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Discovery of RCB-type (disappearing) stars from dense-cadence observation of M31

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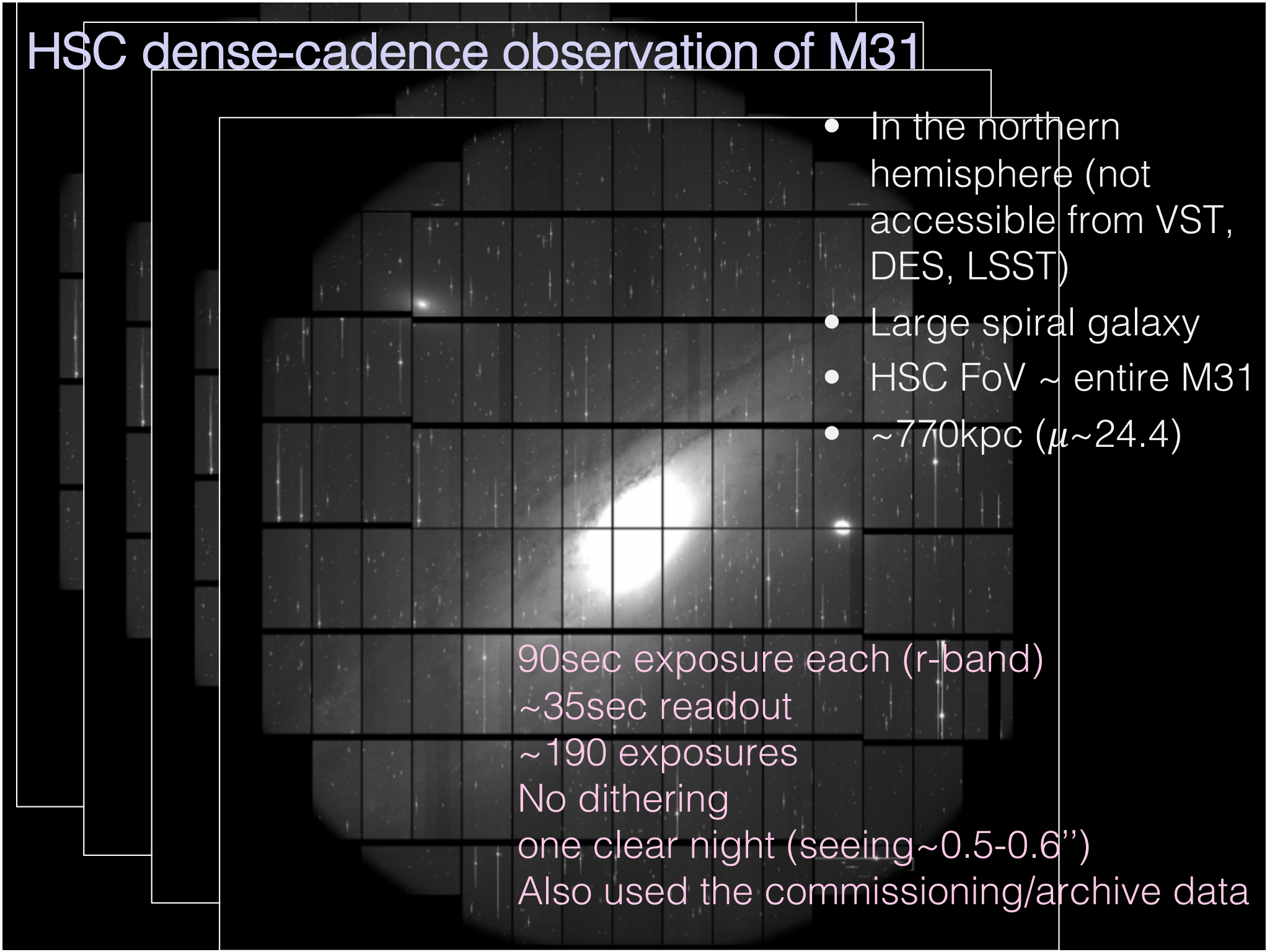
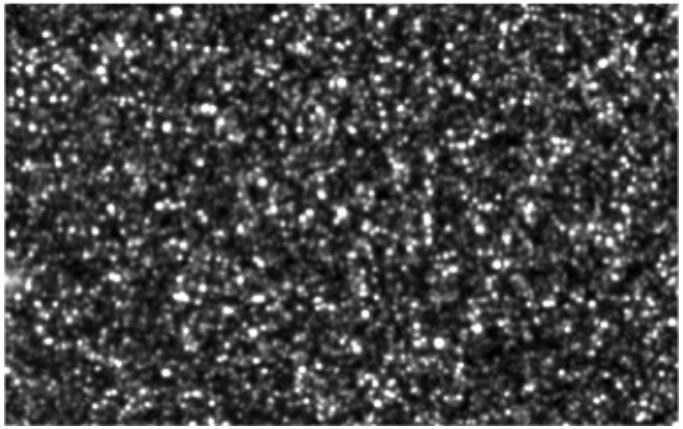
HSC dense-cadence observation of M31



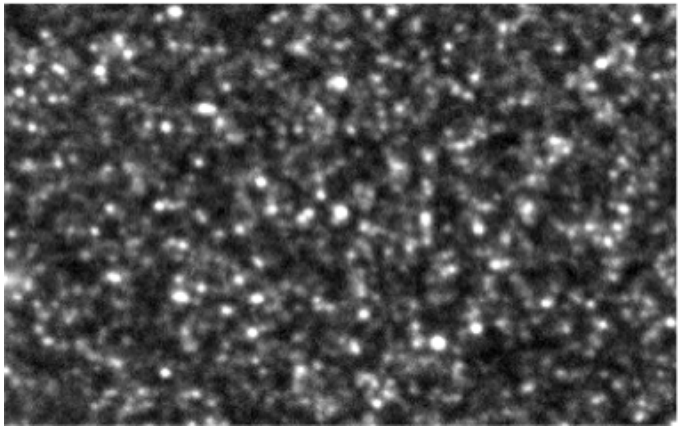
- In the northern hemisphere (not accessible from VST, DES, LSST)
- Large spiral galaxy
- HSC FoV ~ entire M31
- ~770kpc (μ~24.4)

90sec exposure each (r-band)
~35sec readout
~190 exposures
No dithering
one clear night (seeing~0.5-0.6")
Also used the commissioning/archive data

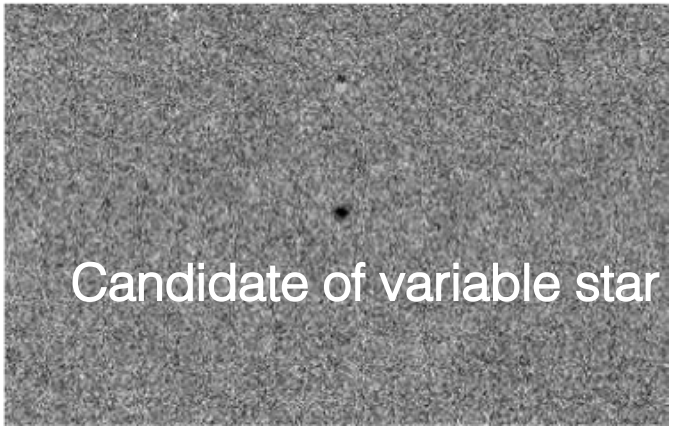
Image difference (subtraction) method



Reference image



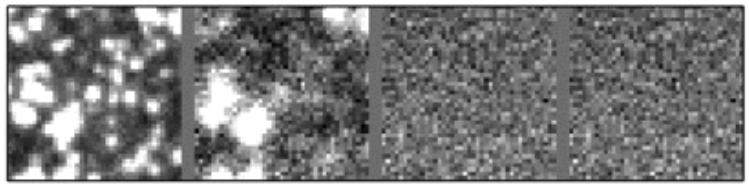
Target image

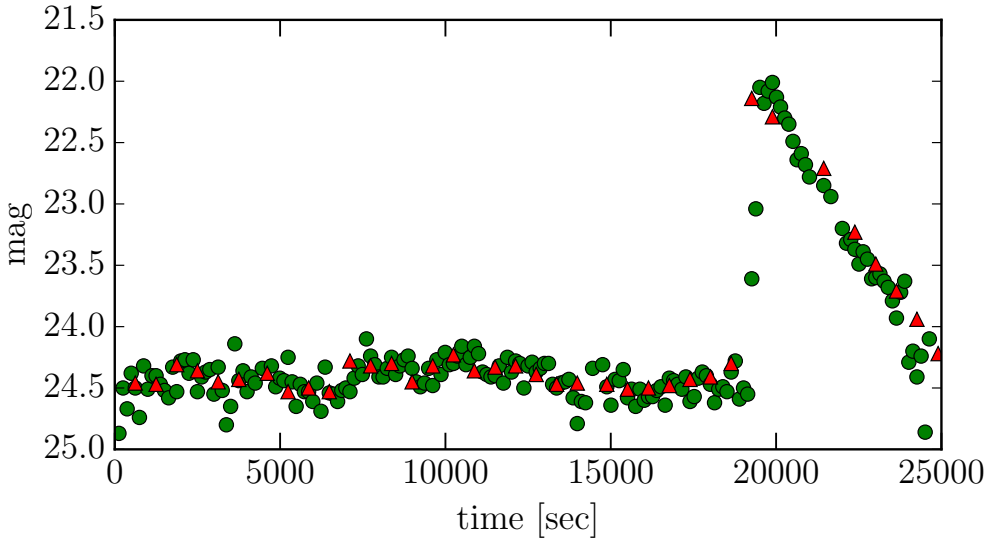


Difference image

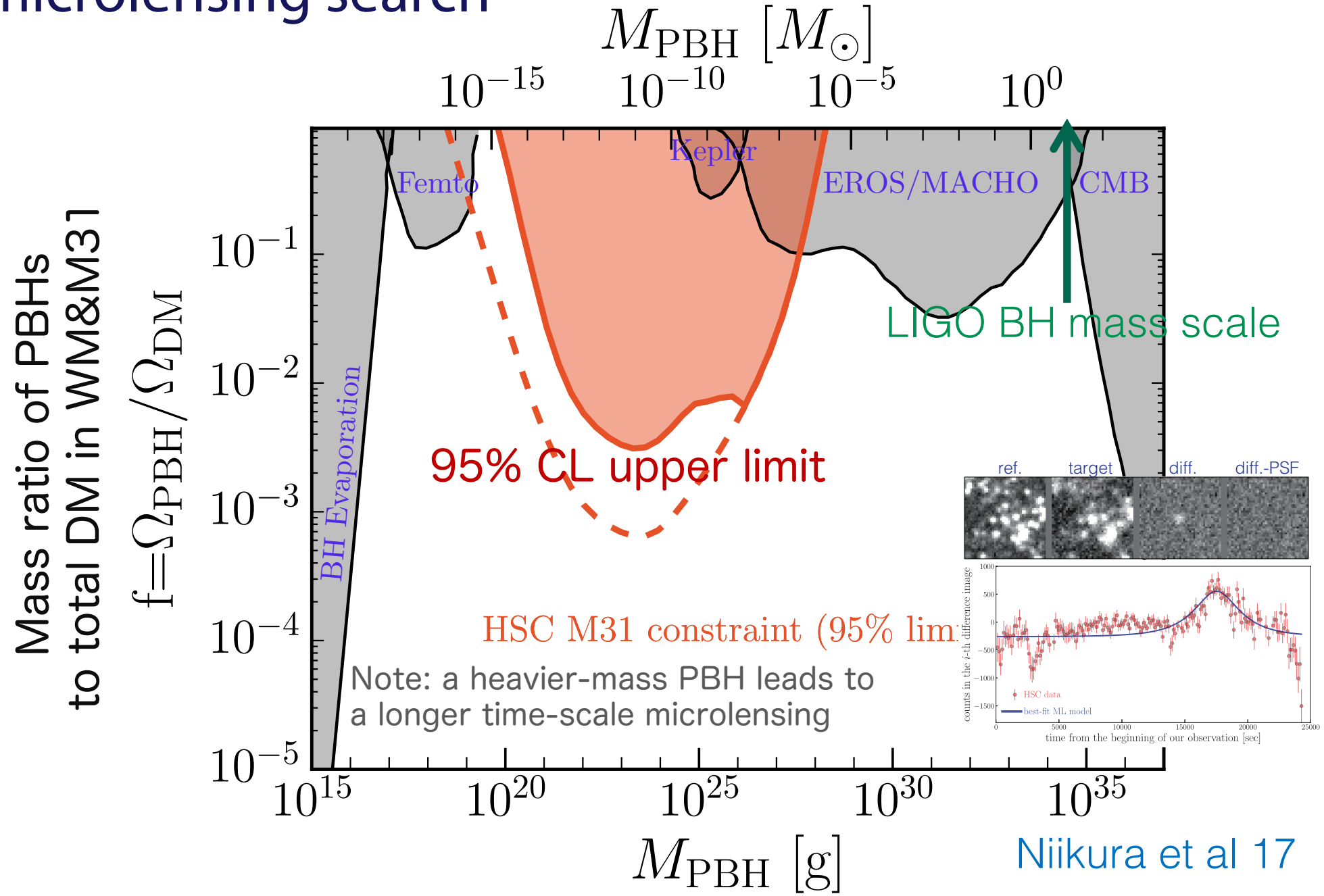
- Integrated in the HSC pipeline (hscPipe); it works!
- With this method, we found ~15,000 candidates of variable stars (Niikura, Takada, Yasuda+)

An example stellar flare





Tightest upper bound on primordial BHs from the microlensing search



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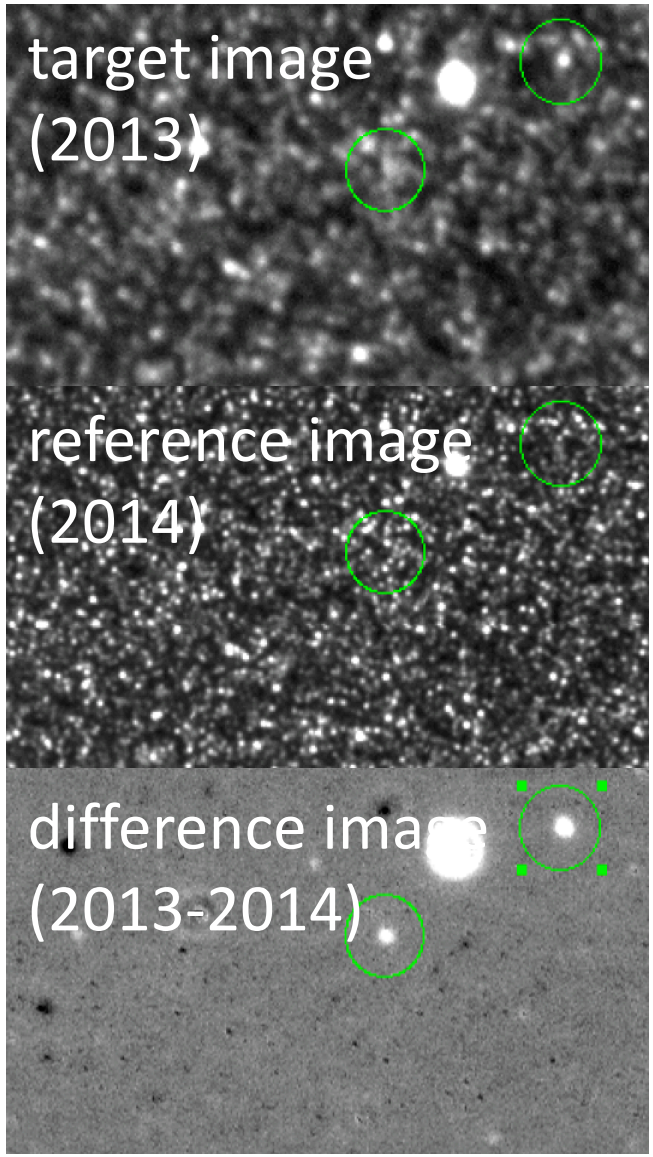
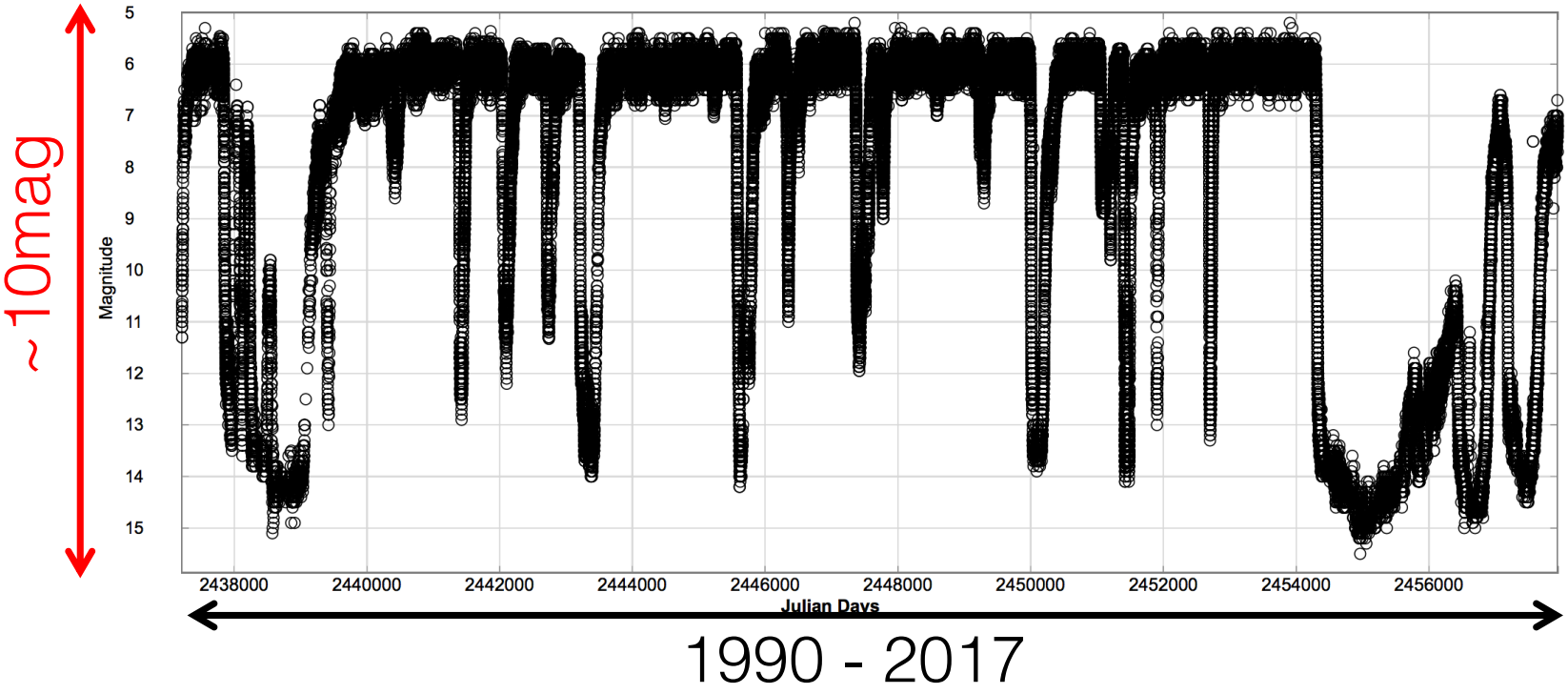
Disappearing stars?



- Compared our data (2014) to the commissioning data (2013) or the archive data (2015)
- Relatively easy to find because we need to search for a disappearance of *bright* stars
- *What are these stars?*

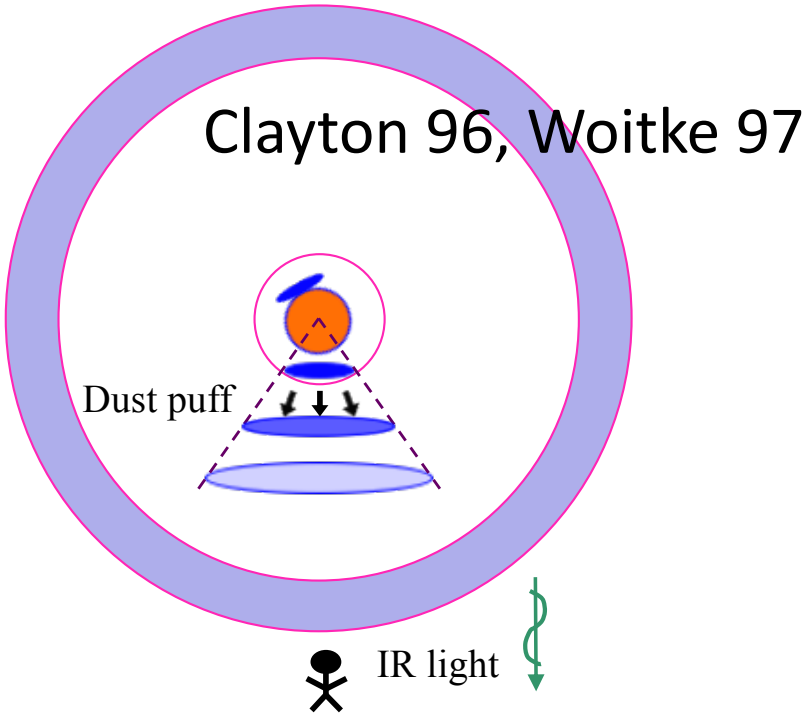
R Coronae Borealis

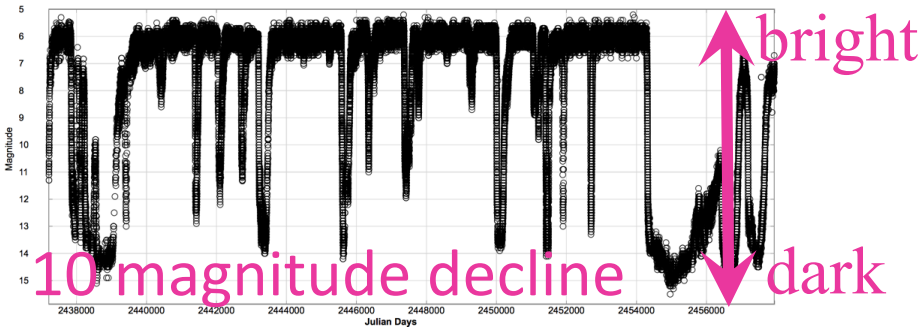
- One type of variable stars
- The origin of RCB stars remains unknown (no periodicity, large variability, …)
- A heterogeneous sample of ~100 RCB stars in MW



R Coronae Borealis (RCB) stars

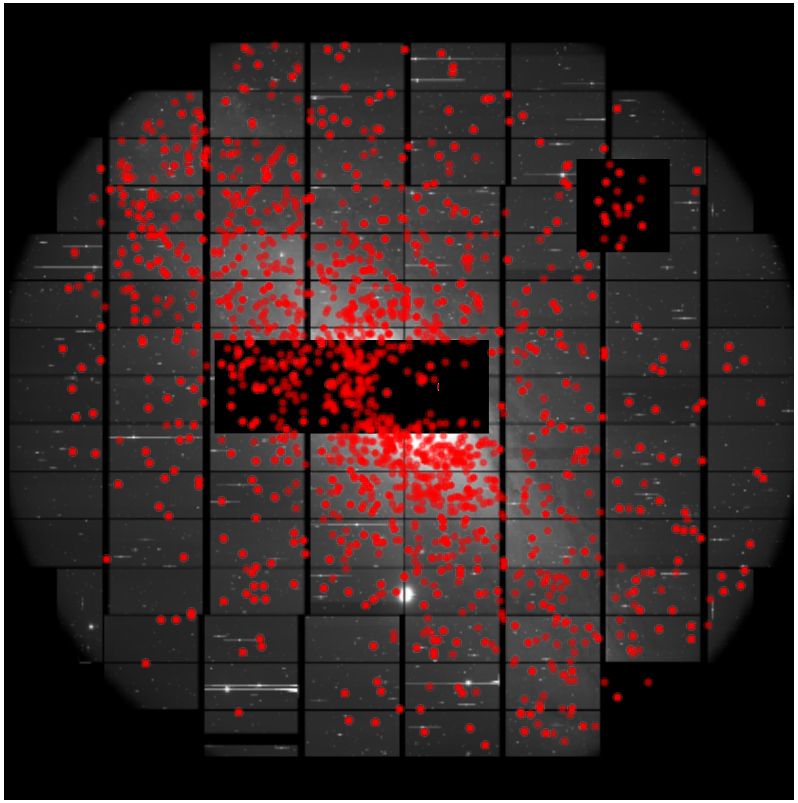
- Darkening due to mass loss
  - Irregular decline of visual brightness for several months
  - Light shielded by carbon dust clouds (Clayton+ 96)
- Many properties still unknown:
  - carbon rich, hydrogen deficient
  - evolutionary path still uncertain: WD mergers or Final helium flush (Iben+ 96, Saio & Jeffery 02)



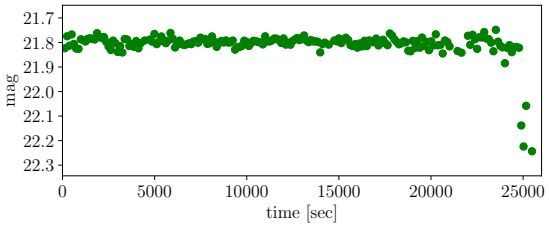


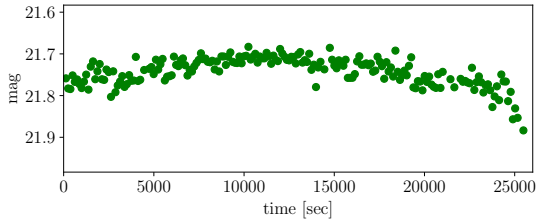
Discovery of RCB-type stars in M31

r-band

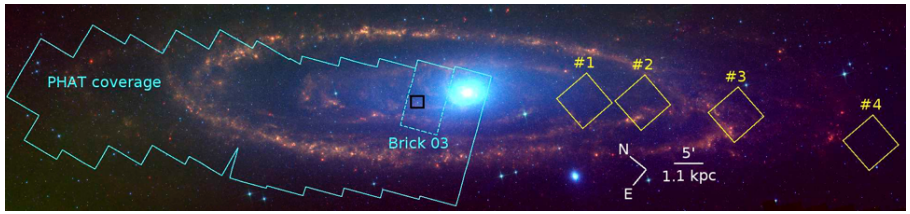


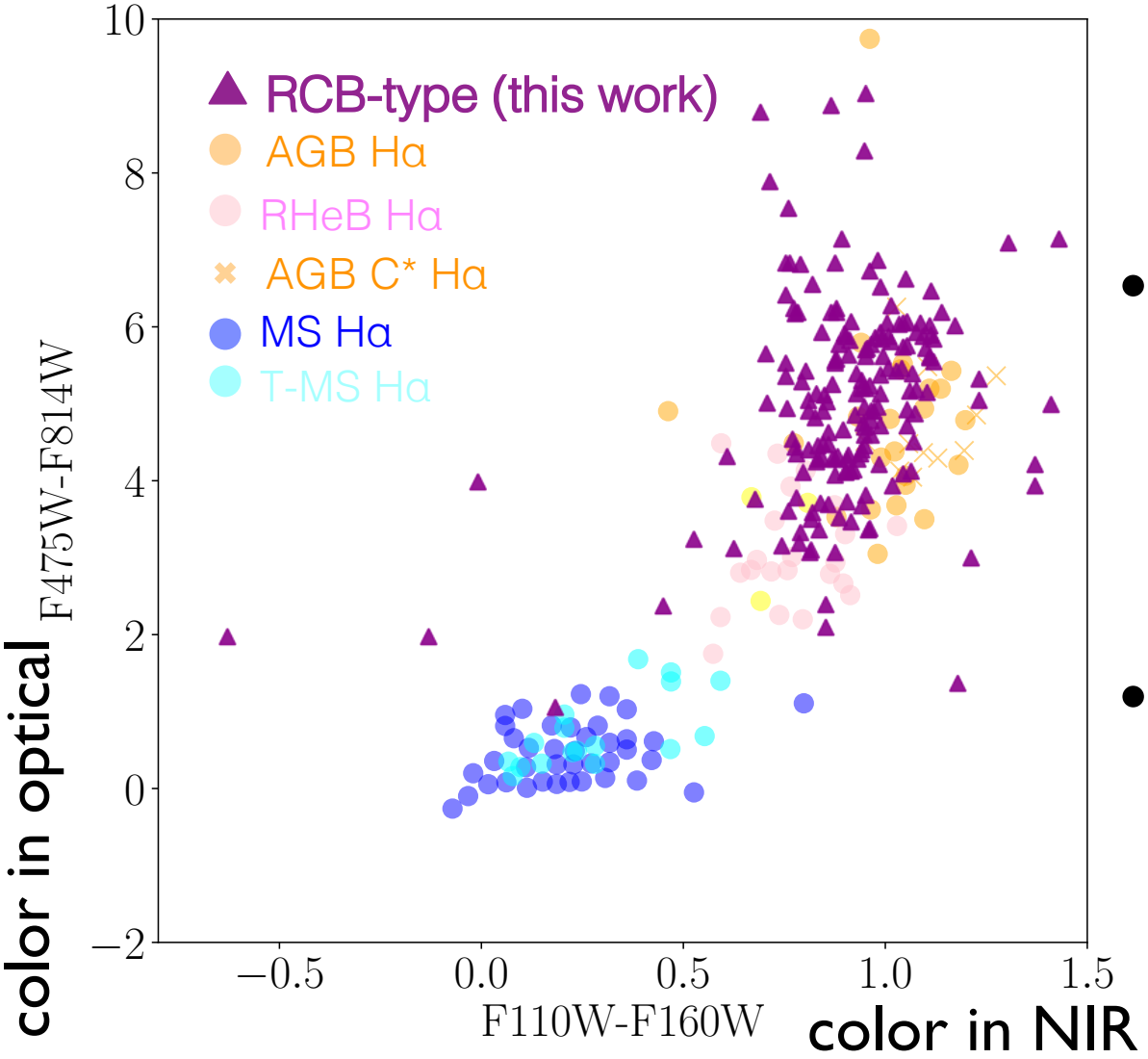
- ~1500 candidates of RCB stars (2014 vs. 2015) (r>26 mag)
- A homogeneous sample
- ~300 stars (r=21 ⇒ r>26)
- RCB candidates has no significant variability in 7-hour observation (2min cadence) in 2014





RCB-type stars in M31





- Matching candidates of RCB stars to the PHAT catalog (HST data; Prichard et al. 2016) in the overlapping region
- Consistent with AGB-type stars

A new path of dust enrichment?

- Dust production per mass loss $M_{\rm dust} \sim 10^{-8} M_\odot$
- Frequency of mass loss: 40 – 100 days
- Dust production rate per RCB star: $\dot{M}_{\rm dust} \sim 10^{-7} M_\odot/{\rm yr}$
- We found ~1,000 RCB-type stars in M31 ⇒

$$\dot{M}_{\rm dust} \sim 10^{-4} M_\odot/{\rm yr/galaxy}$$

Important for galaxy evolution/observation?

Channel	Dust prod. rate (Ms/yr)
O-rich AGB	~3 × 10^{-3}
C-rich AGB	~3 × 10^{-3}
SNe	~1 × 10^{-3}
Novae	~10^{-5}
RCB-type stars	~10^{-4}

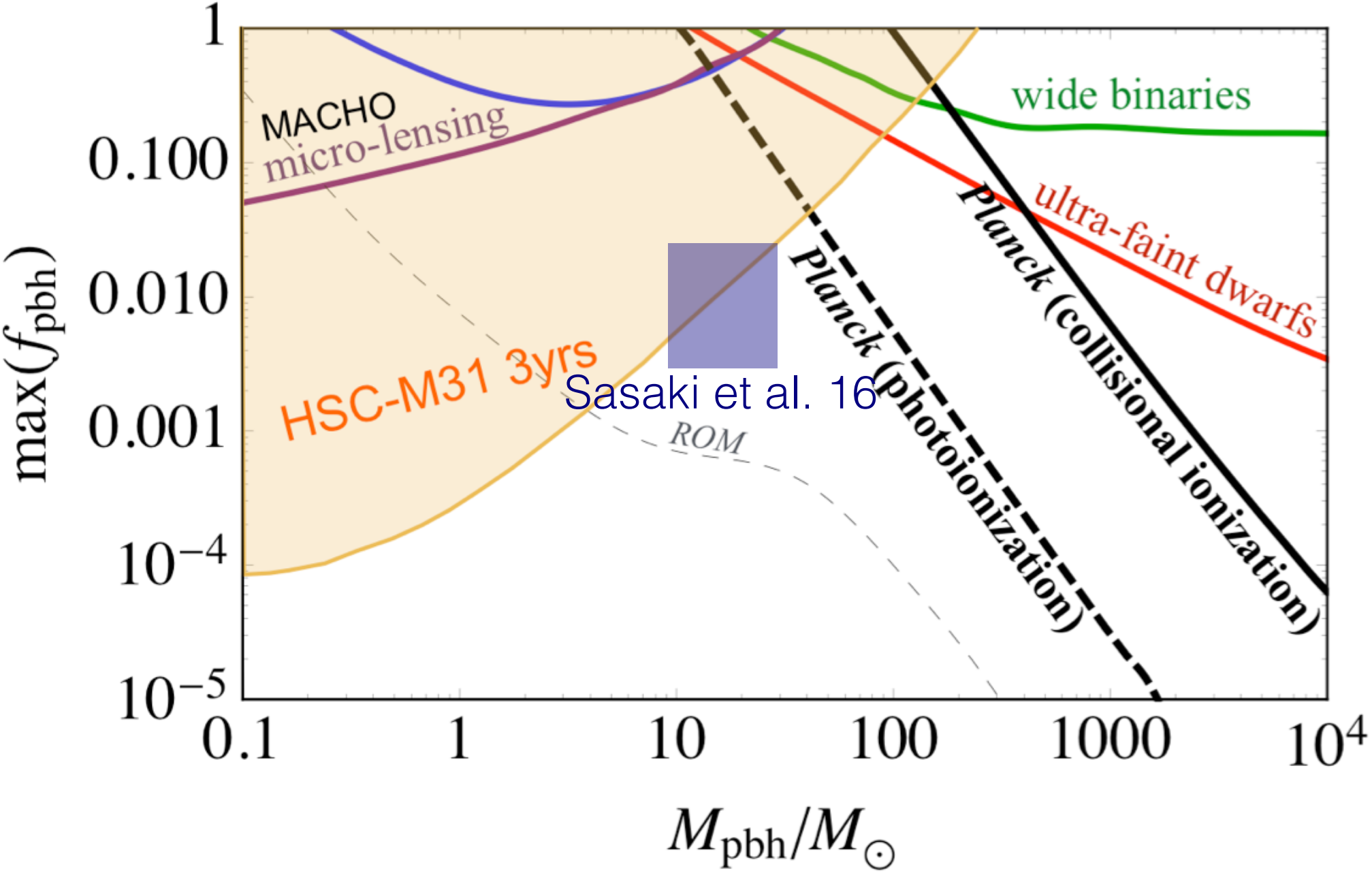
e.g. Whittet 2003; Matsuura et al. 2009

A long-term monitoring HSC obs. of M31

- M31 (μ~24.4) is such a unique target for HSC (can't be observed by DECam & LSST)
- **We are planning to propose** (to submit for S18B)
  - ~10min HSC obs very HSC run (1 obs/month)
  - ~8 HSC obs./year
  - Monitoring over ~3 years (intensive program)
  - <1 HSC night in total
- Explore many variable stars
  - Microlensing due to PBH and free-floating planets
  - RCB-type stars
  - Direct-collapsing stars (massive BH)
  - Supernovae (synergy with Super-K, …)
  - Other exotic variability stars

Prospect for further HSC observation

only one or a few Subaru nights in total, sparsely sampled over 3yrs



Summary

- Unique capability of HSC for time domain astronomy
  - Planet Nine, GW counterparts, moving objects, FRB, …. cosmic string
- A long-term monitoring HSC-obs of M31
  - M31 is such a unique target (can't be observed by LSST)
  - Found ~1,000 RCB-type star candidates (a homogeneous sample)
  - A new channel for the dust enrichment in galaxy
  - Microlensing events of PBH and/or planets, RCB-types tars, SNe, direct collapose, …