Paleoclimate Causal Inference DAG Formulation

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DAG Variables

- Let Y be anomaly (outcome), the deviation of global temperature from the 1961-1990 Berkeley Earth baseline.
- Let A designate CO2 concentration.
- Let X1 designate a variable representing the combined effect of the Milankovitch orbital parameters:
    1. Eccentricity
    2. Obliquity
    3. Perihelion
    4. 65°N Insolation
    5. Global Insolation
- Let X2 designate the Beryllium-10 concentration, a proxy for cosmic ray flux.
- Let X3 designate VADM, a proxy for geomagnetic field strength.
- Let X4 designate solar modulation, a derived value based on Be-10 concentration and VADM, representing the effect of solar activity on cosmic ray flux.
- Let X5 designate CO2 radiative forcing (treatment), a derived value based on CO2 concentration to represent the effect of CO2 on global temperature.
- Let U1 designate the true global anomaly, for which anomaly is a proxy measurement from oxygen isotope ratios, pollen counts, etc.
- Let U2 designate magnetic field strength, for which VADM is a proxy measurement from sediment cores.
- Let U3 designate cosmic ray flux.

DAG Links

- $A \rightarrow X5$: CO2 radiative forcing is directly derived from CO2 concentration.
- $X1 \rightarrow U1$: Milankovitch cycles are exogeneous variables that directly affect global temperatures through season length and sunlight received.
- $X1 \rightarrow A$: Milankovitch cycles affect CO2 concentrations through positive feedback mechanisms during glaciation and deglaciation.
- $X4 \rightarrow U3$: Solar modulation affects cosmic ray flux.
- $X5 \rightarrow U1$: CO2 radiative forcing directly affects global temperatures.
- $U1 \rightarrow Y$: True global anomaly affects measured anomaly proxies.

- $U2 \rightarrow X3$: Magnetic field strength affects VADM measurements.
- $U2 \rightarrow U3$: Magnetic field strength affects cosmic ray flux.
- $U3 \rightarrow X2$: Cosmic ray flux affects Be-10 concentration measurements.
- $U3 \rightarrow U1$: Cosmic ray flux affects global temperatures through cloud formation.
- $U3 \rightarrow A$: Cosmic ray flux affects CO2 concentrations through positive feedback mechanisms during glaciation and deglaciation.

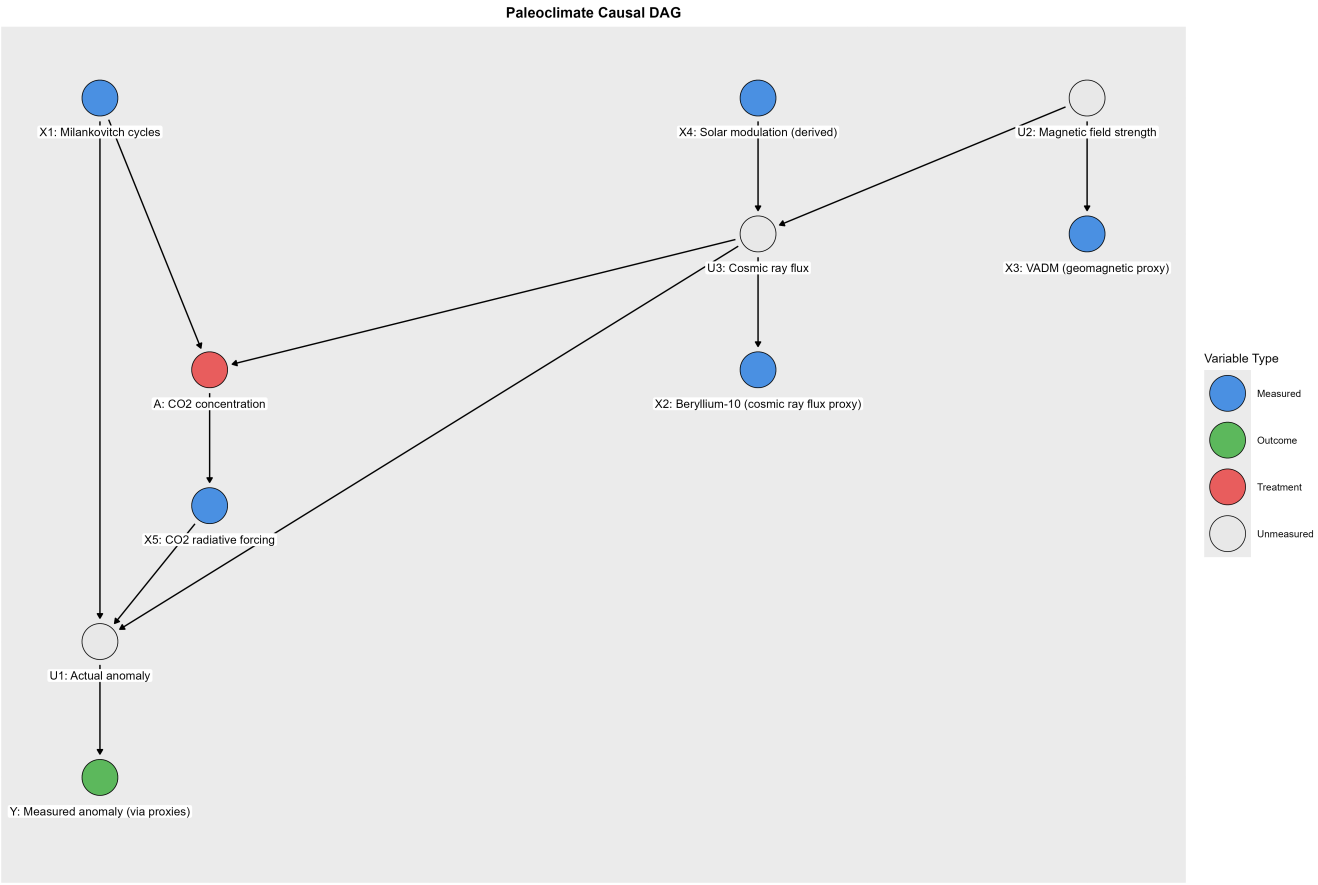

Figure 1: DAG Graphical Representation