

CF03: Cosmic Probes of Dark Matter Physics

SnowMass2021

Conveners: Alex Drlica-Wagner, Chanda
Prescod-Weinstein, Hai-Bo Yu

April 5th, 2022

CF03: Cosmic Probes of Dark Matter

Cosmological and astrophysical measurements provide the **only** robust, positive empirical measurements of dark matter.

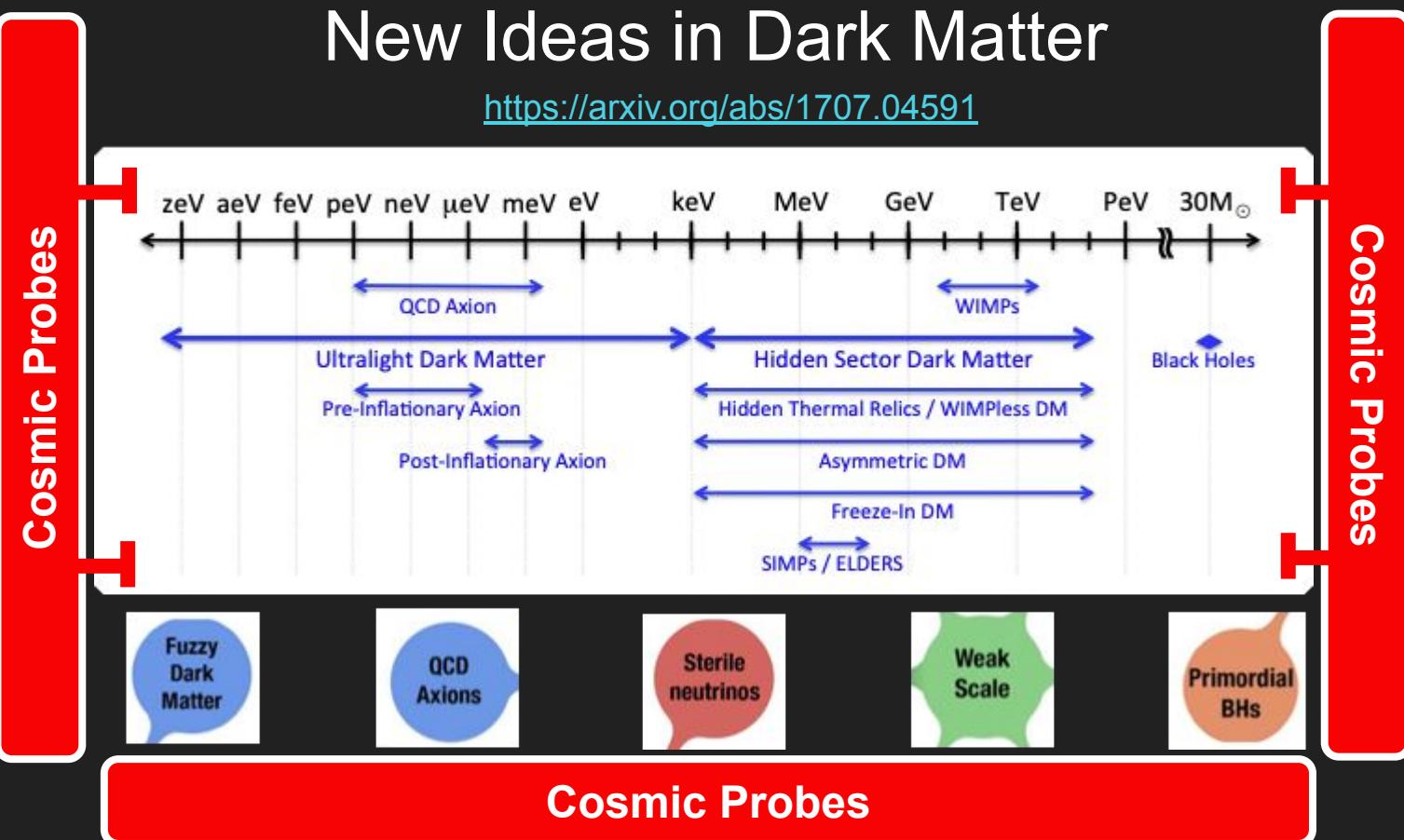
Cosmic probes are **unique** in that they do not rely on the assumption that dark matter has interactions with normal matter beyond gravity; thus they are the most “expansive” (and could be the **only** viable) approach to the dark matter problem.

Cosmic probes require strong synergy among particle theorists, dynamists, simulators, observers, and experimentalists; need a **new mechanism** to support these emerging, collaborative efforts.

Cosmic probes are highly relevant and complementary to search efforts in CF1, CF2, CF7 and other frontiers, and there is strong **experimental synergy** with cosmological probes of dark matter, dark energy, and inflation (CF4, CF5, CF6).

New Ideas in Dark Matter

<https://arxiv.org/abs/1707.04591>



Astrophysics provides the **only** robust, positive measurement of dark matter and bounds the mass range of dark matter candidates

Letters of Interest and Solicited White Papers

- CF03 received **~75 Letters of Interest** from the community.
- Through a series of discussions (including the Community Planning Meeting), we arrived at a list of **5 solicited white papers** with designated facilitators. All have been submitted.
- CF03 has received **5 additional white papers** (to date). Other relevant white papers include **~15 white papers** submitted to other CF topical groups and other frontiers.

**THANK YOU
white paper facilitators and authors!**

CF03 “Solicited” White Paper Topics

- **Dark matter physics from halo measurements** [2203.07354]

Dark matter physics from dark matter halos ranging from large-scale structure to sub-galactic scales.

Facilitators: **Keith Bechtol, Simon Birrer, Francis-Yan Cyr-Racine, Katelin Schutz**

- **Numerical simulations and systematics** [2203.07049]

Importance of numerical simulations for extracting dark matter physics

Facilitators: **Arka Banerjee, Ferah Munshi, Annika Peter**

- **Primordial Black Holes & Gravitational Waves** [2203.08967]

Primordial black holes as dark matter and probes of inflation

Facilitators: **Andrea Albert, Simeon Bird, Will Dawson**

- **Dark matter physics in extreme astrophysical environments** [2203.07984]

Includes stellar interiors, neutron stars, non-primordial black holes

Facilitators: **Masha Baryakhtar, Regina Caputo, Djuna Croon, Kerstin Perez**

- **Facilities for cosmic probes of dark matter physics** [2203.06200]

Proposed facilities for cosmic probes of dark matter

Facilitators: **Sukanya Chakrabarti, Ting Li, Neelima Sehgal, Josh Simon**

ATTN: CF01, CF02

Snowmass2021 Cosmic Frontier White Paper: Dark Matter Physics from Halo Measurements

Keith Bechtol¹, Simon Birrer^{2,3,4}, Francis-Yan Cyr-Racine⁵, Katelin Schutz⁶, Susmita Adhikari^{7,8}, Arka Banerjee^{7,9}, Simeon Bird¹⁰, Nikita Blinov¹¹, Kimberly K. Boddy¹², Celine Boehm¹³, Kevin Bundy^{14,15}, Malte Buschmann¹⁶, Sukanya Chakrabarti¹⁷, David Curtin¹⁸, Liang Dai¹⁹, Alex Drlica-Wagner^{8,9,20}, Cora Dvorkin²¹, Adrienne L. Erickcek²², Daniel Gilman²³, Saniya Heeba⁶, Stacy Kim²⁴, Vid Irsic^{25,26}, Alexie Leauthaud¹⁴, Mark Lovell²⁷, Zarija Lukic²⁸, Yao-Yuan Mao²⁹, Sidney Mau^{2,3}, Andrea Mitridakis³⁰, Philip Mocz³¹, Julian B. Muñoz³², Ethan O. Nadler^{33,34}, Annika H. G. Peter³⁵, Adrian Price-Whelan³⁶, Andrew Robertson³⁷, Nashwan Sabti³⁸, Neelima Sehgal³⁹, Nora Shipp^{8,20}, Joshua D. Simon³³, Rajeev Singh⁴², Ken Van Tilburg^{35,40}, Risa H. Wechsler^{2,3,4}, Axel Widmark⁴¹, and Hai-Bo Yu¹⁰

2 Classes of Dark Matter Behavior

2.1	<i>Ab Initio</i> Impact on Structure Formation	.....
2.1.1	Thermal history	.....
2.1.2	Non-thermal history	.....
2.1.3	Early departures from radiation domination	.....
2.1.4	Interactions with the SM	.....
2.2	<i>In Situ</i> Impact on Structure Formation	.....
2.2.1	Self-interacting dark matter	.....
2.3	Hybrid Impact on Structure Formation	.....
2.3.1	Composite dark matter	.....
2.3.2	Low-mass bosons	.....

3 Cluster Scale

3.1	Scale and Objects	.....
3.2	Observational Probes	.....
3.2.1	Density profiles of clusters	.....
3.2.2	Merging clusters	.....
3.2.3	Brightest cluster galaxy oscillations	.....
3.2.4	Substructure in massive clusters	.....
3.3	Theory Connections	.....

4 Galaxy Scale

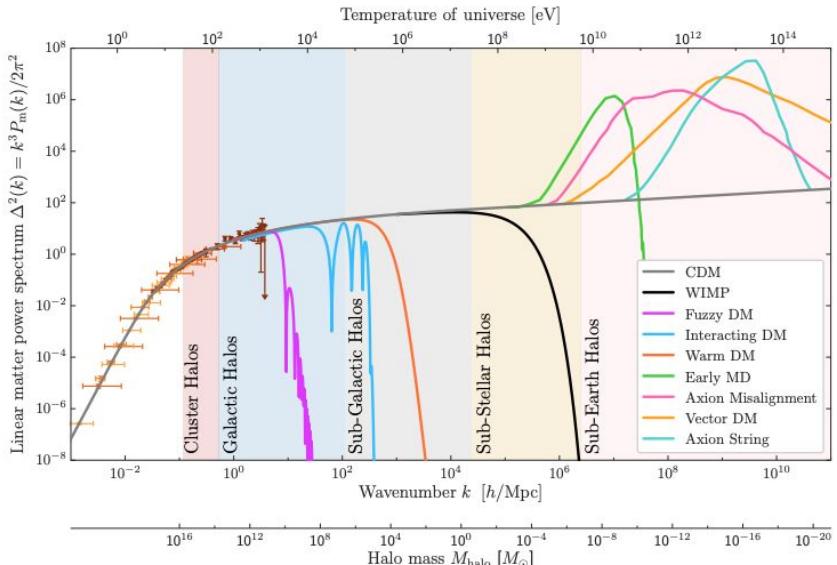
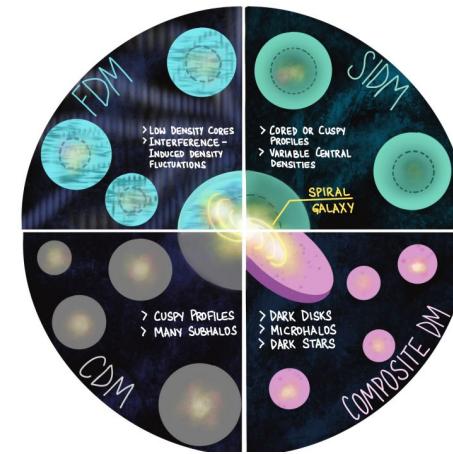
4.1	Scale and Objects	.....
4.2	Observational Probes	.....
4.2.1	Dwarf galaxy lensing	.....
4.2.2	Milky Way stellar dynamics	.....
4.2.3	Galactic rotation curves	.....
4.2.4	Ultraviolet luminosity function	.....
4.3	Theory Connections	.....

5 Beyond the Threshold of Galaxy Formation

5.1	Scale and Objects	.....
5.2	Observational Probes	.....
5.2.1	Ultra-faint galaxies	.....
5.2.2	Lyman-alpha forest	.....
5.2.3	Stellar streams	.....
5.2.4	Galaxy strong lensing	.....
5.2.5	21-cm at cosmic dawn	.....
5.2.6	Extreme CMB lensing	.....
5.3	Theory Connections	.....

6 Stellar and Planet Mass Scale

6.1	Scale and Objects	.....
6.2	Observational Probes	.....
6.2.1	Precision astrometry	.....
6.2.2	Cluster caustics	.....
6.2.3	Gravitational microlensing	.....
6.2.4	Gravitational waves	.....
6.2.5	Pulsar timing arrays	.....
6.2.6	Lensed fast radio bursts	.....
6.3	Theory Connections	.....



ATTN: CF04, TF09, CompF02

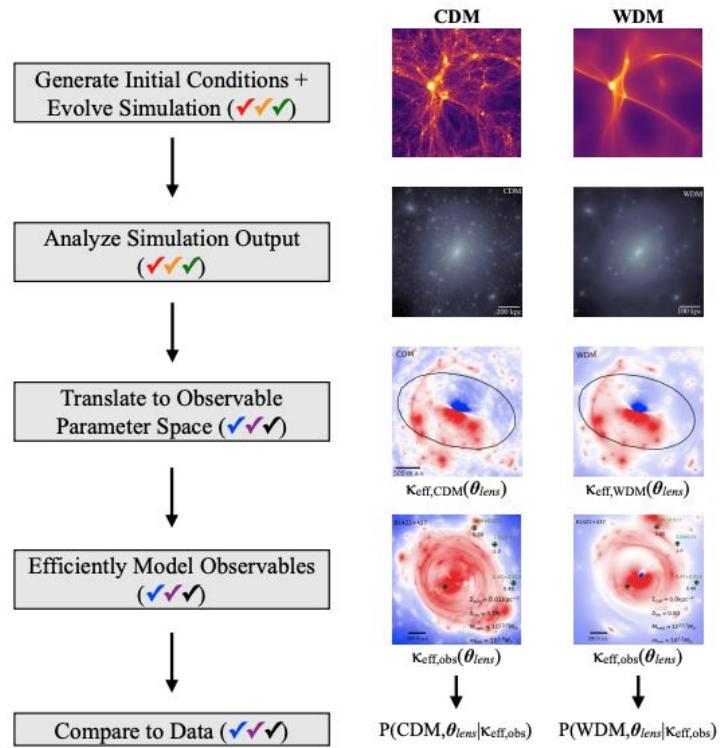
Snowmass2021 Cosmic Frontier White Paper: Cosmological Simulations for Dark Matter Physics

Arka Banerjee^{1,2,†}, Kimberly K. Boddy³, Francis-Yan Cyr-Racine⁴, Adrienne L. Erickcek⁵, Daniel Gilman⁶, Vera Gluscevic⁷, Stacy Kim⁸, Benjamin V. Lehmann^{9,10}, Yao-Yuan Mao¹¹, Philip Mocz¹², Ferah Munshi^{13,†}, Ethan O. Nadler^{14,7}, Lina Necib¹⁵, Aditya Parikh¹⁶, Annika H. G. Peter^{17,†}, Laura Sales¹⁸, Mark Vogelsberger¹⁵, and Anna C. Wright¹⁹

1. **Close collaboration between simulators and particle theorists** to both identify key models and areas of parameter space and to successfully implement these models. This includes starting from appropriate initial conditions to providing simulation outputs in a manner that is meaningful to particle theorists, simulators and observers alike.
2. **Algorithm development and code comparison tests** ensuring that simulations meet the required precision targets set by the sensitivity of the new facilities. For hydrodynamic modeling, this includes evaluation and comparison of different subgrid physics parameterizations.
3. **Performing simulations with full hydrodynamics with validated subgrid models and numerical resolution** at the relevant redshifts and cosmological scales.
4. **Analysis of outputs in the realm of observations** including mass functions, luminosity functions, galaxy morphology, kinematics, intracluster light all measured in an apples-to-apples manner with observations from current and upcoming facilities.
5. **Fast realizations of observables for inference of DM properties** in order to constrain DM particle parameters from observation on feasible timescales.
6. **Identifying novel signatures from simulations and guidance to observers** derived both from numerical simulations and fast realizations that point to signatures of DM physics.

<https://arxiv.org/abs/2203.07049>

Measuring Dark Matter Physics using Cosmological Simulations



Need #1: Collaboration between simulators and particle theorists

Need #2: Algorithm development and code comparison tests

Need #3: Hydrodynamic simulations for observational targets

Need #4: Compare simulations to data in observable parameter space

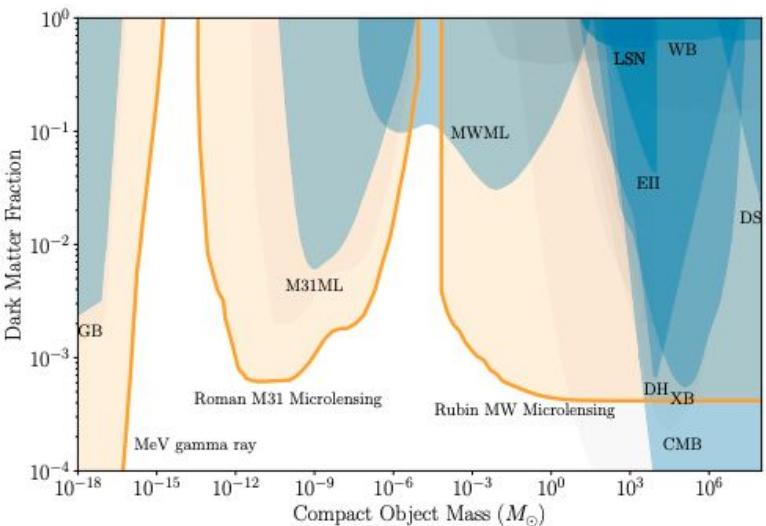
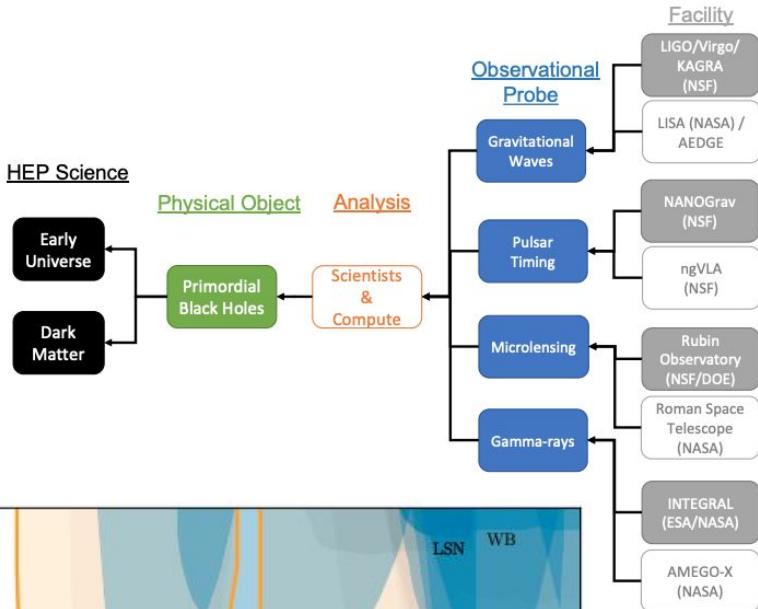
Need #5: Fast realizations of observed systems to constrain dark matter

Need #6: Provide guidance to observers about dark matter signatures

Snowmass2021 Cosmic Frontier White Paper: Primordial Black Hole Dark Matter

Simeon Bird¹, Andrea Albert², Will Dawson³, Yacine Ali-Haimoud⁴, Adam Coogan^{5,6}, Alex Drlica-Wagner^{7,8,9}, Qi Feng¹⁷, Derek Inman¹⁰, Keisuke Inomata⁸, Ely Kovetz¹¹, Alexander Kusenko^{10,12}, Benjamin V. Lehmann^{13,14}, Julian B. Muñoz¹⁵, Rajeev Singh¹⁸, Volodymyr Takhistov¹⁰, and Yu-Dai Tsai¹⁶

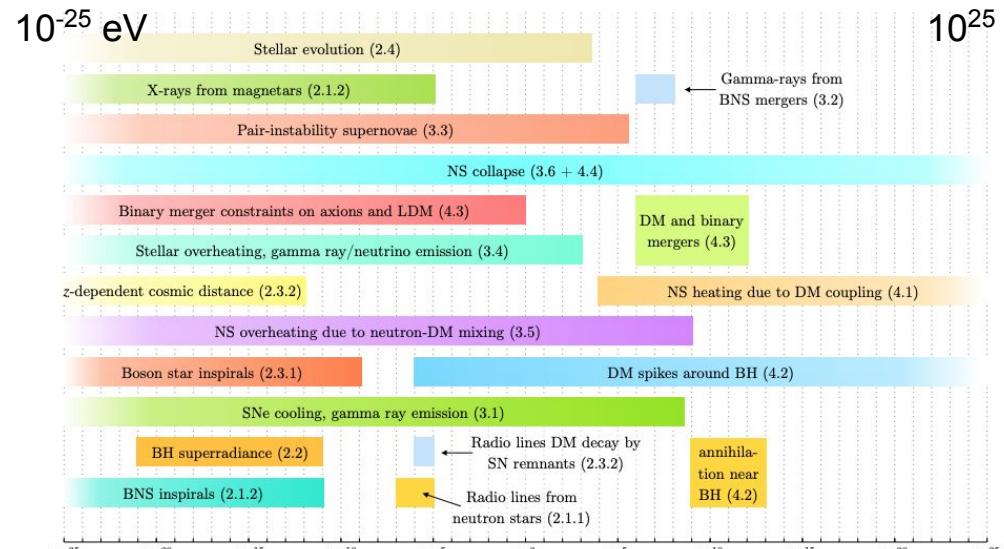
1. Current and near-future observations can provide unprecedented sensitivity to PBH physics. However, it is necessary to ensure that these facilities acquire their data with a cadence and sky coverage that enables PBH searches [e.g. 1–3].
2. The sensitivity of PBH searches will be maximized by combining data sets from multiple observational facilities. Development of joint processing and analyses of Rubin Observatory, Roman Space Telescope, and Euclid will maximize the opportunity to detect PBHs.
3. Current and future gravitational wave facilities will provide an unparalleled opportunity to detect PBHs directly through gravity. These facilities should be supported by the HEP community and include both ground-based detectors such as LIGO and Cosmic Explorer and space-based such as LISA and AEDGE.
4. The scale of current and near-future data sets and the complexity of PBH analyses will benefit from collaborative scientific teams. These teams will develop the tools to perform rigorous and sensitive searches for PBHs in current and near-future observational data. The computational challenges presented by these searches are well-matched to the capabilities of HEP scientists and facilities.
5. Theoretical research will help us better understand the production mechanisms, clustering, and spin properties of PBH. These characteristics will inform the expected abundance of black hole microlensing/GW events and systematics with cosmic surveys, as well as PBH connections to primordial physics. Furthermore, improved simulations of the PBH merger rate and of PBH-specific accretion rates will help inform observational constraints.



Dark Matter In Extreme Astrophysical Environments

Editors: Masha Baryakhtar¹, Regina Caputo², Djuna Croon^{3,4}, Kerstin Perez⁵,

Authors: Emanuele Berti⁶, Joseph Bramante^{7,8}, Malte Buschmann⁹, Richard Brito¹⁰, Philippa S. Cole¹¹, Adam Coogan^{12,13}, William E. East⁸, Joshua W. Foster⁵, Marios Galanis¹⁴, Maurizio Giannotti¹⁵, Bradley J. Kavanagh¹⁶, Ranjan Laha¹⁷, Rebecca K. Leane^{18,19}, Benjamin V. Lehmann^{20,21}, Gustavo Marques-Tavares²², Jamie McDonald^{4,23}, Ken K. Y. Ng^{5,24}, Nirmal Raj²⁵, Laura Sagunski²⁶, Jeremy Sakstein²⁷, Sarah Shandera^{28,29}, Nils Siemonsen^{7,8,30}, Olivier Simon¹³, Kuver Sinha³¹, Rajeev Singh³², Chen Sun³³, Ling Sun³⁴, Volodymyr Takhistov³⁵, Yu-Dai Tsai³⁶, Edoardo Vitagliano³⁷, Salvatore Vitale^{5,23}, Huan Yang^{8,38}, and Jun Zhang^{39,40}



2 Ultralight dark matter (<keV)

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3 Light Dark Matter (keV–MeV)

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3.4	Heating and gamma rays from astrophysical objects through LDM scattering and annihilation	21
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3.6	LDM-driven collapse of astrophysical objects	23

4 Heavy Dark Matter (\gtrsim GeV)

4.1	Capture in neutron stars: heating signatures	24
4.2	Signatures of DM spikes around black holes	25
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4.4	Formation of (sub)solar mass black holes from DM capture inside compact objects	30

Snowmass2021 Cosmic Frontier White Paper: Observational Facilities to Study Dark Matter

Sukanya Chakrabarti,¹ Alex Drlica-Wagner,^{2,3,4} Ting S. Li,⁵ Neelima Sehgal,⁶ Joshua D. Simon,⁷ Simon Birrer,^{8,9} Duncan A. Brown,¹⁰ Rebecca Bernstein,⁷ Alberto D. Bolatto,¹¹ Philip Chang,¹² Kyle Dawson,¹³ Paul Demorest,¹⁴ Daniel Grin,¹⁵ David L. Kaplan,¹⁶ Joseph Lazio,¹⁷ Jennifer Marshall,¹⁸ Eric J. Murphy,¹⁹ Scott Ransom,¹⁹ Brant E. Robertson,²⁰ Rajeev Singh,²¹ Anže Slosar,²² Tommaso Treu,²³ Yu-Dai Tsai,²⁴ and Benjamin F. Williams²⁵

IV. Current and Near-Future Facilities

- A. CMB-S4
- B. Dark Energy Survey (DES)
- C. Dark Energy Spectroscopic Instrument (DESI)
- D. Rubin Observatory LSST
- E. James Webb Space Telescope
- F. Nancy Grace Roman Space Telescope
- G. Advanced LIGO

V. Future CMB Facilities

- A. Key Measurement Opportunities
- B. CMB-HD

VI. Future Pulsar Timing Facilities

- A. Key Measurement Opportunities
- B. ngVLA & DSA-2000

VII. Future 21cm Facilities

- A. Key Measurement Opportunities
- B. LuSEE-Night
- C. PUMA

VIII. Future Optical Facilities

- A. Key Measurement Opportunities
- B. Extremely Large Telescopes
- C. Wide-field Multi-Object Spectroscopy Facilities
 - 1. DESI-II
 - 2. MegaMapper
 - 3. Maunakea Spectroscopic Explorer
 - 4. SpecTel
 - 5. Comparison and Summary

IX. Future Gravitational Wave Facilities

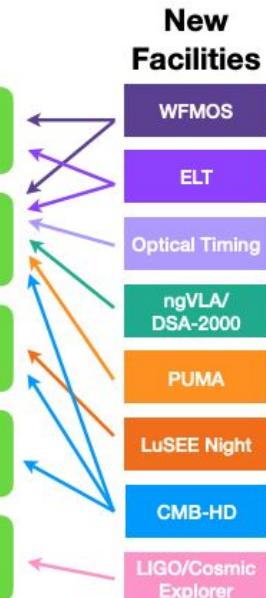
- A. Key Measurement Opportunities
- B. Cosmic Explorer and Einstein Telescope
- C. LIGO Voyager

Dark Matter Models

- CDM
- WDM
- FDM
- SIDM
- Dissipative
- Axion-like
- Vector
- Scalar
- Primordial Black Holes

Dark Matter Probes

- Halo Density Profiles
- Structure Distribution
- Interactions with Standard Model
- Number of Light Thermal Particle Species
- Binary Black Hole and Binary Neutron Star Mergers



- 7. Contributions to the technical development and construction of observational dark matter facilities will leverage the core technical and scientific capabilities of the HEP community. Furthermore, the involvement of the HEP community will maximize the scientific output of these facilities.
- 8. Many proposed dark matter facilities will also offer complementary capabilities to explore dark energy, neutrino properties, and inflationary physics. The capability to probe dark matter physics should be considered in the design phase of these facilities.

ATTN: CF04, CF05, CF06

Dark Matter Physics from Current and Near-Future Cosmic Frontier Projects

Table 1
Summary of Scenarios

[Taken from the 2014 P5 Report]

Project/Activity	Scenarios			Science Drivers			
	Scenario A	Scenario B	Scenario C	Higgs	Neutrinos	Dark Matter	Cosm. Accel. The Unknown Technique (Frontier)
Medium Projects							
LSST	Y	Y	Y	✓	✓		C
DM G2	Y	Y	Y		✓		C
Small Projects Portfolio	Y	Y	Y	✓	✓	✓	All
Accelerator R&D and Test Facilities	Y, reduced	Y, some reductions with redirection to PIP-II development	Y, enhanced	✓	✓	✓	E,I
CMB-S4	Y	Y	Y	✓	✓		C
Additional Small Projects (beyond the Small Projects Portfolio above)							
DESI	N	Y	Y	✓	✓		C

Snowmass2021 Cosmic Frontier White Paper: Prospects for obtaining Dark Matter Constraints with DESI

Monica Valluri¹, Solene Chabanier², Vid Iršič^{3,4}, Eric Armengaud⁵, Michael Walther^{6,7}, Connie Rockosi⁸, Miguel A. Sánchez-Conde⁹, Leandro Beraldo e Silva¹, Andrew P. Cooper¹⁰, Elise Darragh-Ford¹¹, Kyle Dawson¹², Alis J. Deason¹³, Simone Ferraro², Jaime E. Forero-Romero¹⁴, Antonella Garzilli¹⁵, Ting Li¹⁶, Zaria Lukić², Christopher J. Manser¹⁷, Nathalie Palanque-Delabrouille^{2,5}, Corentin Ravoux⁵, Ting Tan¹⁸, Wenting Wang¹⁹, Risa H. Wechsler¹¹, Andreia Carrillo¹³, Arjun Dey²⁰, Sergey E. Koposov²¹, Yao-Yuan Mao²², Paulo Montero-Camacho²³, Ekta Patel^{24,25}, Graziano Rossi²⁶, L. Arturo Ureña-López²⁷, and Octavio Valenzuela²⁸

<https://arxiv.org/abs/2203.07491>

Snowmass2021 Cosmic Frontier White Paper: Vera C. Rubin Observatory as a Flagship Dark Matter Experiment

Yao-Yuan Mao¹, Annika H. G. Peter², Susmita Adhikari^{3,4}, Keith Bechtol⁵, Simeon Bird⁶, Simon Birrer⁷, Jonathan Blazek⁸, Jeffrey L. Carlin⁹, Nushka Chamba¹⁰, Johann Cohen-Tanugi^{11,12}, Francis-Yan Cyr-Racine¹³, Tansu Daylan^{14,15}, Birendra Dhanasisingham¹³, Alex Drlica-Wagner^{3,16,17}, Cora Dvorkin¹⁸, Christopher Fassnacht¹⁹, Eric Gawiser¹, Maurizio Giannotti²⁰, Vera Gluscevic²¹, Alma Gonzalez-Morales^{22,23}, Renée Hložek²⁴, M. James Jee^{19,25}, Stacy Kim²⁶, Akhtar Mahmood²⁷, Rachel Mandelbaum²⁸, Siddharth Mishra-Sharma^{18,29,30}, Marc Moniez³¹, Ethan O. Nadler^{21,32}, Chanda Prescod-Weinstein³³, J. Anthony Tyson¹⁹, Risa H. Wechsler^{7,34}, Hai-Bo Yu⁶, and Gabrijela Zaharijas³⁵

<https://arxiv.org/abs/2203.07252>

Dark Matter Physics from the CMB-S4 Experiment

Cora Dvorkin¹, Renée Hložek^{2,3}, Rui An⁴, Kimberly K. Boddy⁵, Francis-Yan Cyr-Racine⁶, Gerrit S. Farrer⁷, Vera Gluscevic⁴, Daniel Grin⁸, David J. E. Marsh⁹, Joel Meyers¹⁰, Keir K. Rogers², Katelin Schutz¹¹, and Weishuang Linda Xu¹²

<https://arxiv.org/abs/2203.07064>

Relevant White Papers from CF and other Frontiers

Snowmass2021 Cosmic Frontier White Paper: Probing dark matter with small-scale astrophysical observations

Richard Brito¹, Sukanya Chakrabarti², Sébastien Clesse³, Cora Dvorkin⁴, Juan García-Bellido⁵,
Joel Meyers⁶, Ken K. Y. Ng⁷, Andrew L. Miller⁸, Sarah Shandera⁹, and Ling Sun¹⁰

Snowmass2021 Cosmic Frontier: Synergies between dark matter searches and multiwavelength/multimessenger astrophysics

Shin'ichiro Ando^{1,2}, Sebastian Baum³, Michael Boylan-Kolchin⁴, Esra Bulbul⁵, Michael Burgess⁵,
Ilias Cholis⁶, Philip von Doetinchem⁷, JiJi Fan⁸, J. Patrick Harding^{*9}, Shunsaku Horiuchi^{†10,2},
Rebecca K. Leane^{11,12}, Oscar Macias¹, Katie Mack¹³, Kohta Murase^{14,15}, Lina Necib¹⁶, Ibles
Olcina^{17,18}, Laura Olivera-Nieto¹⁹, Jong-Chul Park²⁰, Kerstin Perez²¹, Marco Regis^{22,23}, Nicholas L.
Rodd²⁴, Carsten Rott^{25,26}, Kuver Sinha²⁷, Volodymyr Takhistov², Yun-Tse Tsai¹¹, and Devin
Walker^{‡28}

Snowmass2021 Cosmic Frontier White Paper: Rubin Observatory after LSST

Bob Blum¹, Seth W. Digel^{2,3}, Alex Drlica-Wagner^{4,5}, Salman Habib^{6,7}, Katrin Heitmann⁷,
Mustapha Ishak⁸, Saurabh W. Jha⁹, Steven M. Kahn^{2,3,10}, Rachel Mandelbaum¹¹, Phil Marshall^{2,3},
Jeffrey A. Newman¹², Aaron Roodman^{2,3}, and Christopher W. Stubbs¹³

Snowmass2021 CMB-HD White Paper

The CMB-HD Collaboration¹, Simone Aiola², Yashar Akrami^{3,4,5,6}, Kaustuv Basu⁷, Michael
Boylan-Kolchin⁸, Thejs Brinckmann^{9,10}, Sean Bryan¹¹, Caitlin M Casey⁸, Jens Chluba¹², Sébastien
Clesse¹³, Francis-Yan Cyr-Racine¹⁴, Luca Di Mascolo^{15,16,17}, Simon Dicker¹⁸, Thomas
Essinger-Hileman¹⁹, Gerrit S. Farren^{20,21}, Michael A. Fedderke²², Simone Ferraro^{23,24}, George M.
Fuller²⁵, Nicholas Galitzki²⁶, Vera Gluscevic²⁷, Daniel Grin²¹, Dongwon Han²⁰, Matthew Hasselfield²,
Renée Hložek^{28,29}, Gil Holder³⁰, Selim C. Hotinli²², Bhuvnesh Jain¹⁸, Bradley Johnson³¹, Matthew
Johnson^{32,33}, Pamela Klaassen³⁴, Amanda MacInnis³⁵, Mathew Madhavacheril^{13,27}, Sayan Mandal³⁵,
Philip Mauskopf^{36,37}, Daan Meerburg³⁸, Joel Meyers³⁹, Vivian Miranda³⁵, Tony Mroczkowski⁴⁰, Sudip
Mukherjee^{33,41,42,43}, Moritz Münnchmeyer⁴⁴, Julian Munoz⁴⁵, Sigurd Naess², Daisuke Nagai⁴⁶, Toshiya
Namikawa⁴⁷, Laura Newburgh⁴⁶, Hồ Nam Nguyễn⁴⁸, Michael Niemack⁴⁹, Benjamin D. Oppenheimer^{50,45},
Elena Pierpaoli²⁷, Srinivasan Raghunathan⁵¹, Emmanuel Schaan^{23,24}, Neelima Sehgal³⁵, Blake Sherwin²⁰,
Sara M. Simon⁵², Anže Slosar⁵³, Kendrick Smith³³, David Spergel², Eric R. Switzer¹⁹, Pranjal Trivedi⁵⁴,
,

Snowmass 2021 CMB-S4 White Paper

The CMB-S4 Collaboration

Not a complete list; many CF01 and CF02 WPs
are relevant to CF03 and vice versa (e.g., halo
measurements are important for direct and
indirect searches)

Connections with White Papers from CF and other Frontiers

Machine Learning and Cosmology

Cora Dvorkin^{*1}, Siddharth Mishra-Sharma^{†1,2,3}, Brian Nord^{‡4,5,6}, V. Ashley Villar^{§7,8,9}, Camille Avestruz¹⁰, Keith Bechtol¹¹, Aleksandra Ćiprijanović⁴, Andrew J. Connolly¹², Lehman H. Garrison¹³, Gautham Narayan¹⁴, and Francisco Villaescusa-Navarro^{15,16}

Snowmass2021 Computational Frontier White Paper: Cosmological Simulations and Modeling

Marcelo A. Alvarez¹, Arka Banerjee^{2,3}, Simon Birrer⁴, Salman Habib^{5,†}, Katrin Heitmann⁵, Zarija Lukic^{1,†}, Julian B. Muñoz⁶, Yuuki Omori⁴, Hyunbae Park¹, Annika H. G. Peter⁷, Jean Sexton¹, and Yi-Ming Zhong⁸

**More is Different:
Non-Minimal Dark Sectors and their Implications
for Particle Physics, Astrophysics, and Cosmology**
— 13 Take-Away Lessons for Snowmass 2021 —

Keith R. Dienes,^{1,2,*} Brooks Thomas^{3,†}

Astrophysical and Cosmological Probes of Dark Matter

Kimberly K. Boddy^{*1}, Mariangela Lisanti^{*2,3}, Samuel D. McDermott^{*4}, Nicholas L. Rodd^{*5}, Christoph Weniger^{*6}, Yacine Ali-Haïmoud¹⁹, Malte Buschmann², Ilias Cholis⁷, Djuna Croon⁸, Adrienne L. Erickcek⁹, Vera Gluscevic¹⁷, Rebecca K. Leane^{10,11}, Siddharth Mishra-Sharma^{12, 13, 14}, Julian B. Muñoz¹⁵, Ethan O. Nadler^{16, 17}, Priyamvada Natarajan^{20, 21}, Adrian Price-Whelan³, Simona Vegetti¹⁸, and Samuel J. Witte⁶

Early-Universe Model Building

Pouya Asadi,¹ Saurabh Bansal,² Asher Berlin,^{3, 4, *} Raymond T. Co,⁵ Djuna Croon,⁶ Yanou Cui,⁷ David Curtin,^{8, †} Francis-Yan Cyr-Racine,⁹ Hooman Davoudiasl,¹⁰ Luigi Delle Rose,¹¹ Jeff A. Dror,¹² Gilly Elor,¹³ Oliver Gould,¹⁴ Keisuke Harigaya,^{15, *} Saniya Heeba,¹⁶ Yonit Hochberg,^{17, †} Anson Hook,¹⁸ Seyda Ipek,¹⁹ Eric Kuflik,^{17, †} Andrew J. Long,²⁰ Robert McGehee,²¹ Nadav Joseph Outmezguine,^{22, 23} Giuliano Panico,²⁴ Vivian Poulin,²⁵ Josef Pradler,²⁶ Katelin Schutz,¹⁶ Nausheen R. Shah,²⁷

The Physics of Light Relics

Cora Dvorkin^{*1}, Joel Meyers^{†2}, Peter Adshead³, Mustafa Amin⁴, Carlos A. Argüelles¹, Thejs Brinckmann^{5,6}, Emanuele Castorina⁷, Timothy Cohen⁸, Nathaniel Craig⁹, David Curtin¹⁰, Francis-Yan Cyr-Racine¹¹, Peizhi Du¹², Lloyd Knox¹³, Bohua Li^{14,15}, Marilena Loverde¹⁶, Kaloian Lozanov³, Julian B. Muñoz¹⁷, Katelin Schutz¹⁸, Paul Shapiro¹⁹, Benjamin Wallisch^{20,21}, Zachary J. Weiner¹⁶, and Weishuang Linda Xu²²

Early Takeaways

Broad Dark Matter Reach: Cosmic probes span ~90 orders of magnitude in dark matter mass and provide experimental sensitivity to a wide range dark matter models.

Interdisciplinary Synergies: Cosmic probes of dark matter require strong synergy between particle theorists, simulators, dynamists, observers, and experimentalists. Need a new mechanism to support these efforts, strengthened by agency coordination.

Experimental Complementarity: There is strong experimental complementarity between cosmological probes of dark matter, dark energy, and inflation. Future projects promise a strong, multi-dimensional fundamental physics program.