Neutrinos are the key to solve the century-old question about the origin of cosmic rays.

- Cosmic-rays are charged particles produced in the Universe with energies 10 million times larger than we can archive at the Large Hadron Collider at CERN.
- Cosmic-rays are deflected by magnetic fields → sources are unknown.
- Neutrinos are produced in interactions of cosmic-rays with ambient radiation fields or matter.
- Various types of optical counterparts to neutrino sources are expected (e.g. SN Ic, Kilonovae, SN IIn, TDE, GRB).

**Searching for Optical Counterparts to High-Energy Neutrino Sources with the Zwicky Transient Facility**

**The Mystery of the Cosmic Particles**

**Real Time Neutrino - Transient Trigger**

- Ice as natural detector medium
  - 1km² of transparent ice instrumented with light sensors
  - Neutrino direction and energy are measured

- Alert Management, Photometry and Evaluation of Light curves: AMPEL
  - Novel real time alert management and trigger software

- Zwicky Transient Facility
  - High cadence and very large field-of-view → ZTF can scan the entire northern sky every night

**Primary transient selection**

- Short transients (GRB-like)
  - More than 2 detections in < 12h
  - Falling light curve
  - Realtime maximum likelihood calculation of test statistic

- Medium length transients (SN Ic, Kilonova)
  - Time window of 2 weeks
  - More than 3 optical detections

- Long transients (SN IIn, SLSN, TDE)
  - Time window of 8 weeks
  - More than 5 optical detections

**Realtime Search for Counterparts**

- Background discrimination:
  - Trained neural network estimates redshift of host galaxy
  - Neutrino counterparts (signal) show generally smaller redshifts → Enables rejection of transients showing no significant neutrino emission (background)

- Spectroscopic follow up
  - Real time maximum likelihood calculation
  - Statistical excess between neutrino and optical counterpart will trigger spectroscopic follow up
  - Optimised on false positive rate of < 100 per year.

- Goal
  - Target of opportunity program for most promising neutrinos
  - Statistical correlation between all Ice Cube neutrinos and full catalogue of ZTF optical transients

**References**