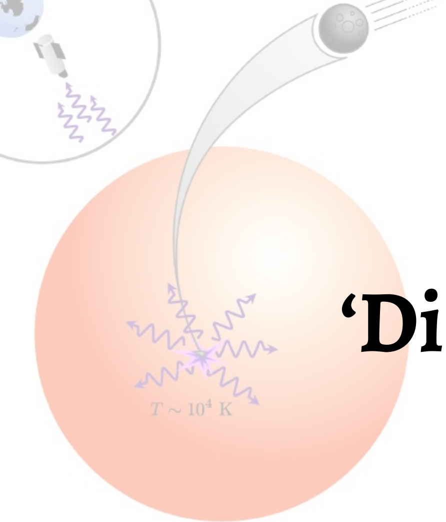


‘Direct Detection’ of Dark Asteroids

Anirban Das
SLAC National Accelerator Laboratory

arXiv:2106.09033

w/ Sebastian Ellis, Philip Schuster, and Kevin Zhou

Brookhaven Forum 2021
Opening New Windows to the Universe (BF2021)

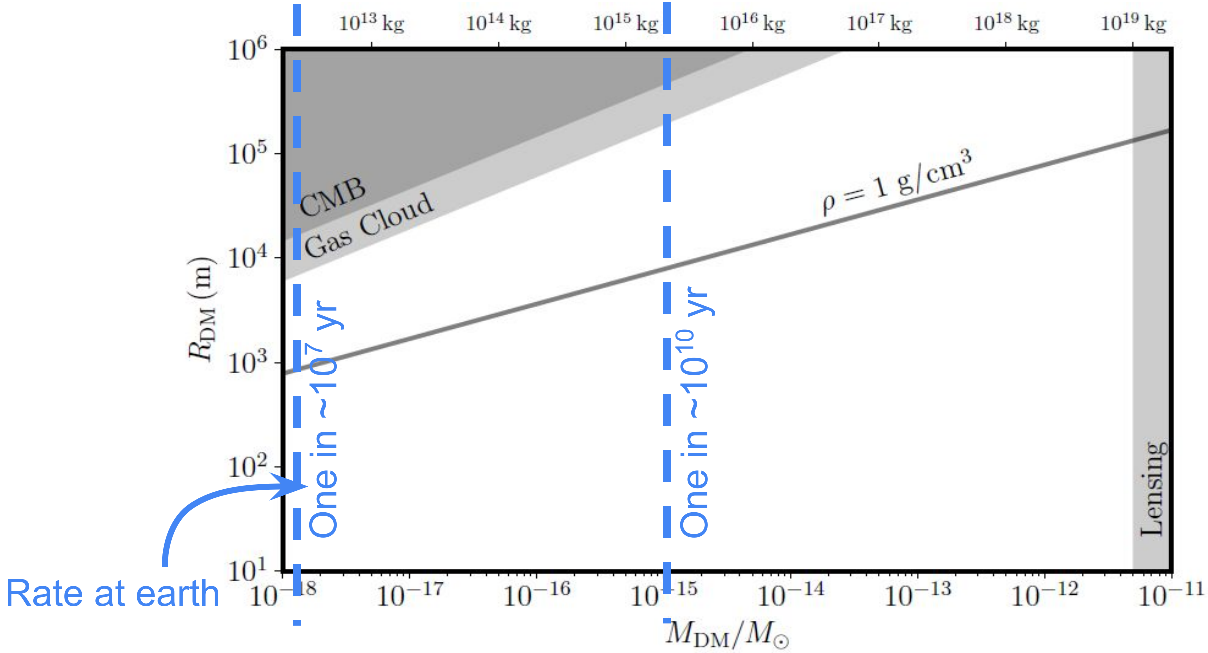
SLAC NATIONAL ACCELERATOR LABORATORY

Macroscopic Dark Matter

Composite macroscopic dark objects may form in a broad class of models:

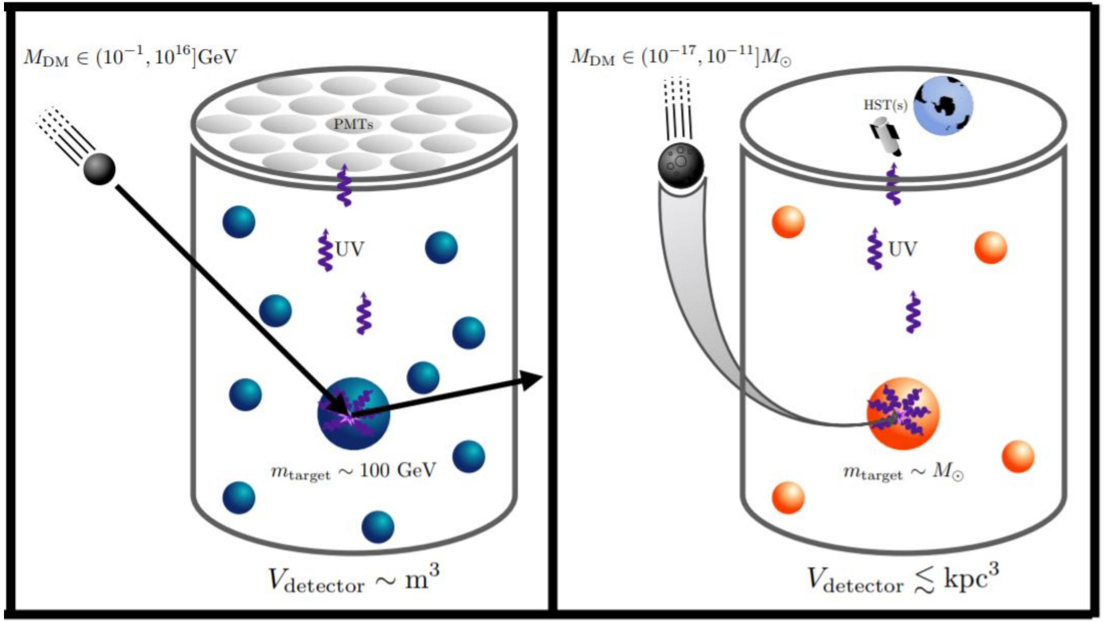
- Nuggets or solitons from phase transition 1810.04360, 2105.02840
- Dissipative dark sector with light mediator 1707.03829, 1812.07000
- Dark nucleosynthesis - elementary particles form nuclei which may form composite objects 1411.3739, 1707.02316, 1807.03788

Low encounter rate of Dark Asteroids

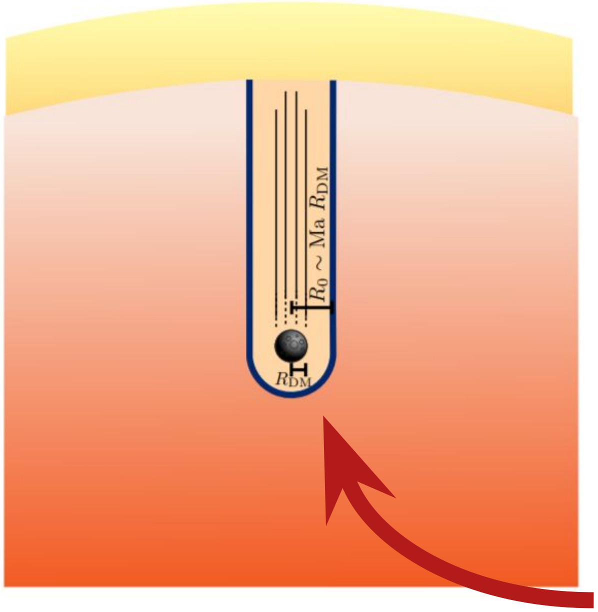


Look for many of them in a bigger 'detector', like a star

Direct Detection with Stars



Shock Wave from Collision



For Sun-like star,

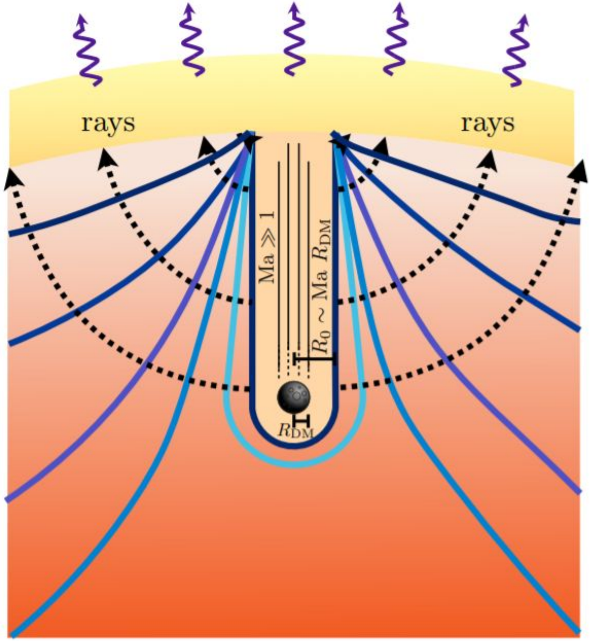
$$v_{\rm coll} = \sqrt{v_{\rm DM}^2 + v_{\rm esc}^2} \simeq 656\,{\rm km\,s^{-1}}$$

$$c_s \simeq \mathcal{O}({\rm few})\,{\rm km\,s^{-1}}\ \text{at surface}$$

$$\mathrm{Ma} \gg 1$$

Hypersonic collision

Emission from the Stellar Surface

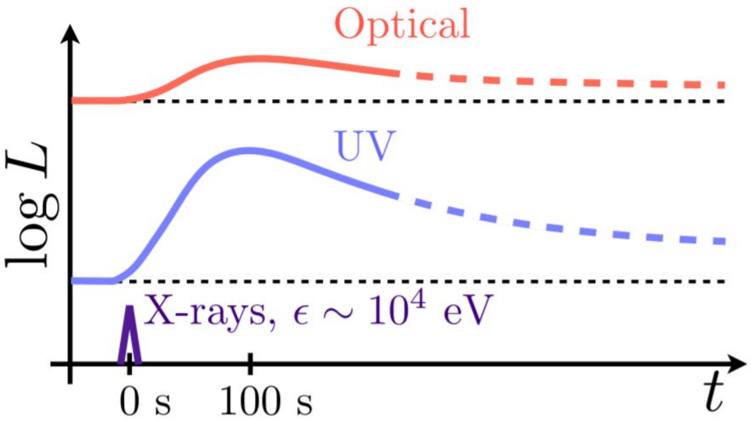


Once the shock wave reaches the surface, it gets strong again due to steep fall in density

We assume the shock heats the surface to a temperature T_f that sets the emission waveband

A prompt emission of x-ray followed by UV and visible light

Emission from the Stellar Surface



Once the shock wave reaches the surface, it gets strong again due to steep fall in density

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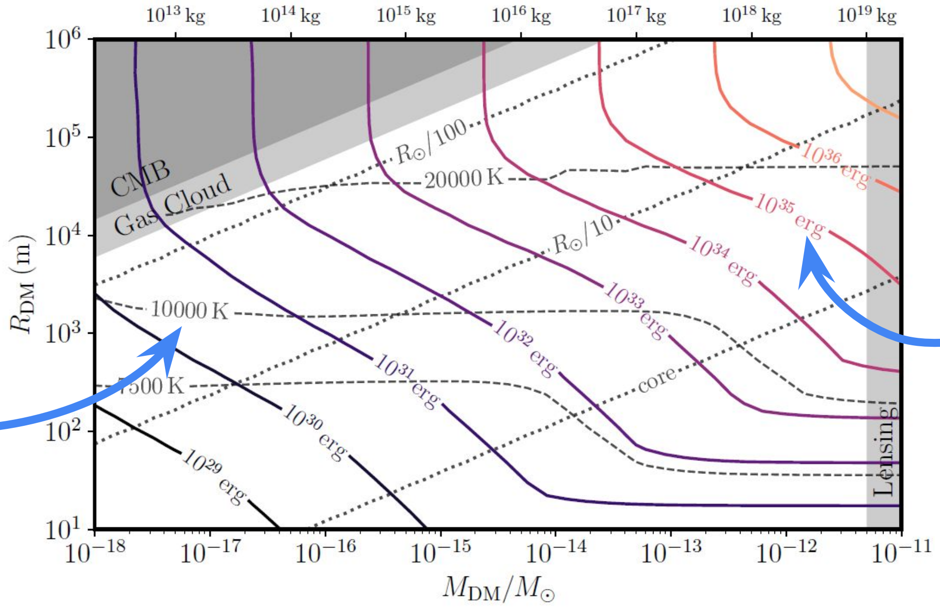
A prompt emission of x-ray followed by UV and visible light

Energy Release from Sun-like Star



Typical temperature of emission

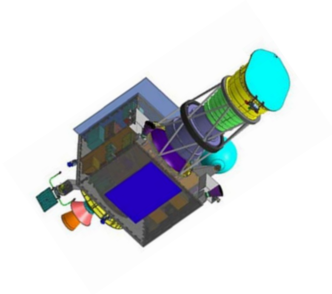
Energy released from star surface

The energy release increases with M_{DM} and R_{DM}, but saturates at large values

Transient Search

Key concerns -

- Observe as many stars at a time as possible
- Distinguish from stellar flare events
- Dark matter dense regions



Transient Search

Local Neighborhood

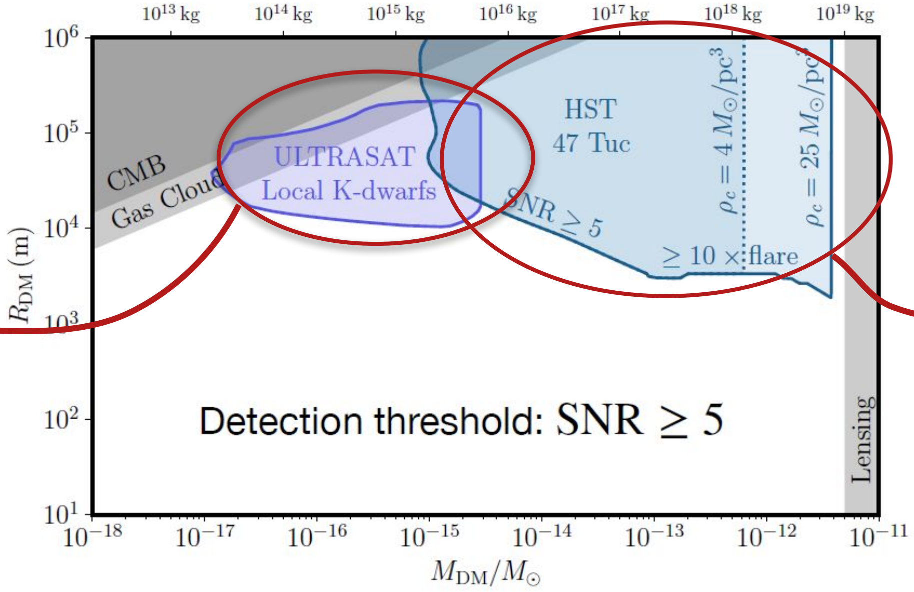
- ULTRASAT, LSST would be ideal for transient UV search
- K-dwarfs/Sun-like stars are ideal due to large mass
- Red/M-dwarfs have greater number density but show more flare activity
- Red giants have larger encounter rate but energy output is smaller

Globular Cluster 47 Tuc

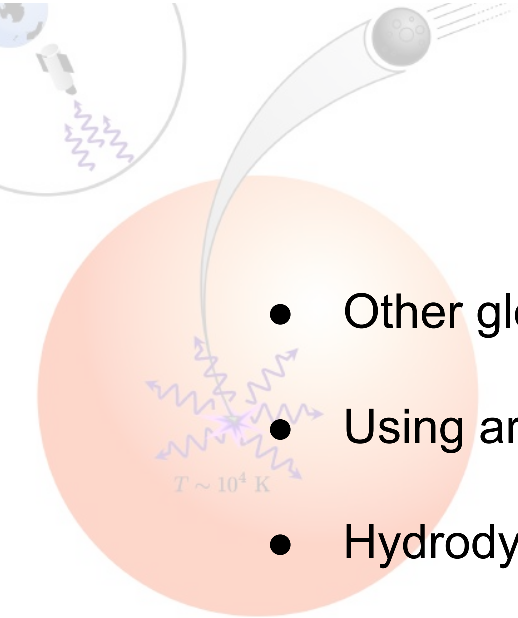
- Millions of stars within a radius of several pc
- Relatively closer to us - 4.5 kpc
- Away from the galactic center, l = 305.89^{o}, b = -44.89^{o}
- Very little UV dust extinction
- HST has already observed 47 Tuc for a long period of time

Transient Search

Low rate, probes low mass region



High rate, flare bkg negligible



Future Outlook

- Other globular cluster with IMBH
- Using archival data from HST and other telescopes
- Hydrodynamic simulation of shock propagation and cooling
- Simulate the expected signal and use for flare bkg rejection
- Brown dwarfs could be a good target
- Galactic center: high dark matter, SMBH, but large foreground