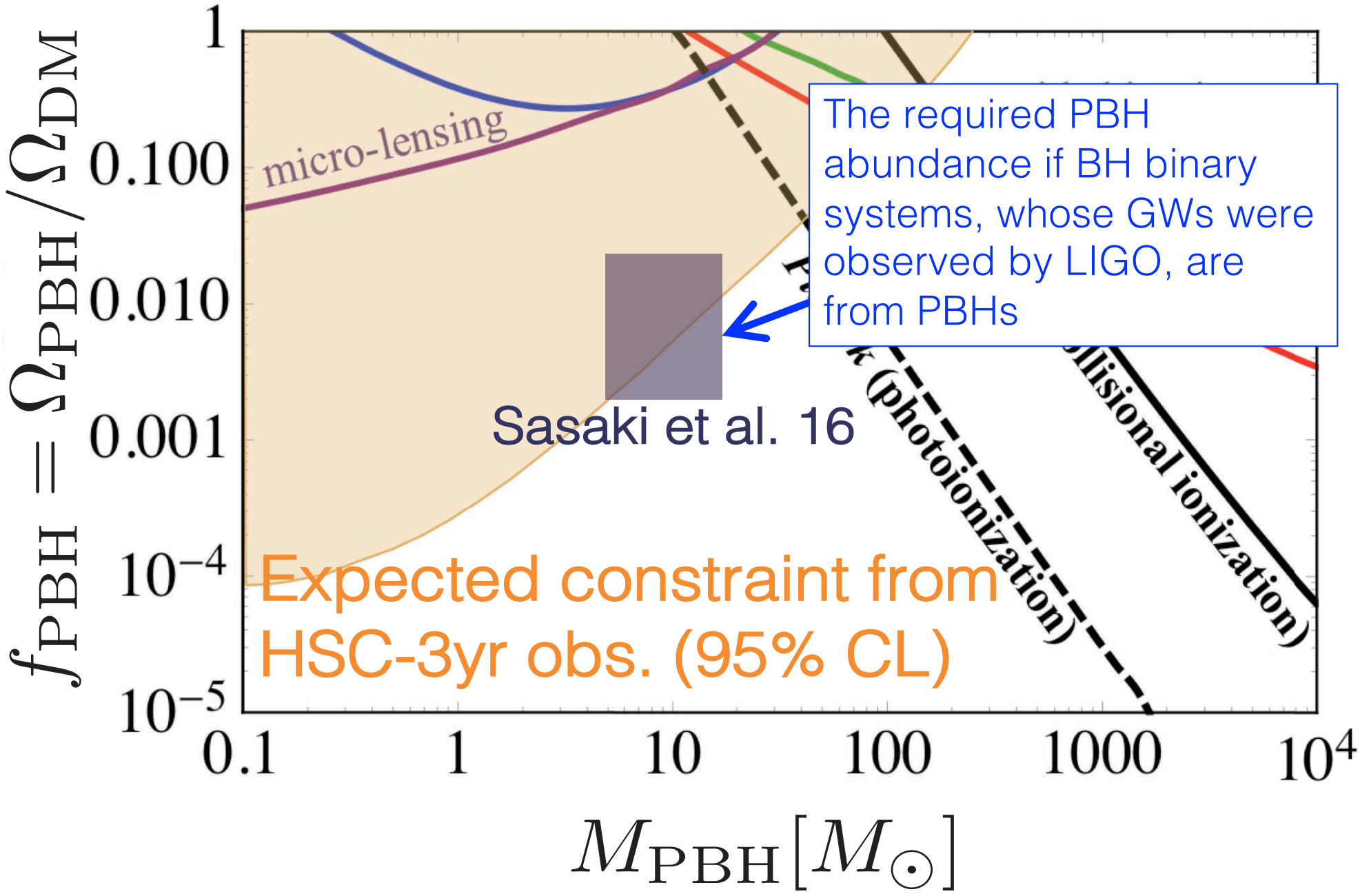
# Event rates of microlensing

$$t_{\rm lc} \simeq \frac{R_{\rm E}}{v} \simeq 25\ {\rm months} \left(\frac{M_{\rm PBH}}{10 M_\odot}\right)^{1/2} \left(\frac{D}{100\ {\rm kpc}}\right)^{1/2} \left(\frac{v}{200\ {\rm km/s}}\right)^{-1}$$




Event rate per **3yr-obs. time** and per **a single star** in M31 for **a given timescale of light curve** (we monitor **~$10^8$ stars** in M31 thanks to FoV and depth of HSC/Subaru)

# Expected PBH constraint



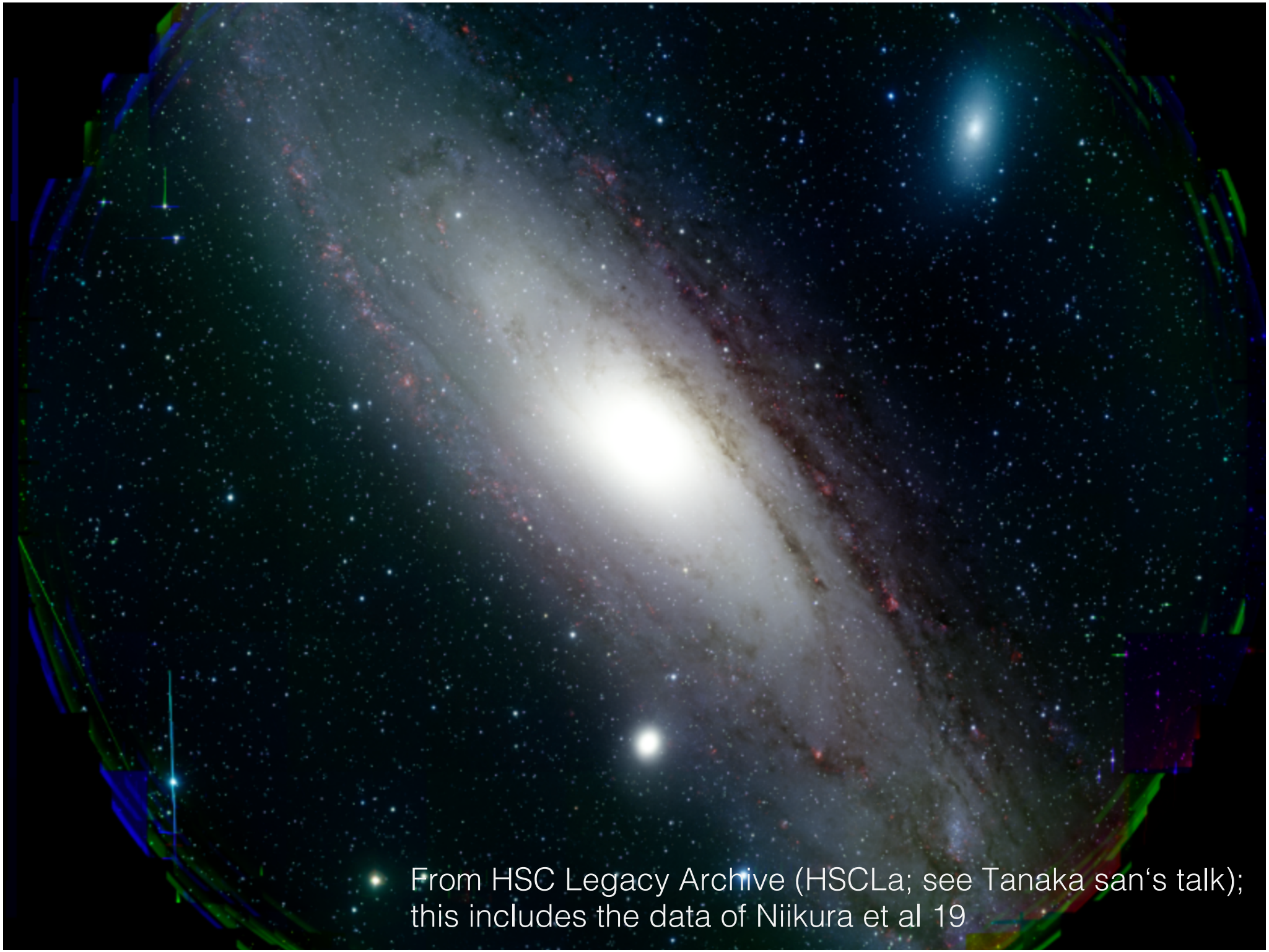
# The current status: observation completed

- M31 is accessible for June - Feb
- The data taken: the observation completed
  - 2018 Nov, r2, 11 × 90sec, ~0.9”
  - 2018 Nov, g, 14 × 90sec, ~0.7”
  - 2018 Dec, r2, 10 × 90sec, ~0.8”
  - 2018 Dec, g, 12 × 90sec, ~0.9”
  - 2019 Jan, g, 19 × 90sec, ~1.0”
  - 2019 June, r2, 4 × 90sec, ~0.8”
  - 2019 Sep, g, 10 × 90sec, ~0.7”
  - 2019 Oct, g, 10 × 90sec, ~0.9”
  - 2020 Oct, g, 10 × 90sec, ~0.9”
  - 2020 Oct, r2, ~20 × 90sec, ~0.7-0.9”
  - 2020 Nov, r2, ~20 × 90sec, ~0.9”
  - 2020 Nov, g, ~13 × 90sec, ~0.9-1.0”

8 epochs (~16 epochs requested)

Total exposure: ~4 hours
(~0.5 nights allocated)

- Sunao Sugiyama (IPMU) is now working very hard on data reduction of the M31 data, using HSCpipe8 (Niikura et al. used HSCpipe4)


From HSC Legacy Archive (HSCLa; see Tanaka san‘s talk);
this includes the data of Niikura et al 19

# Summary

- HSC is the most powerful instrument to search for PBH, which is a viable dark matter candidate
  - This program aims at using HSC data of M31 to test the PBH scenario for LIGO BBH (~40Msun BHs) counterparts
- This intensive program observation completed
  - We got 8 epochs data (~months cadence) so far, compared to ~16 epochs requested (probably because of complication in our requested time allocation)
- Now Sunao Sugiyama (with help from Yasuda san) is working on the data reduction, in combination with other available HSC M31 data (2014, 2015, …)
- Many thanks to staff at the observatory for their support