Stars and Stellar Evolution

Astro2010 Science Frontier Panel

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• **Questions:**

  How do Rotation and Magnetic Fields Affect Stars?

  What are Type Ia Supernovae?

  How do Massive Stars End Their Lives?

  What Controls the Masses, Spins, and Radii of Compact Stellar Remnants?

• **Discovery Area:**

  Time Domain Surveys
How do Massive Stars End Their Lives?

• Neutrino explosion mechanism still plausible, but no consensus model

Lentz et al. 2015
• Possible that common, $\sim 10^{51}$ erg, explosions are by neutrinos and energetic, $\sim 10^{52}$ erg, explosions are from rotation energy of compact object tapped by magnetic field.
• Cas A:
  – Blue – $^{44}$Ti, 68 and 78 keV lines
  – Green – X-ray, hot Si
• Inner ejecta ($^{44}$Ti) asymmetric, but not jet-like
Diverse ends

- Superluminous SN
  - Magnetar power or circumstellar interaction favored over $^{56}\text{Ni}$
- Interaction (SN 2010jl)
  - Lost 0.1 M$_{\odot}$/yr in 10s of yrs leading to explosion
- Black hole formation
  - Faint explosion
  - Search for disappearing stars in progress
What Controls the Masses, Spins, and Radii of Compact Stellar Remnants?
NS masses

- $1.97 \pm 0.04 \, M_\odot$ (J1614+2230), from Shapiro delay
- $2.01 \pm 0.04 \, M_\odot$ (J0348+0432), in compact relativistic binary
Modeling of NS atmospheres

• Spectra of quiescent NS in globular clusters give R of 10-13 km for typical M (Heinke et al. 14)

Systematic uncertainties: atmosphere model (composition…), interstellar medium, distance, instrument calibration
Spin of BH from relativistically broadened Fe line

- NuSTAR, Suzaku important to get the higher energy continuum
- Near maximal rotation
- Better models are needed to interpret the data
Discovery: Time domain

- Examples of areas that have developed in last 5 years
- Facilities
Fast radio bursts

- msec timescale
- High dispersion measure
- Distances unknown
- Many models
Tidal disruption events

- Star disrupted by nuclear black hole
- Form disk around BH
- Can generate jets and high energy emission (e.g., Sw J1644+57)
Crab Nebula $\gamma$-ray flares

- GeV photons (AGILE, Fermi)
- Hours
- Not seen at other wavelengths
Optical/IR signal of neutron star merger associated with short GRB

- Radioactive isotopes in lost mass power fast supernova-like event
- May have been observed in a short GRB
Facilities

• Transient search
  – now: ASAS-SN optical; has discovered relatively nearby supernovae and TDEs
  – near future: ZTF (Zwicky Transient Facility)
  – future: LSST
  – multiwavelength

• Time domain accurate photometry (SSE1)