Dark matter distribution in the Solar System

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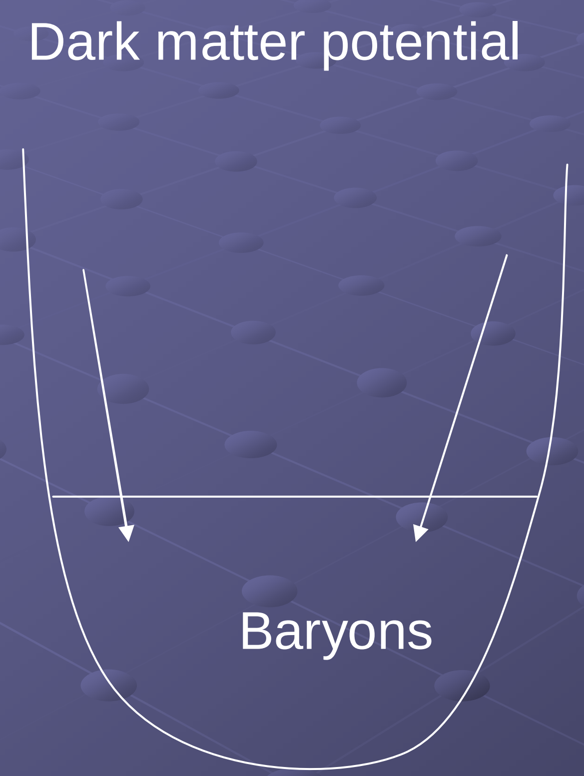
- Galactic dark matter distribution in Solar System vicinity
- Dark matter density enhancement mechanism
  - gravitation-collisional capture
  - gravitational capture
  - particle focusing in Solar System gravitational field
  - baryon compression
- Observational capabilities

Galactic dark matter distribution in Solar System vicinity



$$\rho_{D.M.} = \frac{\rho_0}{\frac{r}{r_0}\left[1+\frac{r}{r_0}\right]^2}$$

$$\rho_{D.M.} \sim \frac{1}{r} \cdots\cdots \frac{1}{r^3}$$

$$\rho_{D.M.}(\text{isothermal sphere}) \sim \frac{1}{r^2}$$

Baryon compression

- L = constant
- Before

$$\rho_{D.M.} \sim r^{-\gamma_d}$$

- After

$$\rho_{D.M.} \sim r^{-\gamma'_d}$$

$$\rho_{baryon} \sim r^{-\gamma'_b}$$

=>

$$\gamma'_d = \frac{3\gamma_b + \gamma_d - \gamma_b \gamma_d}{4 - \gamma_d}$$

Solar System vicinity

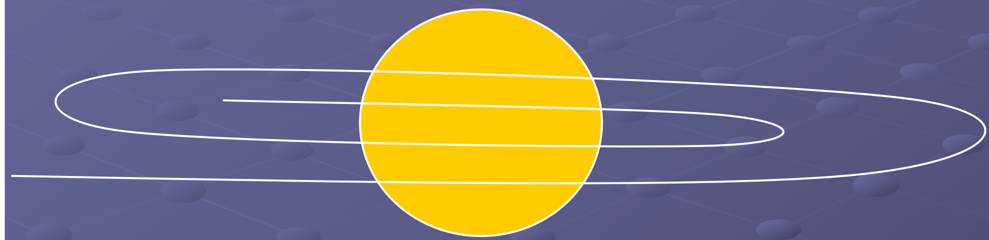
$$\rho_{star\_disk} \approx 10^{-1} \frac{M_{\otimes}}{pc^3} = 10^{-23} \frac{g}{cm^3}$$

$$\rho_{D.M.} \sim \rho_{star\_halo} \approx 10^{-2} \frac{M_{\otimes}}{pc^3} = 10^{-24} \frac{g}{cm^3} = 0.3 \frac{GeV}{cm^3}$$

$$f_{\infty}(V) \sim e^{-\frac{V^2}{\sigma^2}}$$

$$\sigma \approx V_{\otimes} \approx 300 \frac{km}{s}$$

Gravitation - collisional capture



Sun

$V^{\infty}_{D.M.} \sim 300$ km/s

$V_{sun}^{par.} \sim 600$ km/s

$V^{sun}_{D.M.} \sim 660$ km/s

Bound orbit => 10% velocity loss

Particle deceleration in Sun

Electric charge:

e	:	p	:	Fe
1	:	36	:	0.02

Magnetic charge:

e	:	p	:	Fe
1	:	0.02	:	$2*10^{-7}$

Energy lose

Electric:

$$\left(\frac{\delta E}{E}\right)_{kin} \sim 0.56 \times \left(\frac{10^{16}\,GeV}{Mx}\right)$$

Magnetic:

$$\left(\frac{\delta E}{E}\right)_{kin} \sim 0.2 \times \left(\frac{10^{16}\,GeV}{Mx}\right)$$

Major semiaxis

Electric:

$$\frac{R}{R_{\otimes}} \approx \frac{4 \times \left(\frac{Mx}{10^{16}\,Gev}\right)}{2.8 - \left(\frac{Mx}{10^{16}\,Gev}\right)}$$

Magnetic:

$$\frac{R}{R_{\otimes}} \approx \frac{4 \times \left(\frac{Mx}{10^{16}\,Gev}\right)}{1 - \left(\frac{Mx}{10^{16}\,Gev}\right)}$$

Gravitation - collisional capture

Halo:

few solar radius

(1 a.u. = 200 solar radius)

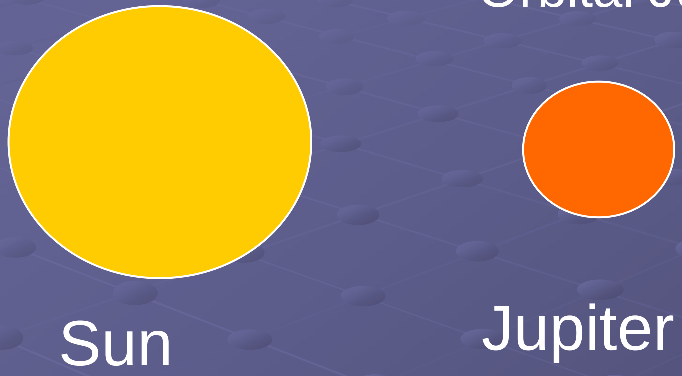
$$\frac{\rho}{\rho_o} \sim 5$$

Fine tuning: (Dark Matter particle mass, cross-sections)

Gravitational capture

Capture condition:

Orbital Jupiter velocity: 13 km/s



$$\vec{V}_{D.M.} \pm 2\times 13\,\frac{km}{s} \approx 13\,\frac{km}{s}$$

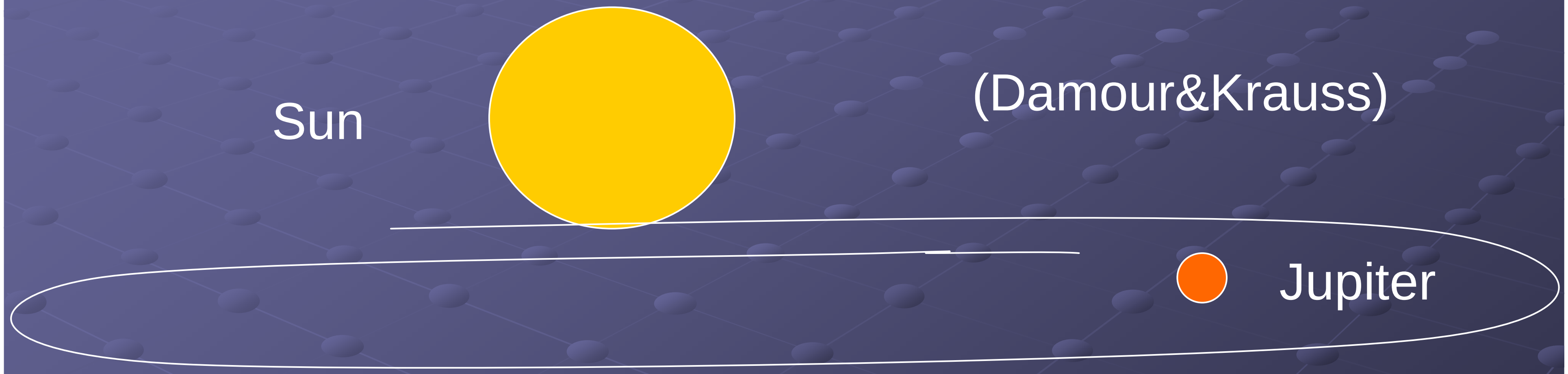
Cross-section: $\sigma = \pi R^2_*$

$$\frac{V^2_{Jupiter}}{2} \sim G\,\frac{M_{Jupiter}}{R_*}$$

=> $R_* = 2R_O$

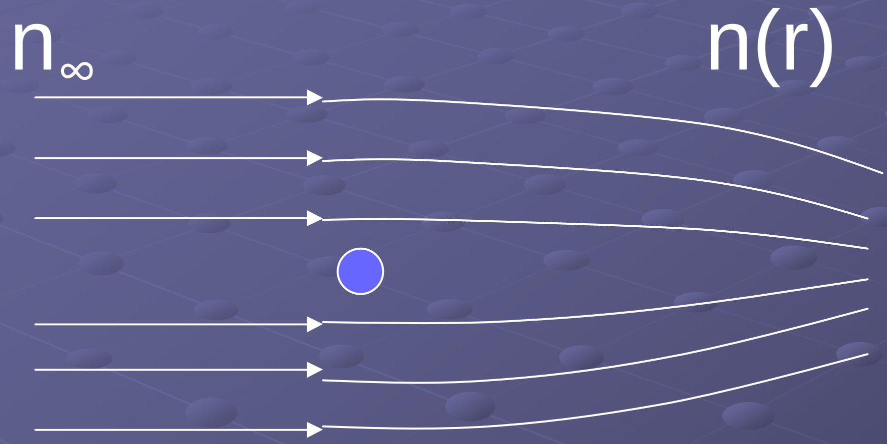
!!! inverse scattering, no cosmological storage

Gravitation - collisional capture
+
Gravitational capture



- Graze the Sun
- Subsequent orbit evolution
  - $U(r) \sim r^2 + 1/r$
  - Perturbation of planets gravitational field

Particle focusing in Solar System gravitational field



$$\frac{n}{V} = const$$

(isotropic case)

$$\frac{\bar{n}}{V} = const$$

$$\bar{n} = \int n(\vec{r})\frac{d\Omega}{4\pi}$$

(anisotropic case)

$$\frac{ndVf(V)}{V}$$ if $$f(V)dV$$

$$V^2(r) = V_{par}^2(r) + V^2(\infty)$$

$$V_{par}(r)\_??\_V(\infty)$$

Sun: $V_{sun}^{par.} \sim 600$ km/s $V^{\infty}_{D.M.} \sim 300$ km/s

$$X_{par}(r) = \frac{V_{par}(r)}{V(\infty)}$$

Sun: $0 \leq X_{par}(r) \leq 2$

1.

$$f_\infty(V) \sim e^{-\frac{V^2}{\sigma^2}}$$

$$\sigma \approx 300 \frac{km}{s}$$

$$X_{par}(r) = \frac{V_{par}(r)}{\sigma}$$

$$n(r) = n_\infty \left(\frac{2X_{par}}{\sqrt{\pi}} + e^{X_{par}^2} \left(1 - erf\left(X_{par}\right)\right) \right)$$

$X_{par}(r)$ <<1

$$n(r) = n_\infty \left(1 + X_{par}^2 - \frac{4}{3\sqrt{\pi}} X_{par}^3 + \ldots \right)$$

$X_{par}(r)$ >>1

$$n(r) = n_\infty \left(\frac{2}{\sqrt{\pi}} X_{par} + \frac{1}{\sqrt{\pi} X_{par}} - \frac{1}{2\sqrt{\pi} X_{par}^3} + \ldots \right)$$

2.

$$f_\infty(V) \sim e^{-\frac{(\vec{V}-\vec{V}_\otimes)^2}{\sigma^2}}$$

$$\sigma \approx V_\otimes \approx 300\frac{km}{s}$$

$$X_{par}(r) = \frac{V_{par}(r)}{\sigma}$$

$$\overline{n}(r) = \frac{n_\infty}{2} X_{par} \frac{\sigma}{V_\otimes}\left(1 + erf\left(\frac{V_\otimes}{\sigma}\right)\right)$$

$$\overline{n}(r) \sim \frac{n_\infty}{2}\frac{V_{par}}{V_\otimes}$$

Particle focusing in Solar System gravitational field

$$\bar{n}(r) \sim V_{par} \sim \frac{1}{\sqrt{r}}$$

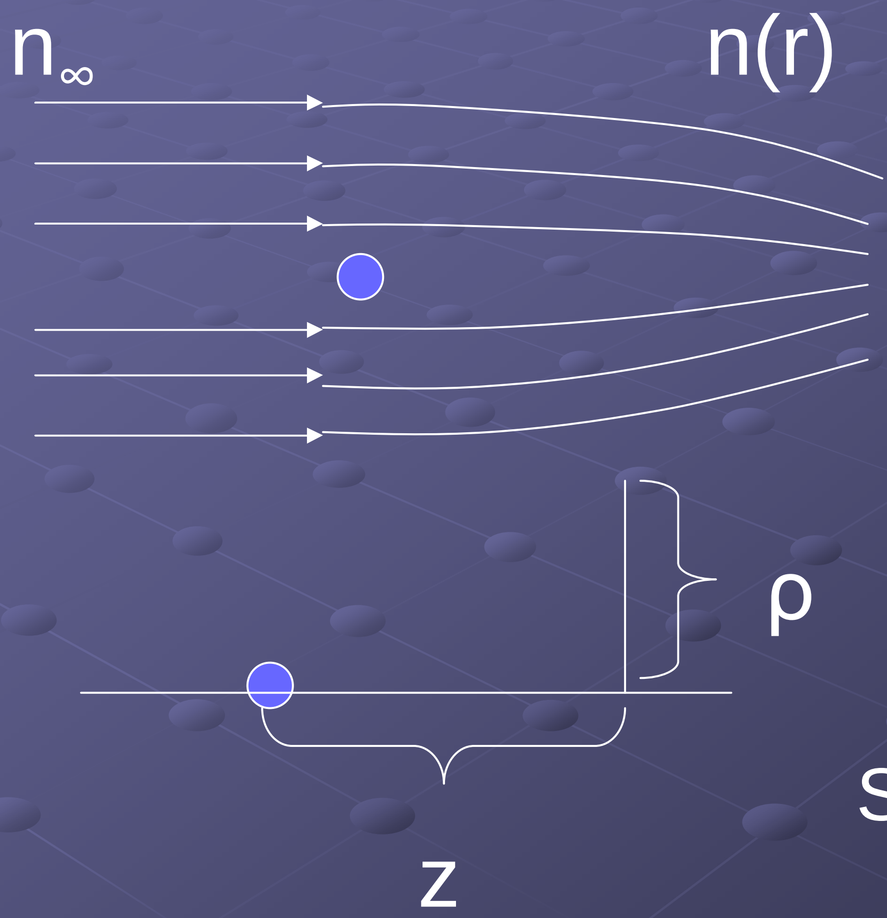
Sun surface: $$\frac{\bar{n}(r)}{n_\infty} \sim 2$$

1. White dwarf: $r \approx \frac{r_\otimes}{10^2}$ => $\frac{\bar{n}(r)}{n_\infty} \sim 20$

2. Neutron star: $r \approx \frac{r_\otimes}{10^5}$ => $\frac{\bar{n}(r)}{n_\infty} \sim 600$

3. Sun: $V_{par}(r=0) \approx 1400 \frac{km}{s}$ => $\frac{\bar{n}(r)}{n_\infty} \sim 5$

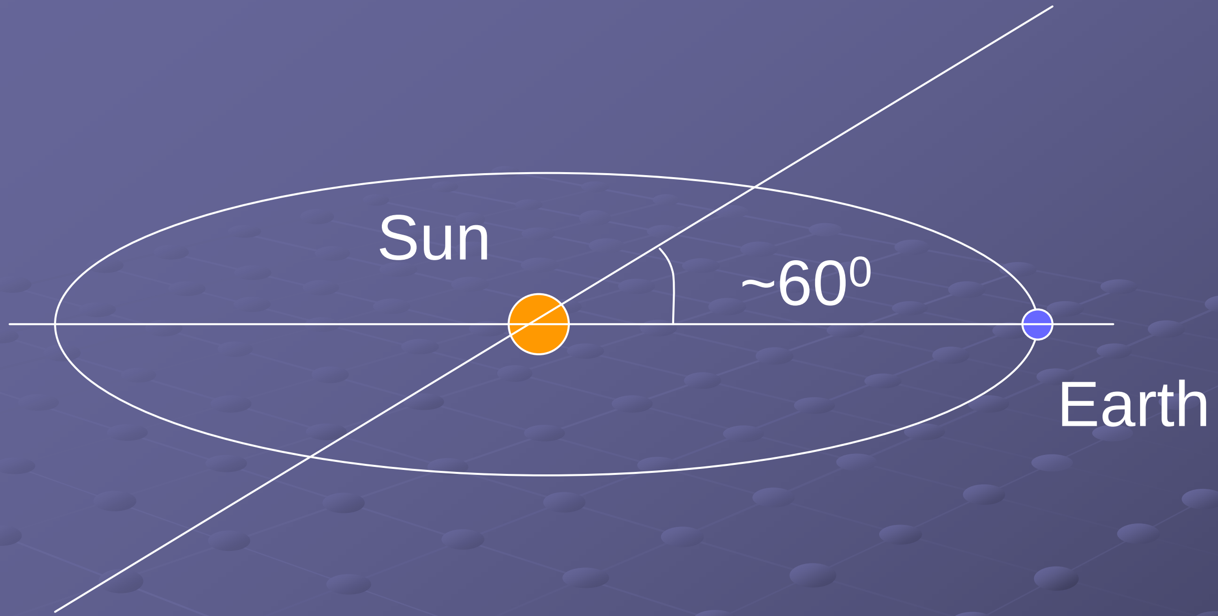
Caustic



$$n(z,\rho) \approx n_\infty \frac{\sqrt{2az}}{\rho}$$

$$a = \frac{GM}{V_\infty^2}$$

Sun: $$n(z,\rho) \approx 2n_\infty \frac{\sqrt{R_\otimes z}}{\rho}$$



$$\frac{n_{Earth}}{n_{\infty}} \sim 1.1$$

Temperature and velocity of interstellar medium were measured (Kurt V.G. et al)

Line HeI (λ = 584Å)

No focusing effect by planet

- Orbital

$$V_{par} = \sqrt{2} \times V_{orbital}$$

$V_{orbital\_Earth}$ = 30 km/s $V_{orbital\_Jupiter}$ = 13 km/s

- Halo around planet

V_{par_Earth} = 11.2 km/s $V_{par\_Jupiter}$ = 61 km/s

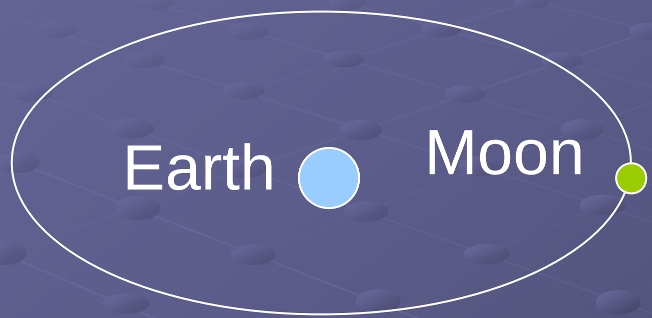
Baryon compression

- Spherical compression $\gamma_d \sim 0$ profile

$$\gamma'_d = \frac{3}{4}\gamma_b$$

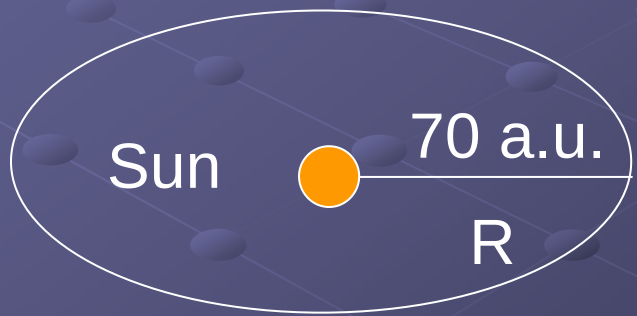
Observational capabilities (gravitational testing of Dark Matter)

$n \sim 10\, n_{\infty}$



$a_{D.M.} \sim 10^{-19}$ cm/s^2

a(RadioAstron) $\sim 10^{-6}$ cm/s^2



$a_{D.M.} \sim 3 \cdot 10^{-15}$ cm/s^2

a(Pioneer) $\sim 8 \cdot 10^{-8}$ cm/s^2

Celestial mechanics in Solar System $\rho_{D.M.} < 10^{-19} - 10^{-20}$ g/cm^3

Conclusion

There are some proved dark matter density enhancement mechanisms in Solar System. The coefficient of amplification is in the order of few units. It is very important for the modulating dark matter detector signals (noon – night, summer – winter effects), but direct detection of dark matter in Solar System by its gravitational effects is quite difficult.