Testing alternative gravity theories with MSE

Guillaume THOMAS

@Thomas_gft

MSE meeting
26th February 2019
The rotation curve problem

- There is **non visible matter**
  → Adding a Dark Matter halo

- **Gravitational law is incomplete**
  → Modifying gravitation
MOnodified Newtonian Dynamics

**MOND Paradigm**

\[ g = g_N \quad \text{if} \quad g_N > a_0 \]

\[ g = \sqrt{g_N a_0} \quad \text{if} \quad g_N < a_0 \]

Famaey et McGaugh 2012

Oman et al., 2015
**MObdified Newtonian Dynamics**

- **QuMOND**: *Quasi-linear formulation of MOND*
  - Mondian Poisson equation
    \[
    \nabla^2 \Phi = 4\pi G (\rho_b + \rho_{ph})
    \]
  - Phantom dark matter
    \[
    \rho_{ph} = \nabla \left[ \nu \left( \frac{\nabla|\Phi_N|}{a_0} \right) \cdot \nabla \Phi_N - \nabla \Phi_N \right]
    \]
- Other formalisms exist, **relativistic** (TEVES, RAQUAL, BiMOND, ...) or **not** (AQUAL, ...)
- **Breaks** the Strong Equivalence Principle (SEP)
- Integrated into the **Phantom-of-Ramses** (POR) code
Globular cluster and the EFE

**Newton**

\[ g_{tot} = g_{GC} + g_{MW} \]

**MOND**

\[ g_{tot} = g_{GC} + g_{MW} + g_{cor} \]

\[ g_{tot} \neq \nu \left( \frac{g_{GC,N}}{a_0} \right) \cdot g_{GC,N} + \nu \left( \frac{g_{MW,N}}{a_0} \right) \cdot g_{MW,N} \]
The external field effect

- Already seen with galaxy clusters:
  - EFE → modifies the shape of the effective potential of a galaxy in a cluster
  - Other phenomena can produce it (ram pressure stripping)

Globular clusters are better tracers of the EFE

Phantom dark matter

Potential MOND

Knebe et al., 2009

Wu et al., 2010
The shape of globular clusters

- Observations of **44 globular clusters around M 31 with HST**
- Obtain the **distances** and fit a **Plummer** profile with an MCMC method using RGB stars
- Use them to obtain the internal potential of GCs and to do N-body simulations in MOND

*Mackey et al., 2013*
The shape of globular clusters

- Calculate analytically the **PDM** distribution around the GCs
- Obtain the **effective potential** with the Ramses code

**Phantom dark**

**Effective potential**

- Sphericals
- Ovoids
- Ellipticals

\[ c = \frac{M_{cl}}{a} D^2 \]

Toward M 31

0.4 kpc
The shape of globular clusters

- **N-body simulations** of Plummer sphere around a point mass in MOND with POR on a **circular orbit**

  Particles follow the effective potential

- Similar **N-body simulations** on **eccentric orbits**

  No significant modification compared to the circular orbits
The Palomar 5 stream

Thomas et al., 2018

Bernard et al., 2016
What MSE can bring?

- Large FoV
- ~4000 spectra per observations

12 GCs in the Northern hemisphere between 15 and 80 kpc

Radial velocities (Individual abundances) → Selection of star member of the GCs in the outskirt