The JVLA Deep Sky Survey
Finding the First Cosmic Explosions

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What are Pop III stars?

- first stars: formed from only H and He.
- thought to be massive ($30 \, M_\odot - 500 \, M_\odot$).
- key to properties of **primeval galaxies**, early cosmological reionization and chemical enrichment, and the origin of **supermassive black holes**.
Los Alamos Supernova Light Curve Project

- Progenitors are evolved in stellar evolution codes like MESA, Kepler, and Geneva to obtain the internal structure of the star at the time of death and then exploded.
- These explosions are then modeled in the Los Alamos radiation hydrodynamics code RAGE.
- RAGE profiles are post processed with the Los Alamos SPECTRUM code to obtain spectra and light curves.
85 - 135 $M_{\odot}$ Progenitors
Hypernovae Explosions
Curves correspond to 0.5 (dotted), 1.4 (solid), 3 (short-dashed), 10 (long-dashed), 25 (dot short-dashed) and 35 (dot long-dashed) GHz.

**Figure:** Whalen and Meiksin 2013
Figure: Condon et al. 2012
Figure: Whalen et al 2013
Birth of Supermassive Black Holes?

1. cloud kept from collapsing by LW background
2. catastrophic collapse from atomic cooling
3. supermassive star? ($\sim 55,500 \, M_\odot$)
4. gravitational instability (Heger et al. 2014)
Introduction
Method
Results/Conclusion

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The JVLA Deep Field Survey

Figure: http://etacar.umn.edu/Workshop2012/Posters/KChen26.pdf
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Figure: Whalen et al 2013
Practical Considerations

- Optimistic estimates place supernovae (with flux $> \mu Jy$) at $< 10$ per square degree of sky
  - Need $\sim 1$ square degree of sky to reject claim with 90% certainty.

- A microjansky survey could detect
  - Pop III Gamma Ray Bursts
  - Pop III Hypernovae
  - Pop III Gravitational Instability Supernovae

- Most likely to be found in multi-epoch studies
- Multi-frequency observations to constrain redshift of explosions
primordial SNe will be visible in the NIR to JWST, WFIRST and the TMT
but some are visible in the radio now to JVLA
we are currently devising surveys for the first cosmic explosions in the radio
the detection of Pop III supernovae will be among the most spectacular discoveries in radio astronomy in the coming decade
RAGE model

\begin{align*}
\frac{\partial}{\partial t}\rho + \nabla \cdot \rho \mathbf{u} &= 0 \\
\frac{\partial}{\partial t}\rho \mathbf{u} + \nabla \cdot (\rho \mathbf{u} \otimes \mathbf{u} + P_e + P_i) + \frac{1}{3} \nabla E_r &= 0 \\
\frac{\partial}{\partial t}\rho e_i + \nabla \cdot (\rho e_i \mathbf{u}) + \nabla \cdot \mathbf{q}_i + P_i : \nabla \mathbf{u} &= \gamma_{ei}(T_e - T_i) + \dot{S}_i \\
\frac{\partial}{\partial t}\rho e_e + \nabla \cdot (\rho e_e \mathbf{u}) + \nabla \cdot \mathbf{q}_e + P_e : \nabla \mathbf{u} &= \gamma_{ei}(T_i - T_e) + c\sigma_a(E_r - aT_e^4) + \dot{S}_e \\
\frac{\partial}{\partial t}\rho E + \nabla \cdot [(\rho E + P) \cdot \mathbf{u}] + \nabla \cdot (\mathbf{q}_e + \mathbf{q}_i) &= c\sigma_a(E_r - aT_e^4) - \frac{1}{3} \mathbf{u} \cdot \nabla E_r + \dot{S}_i + \dot{S}_e \\
\frac{\partial}{\partial t}E_r + \frac{4}{3} \nabla \cdot (u E_r) - \nabla \cdot (\kappa \nabla E_r) &= -c\sigma_a(E_r - aT_e^4) + \frac{1}{3} \mathbf{u} \cdot \nabla E_r
\end{align*}

- Accounts for up to 3 temperature plasma physics (we assume $T_e = T_i$).
1. We include shock heating as an important source of luminosity through RHD.

2. We allow radiation and matter to be out of thermal equilibrium.

3. RHD accounts for radiation acceleration of shock waves and radiative losses.

4. We calculate spectra directly instead of using $L = 4\pi r^2 T^4$ to compute light curves.

5. SPECTRUM uses LANL OPLIB database which includes effects of line and continuum opacities, fluorescence, Doppler shifting, time dilation and limb darkening.