Revealing the Invisible

Strong Lensing Views and Clues of the Nature of Dark Matter Particle(s)

Leonidas Moustakas

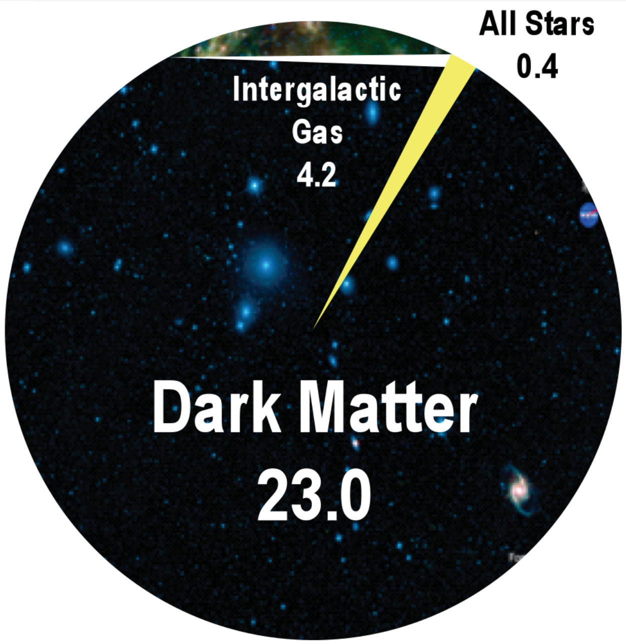
JPL/Caltech

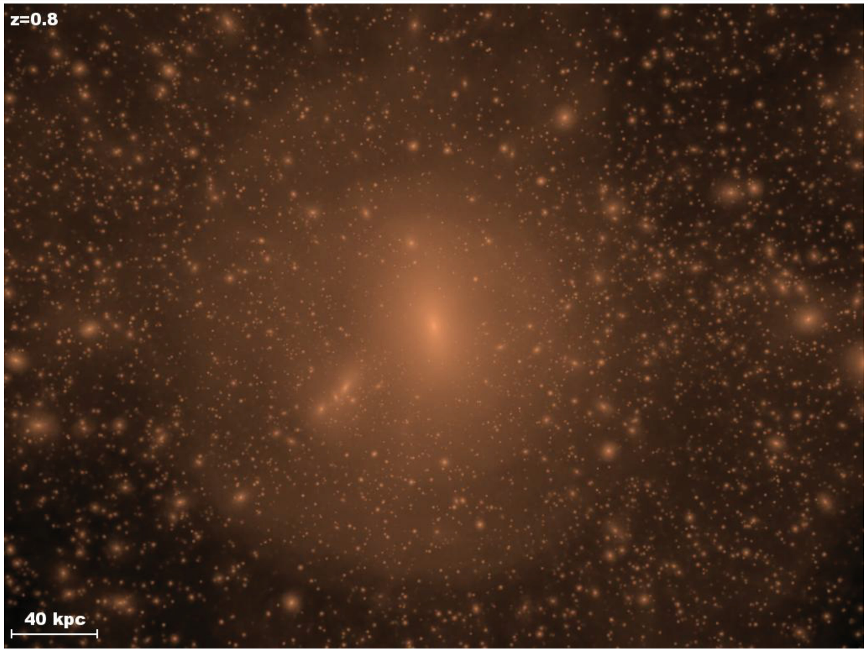
leonidas@jpl.nasa.gov

Dark Matter in the universe

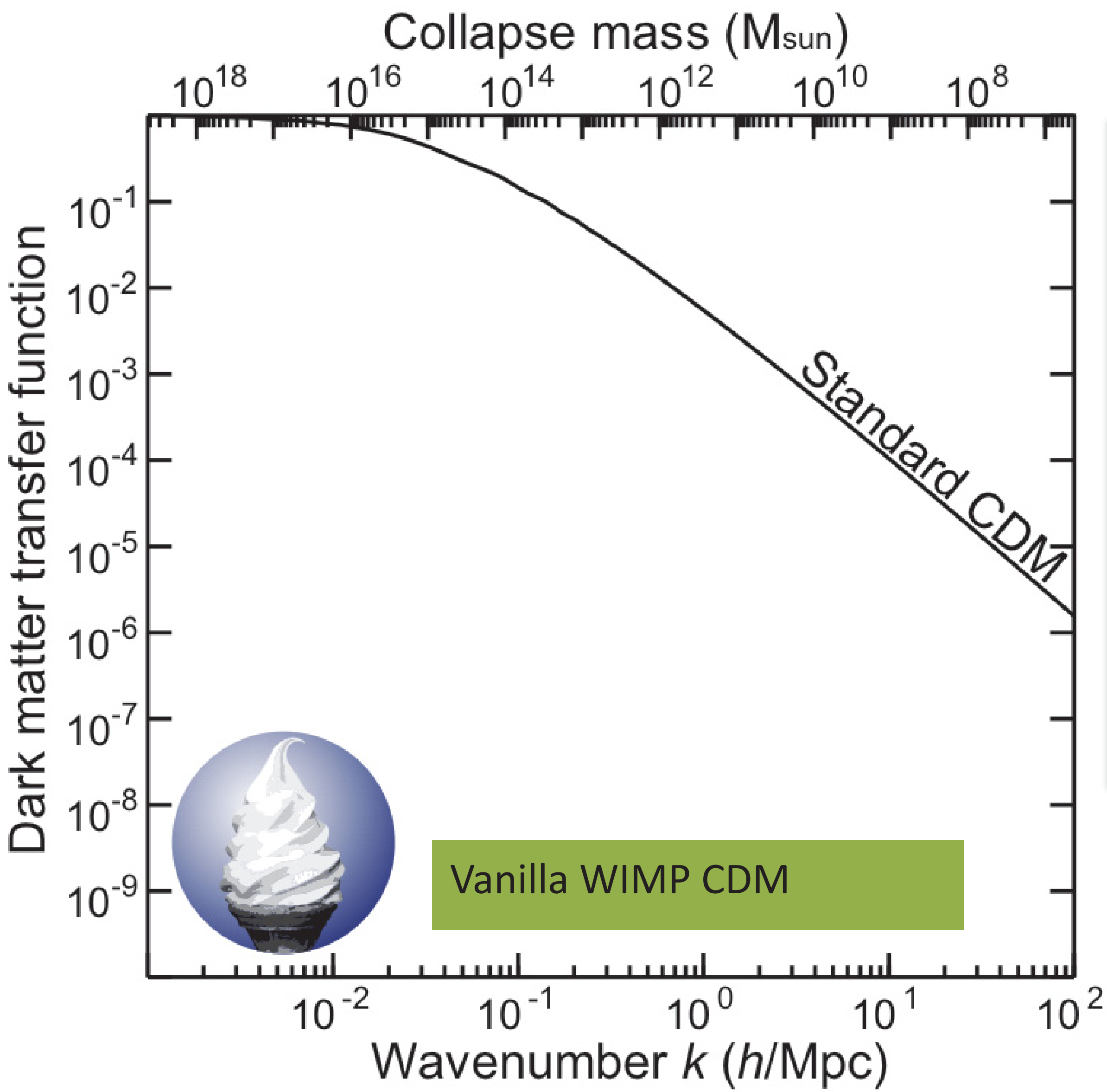
A quarter of the mass energy budget of the universe is in dark matter.

In the successful CDM “Weakly Interacting Massive Particle” (WIMP) scenario, the smallest self-gravitating structures are expected to be as small as 1E-6 Msun: merely the mass of the Earth!





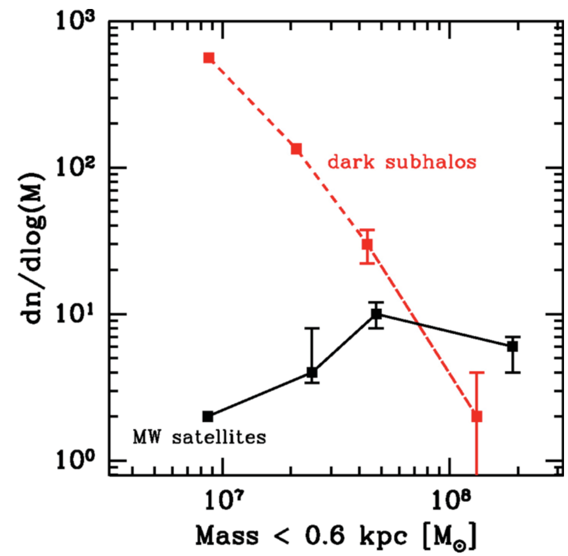
DM Particle physics and “cutoff scales”



We see this from the scales to which the transfer function for (WIMP) matter extends to small scales – FAR to the right of this plot.

Dark matter particle candidates

While WIMP-type dark matter is successful from the horizon scale of 1E4 Mpc to ~1Mpc scales, there has been a lot of tension at smaller scales. Challenges include the “satellite problem” whereby the number of dwarf galaxies found around our Milky Way Galaxy is …dwarfed by the orders of magnitude greater number of predicted WIMP-based subhalos.

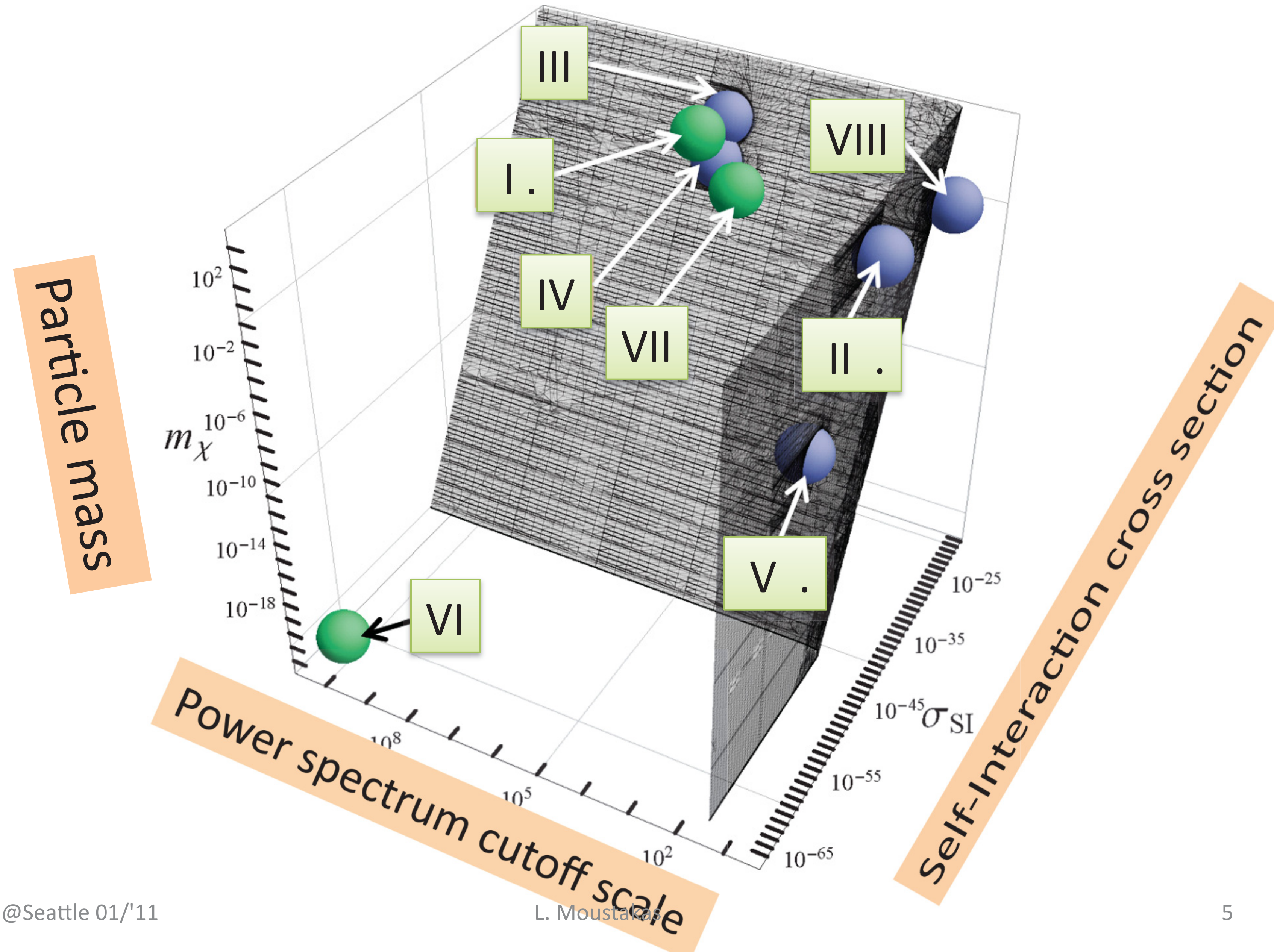


This table shows many of the classes of candidates that satisfy all existing data!

Table D.1-1. Key dark matter particle candidates and their properties that OMEGA will be able to probe, as well as the complementary experimental approaches currently in progress or planned. Candidates I-III arise in SUSY or other weak-scale physics models; the rest are exotic.

	Dark Matter Candidate	Mass Range	Temperature	Complementary Techniques		
				Collider	Direct	Indirect
I	WIMP Neutralino	GeV–TeV	Cold	✓	✓	✓
II	SuperWIMP	GeV–TeV	Cold/Warm	✓		✓
III	Light Gravitino	eV–keV	Cold/Warm	✓		
IV	Hidden Sector	MeV–TeV	Cold/Warm	✓	✓	✓
V	Sterile Neutrino	keV	Warm			✓
VI	Axion	μeV–meV	Cold		✓	✓
VII	Asymmetric	GeV	Cold	✓	✓	

A broad view of DM particle candidates



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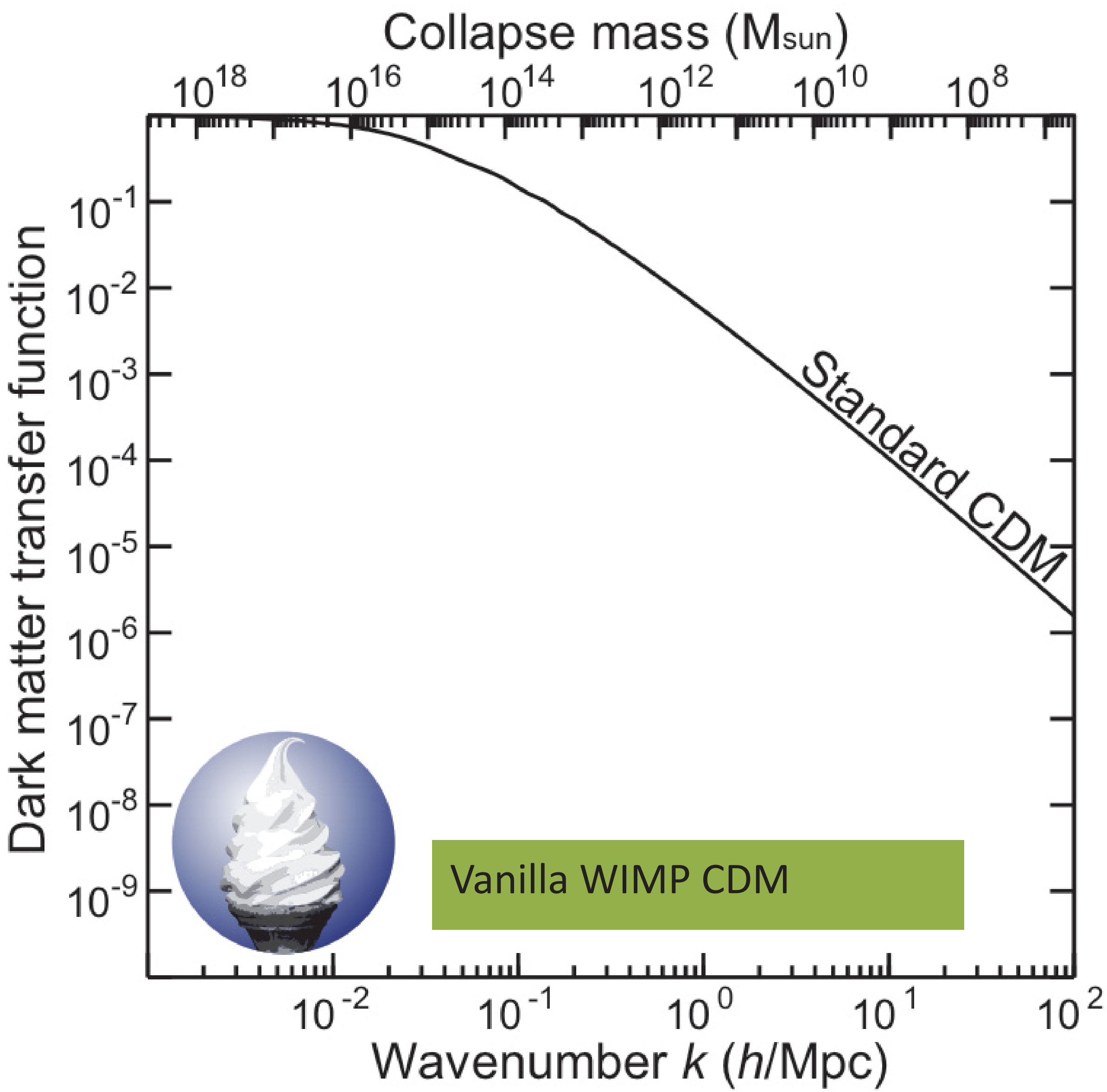

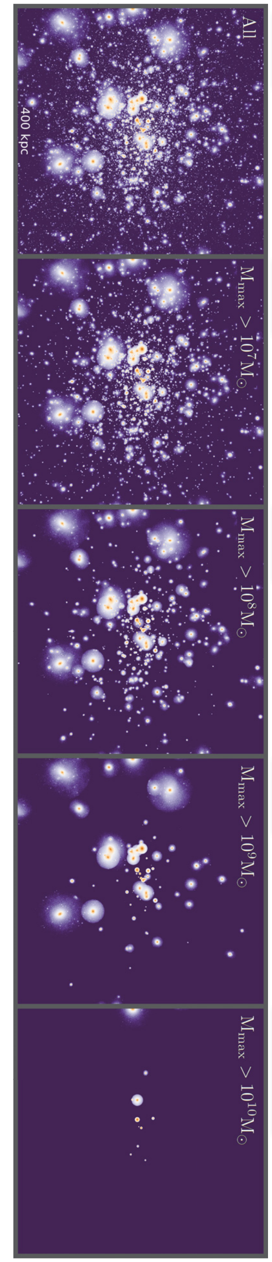

All

M>1E7

M>1E8

M>1E9

M>1E10
Msun

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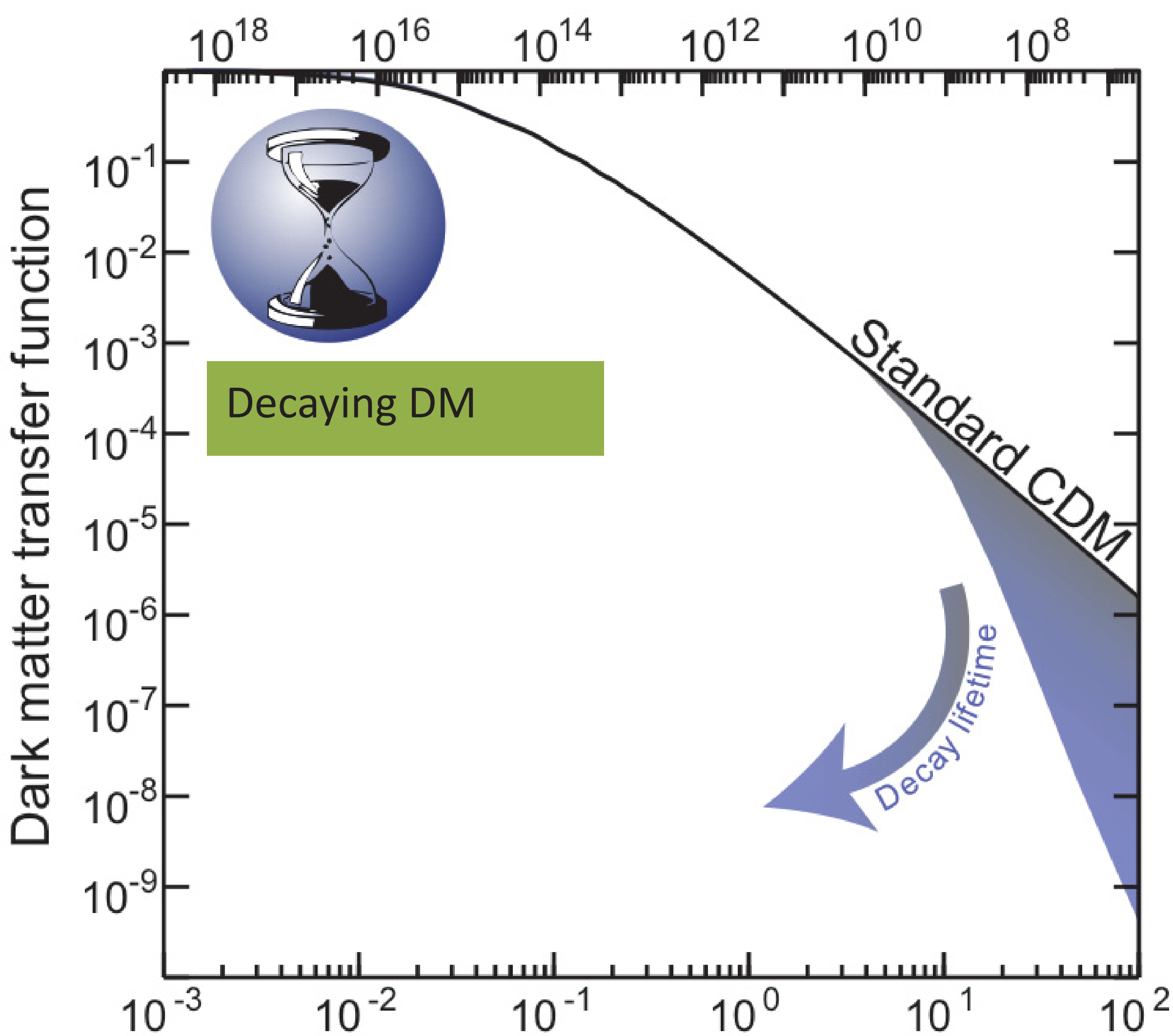
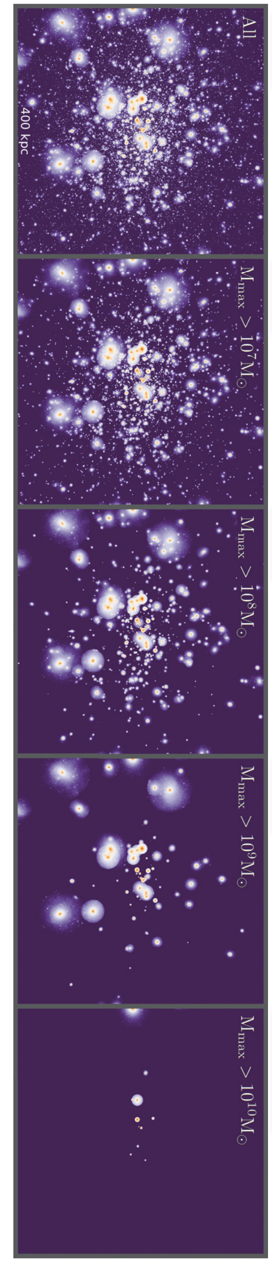




All

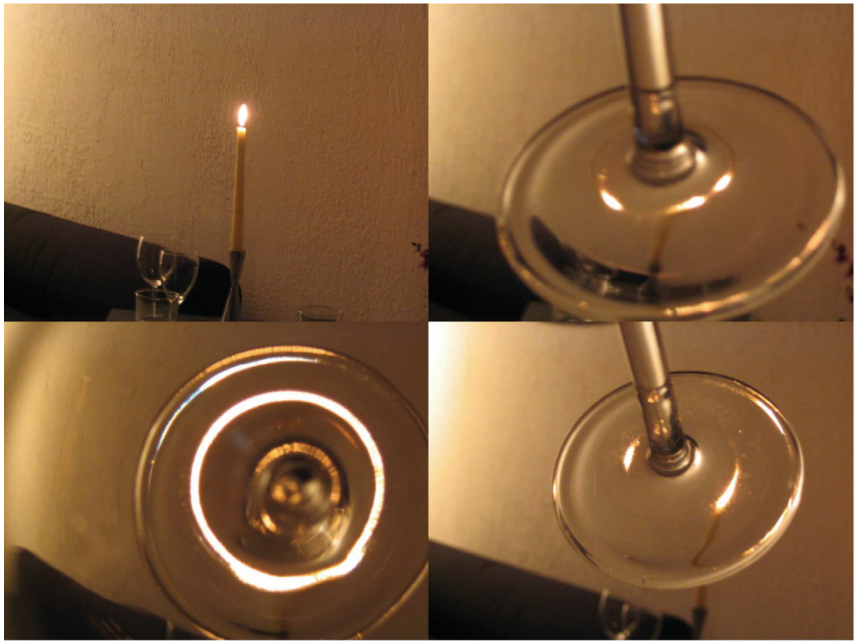
M>1E7

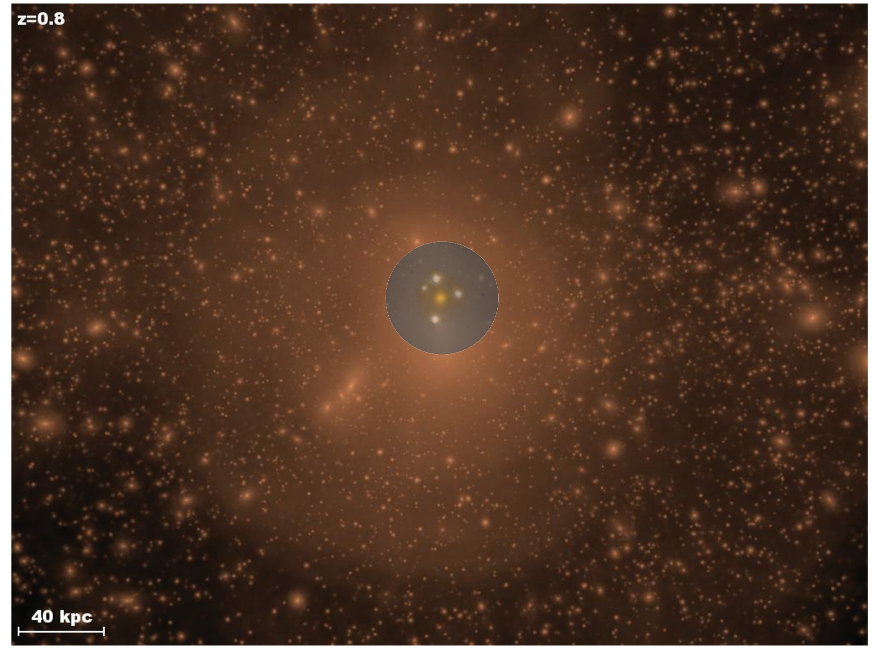
M>1E8

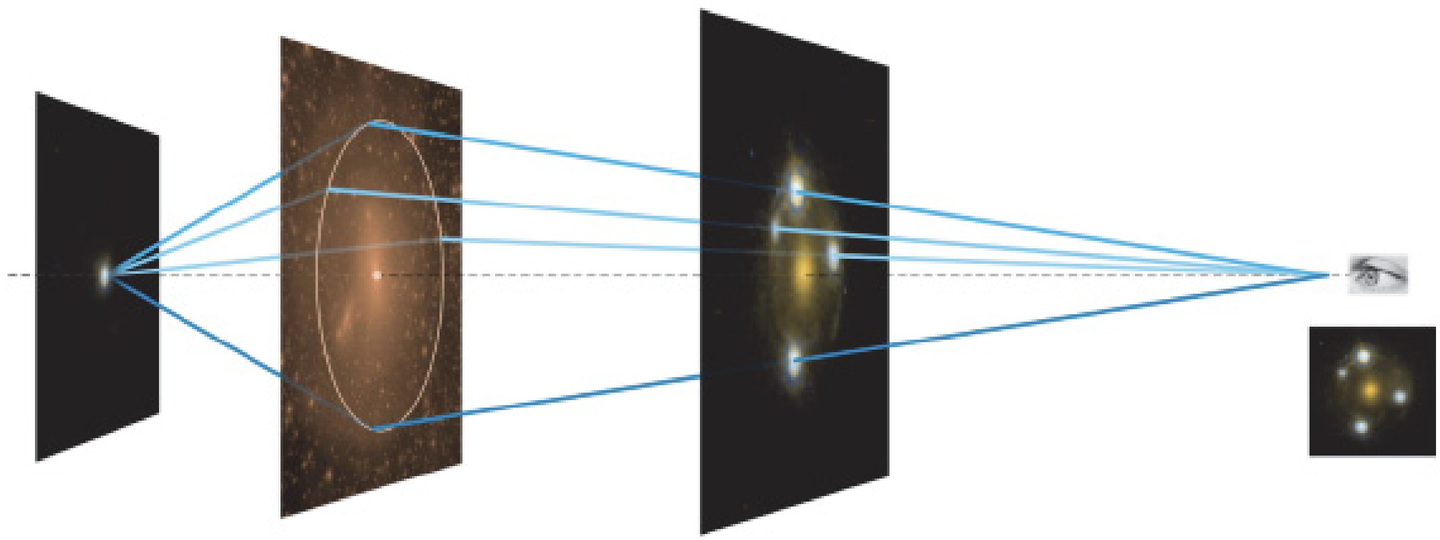
M>1E9

M>1E10 Msun

Strong gravitational lensing probes DM!

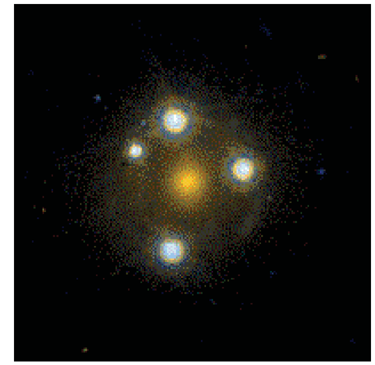


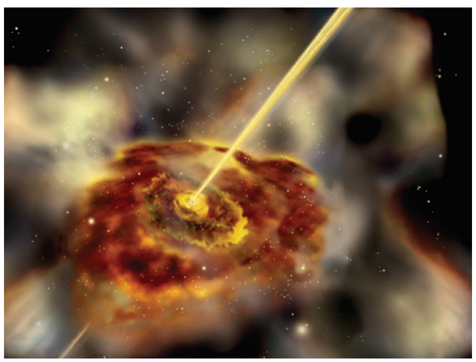




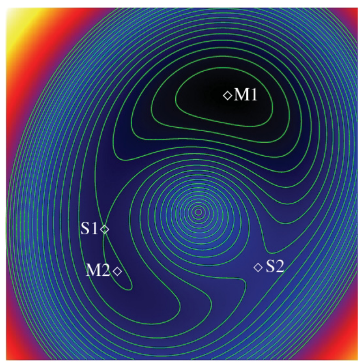
Time delays and magnifications => DM

The apparent brightness of each lensed image *at any one epoch of observation* depends on the combination of several phenomena, which vary on different timescales.
OMEGA will map the time domain data streams well enough to disentangle all of these, to measure the effects due to the dark matter substructure, which is the proxy for the fundamental dark matter constraints.

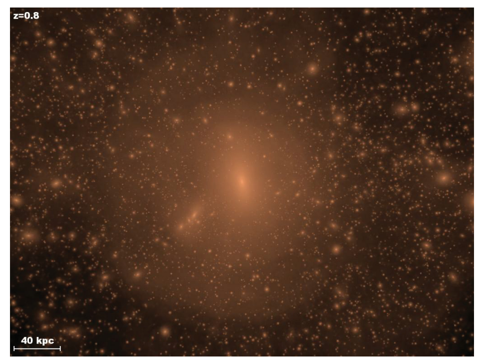




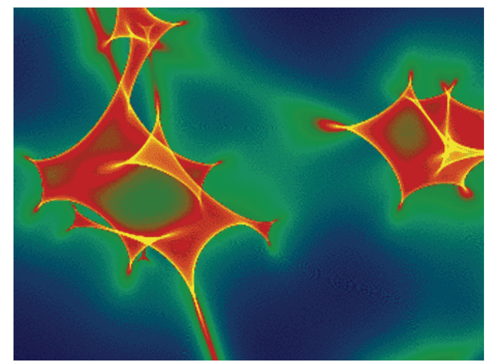
AGN: variability and amplitude is a function of wavelength.



Smooth potential delays and magnifications.

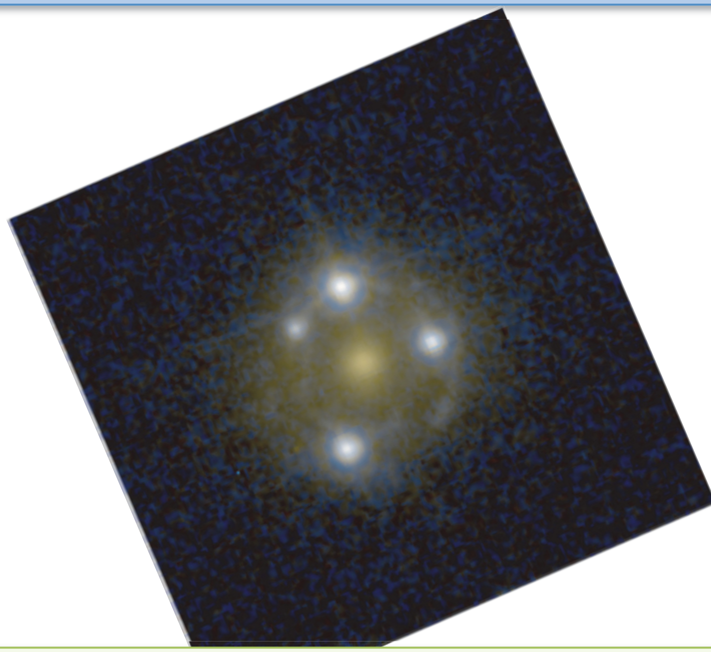


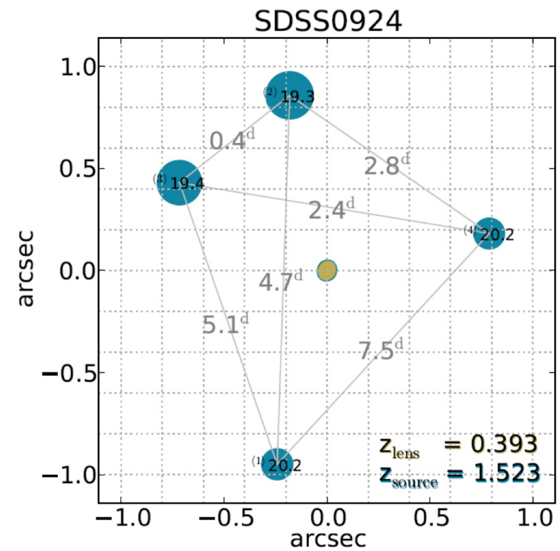
DM potential perturbations affect both delays & magnifications.



Stellar microlensing is *stochastic* by image & depends on parity & f_{DM}/f_{*} .

The key: map delays to *2-hour* precision!





Hour-cadence percent-level precision light curves over *continuous* observing campaigns of 6 weeks or longer allow allow us to map *time delay* and *magnification ratio perturbations* well enough to be sensitive to substructure **to mass scales of 1E6 solar masses.**

The solution: OMEGA

The Observatory for Multi-epoch Gravitational Lens Astrophysics (OMEGA) Explorer:

An 89-cm optical multiwavelength imaging telescope, in Low Earth Orbit, dedicated to time domain observations of a set of 24 four-image strong gravitational lenses, with:

- High angular resolution
- ~1% stable photometric precision
- across the SDSS griz broad bands, with
- Hourly cadences, over
- Contiguous & continuous observing campaigns of more than six weeks for each target.

LOOK FOR THE OMEGA SCIENCE BOOK ON ASTROPH BEFORE SUMMER 2011!

The OMEGA Explorer Science Team

Leonidas Moustakas
Adam Amara
Misty Bentz
Adam Bolton
James Bullock
Remi Cabanac
Ed Cheng
Dan Coe
Art Congdon
Ben Dobke
Greg Dobler
Peter Eisenhardt
Richard Ellis
Chris Fassnacht
Sarah Gallagher
Raphael Gavazzi
Tim Goodsall
Varoujan Gorjian
Manoj Kaplinghat
Chuck Keeton
Jean-paul Keeton
Mike Kuhlen
Charles Lawrence
Phil Marshall
Richard Massey
Ben Metcalf
Priya Natarajan
Patrick Ogle
Masamune Oguri
Annika Peter
Brad Peterson
Jason Rhodes
Kris Sigurdson
Daniel Stern
Harry Teplitz
Tommaso Treu
Joachim Wambsganss