NASSP Master's Project Proposal: Testing Modified Gravity with DECaLS Weak Lensing and WISE Galaxy Cross-Correlations

1. **Primary supervisor:** Prof. Amare Abebe
2. **Institution of supervisor:** Centre for Space Research, North-West University, Potchefstroom, South Africa
3. **Co-supervisor:** Dr. Ayodeji Ibitoye
4. **Institution of co-supervisor:** Centre for Space Research, North-West University, Potchefstroom, South Africa
5. **Contact details:** amare.abebe@nwu.ac.za, ayodeji.ibitoye@nwu.ac.za

While the accelerated expansion is accommodated within General Relativity through the cosmological constant (Λ), its microscopic origin remains unknown. This motivates tests of modified gravity theories (e.g., $f(R)$, $f(T)$, $f(Q)$) as alternatives to the ΛCDM paradigm. These theories predict distinct signatures in the growth of large-scale structure, which can be probed by cross-correlating weak gravitational lensing maps (DECaLS) and galaxy density fields (WISE). The Dark Energy Camera Legacy Survey (DECaLS) provides high-resolution cosmic shear maps, while the Wide-field Infrared Survey Explorer (WISE) offers a dust-insensitive galaxy catalog tracing the matter distribution. This synergy enables robust tests of GR deviations while mitigating systematics like photometric redshift errors.

The Master's student recruited will:

- Process DECaLS weak lensing catalogs to generate convergence (κ) maps and WISE galaxy overdensity (δ_g) maps in tomographic redshift bins.
- Compute the cross-correlation $\langle \kappa \delta_g \rangle$ and compare it to predictions from ΛCDM and MG theories (e.g., $f(R)$'s f_{R0}, $f(Q)/f(T)$ coupling parameters).
- Implement a Markov Chain Monte Carlo (MCMC) pipeline to constrain MG parameters, using mock data from cosmological simulations (e.g., *FLAMINGO* for MG-modified N-body simulations or *FLASK* for fast log-normal mocks) to validate the pipeline. If needed, the student may explore alternative covariance estimation methods (e.g., jackknife resampling or analytical covariance) for cross-validation.
- Model scale-dependent growth rates and halo occupation distributions (HODs) of WISE galaxies to disentangle astrophysical and gravitational effects.

- Compare Bayesian evidence ratios to assess whether the data favor ΛCDM or MG scenarios.

This project will produce:

- First constraints on $f(Q)$ and $f(T)$ gravity using DECaLS-WISE cross-correlations.
- Improved bounds on $f(R)$ gravity (e.g., $|f_{R0}|$).
- A peer-reviewed publication on MG tests with optical-infrared survey synergies.

Requirements for the student:

- Basic familiarity with Python (for data processing and statistical analysis).
- Introductory knowledge of cosmology (e.g., structure formation, dark energy).
- Interest in learning numerical methods (e.g., MCMC, HOD modeling).

Prof. Amare Abebe specializes in modified gravity and dark energy phenomenology. Dr. Ayodeji Ibitoye has expertise in large-scale structure analysis and cosmological simulations. Interested students are encouraged to contact the supervisors for further details or informal discussions. Relevant literature (e.g., DECaLS/WISE data papers, MG theory reviews) will be provided upon request.