ASTR 333/433 DARK MATTER Spring 2016

First class T 1·12·16 (2nd time taught)

- Youtube clip of Monty Python's Holy Grail
  "She's a witch" scene that inspired course poster
  and illustrates the search for solutions

- Discuss syllabus, course work - homeworks, exams
  course website
  333 vs 433 - extra work for 433; also a project

- Overview lecture Keynote / class1

  · Evidence for mass discrepancies
  · DM candidates
  · Modified gravity if time permits

Empasize the distinction between the problem "Mass discrepancy" or "Acceleration discrepancy" vs. the solution Dark matter or Modified dynamics

Evidence on DM tree

- Oort discrepancy - local (1932) — dynamical mass > stars ($\gtrsim 2\times$ - not much) from vertical motions
- Flat rotation curves (1970s, 1980s)
- Cluster velocity dispersions (1930s) - also X-ray Temps & hydrostatic Eq. — Gravitational lensing (more modern)
- Large Scale Structure (70s, 80s) needs time to grow
- $\Omega_m \neq 1$ coincidence problem; $\Omega_m > \Omega_b$ from BBN

Possible solutions: Extra (dark) mass [unseen] OR Equations wrong

- Extra (dark) mass: Baryonic / Non-Baryonic
- Equations wrong: Modified gravity / Modified inertia

▲ Baryonic dark matter candidates

conventional	exotic
Brown dwarfs $< 0.08\,M_\odot$	strange nuggets
Jupiters $\lesssim 12\,M_J$	white dwarfs
Cold (~3K) molecular gas	neutron stars
warm-hot (~10^5K) gas	black holes

▲ Non-Baryonic dark matter candidates

neutrinos ν

- originally thought to have zero rest mass ("had" to be zero)

If there are 3 ν flavors (electron, muon, tao)
need each to weigh ~10 eV to add up to $\Omega_m \approx 0.3$

$$\sum_i m_{\nu,i} = 94\,\Omega_m h^2 \text{ eV}$$

$\Omega_m = \rho/\rho_{crit}$

known from equilibrium in early universe $h = H_0/100 \text{ km s}^{-1} \text{Mpc}^{-1}$

But

- neutrinos free-stream, erasing structure $< 3\times10^{15} \left(\frac{m_\nu}{30\,eV}\right) M_\odot$
  (destroy galaxies before they can form)

- neutrinos obey Pauli exclusion Principle
  (can't pack them too closely)
  Don't get up to observed DM density in dwarf galaxies unless $m_\nu > 30$ eV

neutrinos now known to have mass, but too small to be solution: $m_\nu < 1$ eV (experimental)
probably $\ll 1$ eV (cosmology, assuming structure formation)