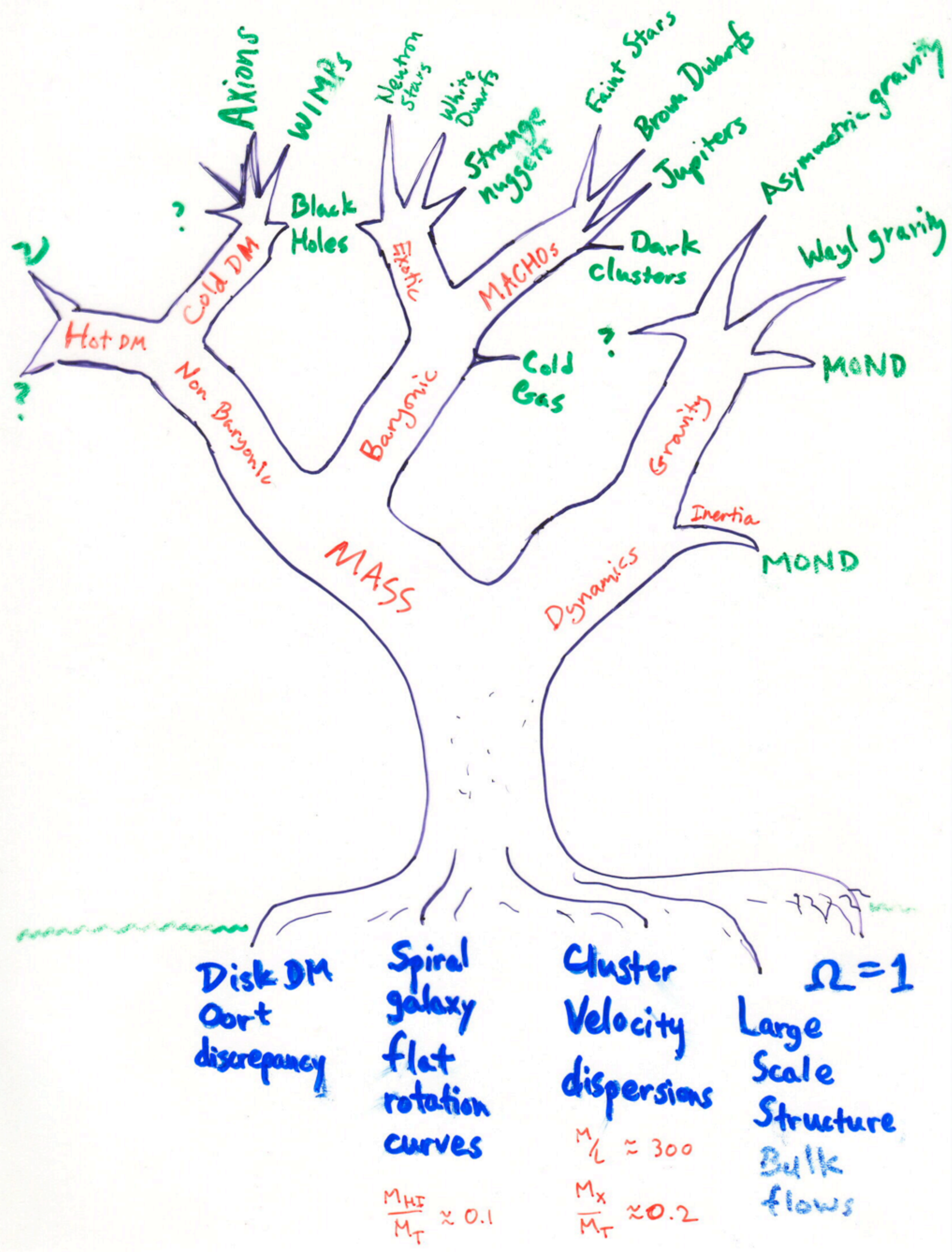
MOND

ASTR 497
Spring 2023
T R 4-5pm
Sears 552

http://astroweb.case.edu/ssm/ASTR497/

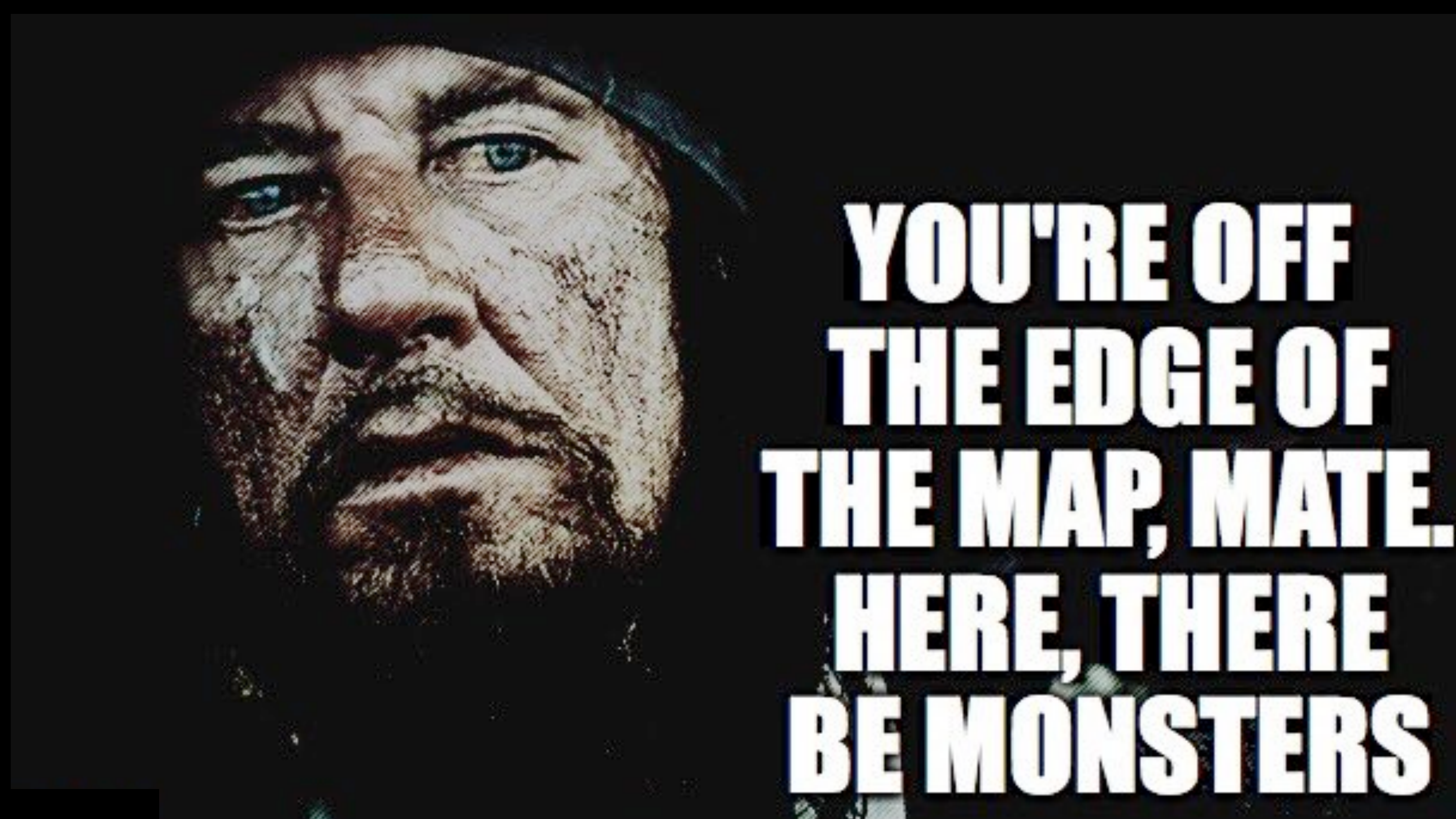
Prof. Stacy McGaugh
Sears 558
368-1808



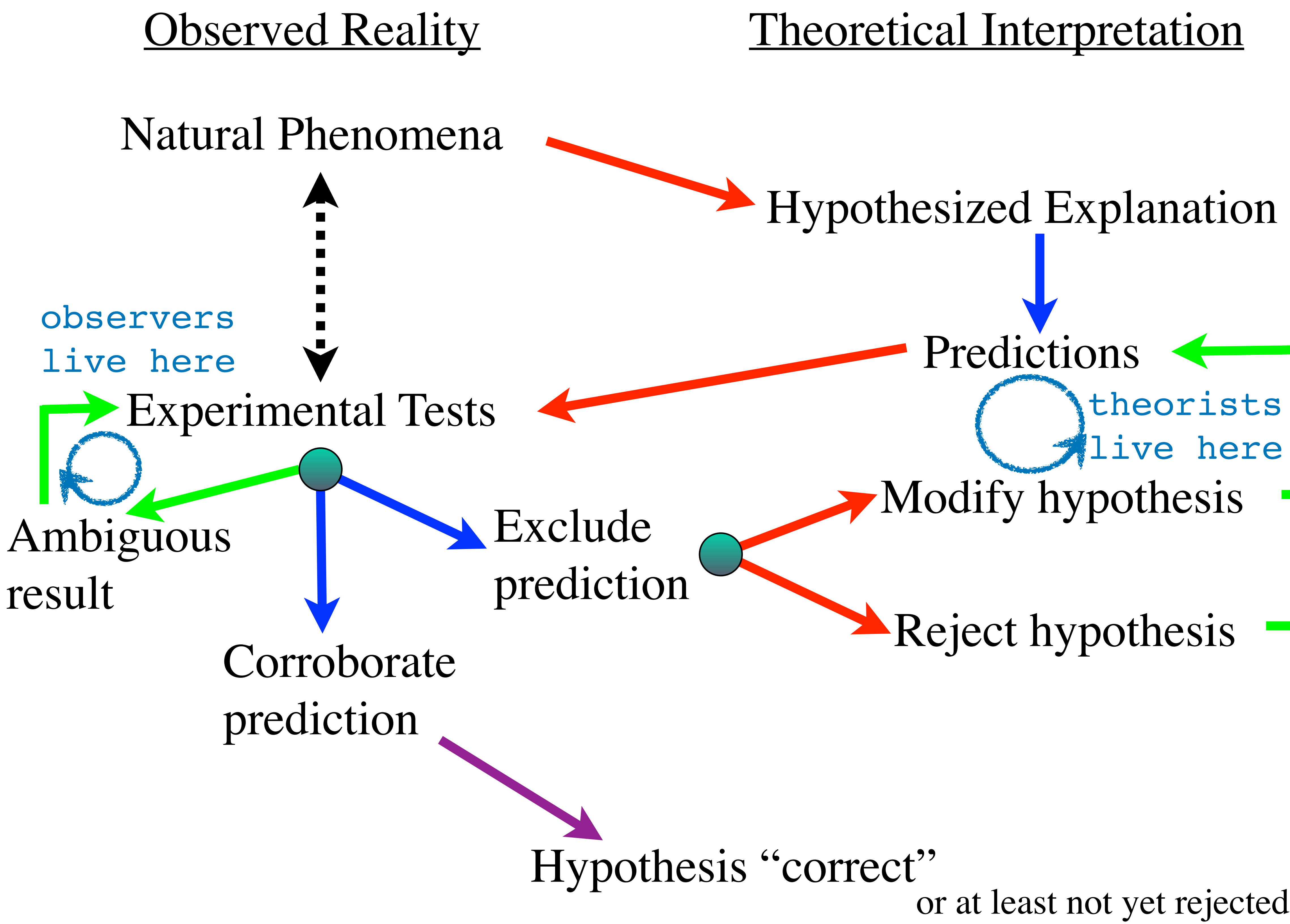
Spring 1999: Cosmology
New as stand-alone course
Several textbooks

Fall 2013: Dark Matter
New as stand-alone course
No book; not duplicated elsewhere

Spring 2023: MOND
New as stand-alone course
Only comes up after Dark Matter



Hypothesis Testing



Predictive power

Predictions are suppose to keep us honest & objective

but come in a variety of flavors

- A priori predictions
  - Gold standard
- Must be so
  - Silver
- Can be fit
  - Bronze

makes good sense

makes little sense

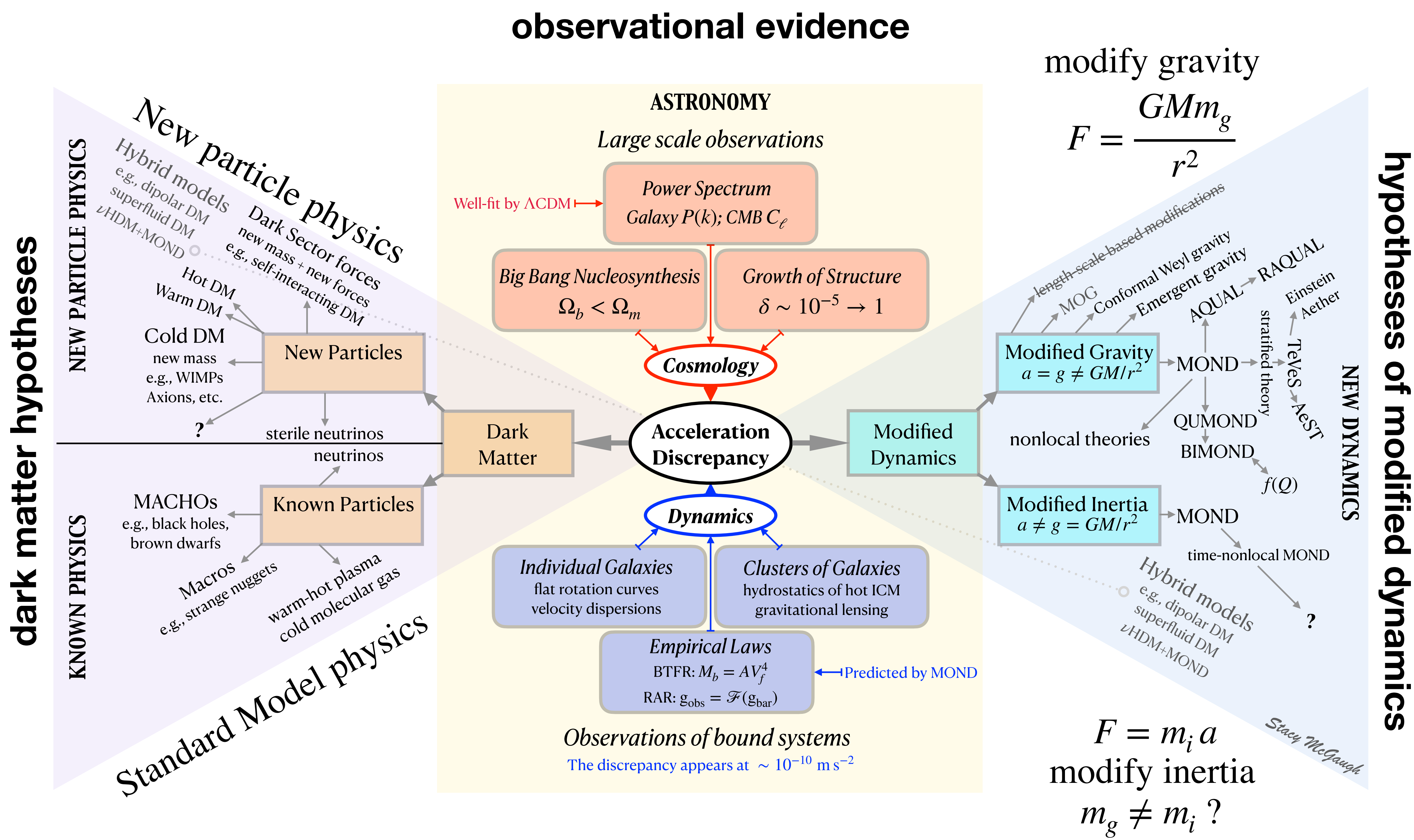
- Just making stuff up
  - too much freedom (e.g., epicycles)

The Principle of Doubt

- Hypotheses can be *rejected* but never completely *confirmed*.
- At best, a theory can be *adequate* for describing a specific set of phenomena.
- Do not trust - verify through experiment.
- Simple theories are preferable to complicated theories (Occam's Razor)
  - Any theory can be made complicated enough to explain anything. It isn't useful unless it can predict new things.
  - If a theory has its predictions come true, we are obliged to acknowledge its efficacy, even if it means rejecting something we formerly believed.

Measurement Uncertainty

- No experiment is perfect
- Experimental uncertainty is often the difference between rejecting a hypothesis and an ambiguous result
- It is important to quantify both measurements AND their accuracy
- This is virtually impossible in astronomy
  - there are often systematic uncertainties that are not easily quantifiable: we can't put the universe in a box and control the experiment.



observational evidence
modify gravity
$F = \frac{GMm_g}{r^2}$
ASTRONOMY
Large scale observations
Power Spectrum
Galaxy $P(k)$; CMB C_ℓ
Well-fit by ΛCDM
Big Bang Nucleosynthesis
$\Omega_b < \Omega_m$
Growth of Structure
$\delta \sim 10^{-5} \rightarrow 1$
Cosmology
Acceleration Discrepancy
Dynamics
Individual Galaxies
flat rotation curves
velocity dispersions
Clusters of Galaxies
hydrostatics of hot ICM
gravitational lensing
Empirical Laws
BTFR: $M_b = AV_f^4$
RAR: $g_{obs} = \mathscr{F}(g_{bar})$
Predicted by MOND
Observations of bound systems
The discrepancy appears at $\sim 10^{-10}$ m s^{-2}
dark matter hypotheses
New particle physics
NEW PARTICLE PHYSICS
Hybrid models
e.g., dipolar DM
superfluid DM
νHDM+MOND
Dark Sector forces
new mass + new forces
e.g., self-interacting DM
Hot DM
Warm DM
Cold DM
new mass
e.g., WIMPs
Axions, etc.
New Particles
?
sterile neutrinos
neutrinos
Dark Matter
Known Particles
MACHOs
e.g., black holes,
brown dwarfs
Macros
e.g., strange nuggets
warm-hot plasma
cold molecular gas
KNOWN PHYSICS
Standard Model physics
Modified Dynamics
Modified Gravity
$a = g \neq GM/r^2$
length-scale based modifications
MOG
Conformal Weyl gravity
Emergent gravity
AQUAL
RAQUAL
Einstein Aether
MOND
stratified theory
TeVeS
AeST
QUMOND
BIMOND
$f(Q)$
nonlocal theories
Modified Inertia
$a \neq g = GM/r^2$
MOND
time-nonlocal MOND
?
Hybrid models
e.g., dipolar DM
superfluid DM
νHDM+MOND
NEW DYNAMICS
hypotheses of modified dynamics
$F = m_i a$
modify inertia
$m_g \neq m_i$?
Stacy McGaugh

CHOOSE YOUR CREW

Need reading groups of 3 or 4 people each to lead discussions of assigned readings. Will rotate the responsibility to do so.

Give your group a name of your own choosing.
Will use this to post assignments on the course web page so keep it short and reasonably polite.