Astrophysical Constraints of Dark Matter Properties

A Special Session at the 227th American Astronomical Society meeting

View the Project on GitHub lmoustakas/specialdark

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Special Session on the Astrophysical Constraints of Dark Matter Properties

Thursday, January 7, 2016, 2:00pm - 3:30pm

What is dark matter, and how can astronomical observations give insights or measurements of its detailed particle properties? How do we coordinate work across vast astronomical approaches? How best can astronomers and particle physicists share ideas and advances? Come to this session to learn new ideas on this front, and to contribute to the discussion!

The rationale for this Special Session is made in the original proposal submitted to the AAS, available here.

Organizers and conveners

Tom Abel (Stanford) & Alex Drlica-Wagner (FNAL) & Justin Read (Surrey) & Alyson Brooks (Rutgers) & Jennifer Gaskins (Amsterdam) & Josh Simon (OCIW) & Matthew Buckley (Rutgers) & Manoj Kaplinghat (UCI) & Rachel Somerville (Rutgers) & James Bullock (UCI) & Charles Keeton (Rutgers) & Erik Tollerud (STScI) & Michelle Collins (Surrey) & Stacy Kim (OSU) & Tommaso Treu (UCLA) & Francis-Yan Cyr-Racine (Harvard) & Leonidas Moustakas (JPL/Caltech) & Risa Wechsler (Stanford) & William Dawson (LLNL) & Annika Peter (OSU)

Astrophysical Constraints of Dark Matter Properties
Special Session

Leonidas Moustakas

JPL/Caltech

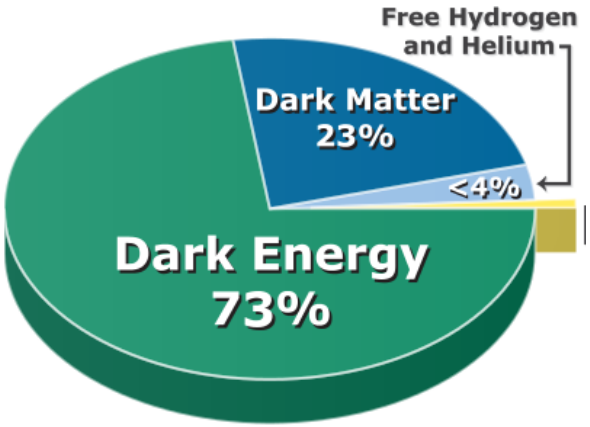
Guidelines for our session

- Please stay for the full session if possible, as it is organized as an arc, leading to the discussion!
- We are looking at two pressing issues that require us to constantly think back to the *big picture.*
- Those of you that have done this type of exercise before, please calmly reassure those next to you.

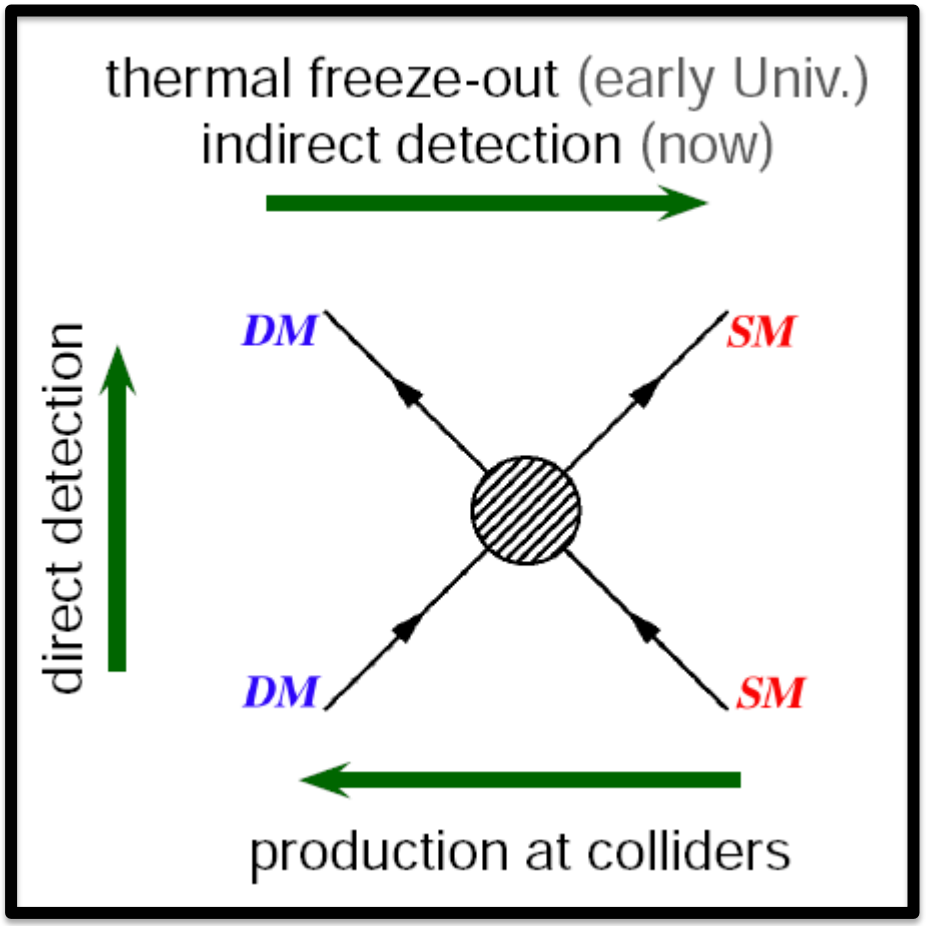
- We expect to continue the discussion beyond today; let us know if you would like to contribute!

Dark matter

- The **evidence for dark matter** is rich and complementary
  - Rotation curves of galaxies
  - Dynamics of galaxy clusters
  - Large scale clustering of matter in the universe
  - Cosmic background radiation (CBR) from the last scattering surface
- We call it "dark" because it **cannot be baryonic**
  - CBR measures both baryonic and dark components
  - Big Bang Nucleosynthesis abundances strongly constrain baryonic density
- **What we know** about dark matter
  - How much there is
  - It is largely "cold" in terms of its thermal motion
  - It is largely or entirely non-interactive
  - It is neutral and non-magnetic
- **What we sort of know** about for dark matter
  - The process of its gravitational evolution
  - Its dynamical, gravitational interaction with baryons
  - There are many attractive particle candidates beyond the Standard Model



Probes of dark matter



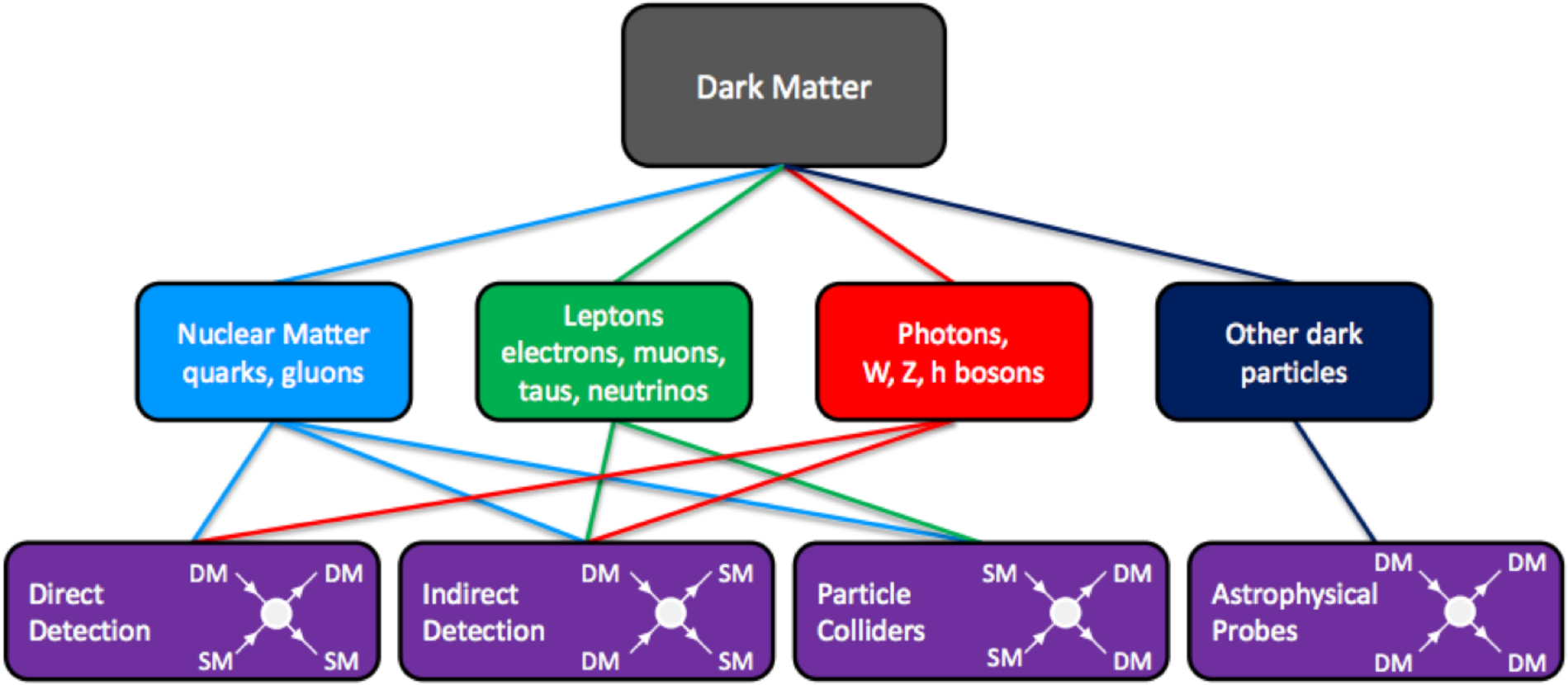
The full diversity of Astrophysics probes of dark matter are buried here!

Arrows show time direction

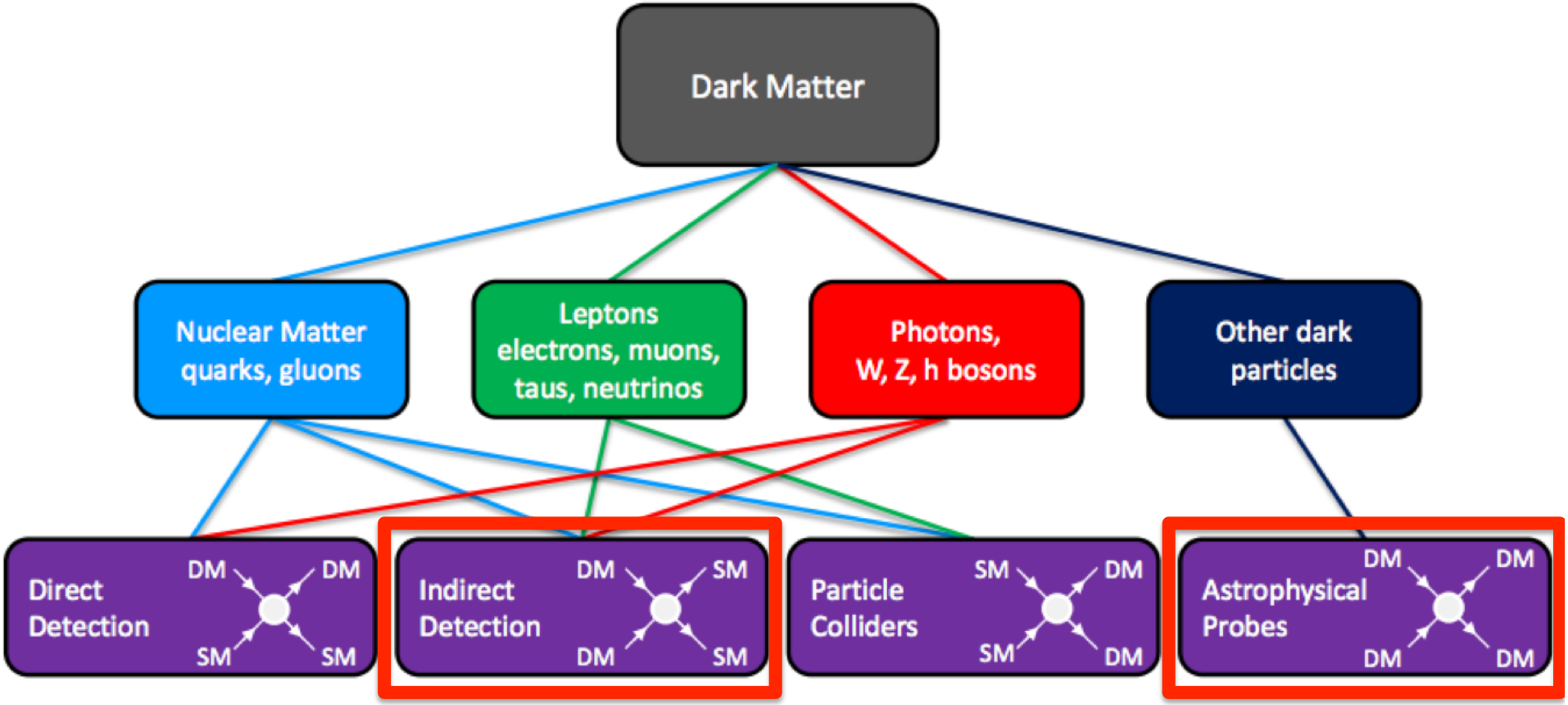
"SM" = Standard Model particles, baryonic matter

Figure credit: http://www.mpi-hd.mpg.de

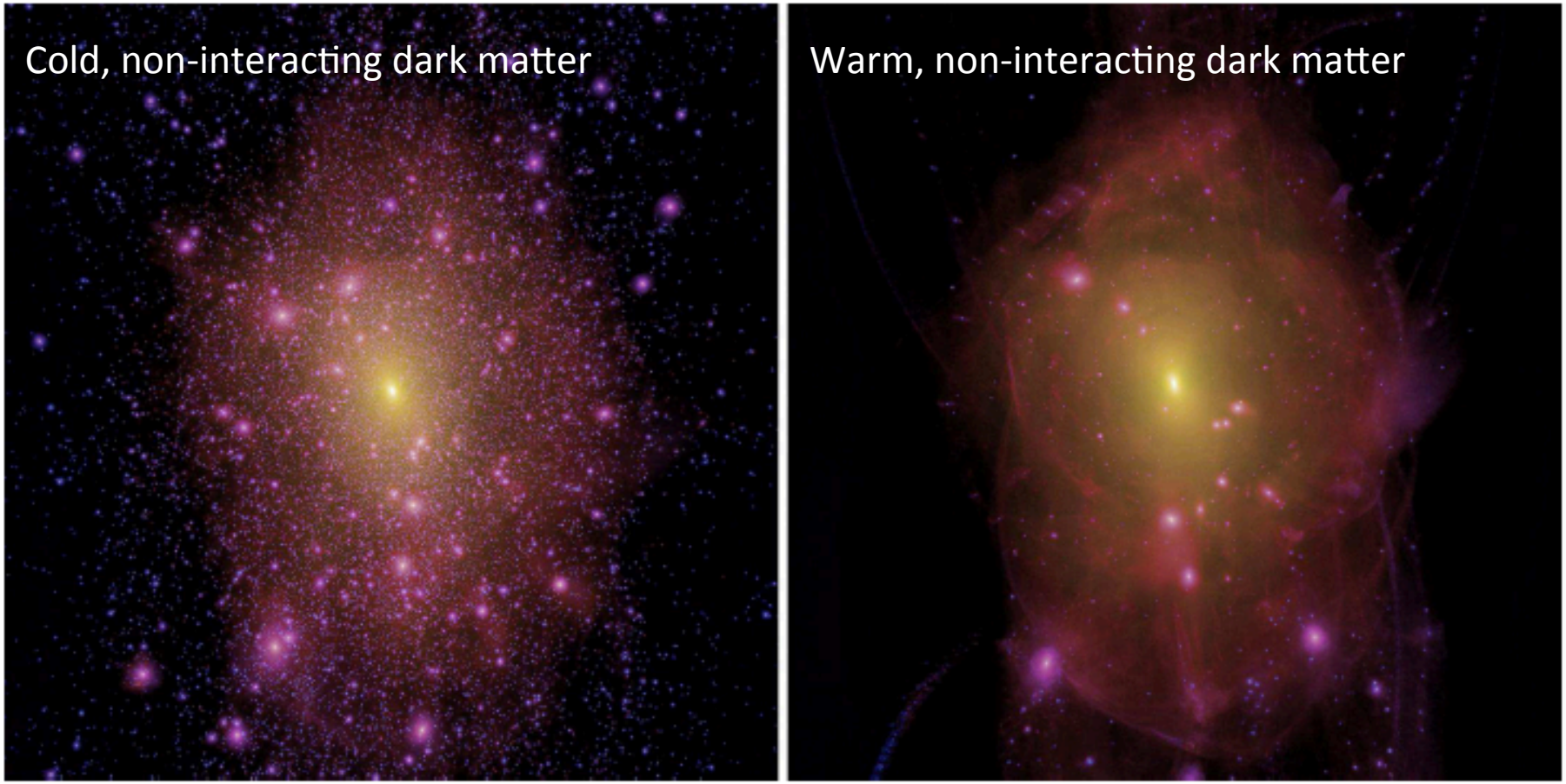
Probes of dark matter (beyond gravity)



Astrophysical probes of dark matter



The nature of dark matter “matters”



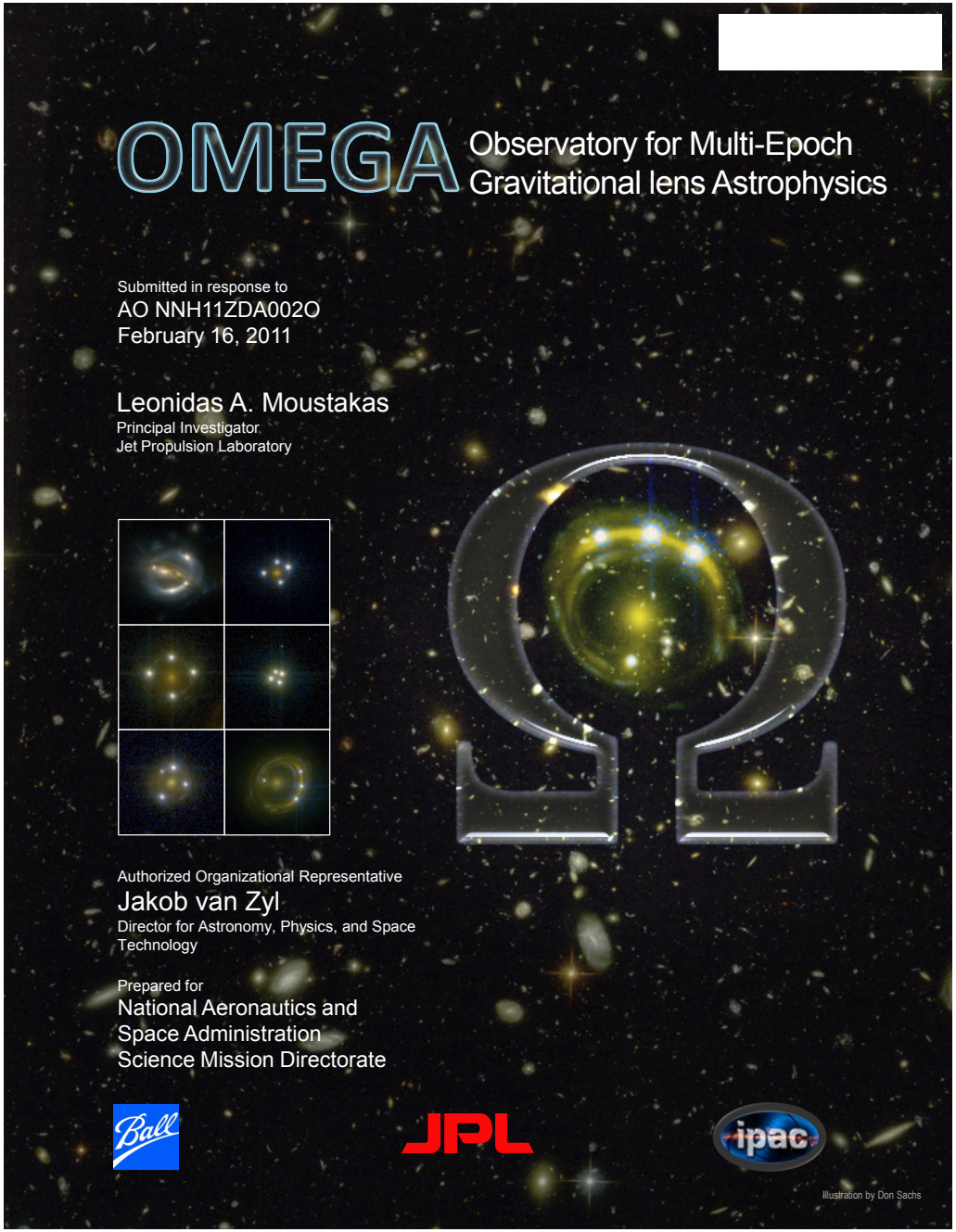
Lovell+2012, MNRAS, 420, 2318
“Warm” = 2keV particles

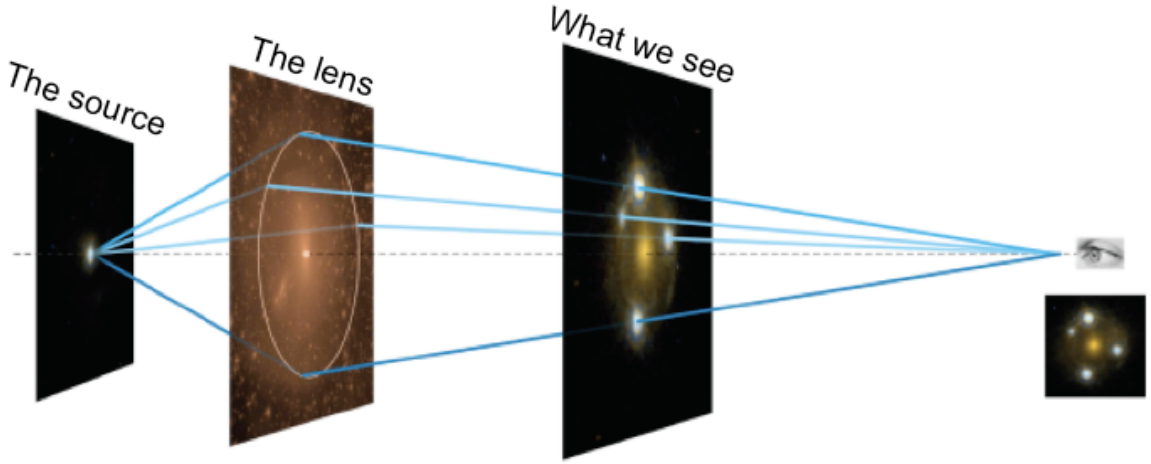
Density-squared maps. M200~1.8E12Msun at z=0

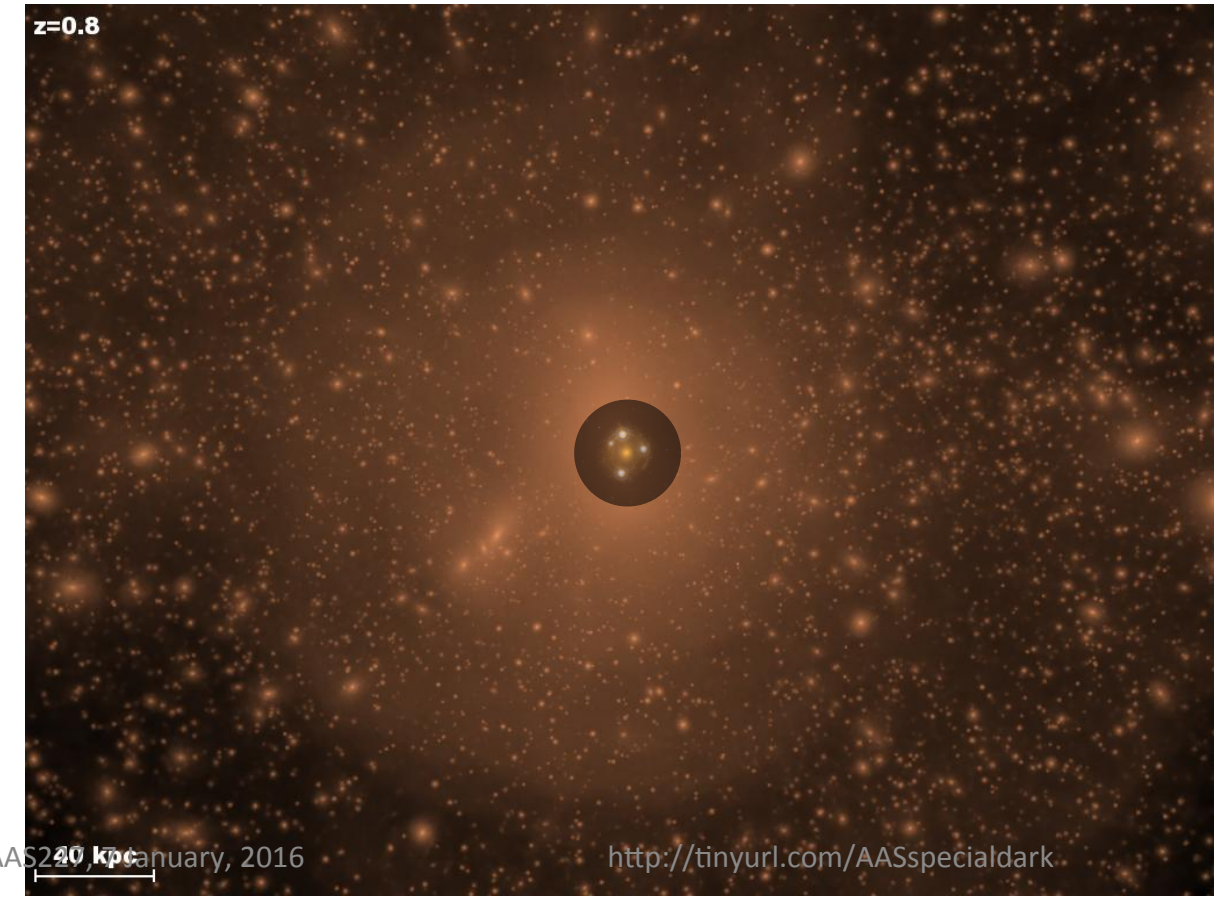
A major personal motivation:

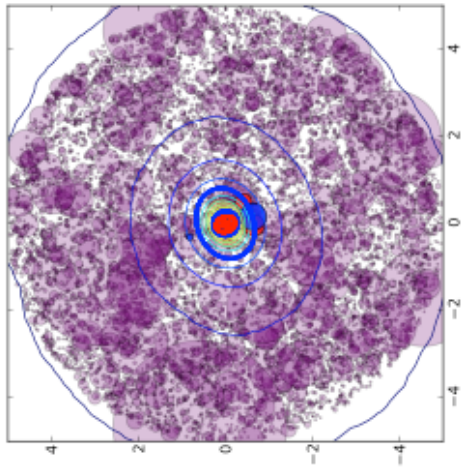
To *meaningfully* quantify the dark matter *particle properties* sensitivity of the dark-matter focused OMEGA Explorer proposal, being submitted this year.

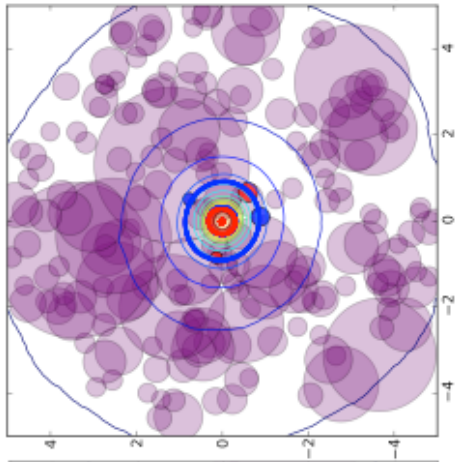
See me for details!

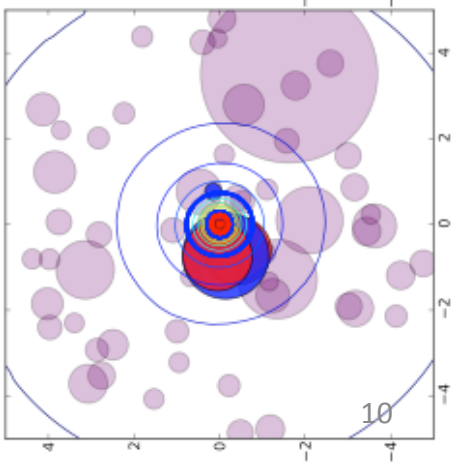


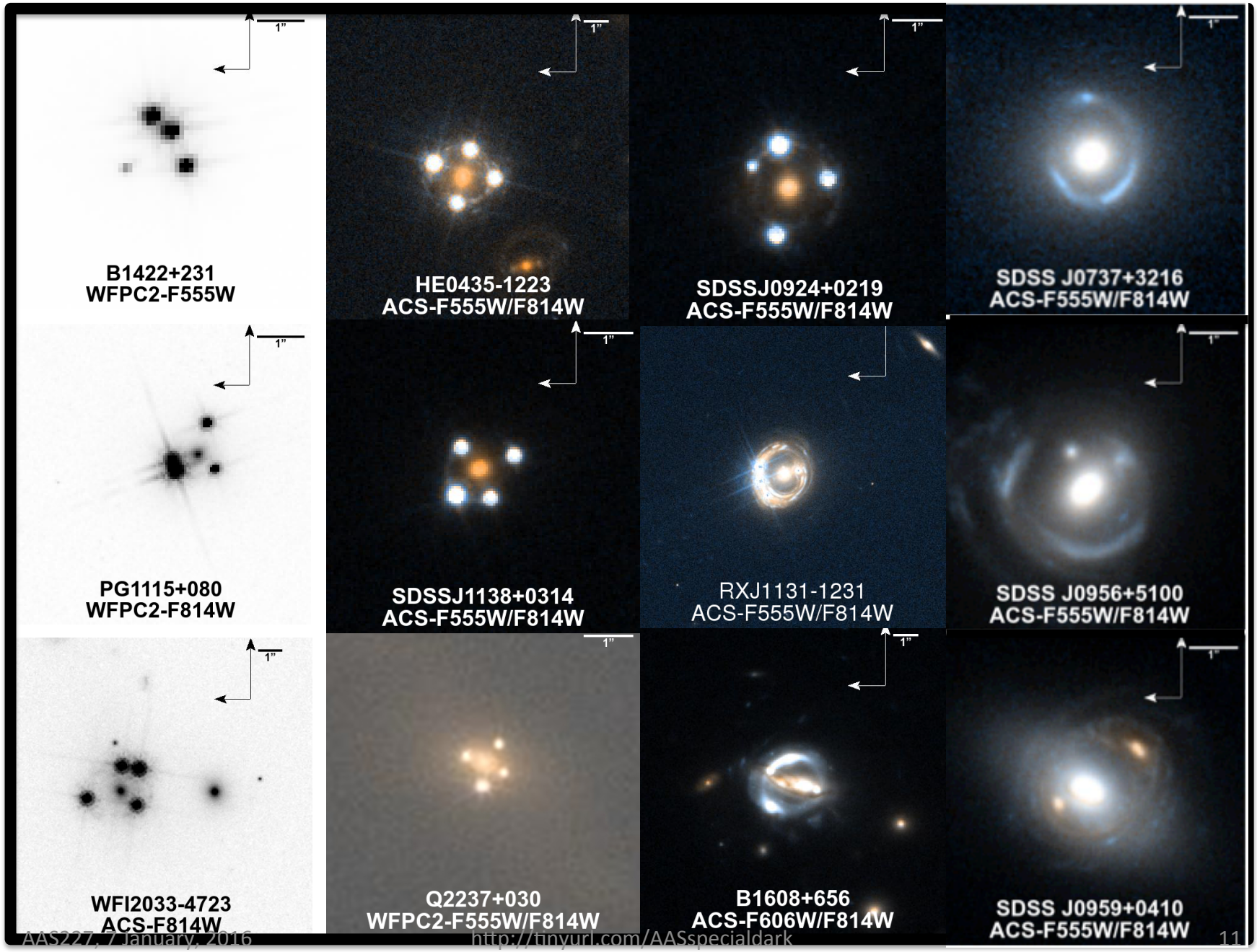

The source
The lens
What we see


z=0.8
40 kpc








1"
B1422+231
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HE0435-1223
ACS-F555W/F814W
SDSSJ0924+0219
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SDSS J0737+3216
ACS-F555W/F814W
PG1115+080
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WFI2033-4723
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Q2237+030
WFPC2-F555W/F814W
B1608+656
ACS-F606W/F814W
SDSS J0959+0410
ACS-F555W/F814W

Steps to dark matter properties…

Earth & Planets	Internal structure
	Caustic concentrations
Sun	Internal structure
	Neutrino emission
MWG stellar streams	Large scale distributions
	Small scale structure
MWG dwarf galaxies	Mass function
	Spatial distribution
	Internal structure
	Gamma ray emission
MWG bulge/center	Gamma ray emission
MWG stellar velocities	Census
MWG halo profile	Ensemble information
MWG satellite galaxies	Census
Lyman alpha clouds	Census
Galaxy TBTF halos	Census
Galaxy halo profiles	Strong lensing+
Group halo profiles	Strong lensing
	Weak lensing stacks
Cluster halo profiles	Strong+weak lensing
Galaxy-cluster mergers	
Cluster-cluster mergers	
EoR structure	
Pop III stars	Census statistics
	Luminosities
Dark stars	Census
CBR P(k)	High-k modes

low mass high mass	Phase space density	Dark Matter Derived Properties
local low z mod z high z	Amount of mass in substructure P(ϕ_k) Power in potential	
local low z mod z high z	Turnover scale (in power spectrum or mass scale)	
1E2km/s 1E3km/s 1E4km/s	Scattering	
local low z mod z high z	Annihilation	

This Session's Focus

A) Discuss a path to systematizing how the diversity of astronomical observations constrain *different aspects* of dark matter properties as they are expressed on astronomical scales.

B) Discuss how these expressed dark matter properties can be connected to *physical* properties of dark matter candidates or classes, towards defining *metrics* or *figures of merit* that are useful for astronomers, and meaningful for particle physicists.

Let us begin!

Resources

- Data/talk/resource repository:
  - https://github.com/lmoustakas/specialdark
- Google doc for notes, recording questions, etc:
  - http://tinyurl.com/AASspecialdark
- Associated Poster session #337, check it out!

Logistics

- All talks will be given in sequence, followed by a long discussion session
- All talks are 8+2 minutes
- Clarifying questions and comments welcome with each talk, save up the big and fun questions for the discussion at the end!