Dark Matter in the Solar System

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OKC-DM meeting
8 May 2012

DM neutrinos from the Sun/Earth

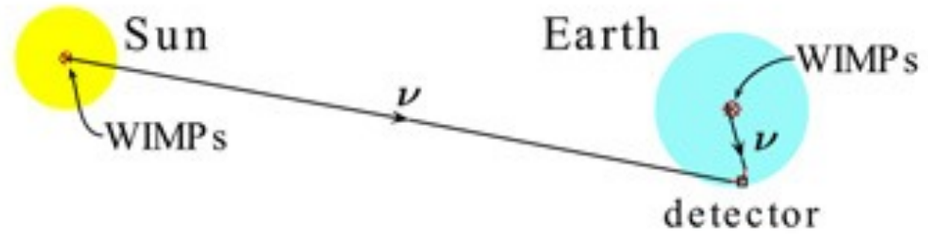
- Galactic WIMPs pass and scatter of nuclei in the Sun & Earth.

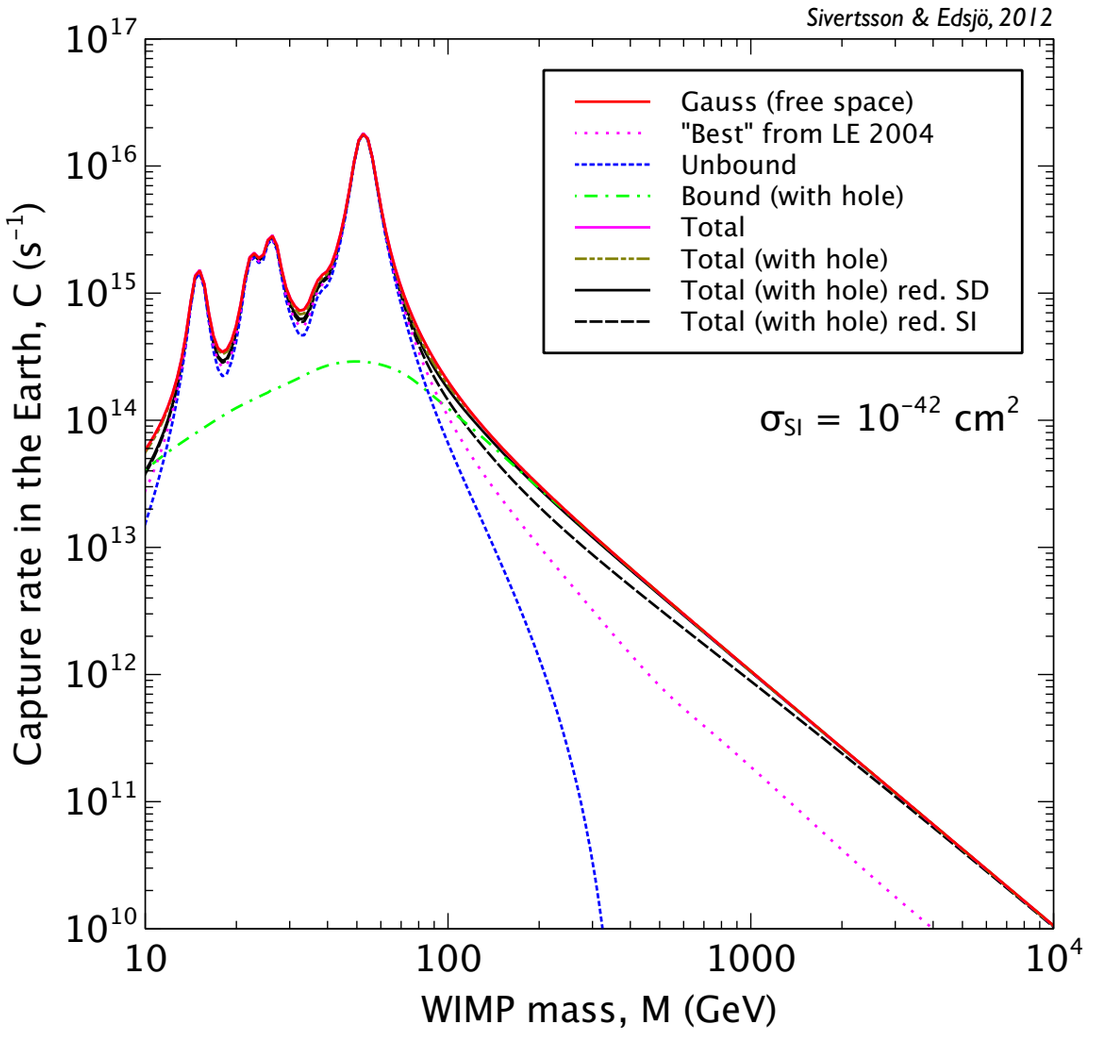
- Some become gravitationally bound in the scatter, accumulate in the centers of the Sun/ Earth.

- WIMPs annihilate -> neutrinos -> IceCube.

- Simple enough?

- Galactic WIMPs passing the Earth are accelerated by the Sun to too high velocities for the Earth to be able to capture heavy WIMPs

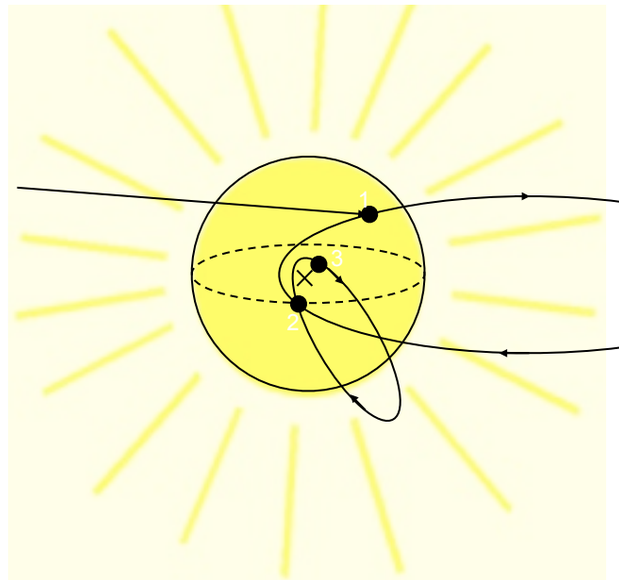




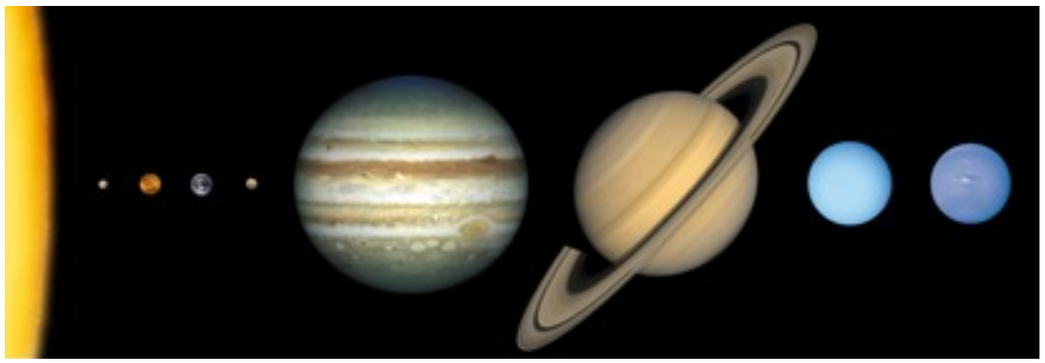
The Solar System has planets

- Planetary interaction give gravitational slingshots, altering the WIMP velocity relative the Sun.

- Jupiter (mass: 318 Earth masses) does this quite efficiently.



- Throw out WIMPs which the Sun has captured.
- Throw in WIMPs from the Galactic halo.
- Generates WIMP population bound to the Solar System from which the Earth can capture WIMPs.



Liouville's theorem

- Liouville's theorem: Gravitational slingshot preserves phase space density. (Generally not true for WIMP-nucleon scatters.)

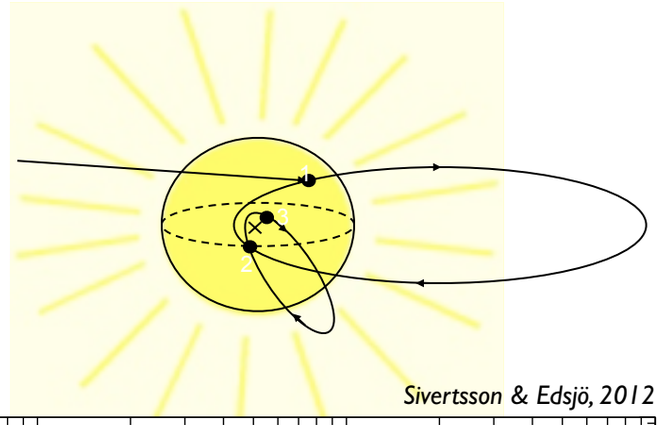
- Hence the WIMP population bound to the Solar System has same phase space density as the Galactic WIMP population.

- Gould 1991: WIMP capture rate can be calculated as if the Earth were alone in the Galaxy.
  (Liouville's theorem + efficient mixing)

- Things simple again?

Solar and Jupiter depletion

- Jupiter depletion (Peter 2009):
  All WIMPs captured by the Sun that reach Jupiter will be disturbed by Jupiter to not cross the Sun.

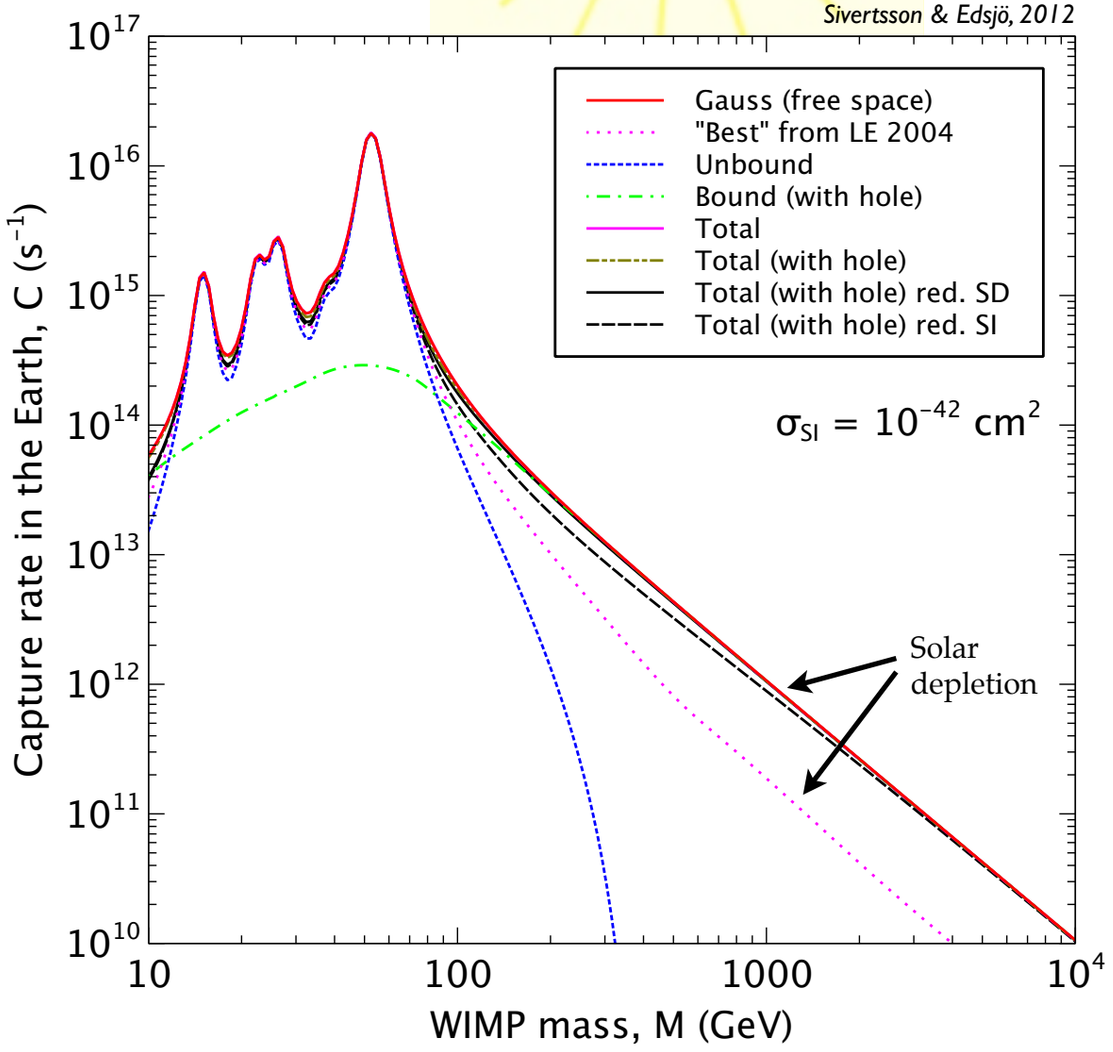


- Substantially reduces the Solar capture rate for heavy WIMPs (10 TeV) which scatter spin-dependently.

- Solar depletion (Lundberg & Edsjö 2004):
  WIMPs bound to the Solar System are efficiently thrown into the Sun by Solar System resonances.

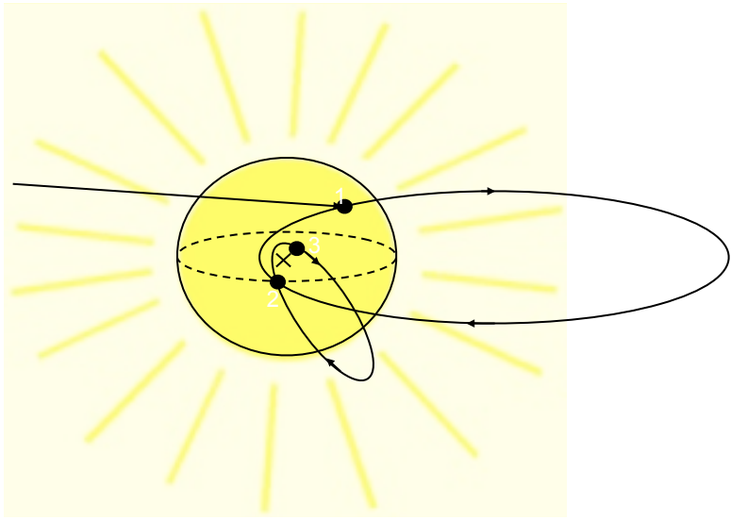
- Reduces the Earth's capture rate by an order of magnitude for heavy WIMPs.

Sivertsson & Edsjö, 2012



Is this the whole story?

- Jupiter depletion also adds WIMPs to the population bound to the Solar System.



- Solar depletions also adds to the Solar capture rate. (adds to the WIMP population crossing the Sun)

- Which is more important?

- Gravitational diffusion between two populations, which phase space density is larger?

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- Jupiter depletion also adds WIMPs to the population bound to the Solar System.

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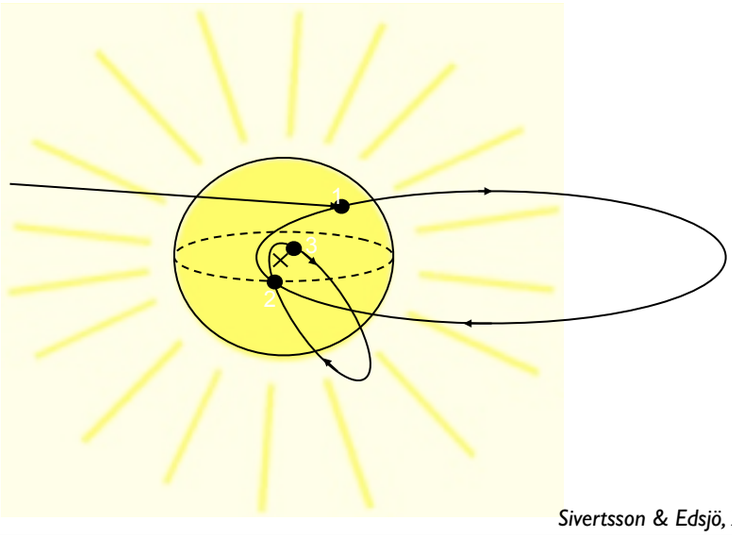
- Which is more important?

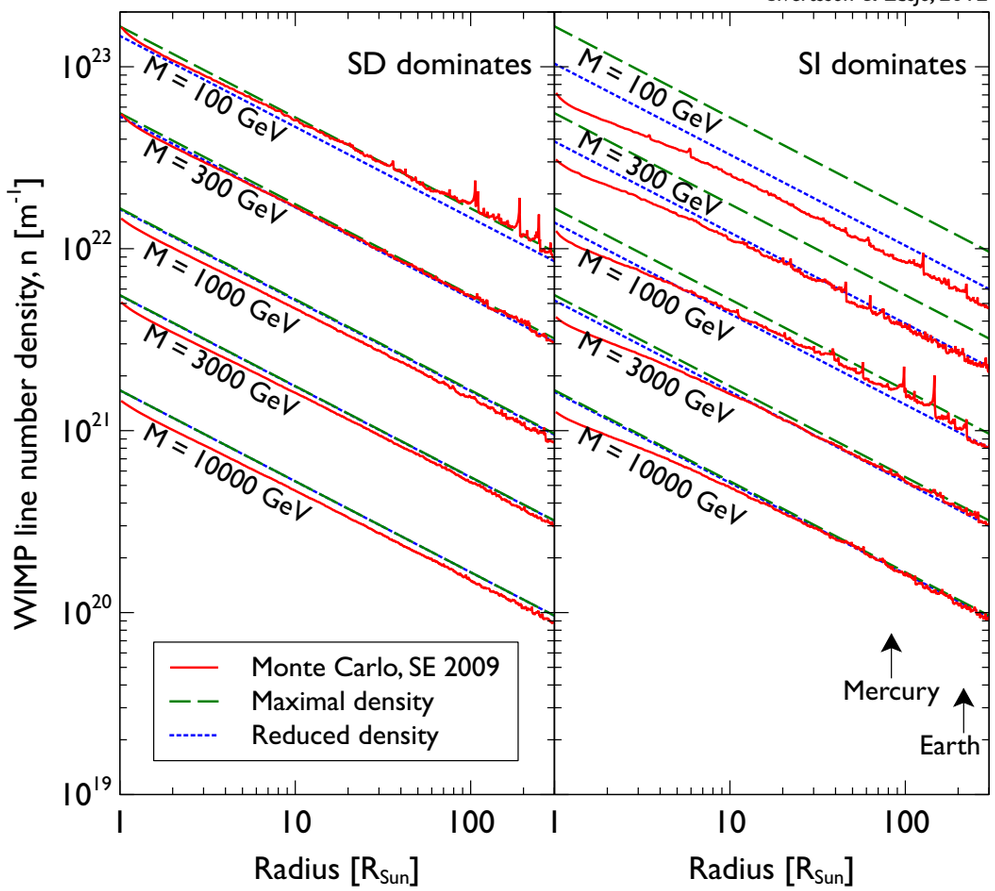
- Gravitational diffusion between two populations, which phase space density is larger?

- Turns out to be essentially the same!

- Can approximately use Liouville's theorem also for WIMPs captured through scatters on nuclei in the Sun!



Sivertsson & Edsjö, 2012



What happens with Jupiter and Solar depletion?

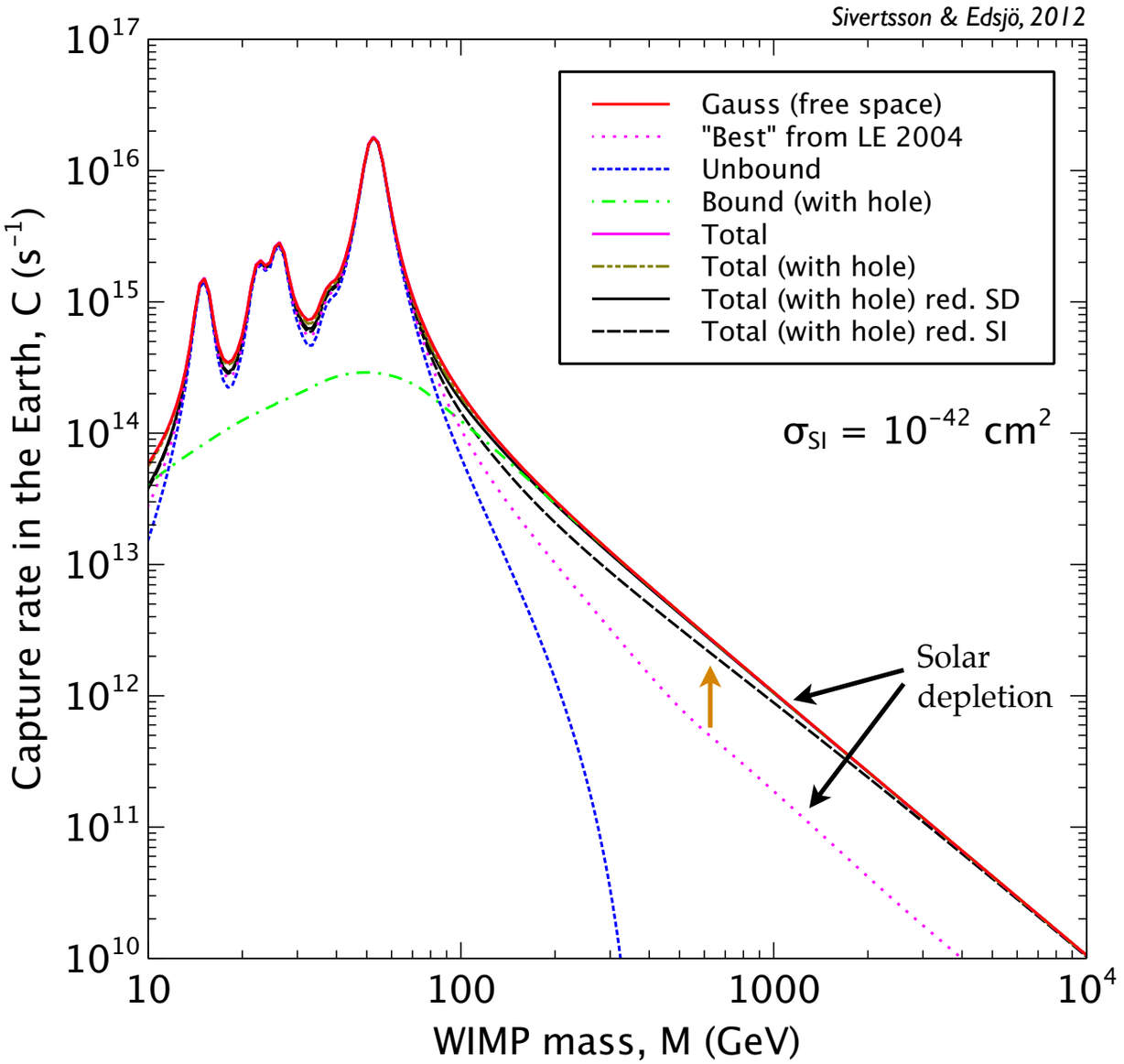
- Jupiter depletion: Cancelled by Jupiter throwing bound WIMPs into the Sun.

- Solar depletion: Almost completely cancelled by Solar crossing WIMPs being gravitationally perturbed.

- Galactic WIMP phase space density depends on WIMP velocity.

- WIMP capture by the Sun/Earth can *almost* be treated as if the Sun/Earth were alone in the Galaxy.

- GOOD NEWS!



The End

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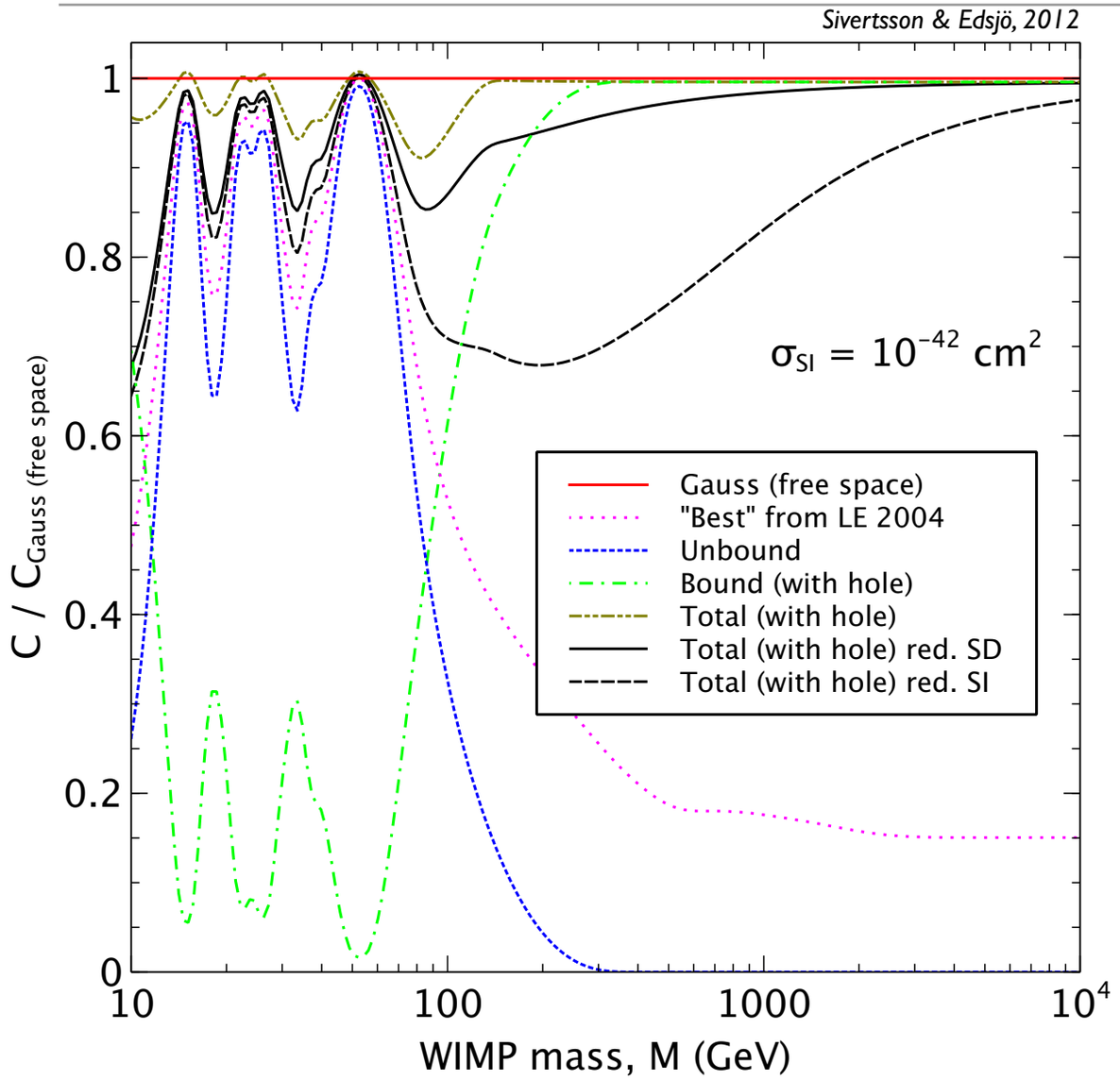
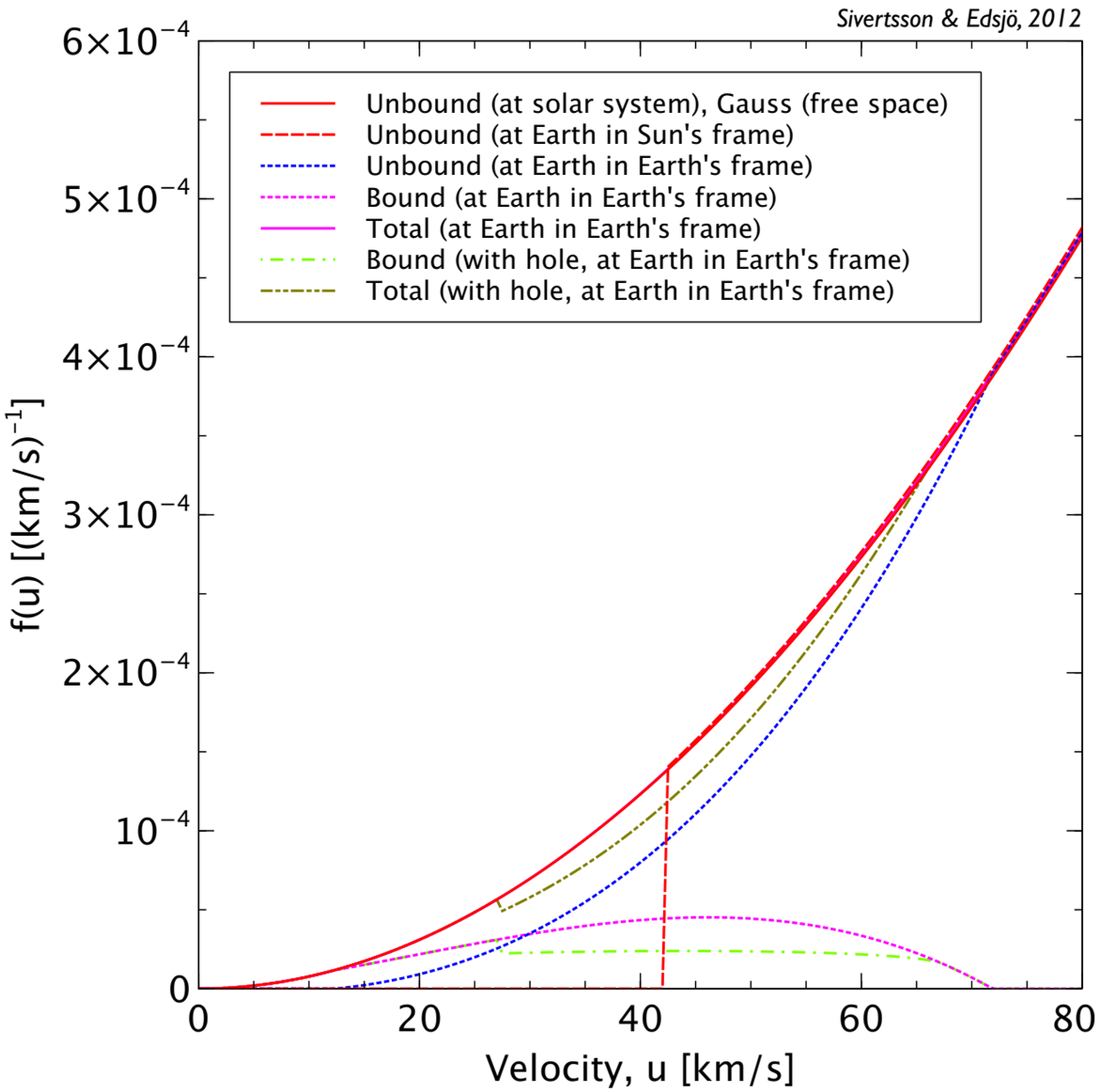
Extra


Sivertsson & Edsjö, 2012
$\sigma_{SI} = 10^{-42}$ cm^2
Gauss (free space)
"Best" from LE 2004
Unbound
Bound (with hole)
Total (with hole)
Total (with hole) red. SD
Total (with hole) red. SI
C / C$_{Gauss (free space)}$
WIMP mass, M (GeV)


Sivertsson & Edsjö, 2012
Unbound (at solar system), Gauss (free space)
Unbound (at Earth in Sun's frame)
Unbound (at Earth in Earth's frame)
Bound (at Earth in Earth's frame)
Total (at Earth in Earth's frame)
Bound (with hole, at Earth in Earth's frame)
Total (with hole, at Earth in Earth's frame)
f(u) [(km/s)$^{-1}$]
Velocity, u [km/s]