Sébastien Clesse
Center for Cosmology, Phenomenology and Particle Physics,
Louvain University,
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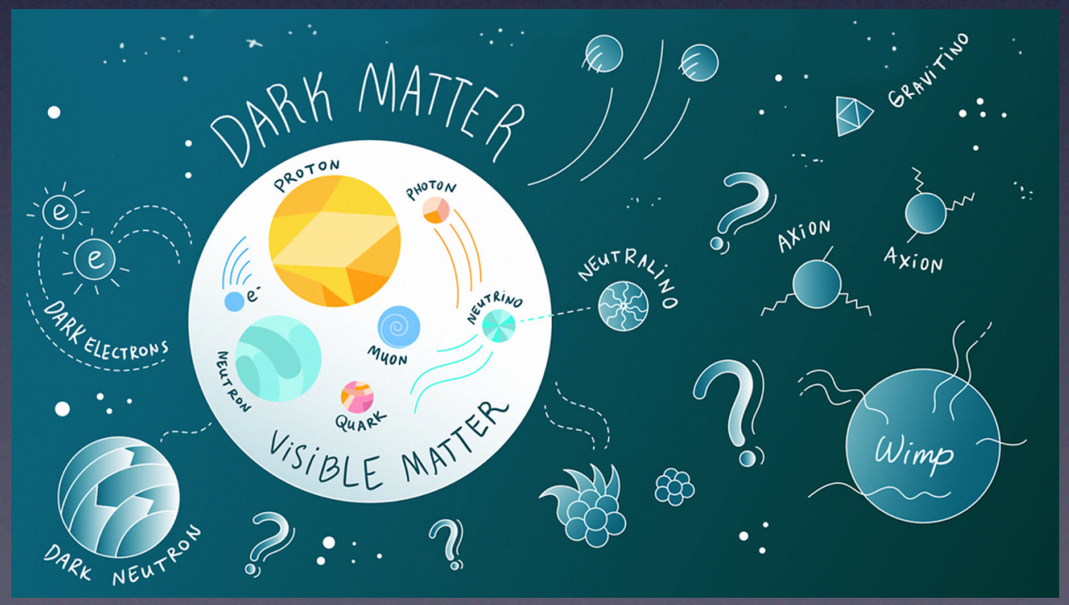
(Seven) Hints for Primordial Black Holes as Dark Matter?

based on arXiv:1711.10458 (with J. Garcìa-Bellido.)



May 17th, 2018, CERN TH-Institute, *Primordial vs Astrophysical Origin of Black Holes*

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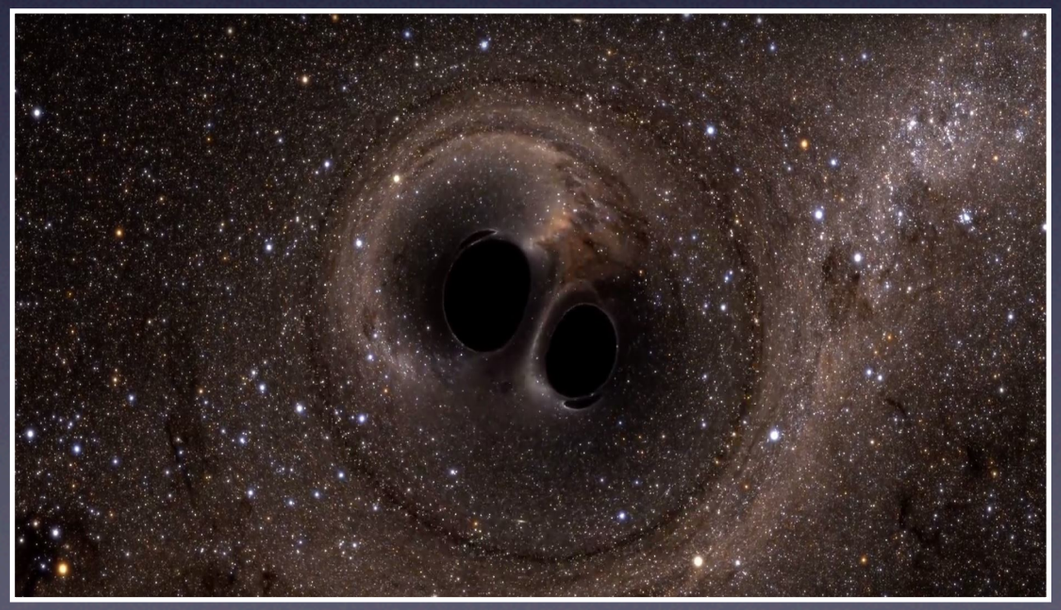

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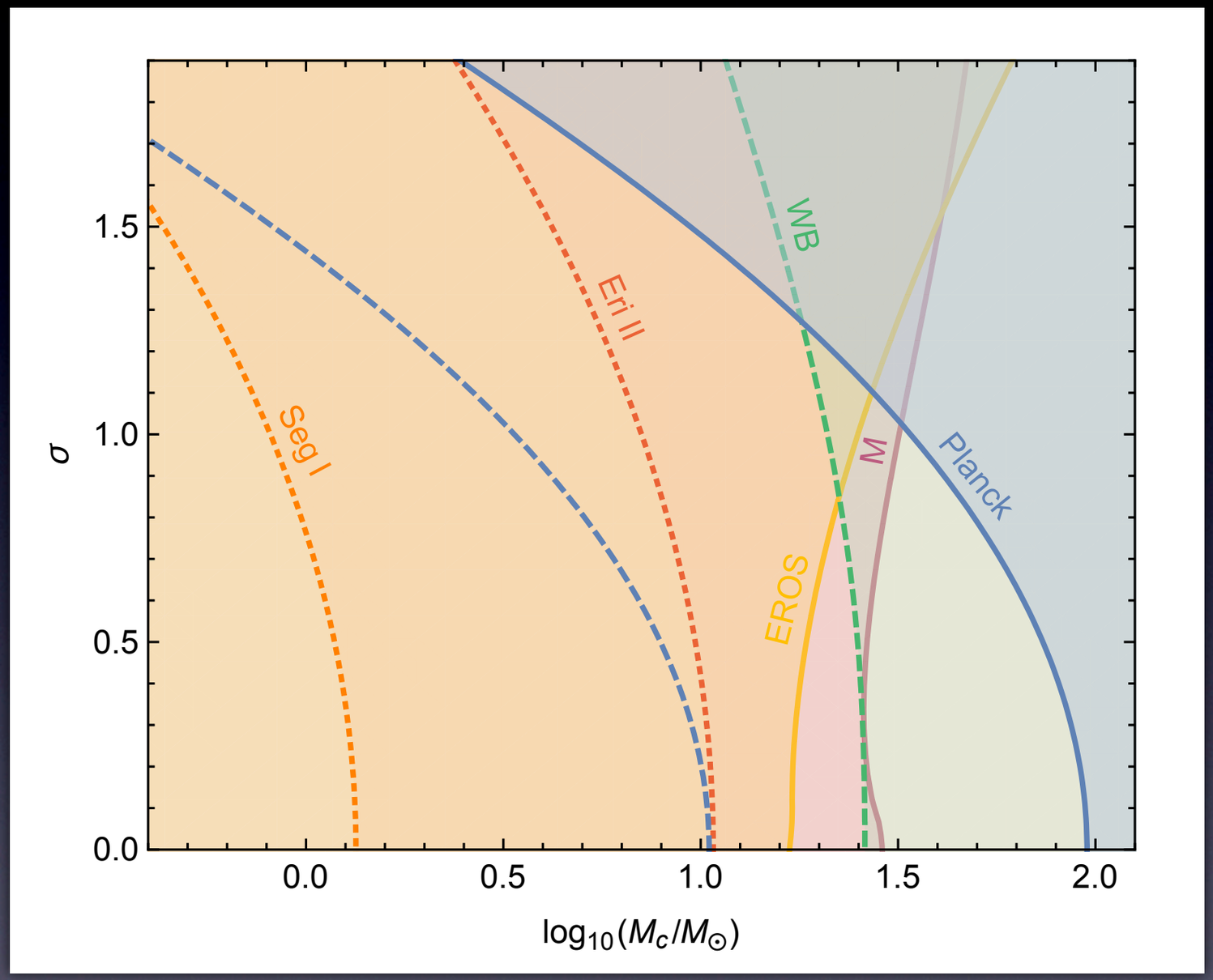
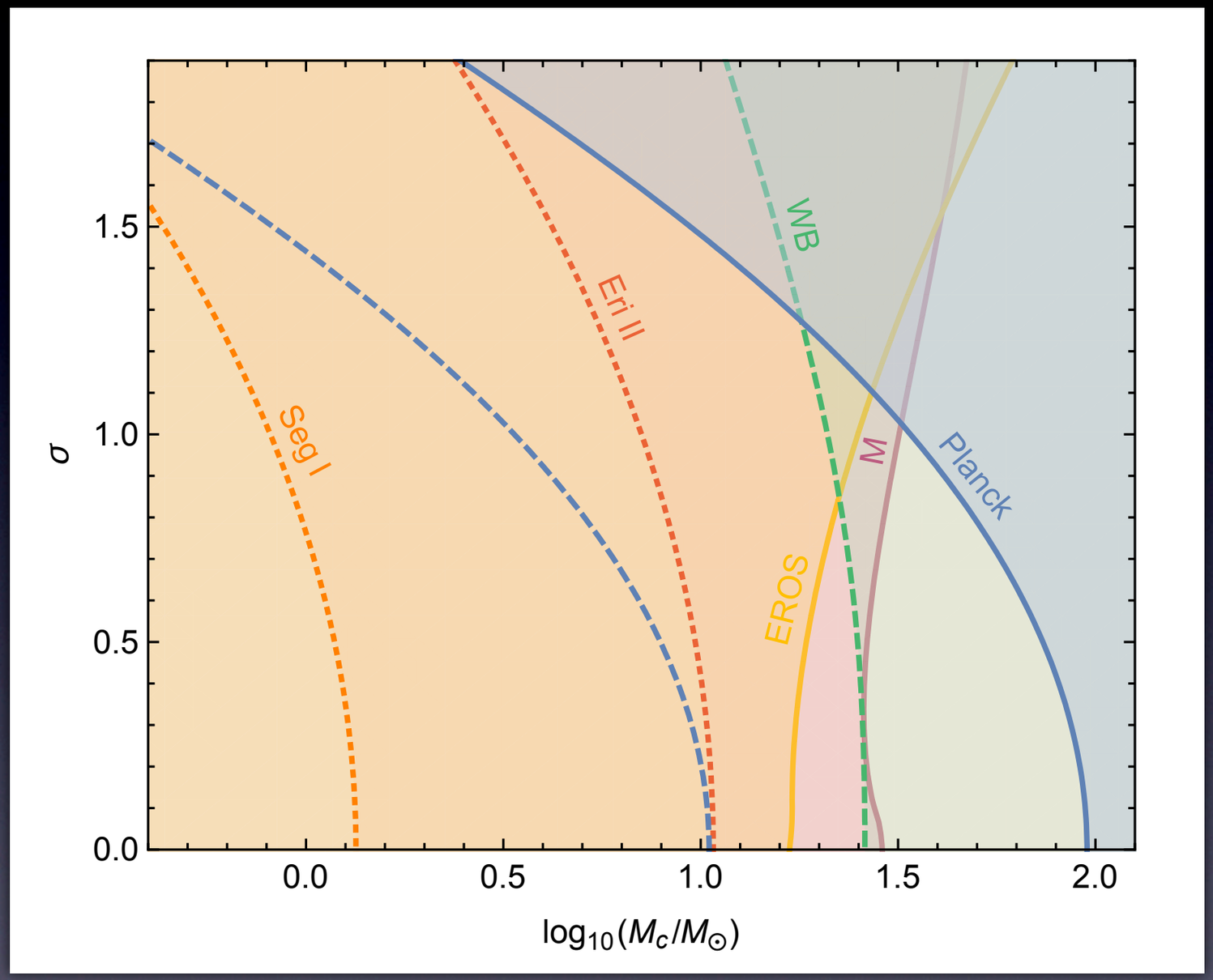
Constraints on PBH abundances



B. Carr et al., 1705.05567

Constraints on PBH abundances



Broad spectrum (log-normal dist): PBH-DM looks excluded in the whole parameter range

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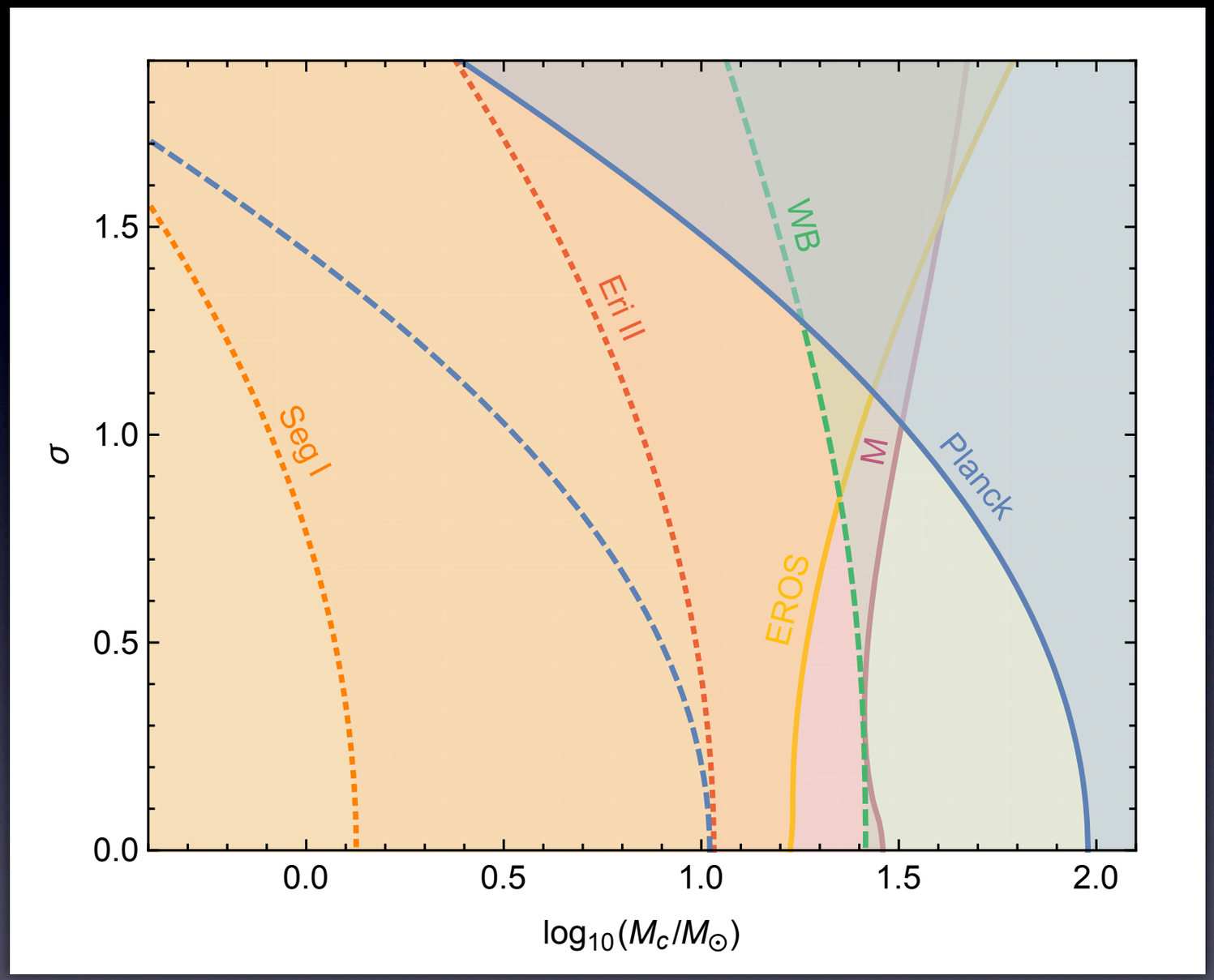

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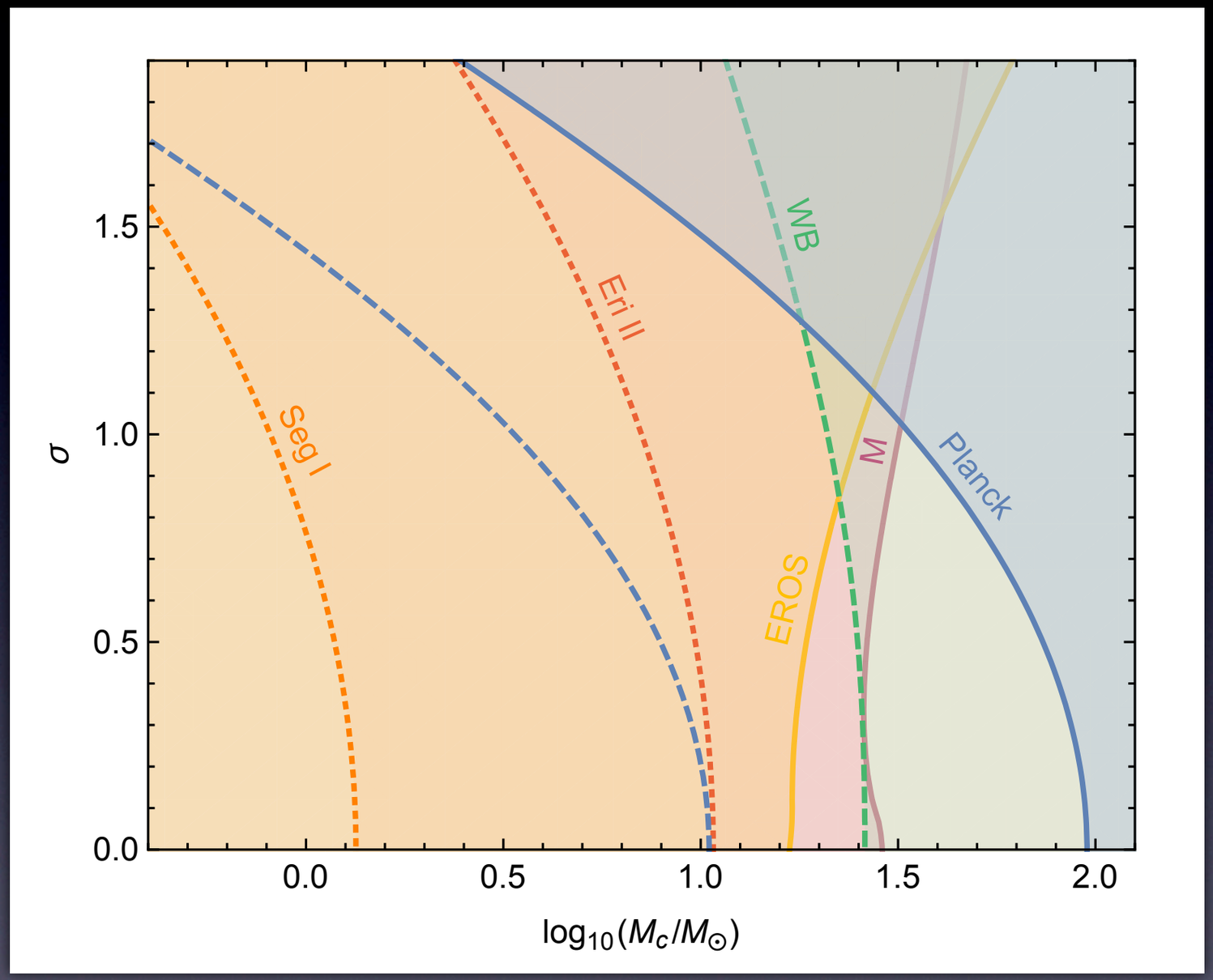

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Segue I constraints cannot be simply extrapolated to the broad case

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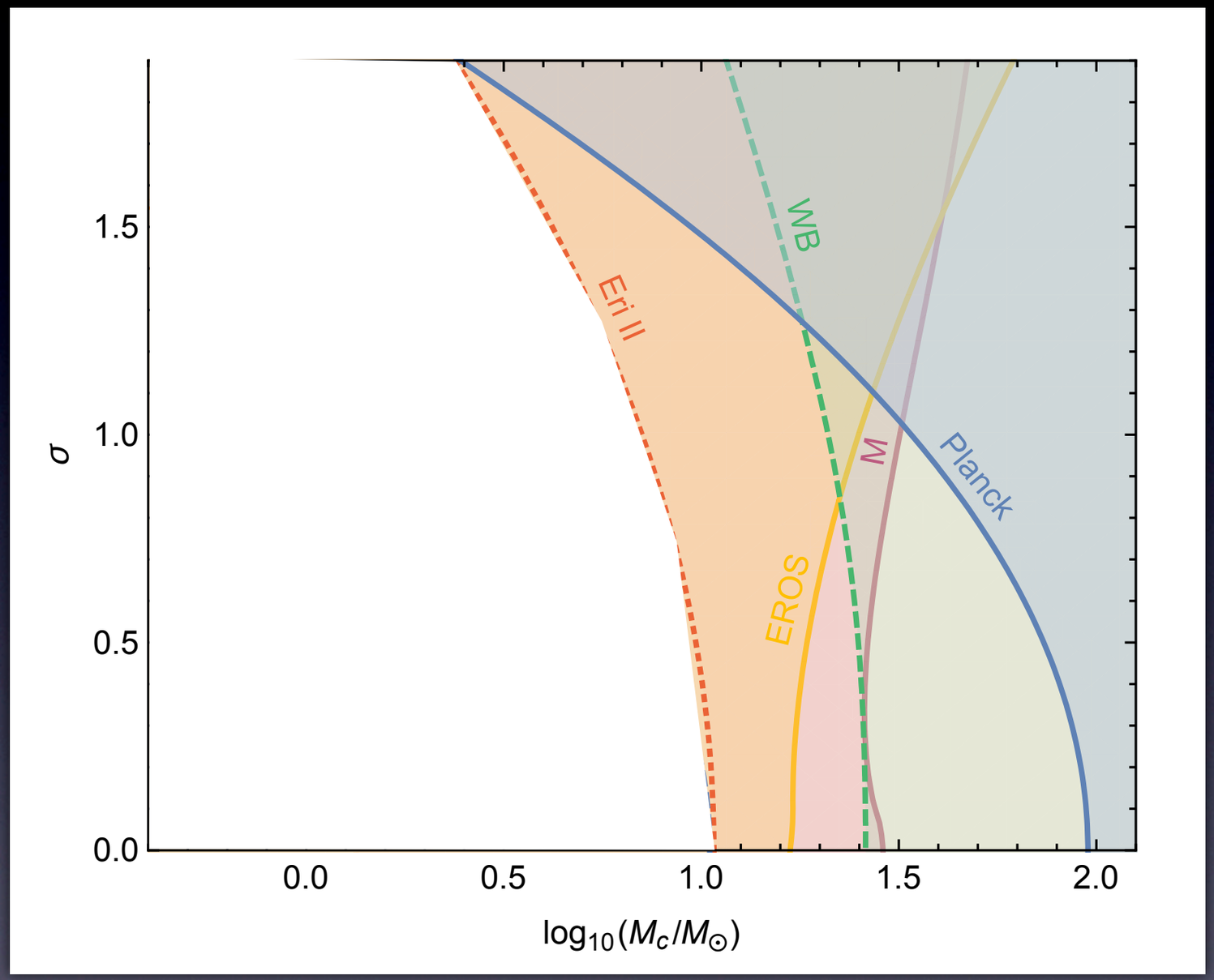

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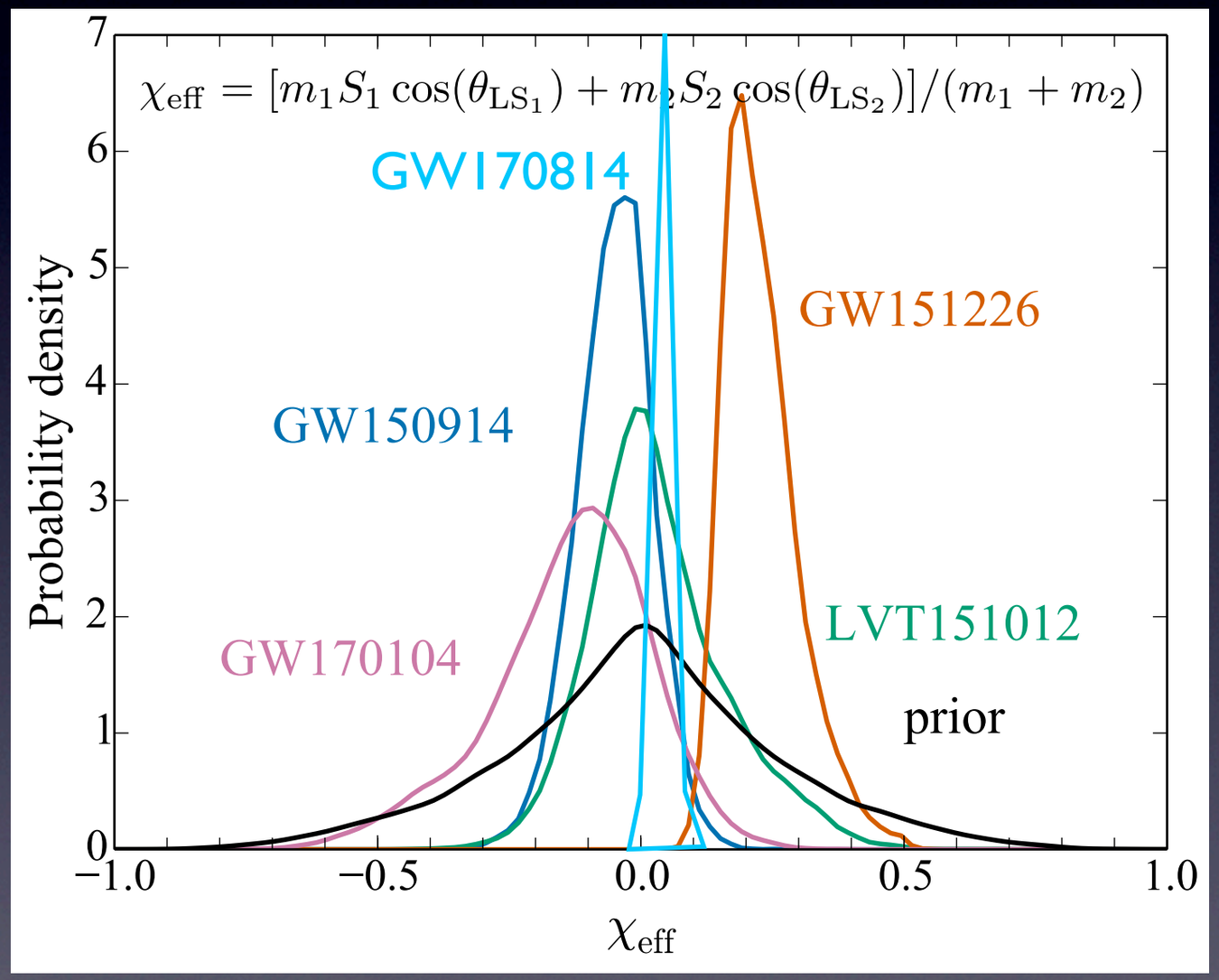
Broad spectrum (log-normal dist): PBH-DM looks excluded in the whole parameter range

Microlensing constraints are debated

Segue 1 constraints cannot be simply extrapolated to the broad case

Seven hints for PBH-DM

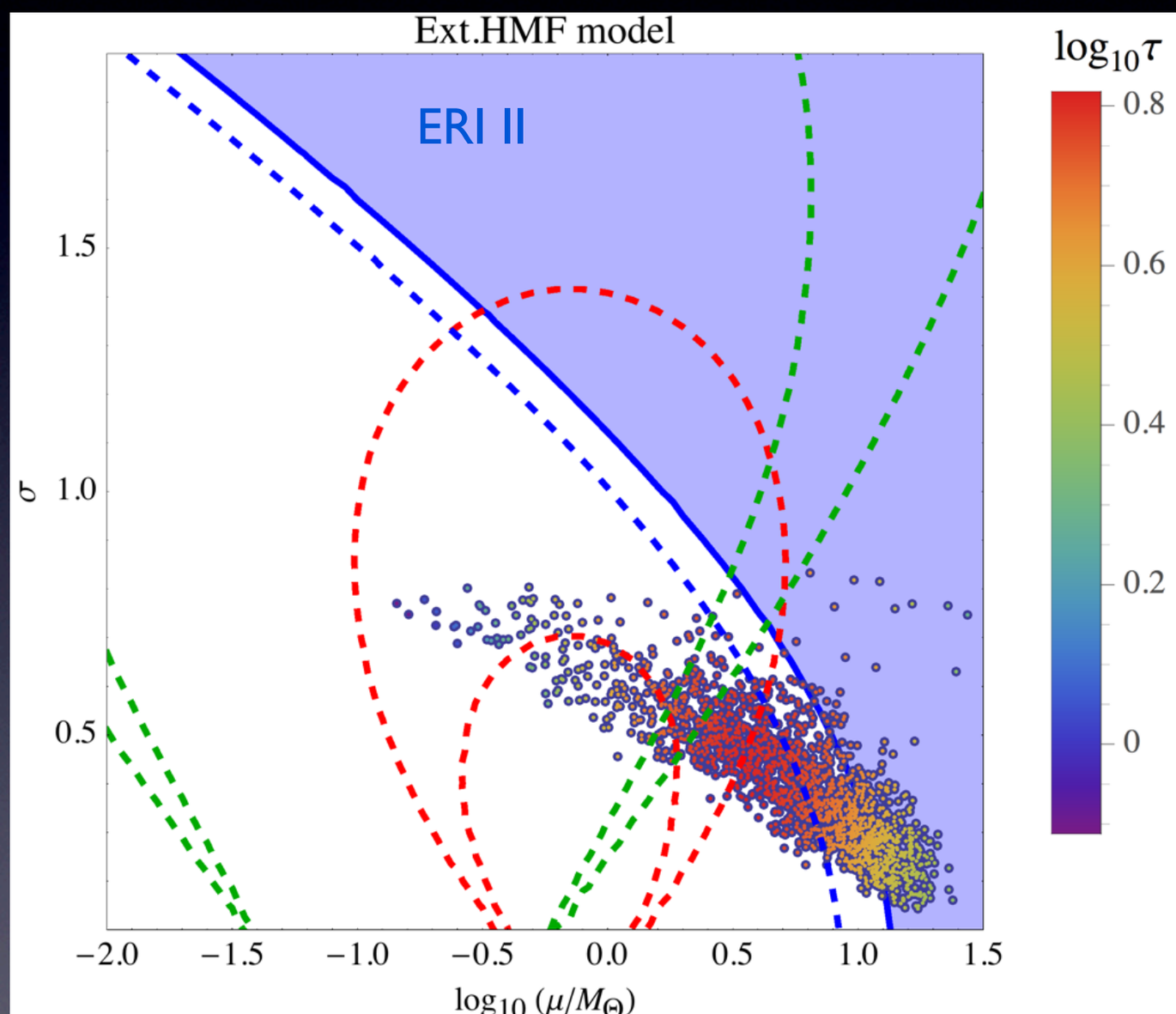
Hint 1: spins of LIGO black holes



Adapted from Adv.LIGO/VIRGO June 2017 release (supl. material)

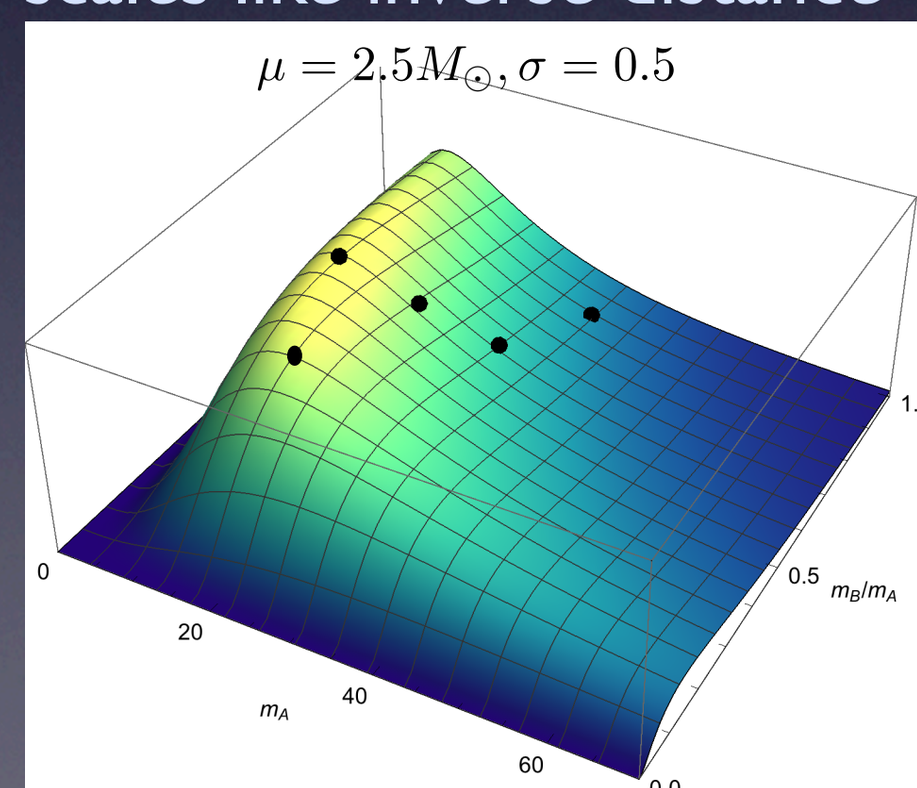
Seven hints for PBH-DM

Hint 2: BH merger masses and rates



S.C., J. Garcia-Bellido, 1711.10458

- MCMC mass spectrum reconstruction from LIGO events and rates
- Event likelihood peaks on large masses: LIGO detectability scales like inverse distance



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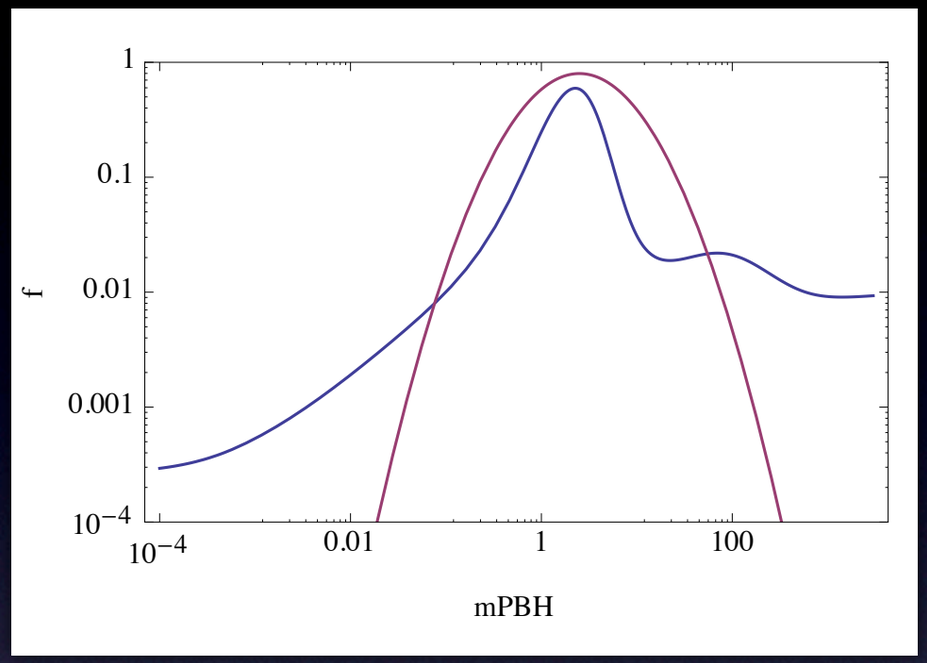
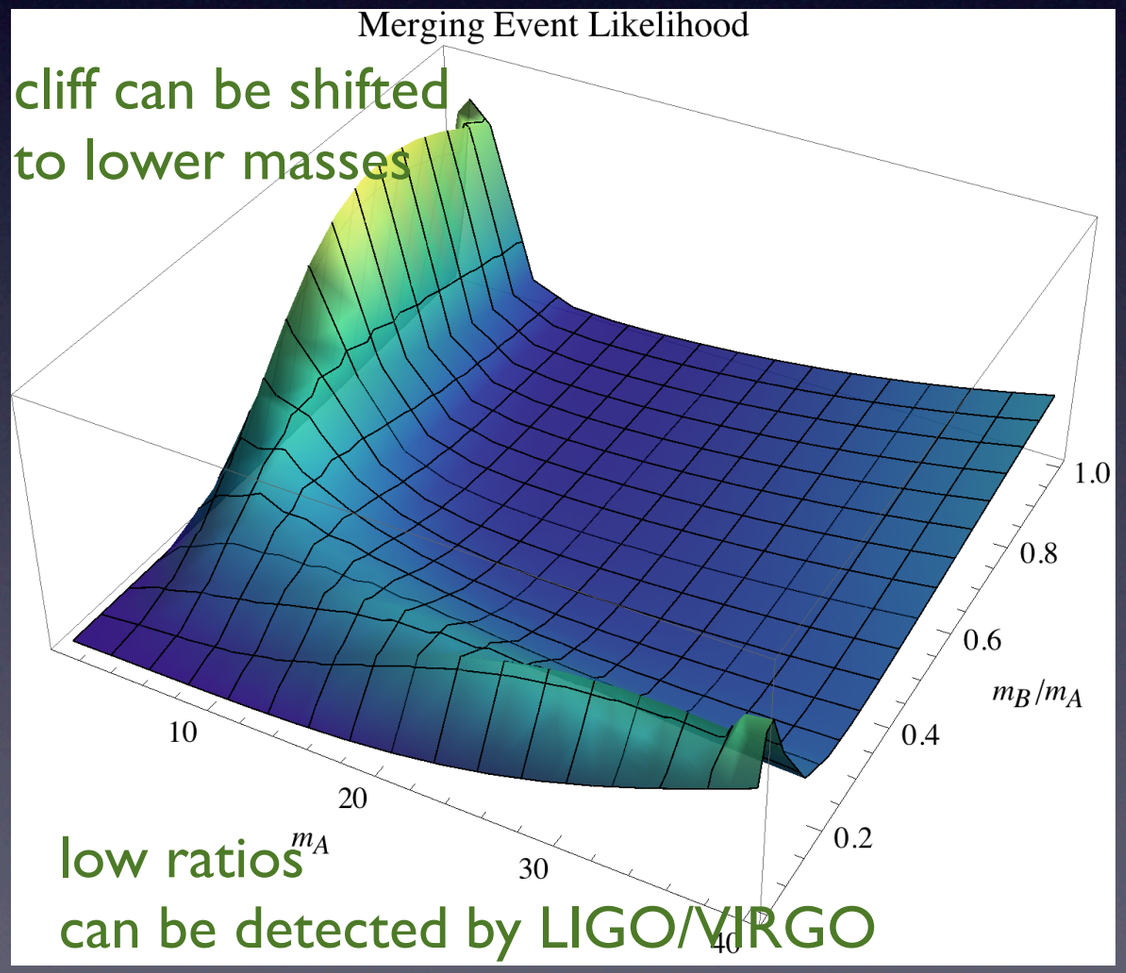
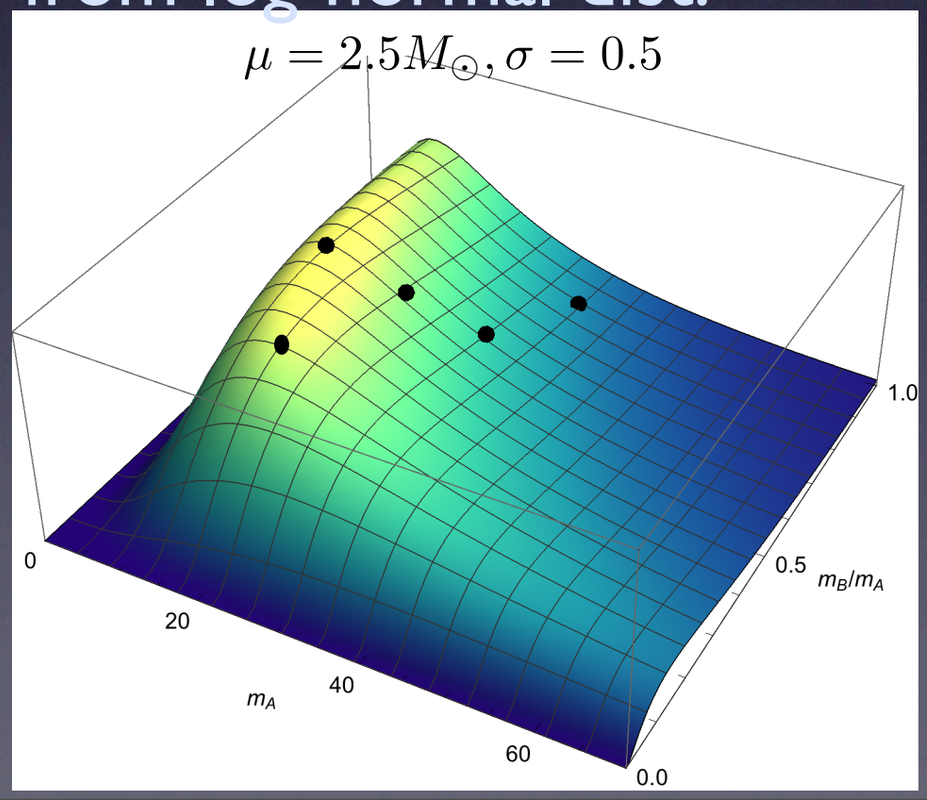


from QCD transition (see Chris Byrnes's talk),
$n_s - 1 = 0.1$, e.o.s. at horizon crossing

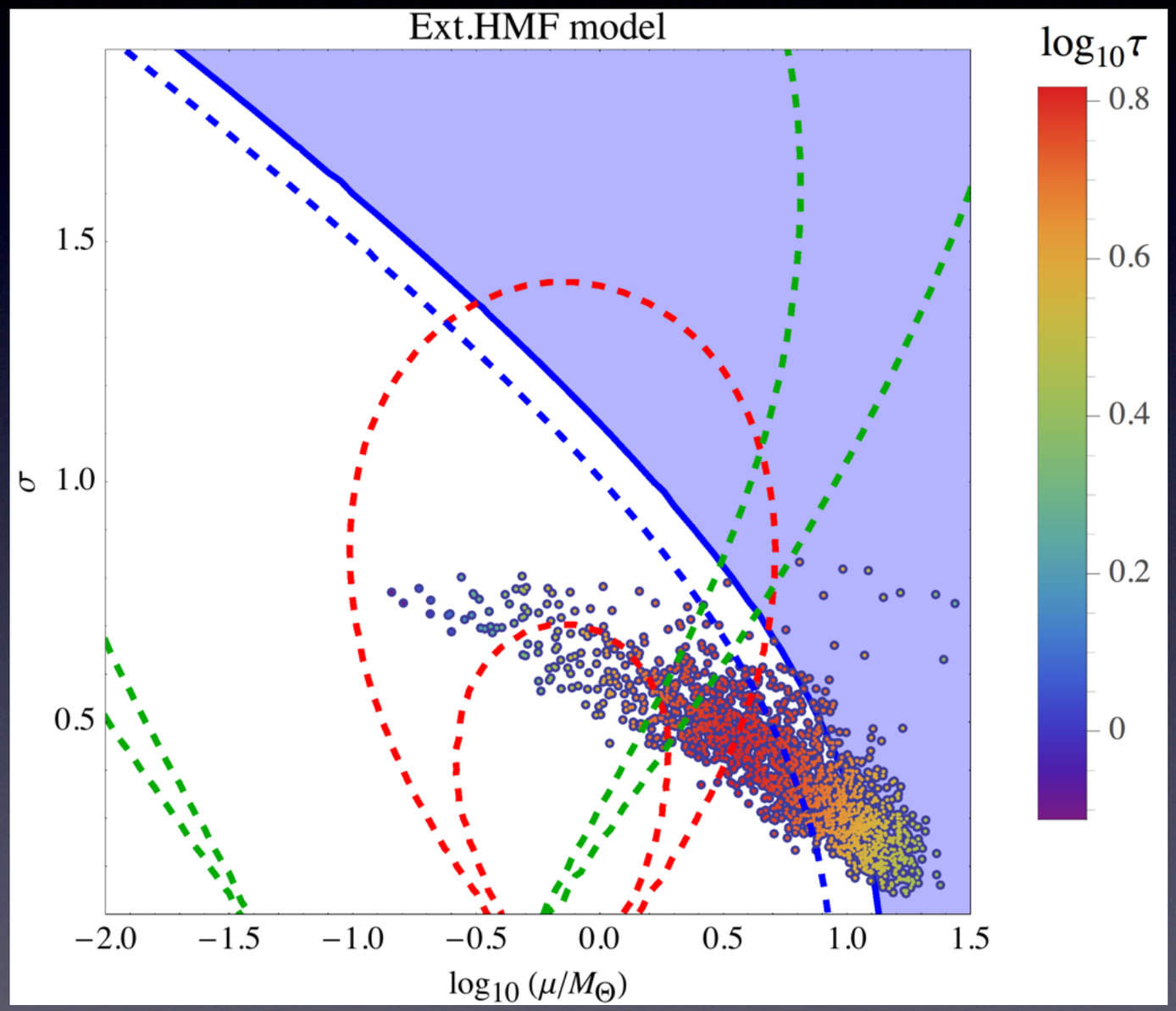


from log-normal dist.



Seven hints for PBH-DM

Hint 3: Microlensing of M31 and quasars



S.C., J. Garcia-Bellido, 1711.10458

- 56 microlensing events in M31: between 15% and 30% of halo compact objects in range [0.5-1] Msun (1504.07246)
- 24 micro-lensing of quasars by galaxies: between 15% and 25% of halo compact objects in range [0.05-0.45] Msun (1702.00947)
- Also in Magellanic cloud surveys, but still controversial

Seven hints for PBH-DM

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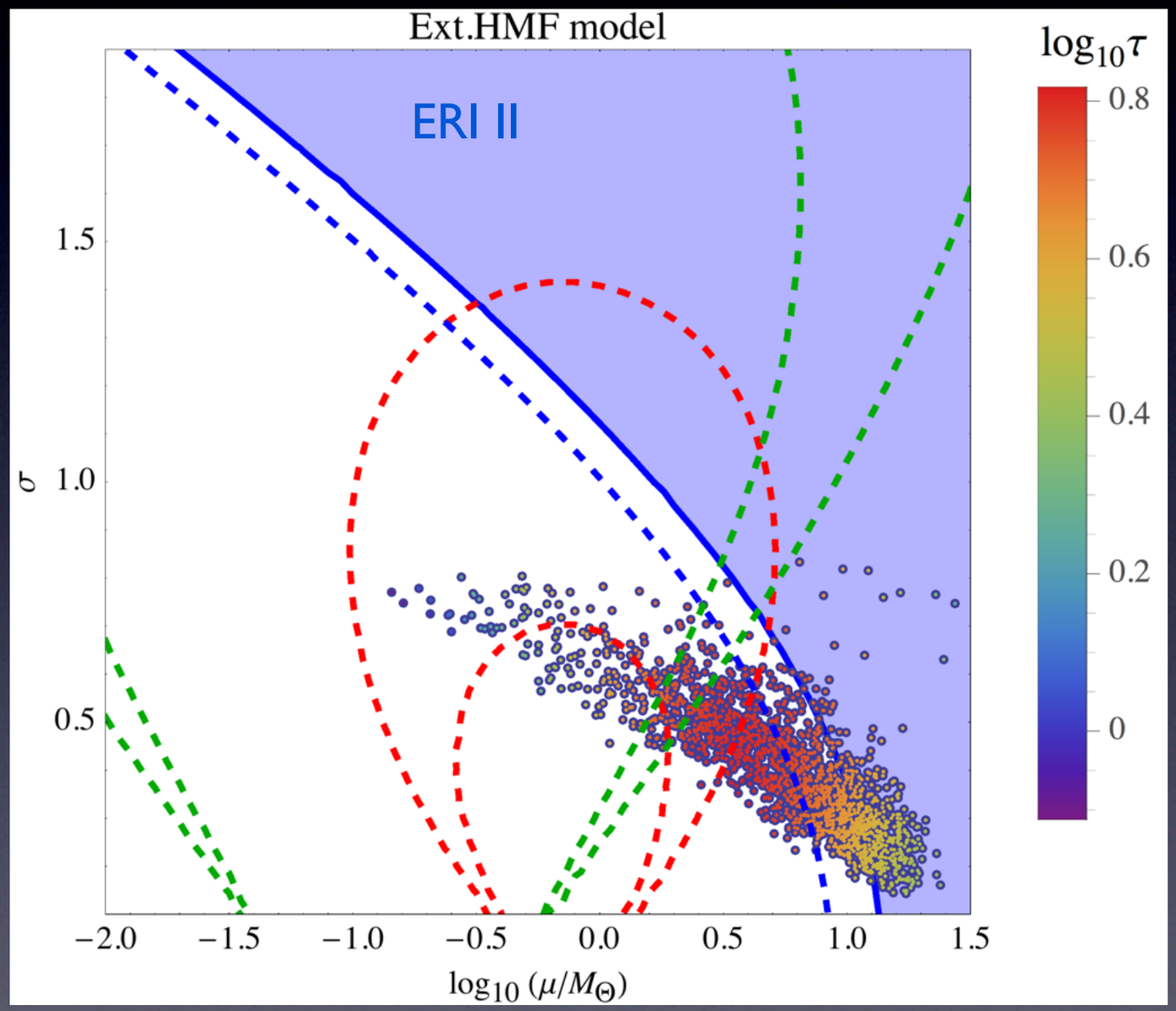

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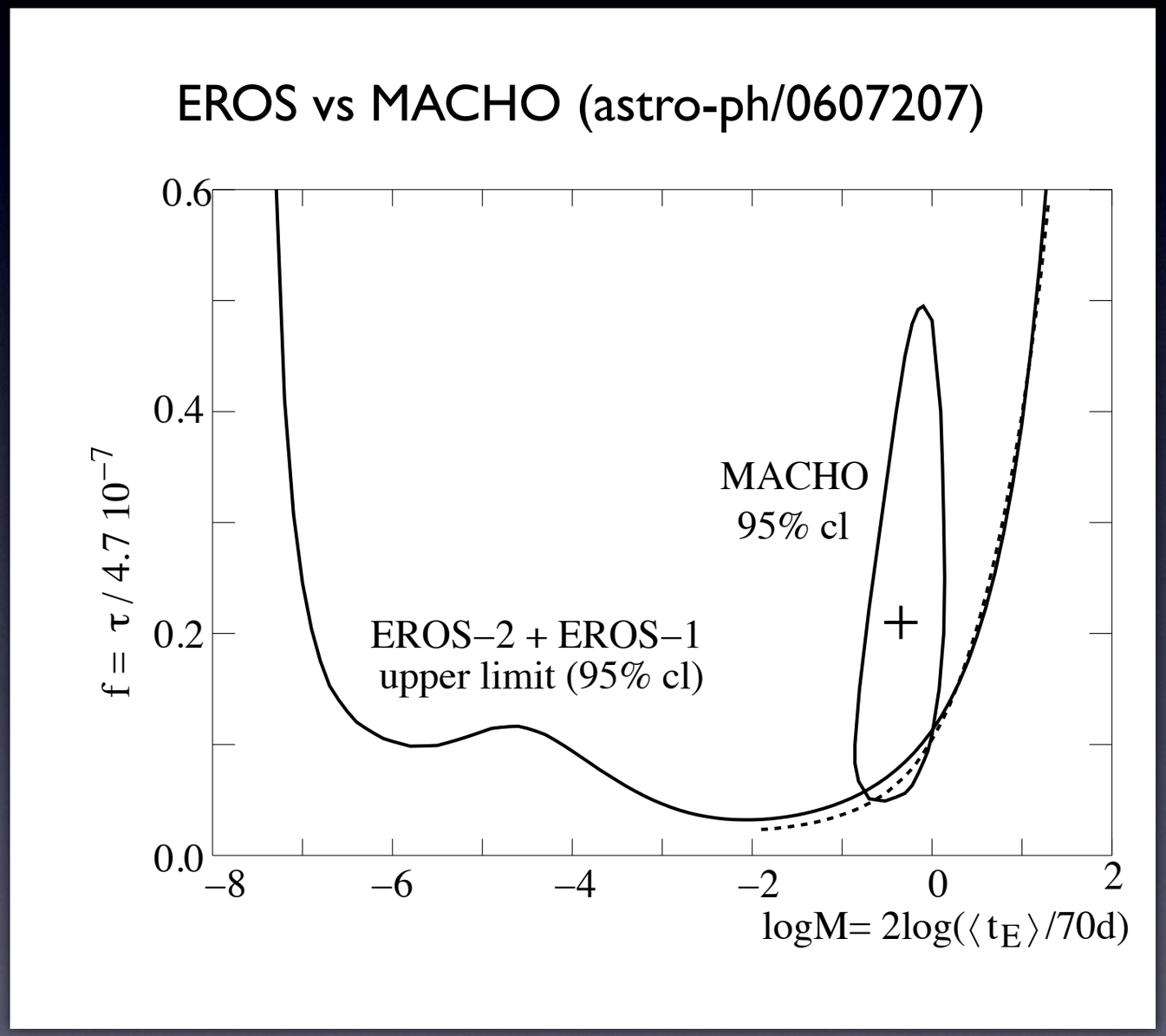

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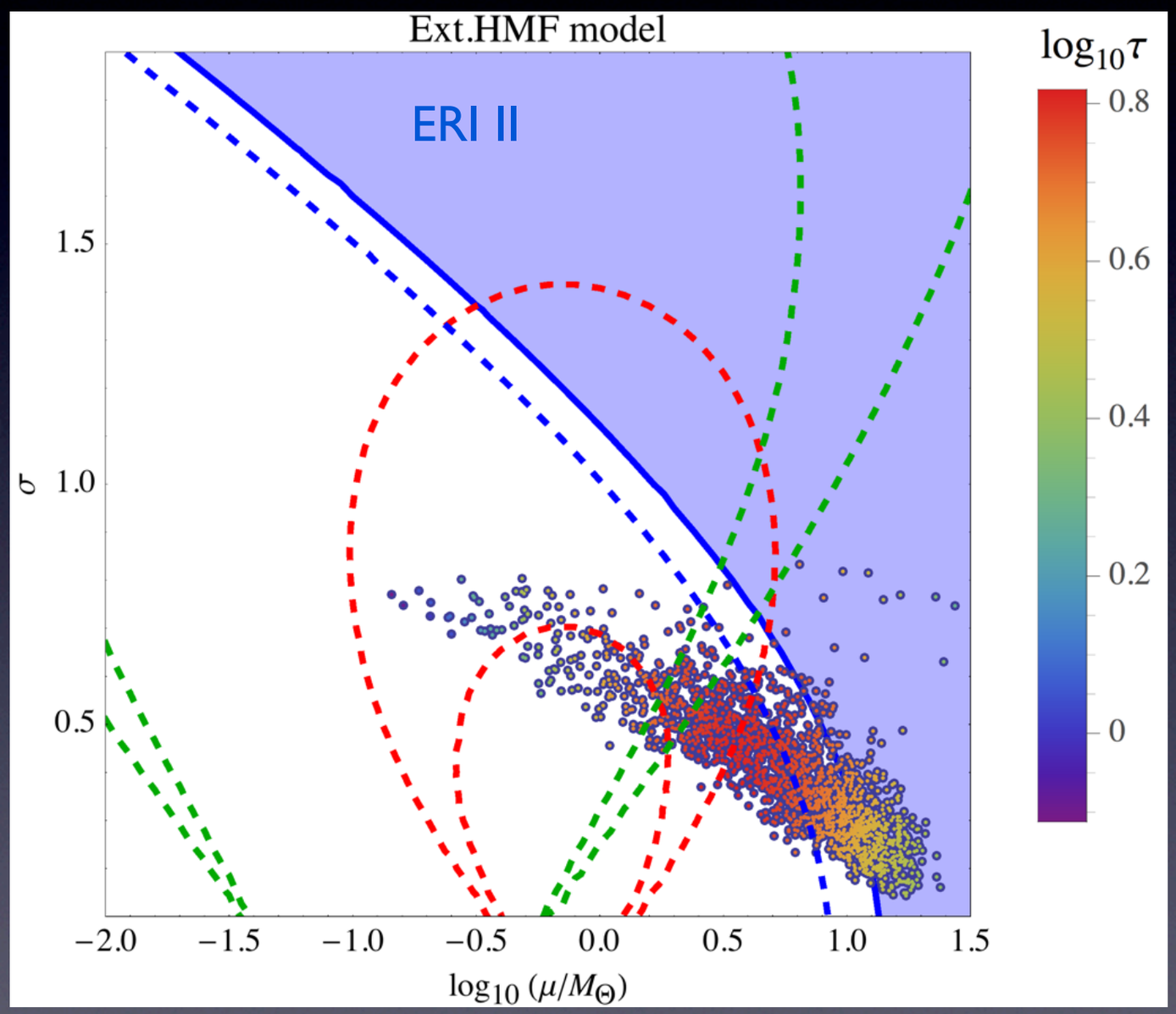
Seven hints for PBH-DM

Hint 4: Star clusters and dynamics of faint dwarf galaxies

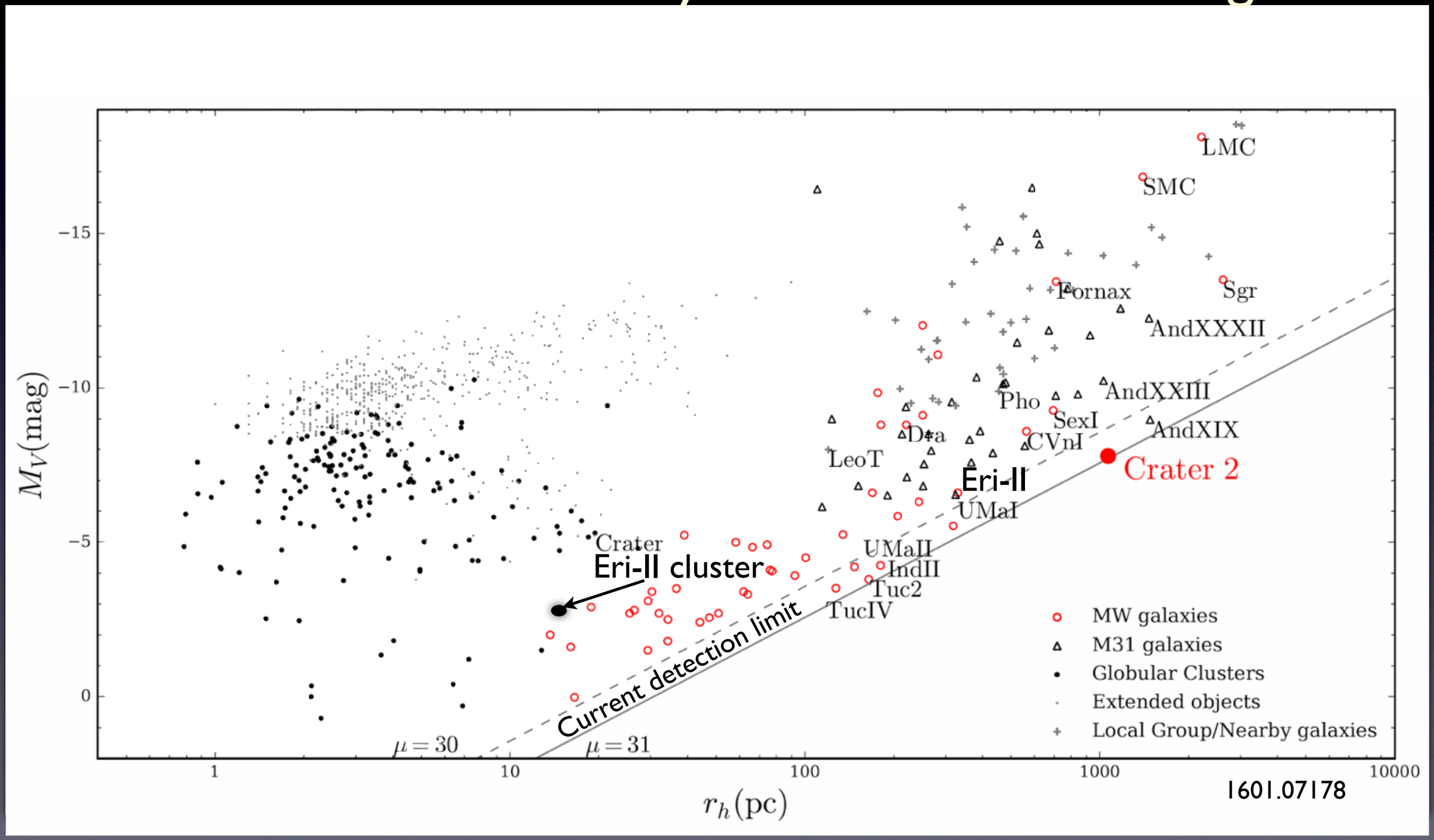


- Dynamical heating of faint dwarfs and their star clusters

S.C., J. Garcia-Bellido, 1711.10458

Seven hints for PBH-DM

Hint 4: Star clusters and dynamics of faint dwarf galaxies



1601.07178

Seven hints for PBH-DM

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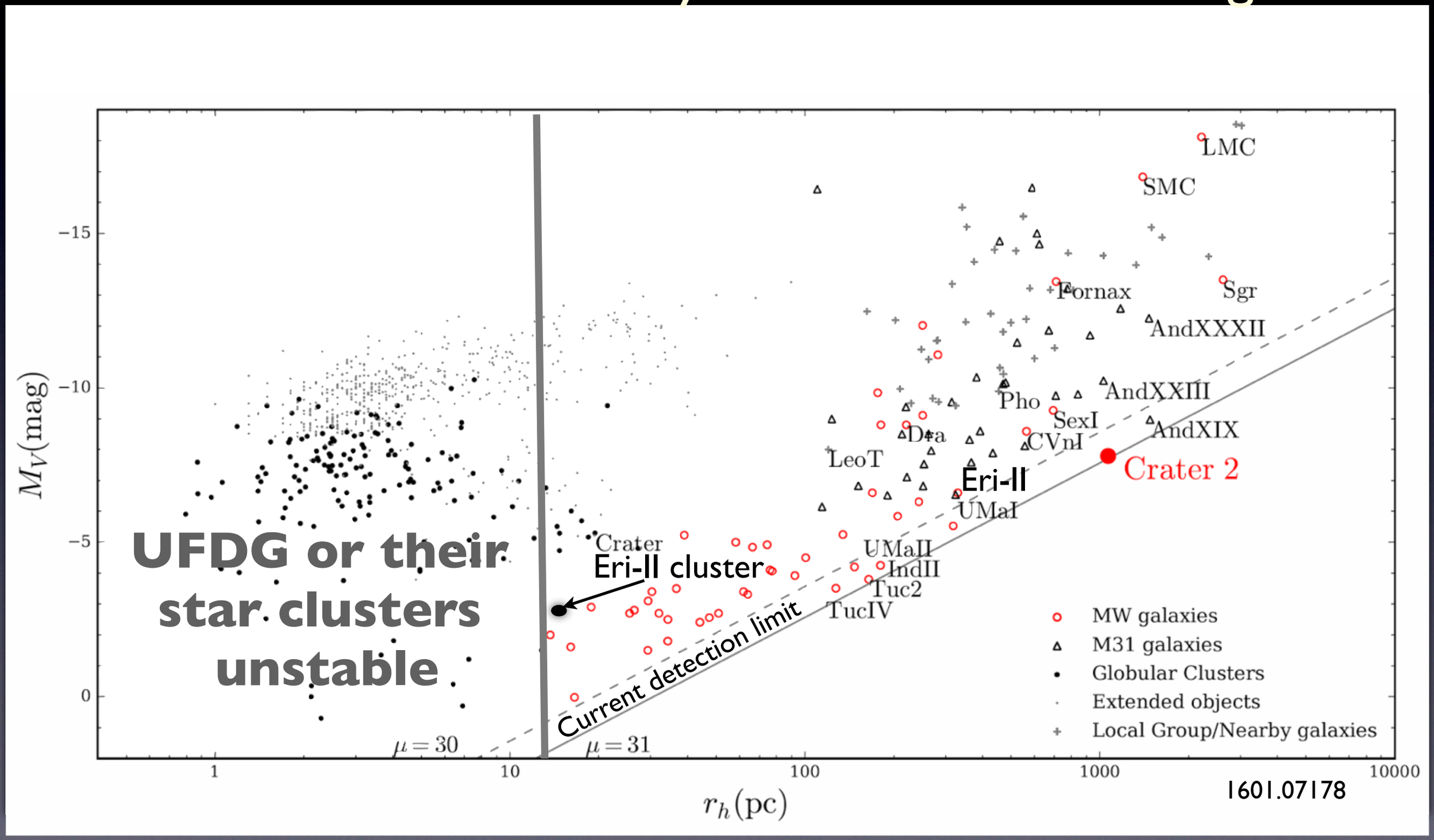

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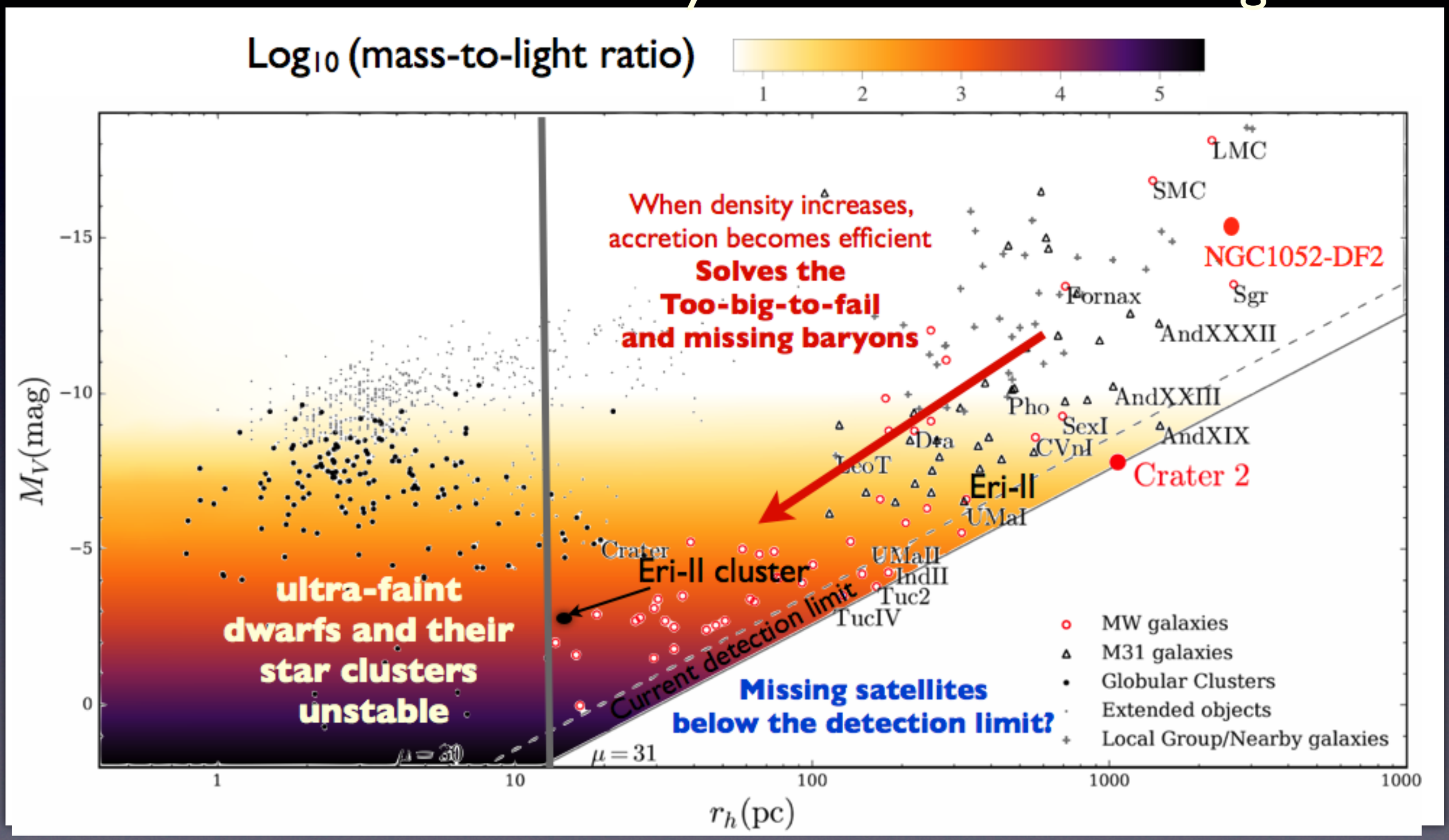

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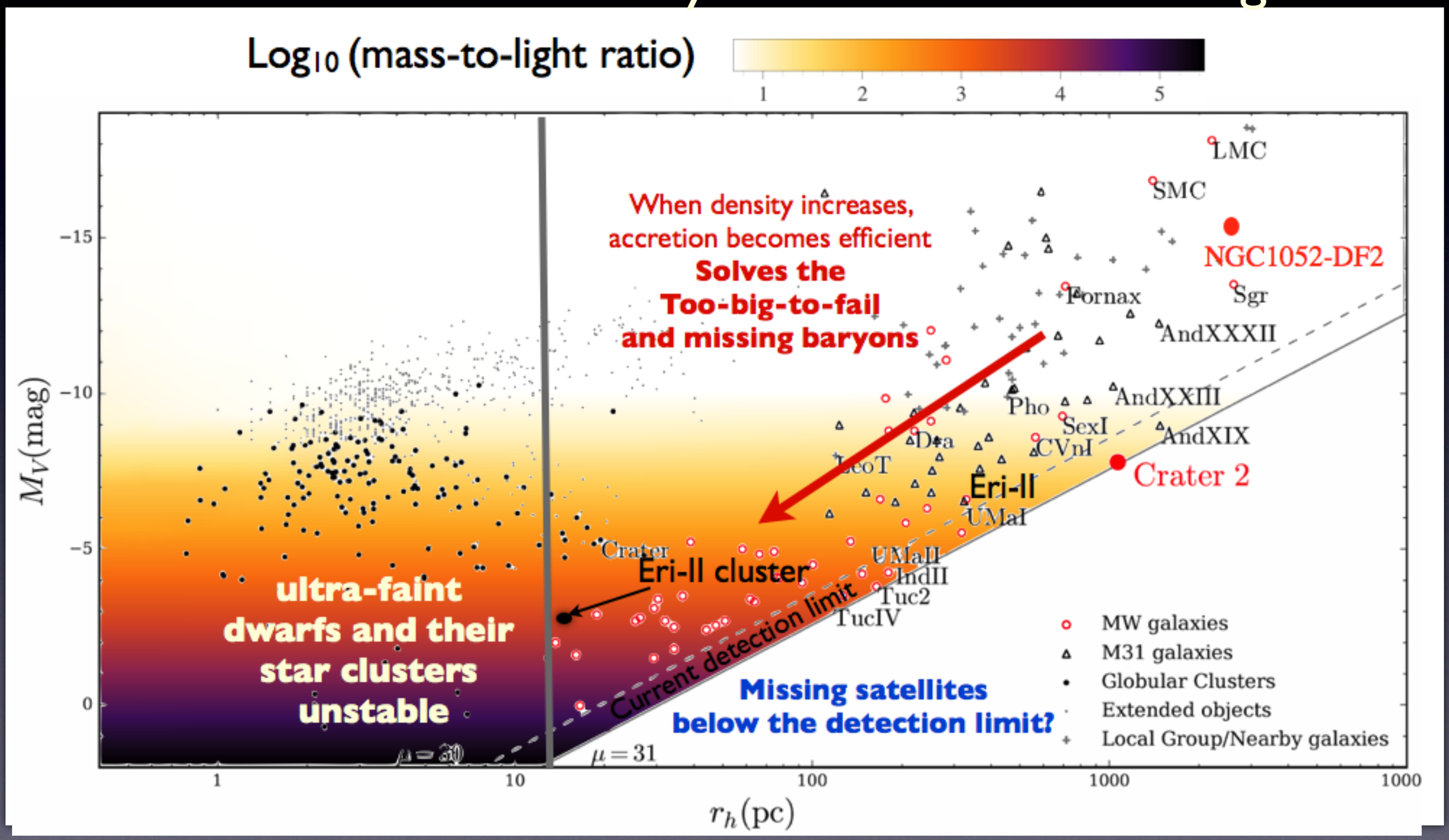

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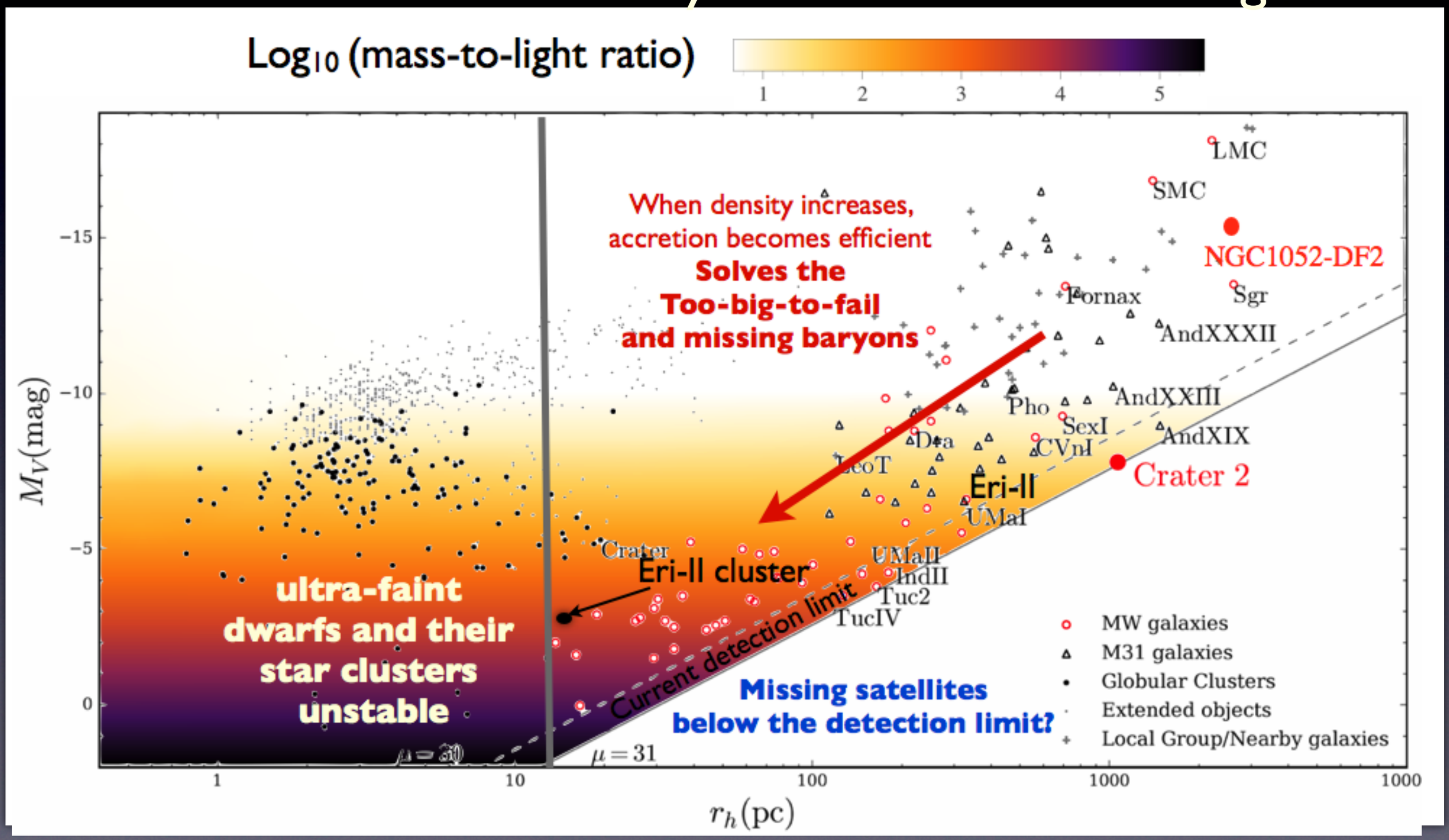


Seven hints for PBH-DM

Hint 5: Core DM density profiles

- Gravitational scattering between PBH: $\frac{\sigma}{m_{\rm PBH}} \sim 0.1 - 1{\rm cm}^2/{\rm g}$
- Dynamical heating of cusps due to two-body interactions
- Relaxation time scale:

$$t_{\rm rel} \approx \frac{r}{v} \frac{N_{\rm PBH}}{8 \ln N_{\rm PBH}}$$

- **Cusps homogenized in ~10 Gyrs up to a radius ~ 1kpc**
- Naturally solves the **core-cusp problem**
- Stable star clusters in UFDG are fine-tuned or require core profile: Amorisco 1704.06262 Contena et al, 1705.01820

Seven hints for PBH-DM

Hint 6: Spatial correlations in CIB and X-ray background

LIGO gravitational wave detection, primordial black holes and the near-II cosmic infrared background anisotropies

A. Kashlinsky[1],

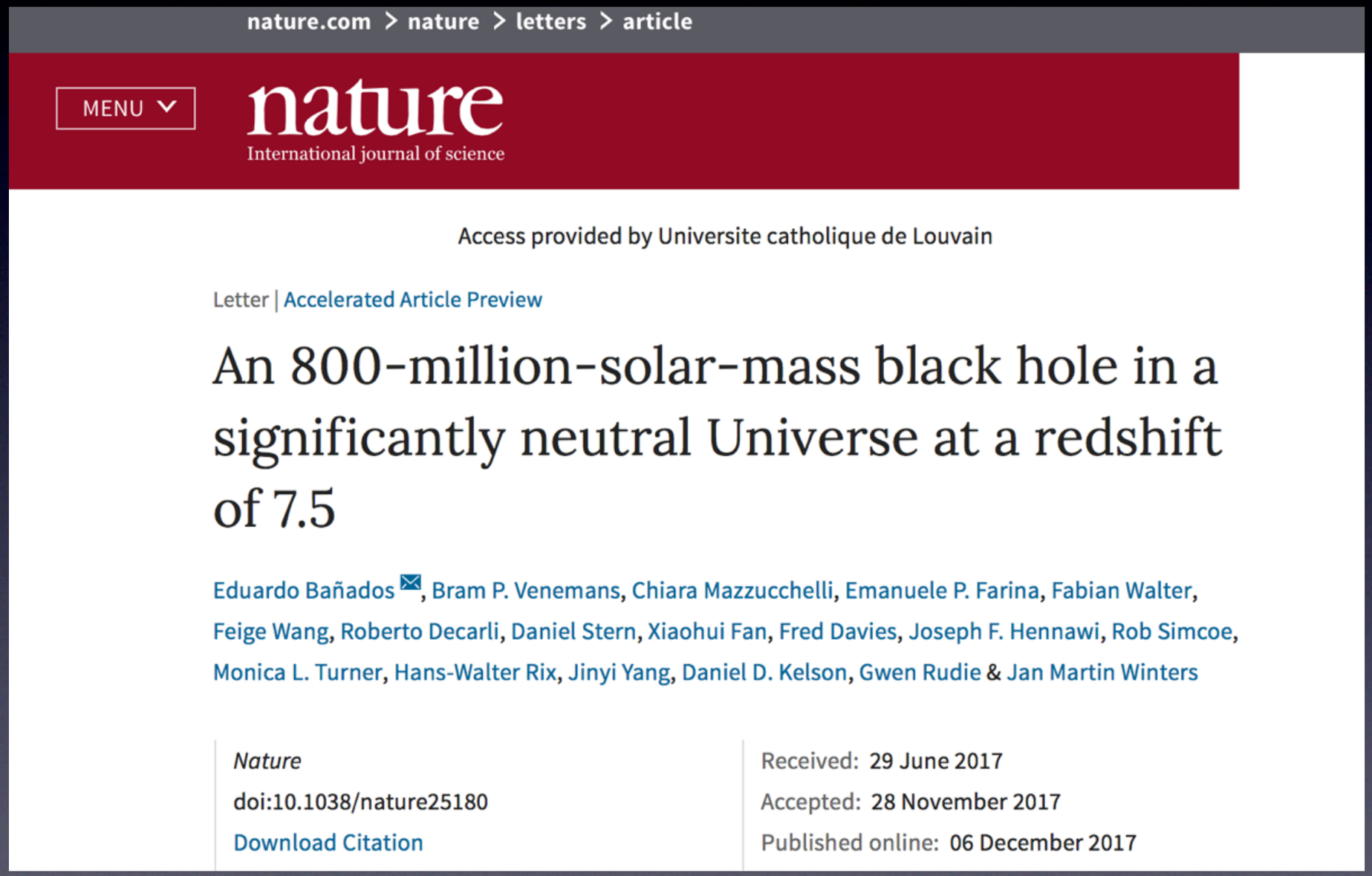
ABSTRACT

LIGO's discovery of a gravitational wave from two merging black holes (BHs) of similar masses rekindled suggestions that primordial BHs (PBHs) make up the dark matter (DM). If so, PBHs would add a Poissonian isocurvature density fluctuation component to the inflation-produced adiabatic density fluctuations. For LIGO's BH parameters, this extra component would dominate the small-scale power responsible for collapse of early DM halos at $z \gtrsim 10$, where first luminous sources formed. We quantify the resultant increase in high-z abundances of collapsed halos that are suitable for producing the first generation of stars and luminous sources. The significantly increased abundance of the early halos would naturally explain the observed source-subtracted near-IR cosmic infrared background (CIB) fluctuations, which cannot be accounted for by known galaxy populations. For LIGO's BH parameters this increase is such that the observed CIB fluctuation levels at 2 to 5 μm can be produced if only a tiny fraction of baryons in the collapsed DM halos forms luminous sources. Gas accretion onto these PBHs in collapsed halos, where first stars should also form, would straightforwardly account for the observed high coherence between the CIB and unresolved cosmic X-ray background in soft X-rays. We discuss modifications possibly required in the processes of first star formation if LIGO-type BHs indeed make up the bulk or all of DM. The arguments are valid only if the PBHs make up all, or at least most, of DM, but at the same time the mechanism appears inevitable if DM is made of PBHs.

1605.04023
1709.02824

Seven hints for PBH-DM

Hint 7: Existence of super-massive BH at high redshifts



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An 800-million-solar-mass black hole in a significantly neutral Universe at a redshift of 7.5

Eduardo Bañados, Bram P. Venemans, Chiara Mazzucchelli, Emanuele P. Farina, Fabian Walter, Feige Wang, Roberto Decarli, Daniel Stern, Xiaohui Fan, Fred Davies, Joseph F. Hennawi, Rob Simcoe, Monica L. Turner, Hans-Walter Rix, Jinyi Yang, Daniel D. Kelson, Gwen Rudie & Jan Martin Winters

Nature
doi:10.1038/nature25180
Download Citation

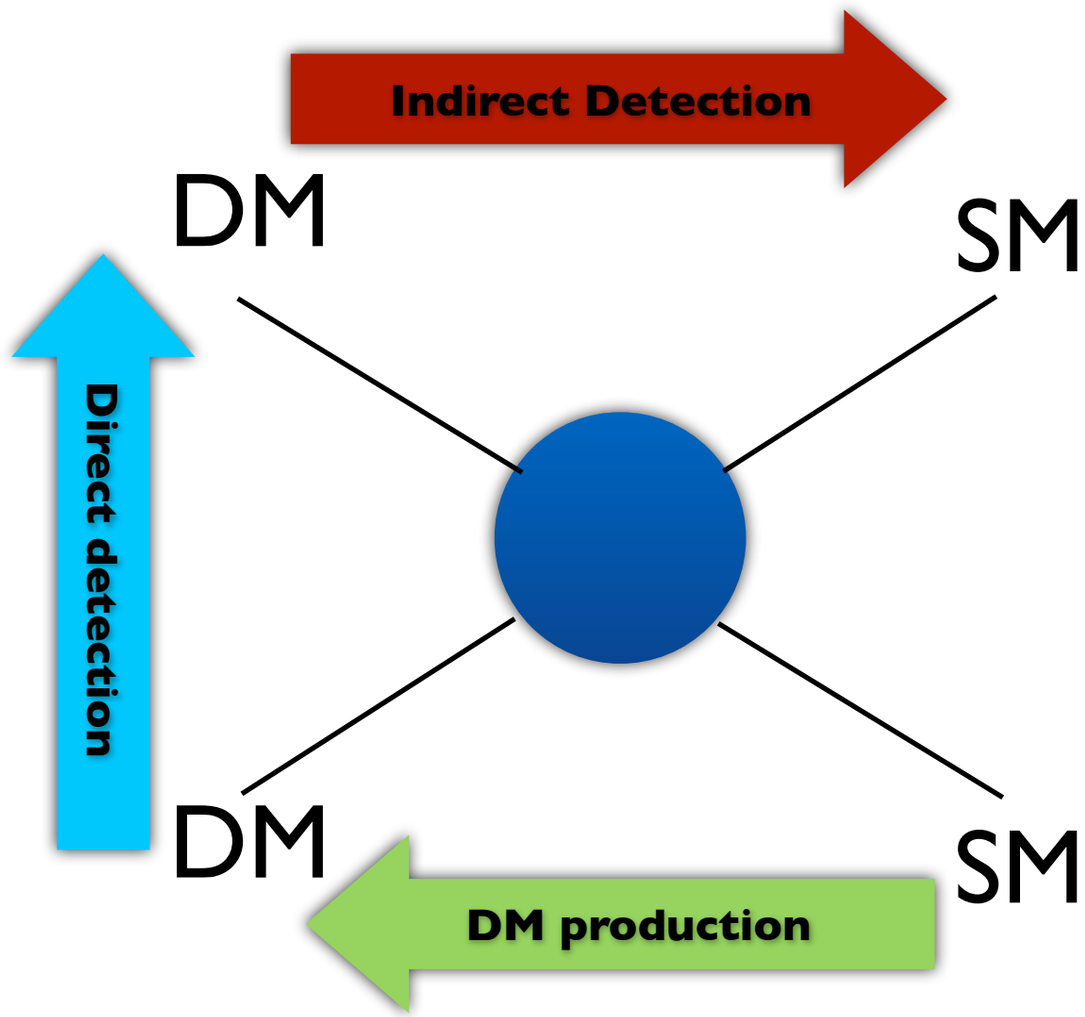
Received: 29 June 2017
Accepted: 28 November 2017
Published online: 06 December 2017

1712.01870

PBH provide the right number of seeds for SMBH

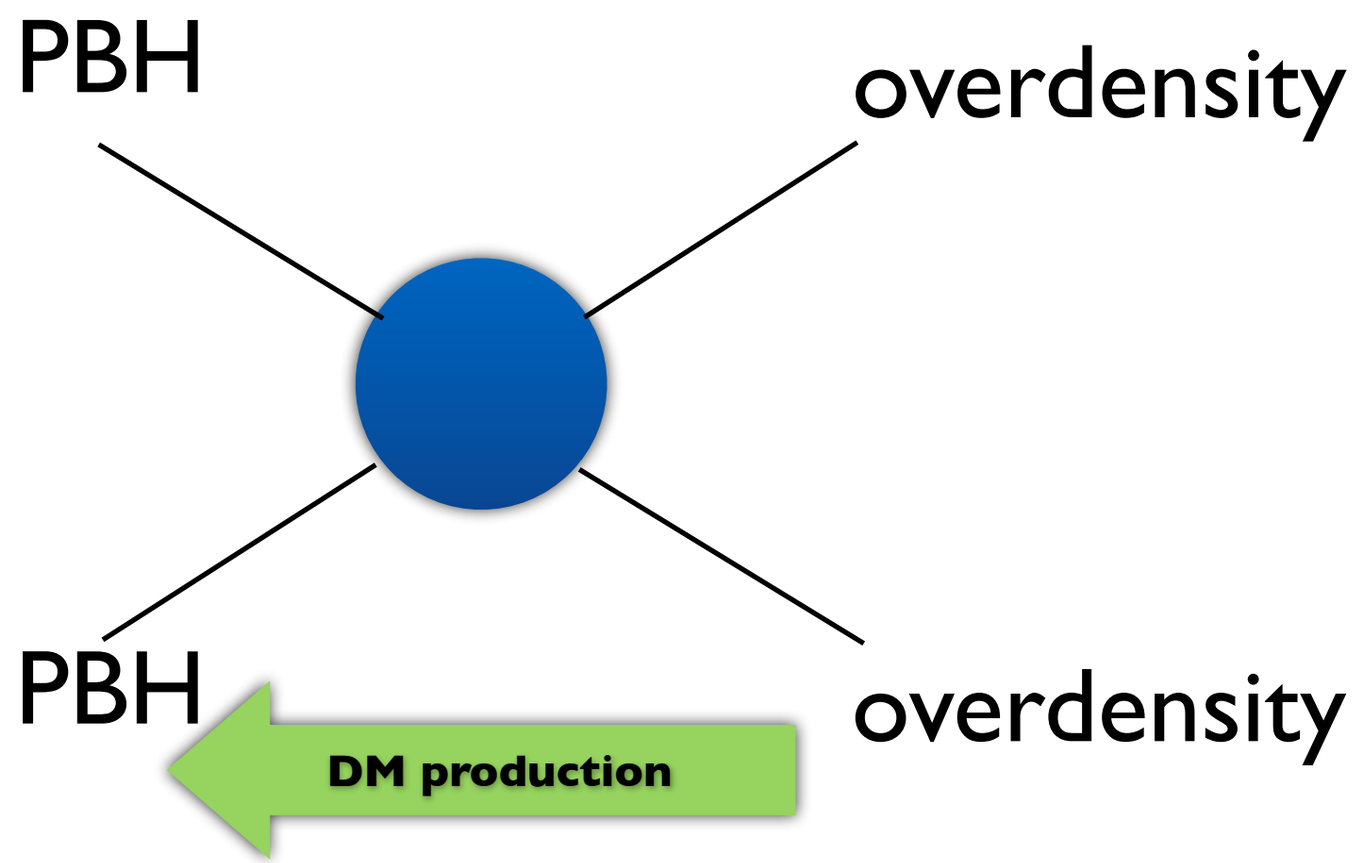
Primordial Black Holes

Rethinking Dark Matter interactions:



Primordial Black Holes

Rethinking Dark Matter interactions: PBH formation

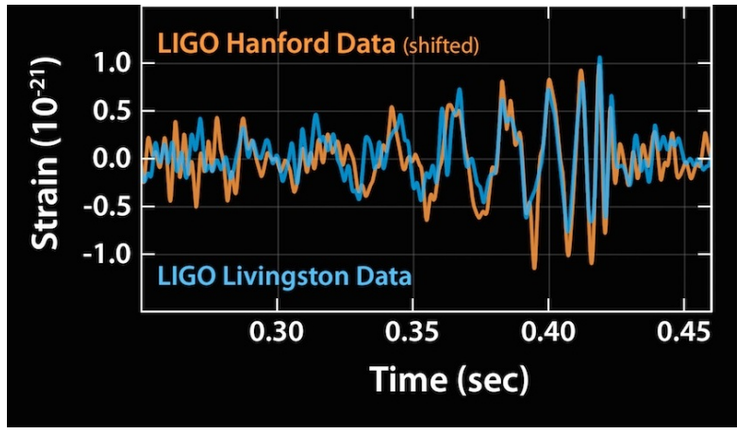


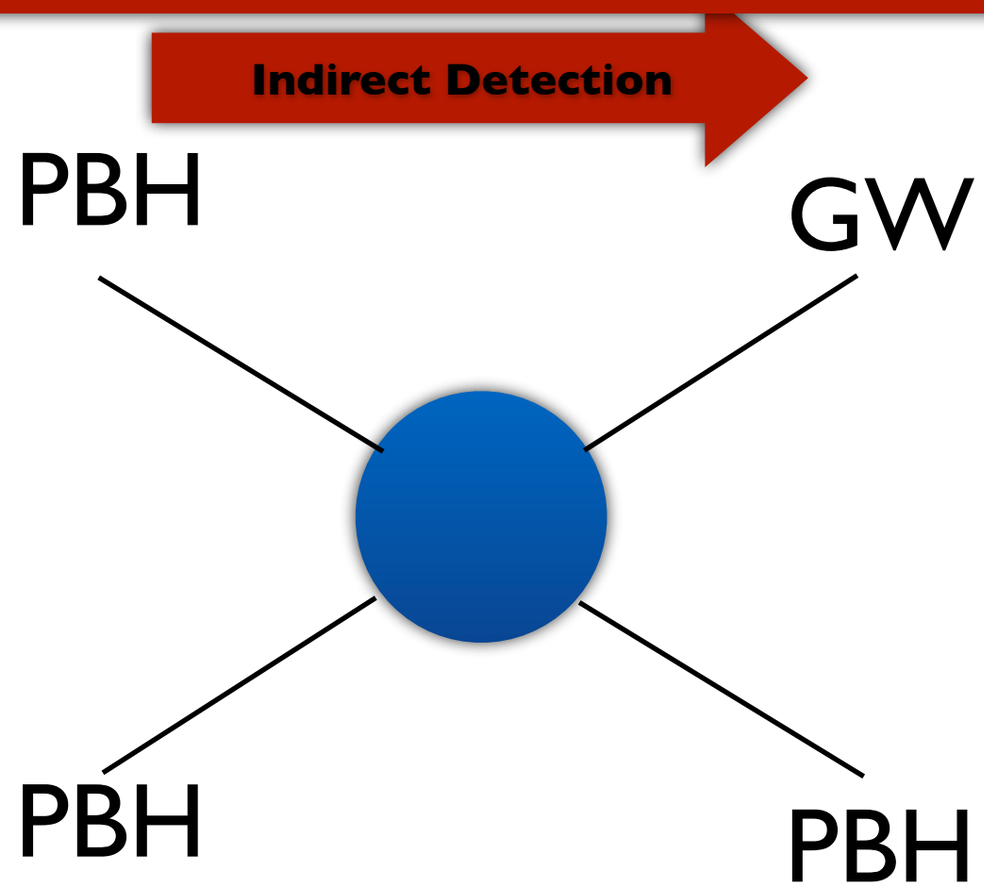
CMB distortions, ultra-compact mini halos
Detectable GW background by Pulsar Timing Arrays (SKA)

Primordial Black Holes

Rethinking Dark Matter interactions: merging of PBH

GW from BH mergers detected by LIGO,
constraints from Dark Radiation





Clue I: LIGO merger rates compatible with PBH-DM

Bird et al ; S.C., J. Garcia-Bellido ; M. Sasaki, T. Suyama, S. Yokoyama, March 2016

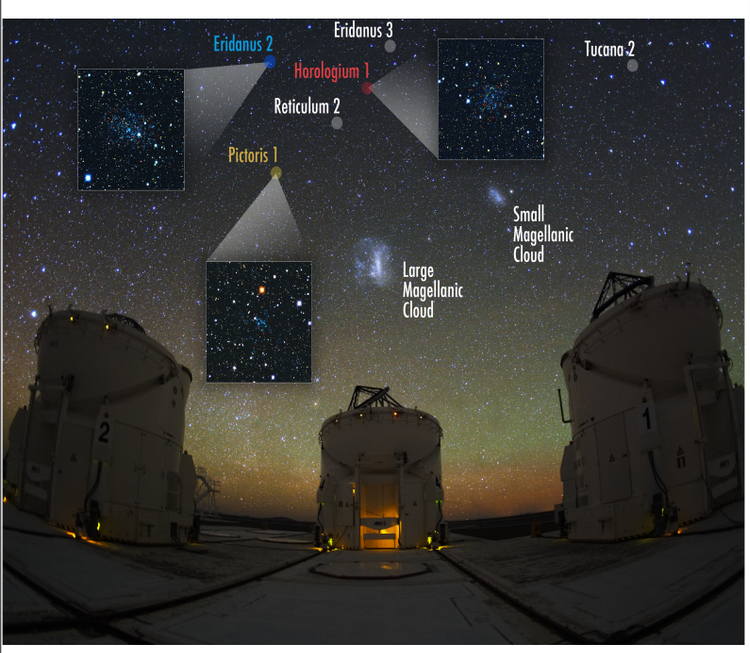
Clue II: Low spin and mass of black hole progenitors

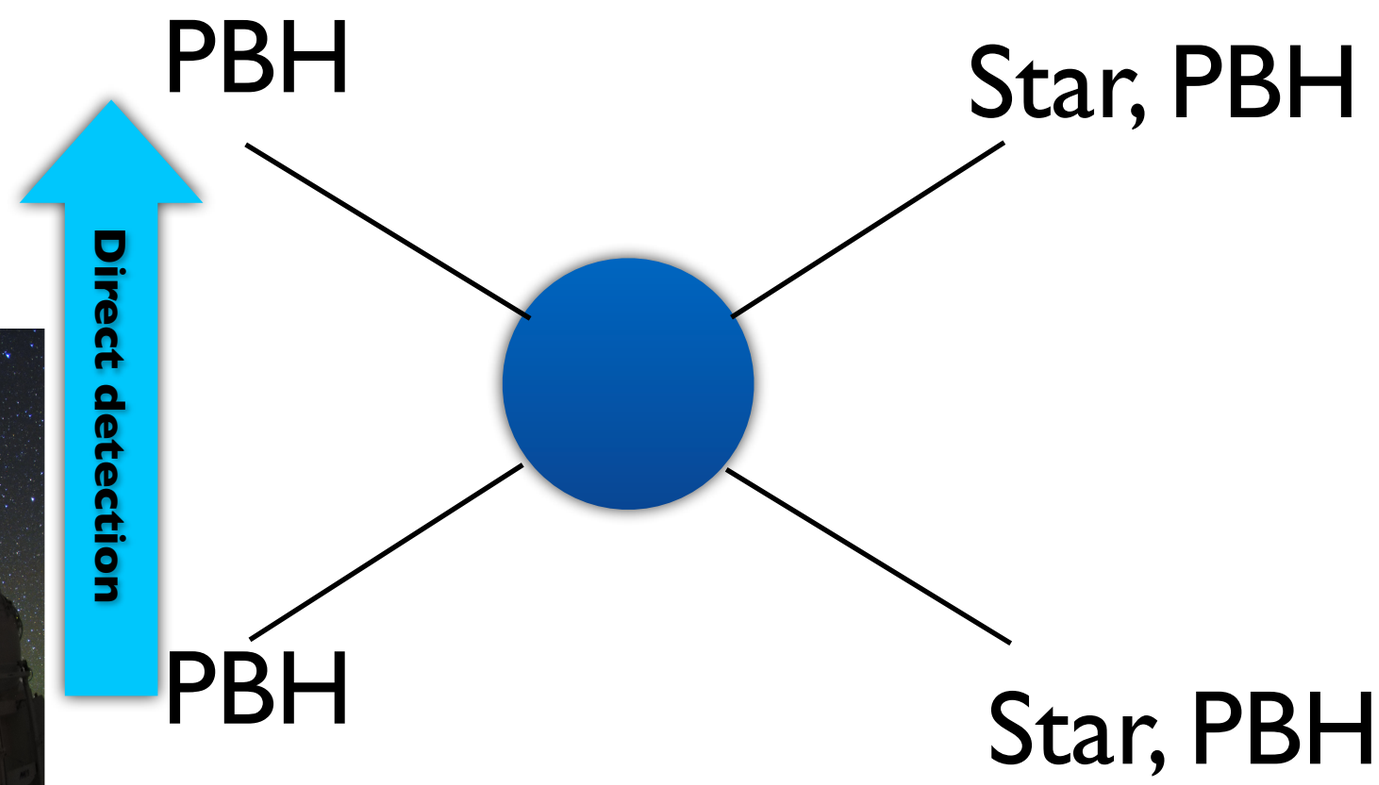
Next step: Black hole below Chandrasekhar mass (ET)

Primordial Black Holes

Rethinking Dark Matter interactions: Gravitational scattering

Ultra-faint dwarf galaxies, core/cusp problem





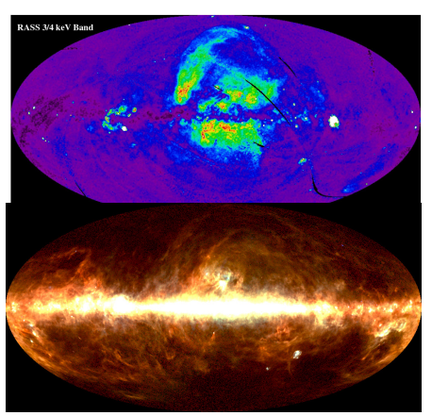
Clue 3: observations of faint dwarf galaxies and their star clusters

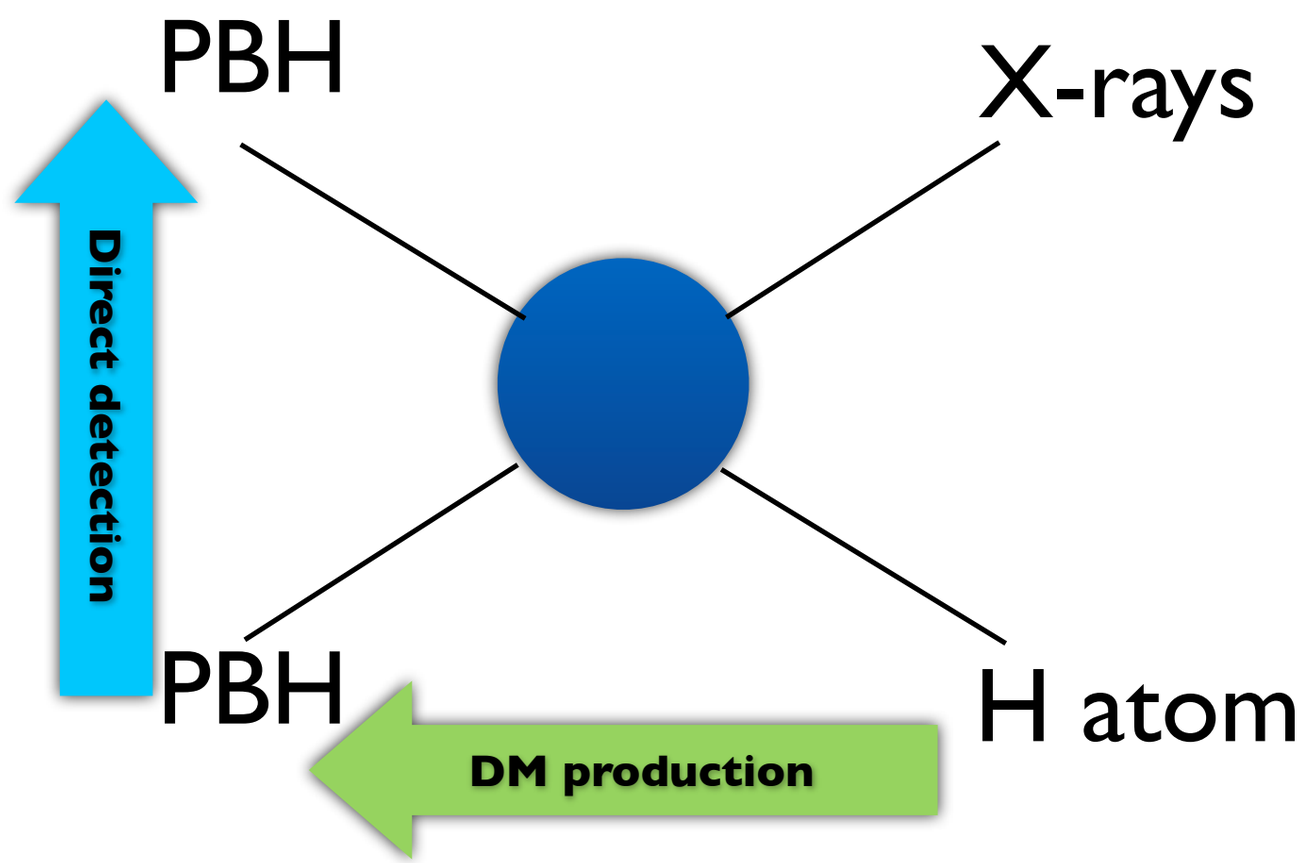
Primordial Black Holes

Rethinking Dark Matter interactions: accretion onto PBH

Clue 5: Correlations between X-ray and infrared backgrounds
Clue 6: Observations of early super-massive BH

X-ray background radiation,
CMB signatures,
21cm signal (SKA)



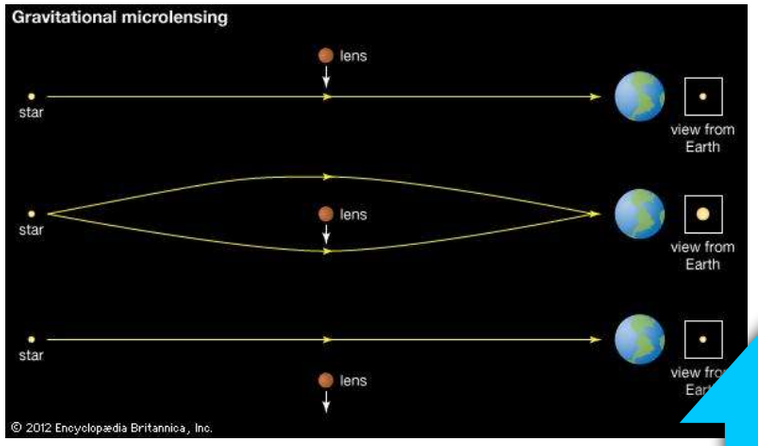


Explains the mass-to-light ratios in dwarf galaxies, missing stellites, too-big-to-fail problem, missing baryons, super-massive black holes

Primordial Black Holes

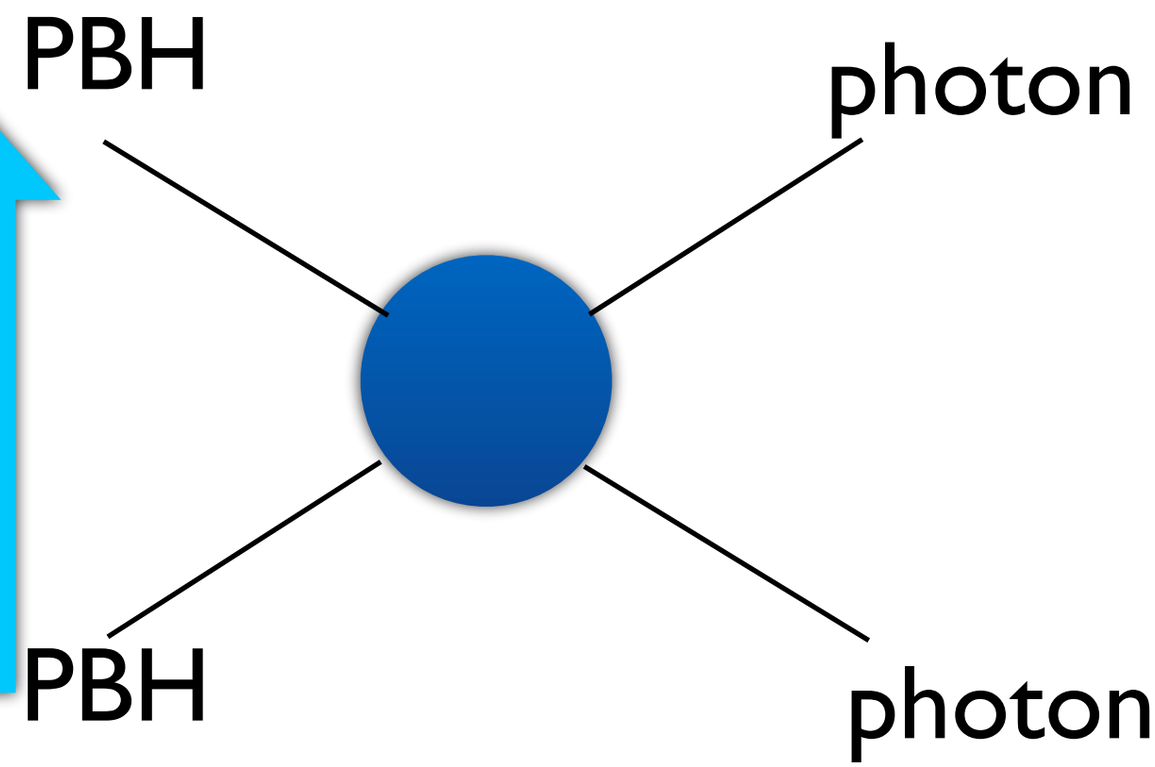
S.C., J. Garcia-Bellido, 1711.10458; ***SciAm****, July 2017*

Rethinking Dark Matter interactions: microlensing surveys



Microlensing of stars in Andromeda and distant quasars, lensing of supernovae

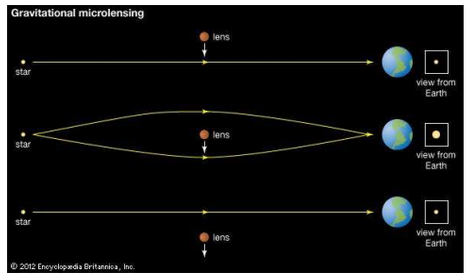
Direct detection

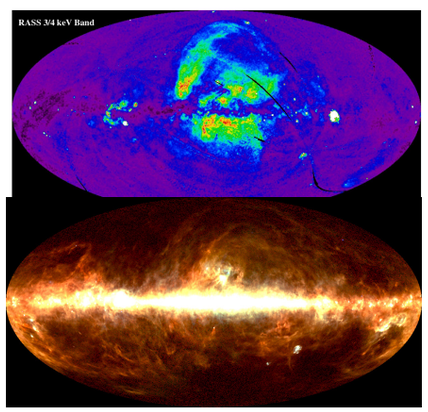


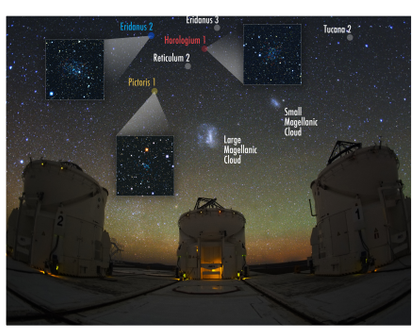
Clue 7: between 15% and 35% of sub-solar compact objects in galactic halos

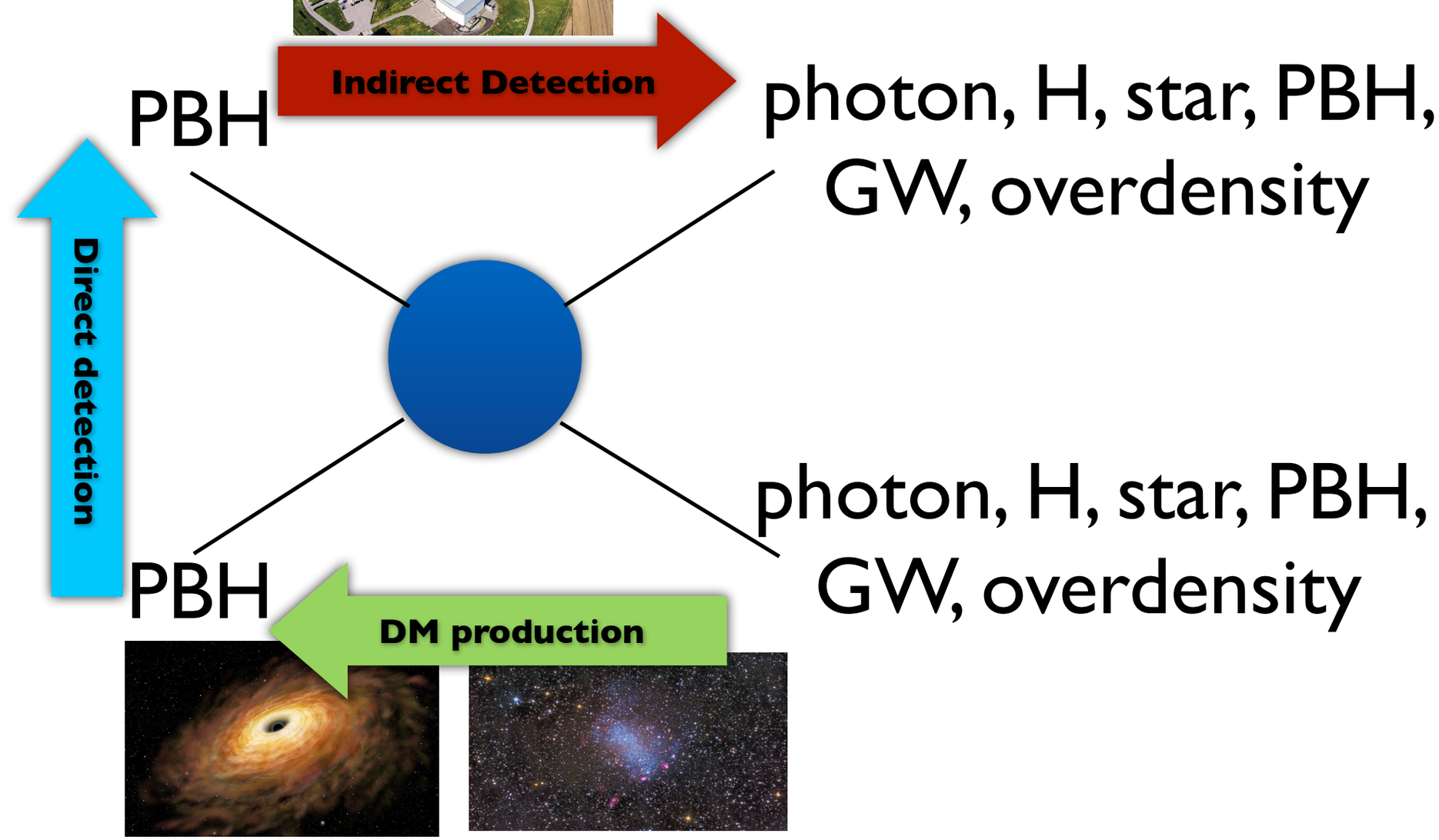
Primordial Black Holes

Exciting times, very active, multi-disciplinary field, some clues in observations, upcoming experiments will challenge the scenario...









Thank you
for your attention

...and future prospects

- Detecting a BH below the Chandrashekar mass (LIGO)
- Numerous merging events seen in GW detectors (LIGO, VIRGO, ET...)
- GW Stochastic Background (PTAs, LISA, LIGO)
- Detecting faint dwarf galaxies (DES, Euclid)
- Microlensing surveys (Euclid)
- 21cm signal (SKA)
- CMB (Planck, S4, LiteBird)
- Star position and velocities (GAIA), LMXB, PS in GC

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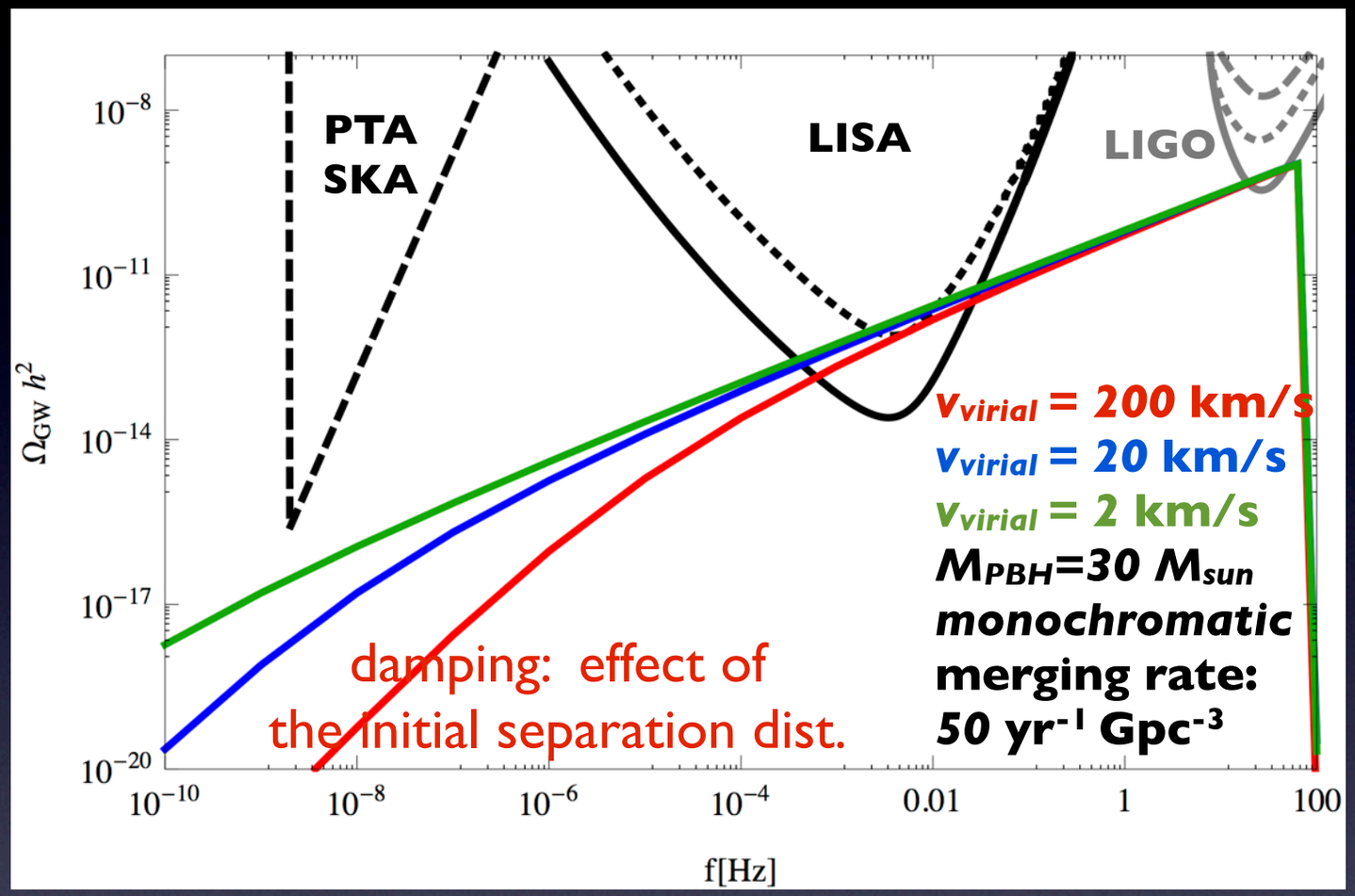

Clustering allows to distinguish stellar and primordial origins
SC, JGB, 1610.08479

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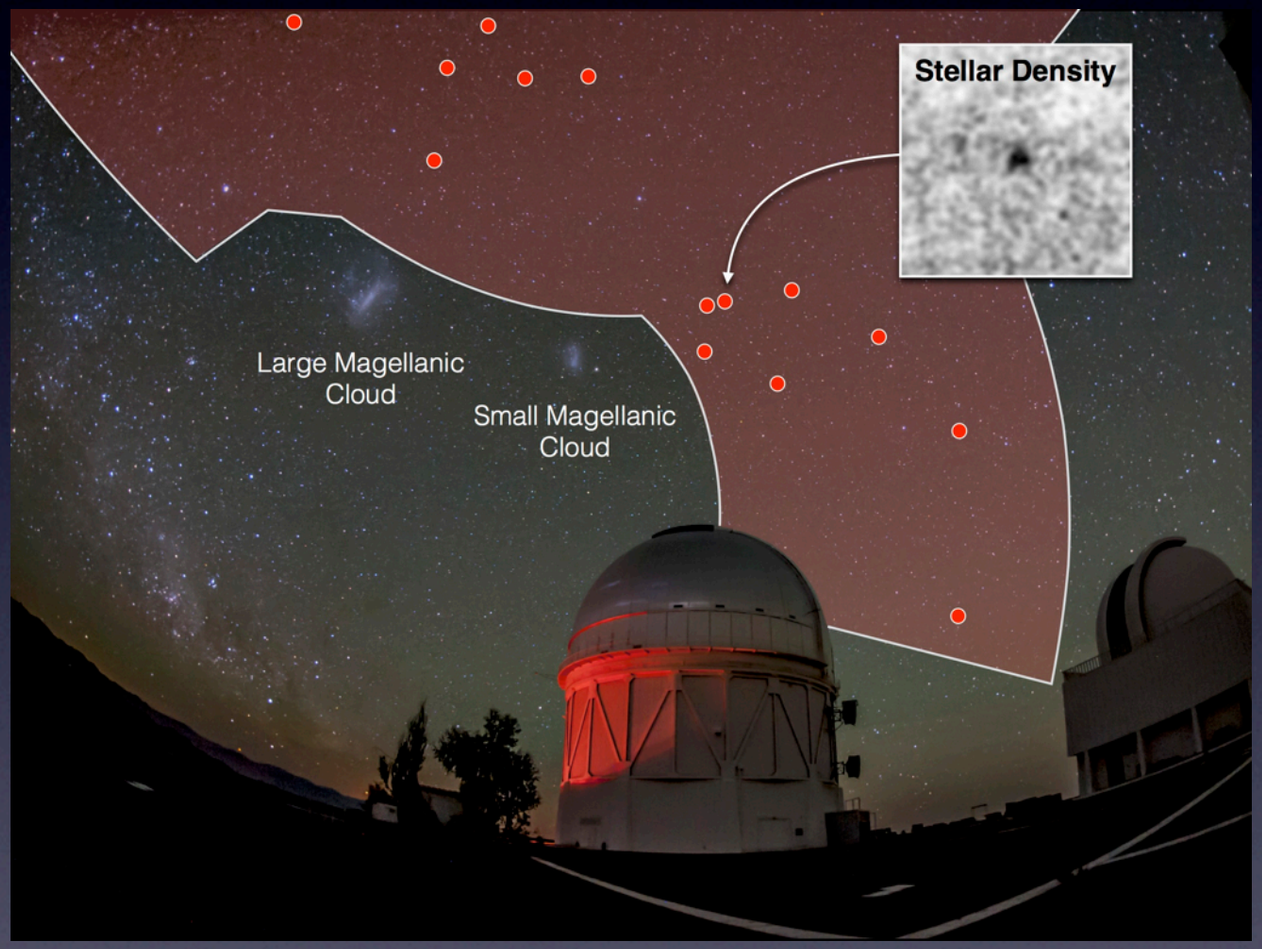

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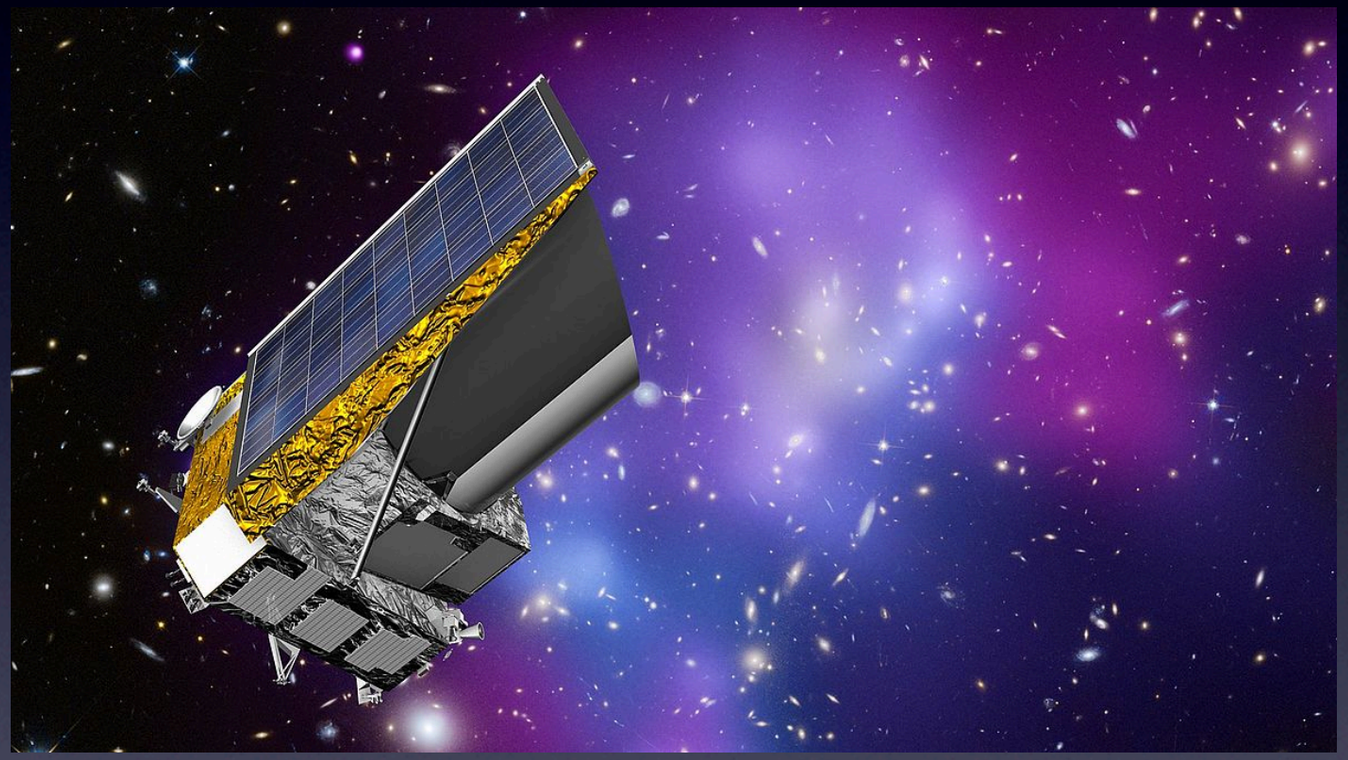
- CMB (Planck, S4, LiteBird)
- Star position and velocities (GAIA), LMXB, PS in GC



...and future prospects

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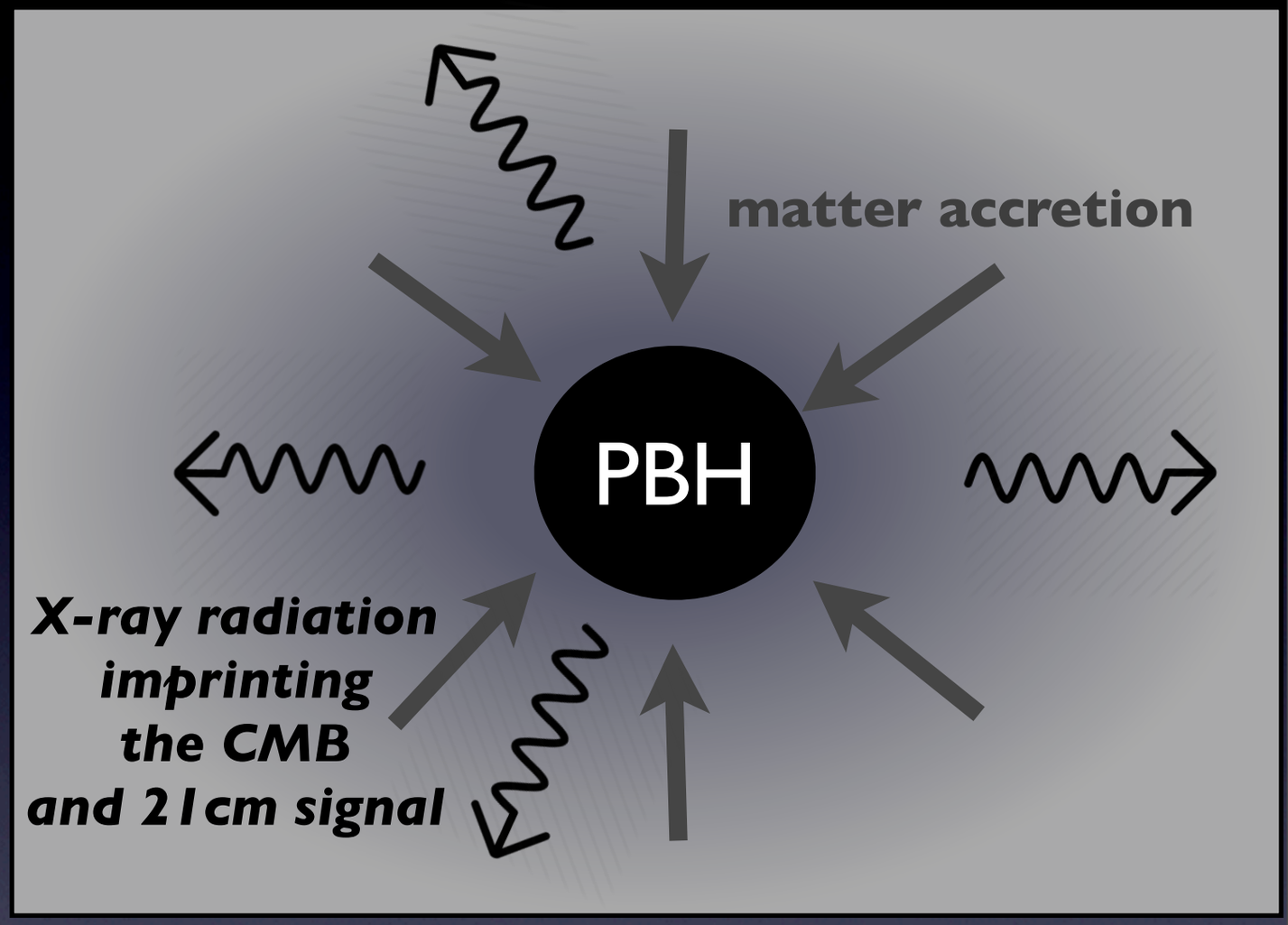

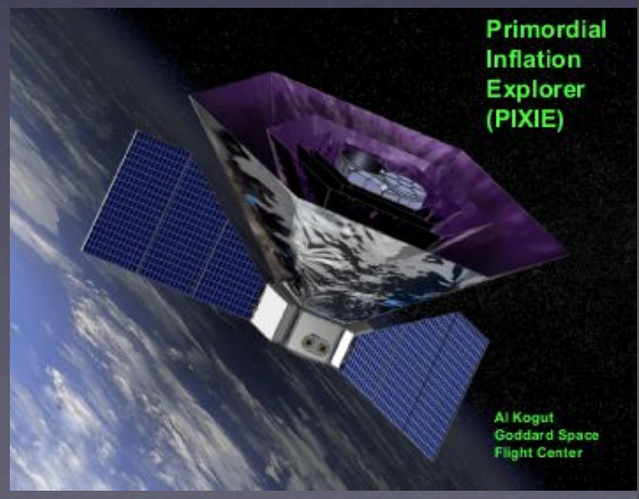

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