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Testing MOND in the Solar neighbourhood

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Conference of young astronomers - Bezovec 2023

Missing mass problem

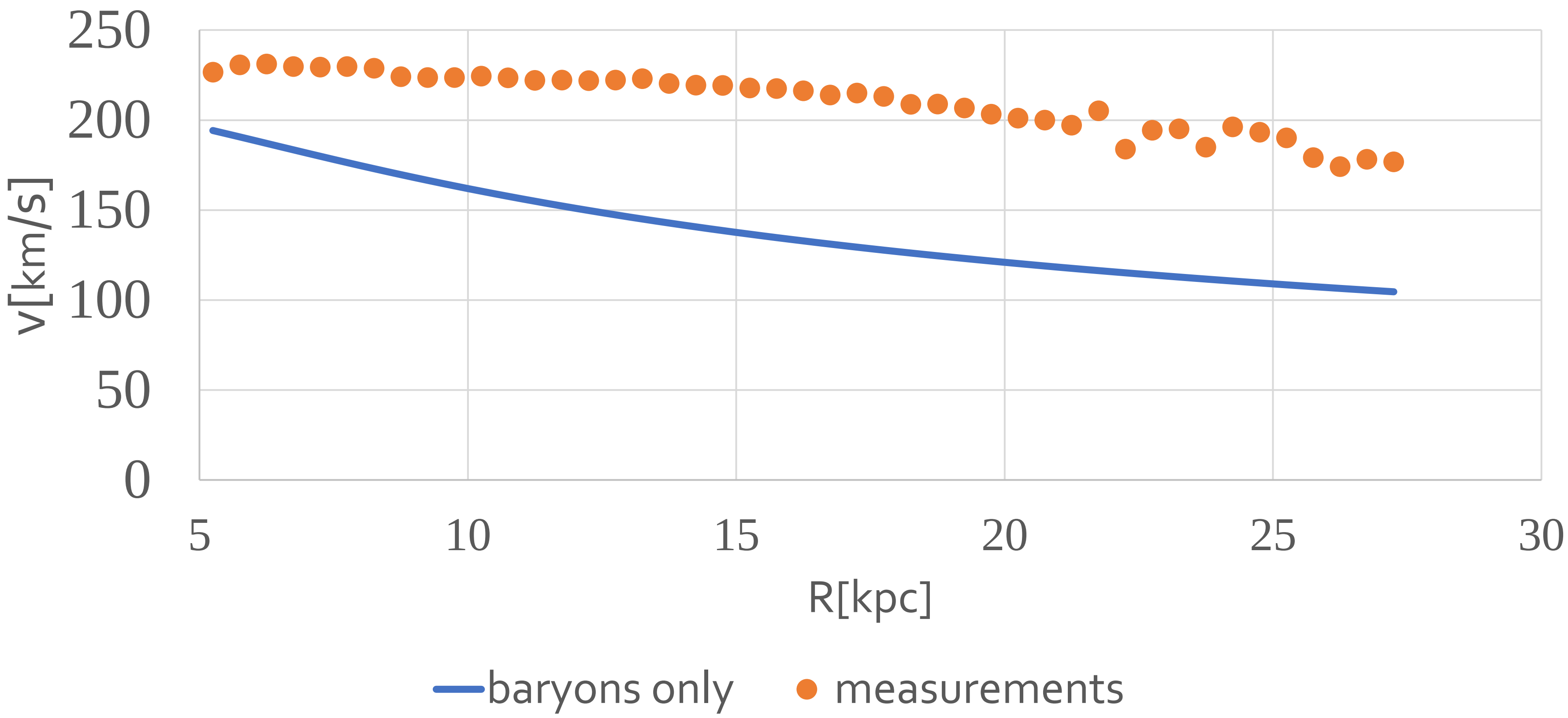
- Rotation curve – circular velocities of stars depending on the galactocentric distance

$$v_C = \sqrt{R g_{BM}}$$

- g_{BM}: total acceleration caused by the baryonic matter

$$g_{BM} = g_{bulge} + g_{thin} + g_{thick}$$

Missing mass problem



- Labini et al., 2023

MOdified Newtonian Dynamics

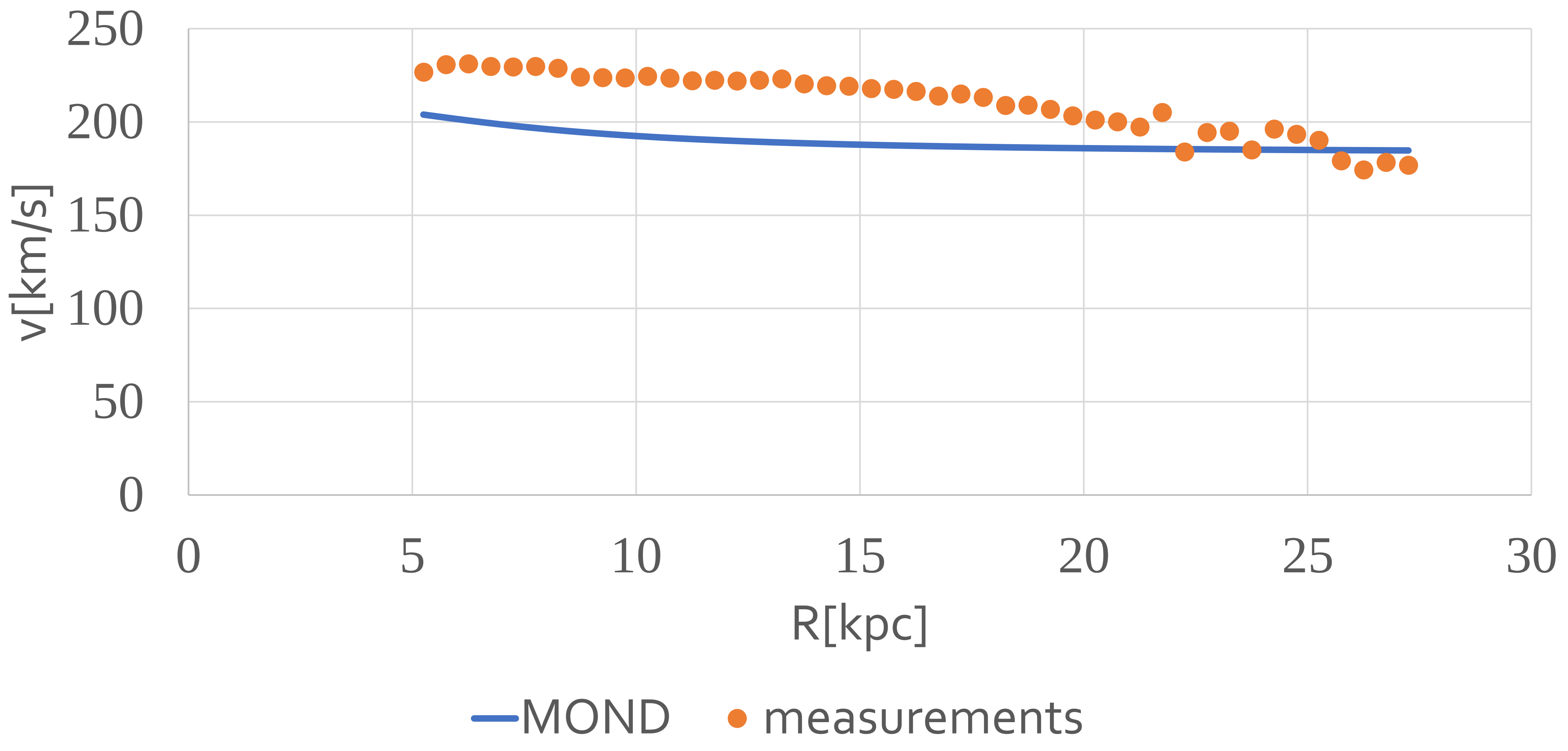
- Milgrom, 1983

$$\frac{ma}{\sqrt{1+\left(\frac{a_0}{a}\right)^2}} = F, a_0 = 1.2 \times 10^{-10}\ \mathrm{ms}^{-2}$$

- Corresponding rotation curve

$$v_C = \sqrt{\frac{\sqrt{2}}{2} R g_{BM} \sqrt{1 + \sqrt{1 + \left(2\frac{a_0}{g_{BM}}\right)^2}}}$$

MOdified Newtonian Dynamics



MOdified Gravity

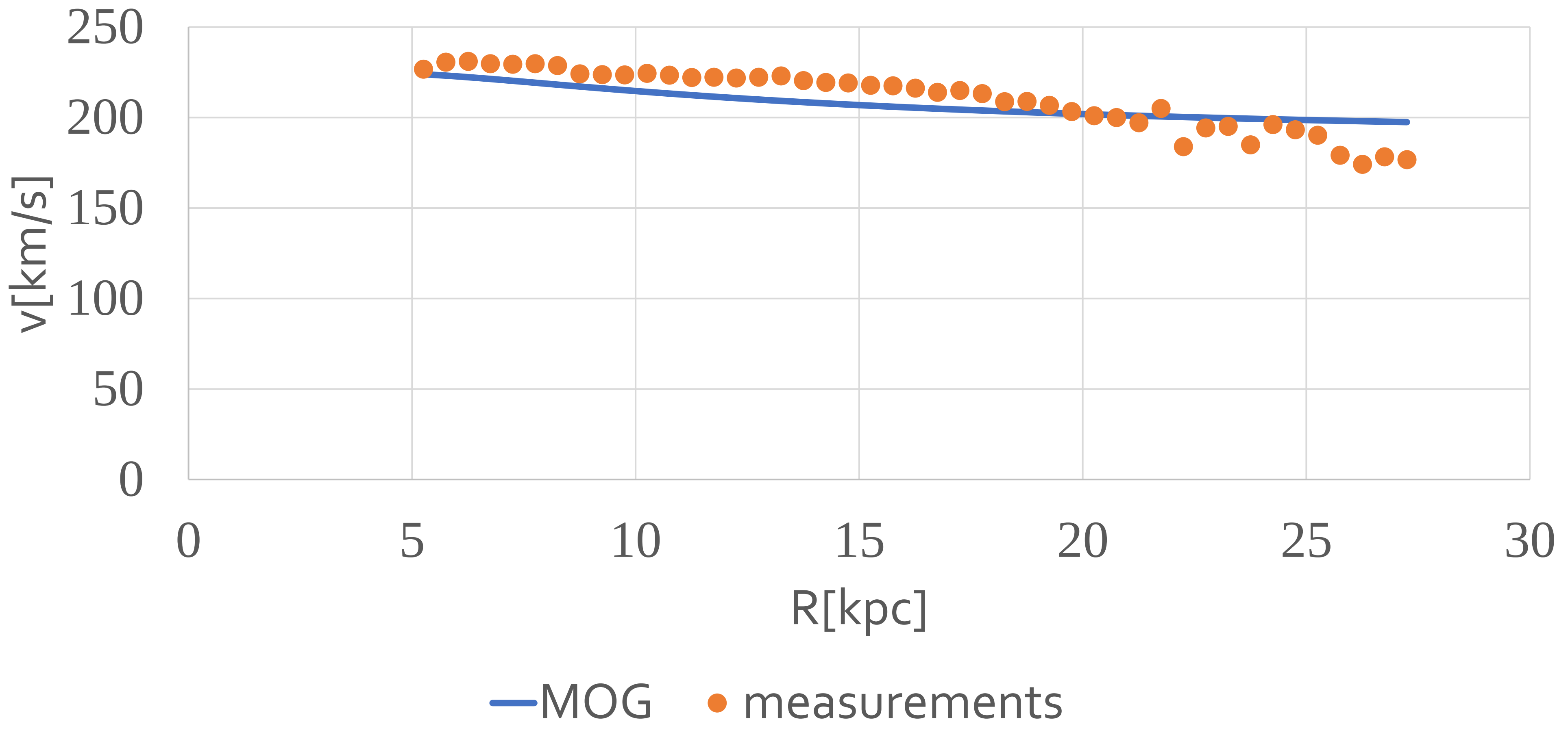
- McGaugh et al., 2016

$$g_{obs} = \frac{g_{BM}}{1 - \exp\left(-\sqrt{g_{BM}/g_+}\right)}, g_+ = 1.2 \times 10^{-10}\ \mathrm{ms}^{-2}$$

- Corresponding rotation curve

$$v_C = \sqrt{\frac{R g_{BM}}{1 - \exp\left(-\sqrt{g_{BM}/g_+}\right)}}$$

MOdified Gravity



Vector forms – two body problem

- NEWT

$$\ddot{\vec{r_1}} = -G\,\frac{m_2}{|\vec{r_1} - \vec{r_2}|^3}\,(\vec{r_1} - \vec{r_2}) \equiv \vec{g_1}$$

- MOND

$$\frac{\ddot{\vec{r_1}}}{\sqrt{1 + \frac{a_0^2}{\left|\ddot{\vec{r_1}}\right|^2}}} = \vec{g_1}$$

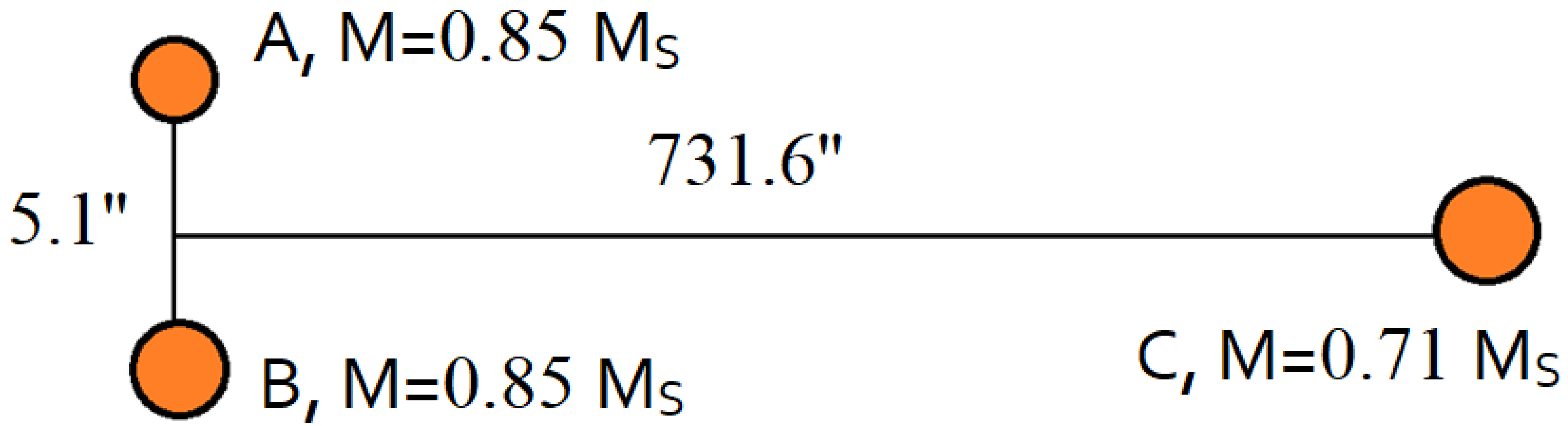
- MOG

$$\ddot{\vec{r_1}} = \frac{\vec{g_1}}{1 - \exp\left(-\sqrt{|\vec{g_1}|/g_+}\right)}$$

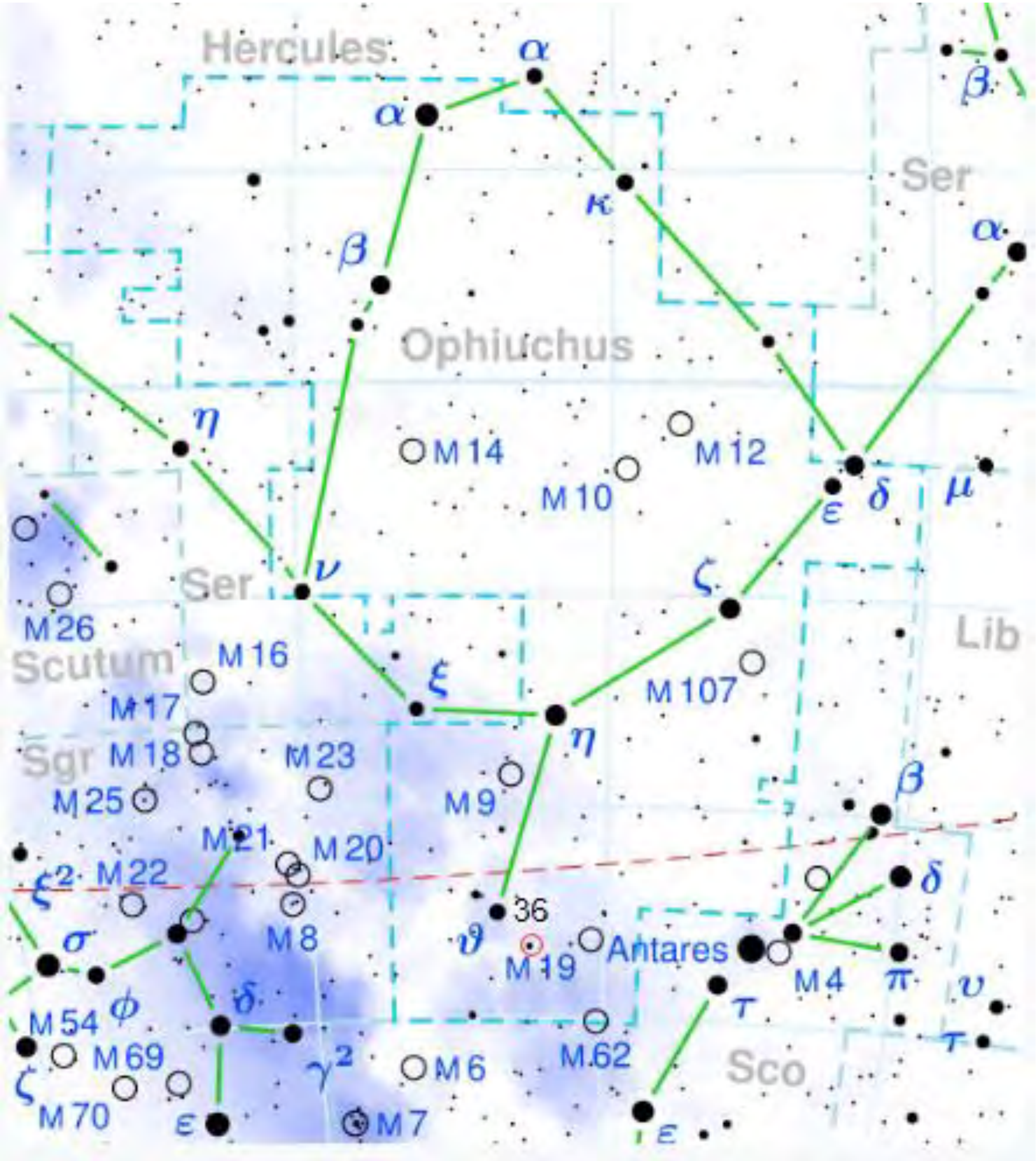
36 Ophiuchi

- Initial conditions (from the SIMBAD database)

Component	RA	Dec	Dist. [pc]	µRA [mas/yr]	µDec [mas/yr]	Rv [km/s]
A	17h 15m 20.851s	-26° 36' 09.04"	5.952	-498.600	-1149.158	-0.6
B	17h 15m 20.978s	-26° 36' 10.18"	5.948	-465.861	-1141.168	0.0
C	17h 16m 13.3624s	-26° 32' 46.129"	5.954	-479.573	-1124.332	-0.04



36 Ophiuchi



Hercules
Ophiuchus
Ser
Ser
Lib
Scutum
Sgr
Sco
M 14
M 12
M 10
M 26
M 16
M 17
M 18
M 23
M 25
M 21
M 20
M 22
M 9
M 107
M 8
M 19
M 4
M 54
M 69
M 70
M 6
M 7
M 62
36
Antares

36 Ophiuchi

- Gravitational acceleration felt by the C component
  - $g_C \approx 5.3 \times 10^{-10}\ \mathrm{ms}^{-2}$
- Contribution of the dark matter (density $\approx 0.1\ \mathrm{M_S pc^{-3}}$)
  - $g_{DM} \approx 10^{-14}\ \mathrm{ms}^{-2}$

- => In MOND/MOG regime **and** dark matter negligible

36 Ophiuchi – MOND and NEWT

- 4th order Runge-Kutta method
  - Step: 17.5 h
  - Integration period: 70 years
  - Comparison between MOND and standard approach
- Results

	Angular separation			
Model	Deg	Min	Sec	Mas
NEWT	0	11	699	61.9531
MOND	0	11	699	61.8675

- Difference between NEWT and MOND regime ≈ 0.08 mas/70yr

36 Ophiuchi – MOG and NEWT

- 4th order Runge-Kutta method
  - Step: 17.5 h
  - Integration period: 70 years
  - Comparison between MOG and standard approach
- Results

	Angular separation			
Model	Deg	Min	Sec	Mas
NEWT	0	11	699	61.9531
MOG	0	11	699	61.9319

- Difference between NEWT and MOG regime $\approx 0.02\ \mathrm{mas}/70\mathrm{yr}$

Current precision - GAIA space satellite

- All components have magnitude ≈ 5.1
- Median position uncertainties $0.01 = 0.02$
- https://www.cosmos.esa.int/web/gaia/dr3

Conclusion

- Angular separation in the sky:
- Newtonian gravity > MOG > MOND
- Differences measurable by current technology

	Angular separation			
Model	Deg	Min	Sec	Mas
NEWT	0	11	699	61.9531
MOND	0	11	699	61.8675
MOG	0	11	699	61.9319

Thank you for you attention

References

- Labini F. S., Chrobáková Ž., Capuzzo-Dolcetta R., López-Corredoira, M, 2023, ApJ 945, 3
- Milgrom M., 1983, ApJ, 270, p. 365-370
- McGaugh S. S., Lelli, F., Schombert J. M., 2016, Phy. Rev. Lett., 117, 20
- https://www.cosmos.esa.int/web/gaia/dr3
- SIMBAD Astronomical Database