

# Insights into the Supernova-GRB Connection from Radio Synchrotron

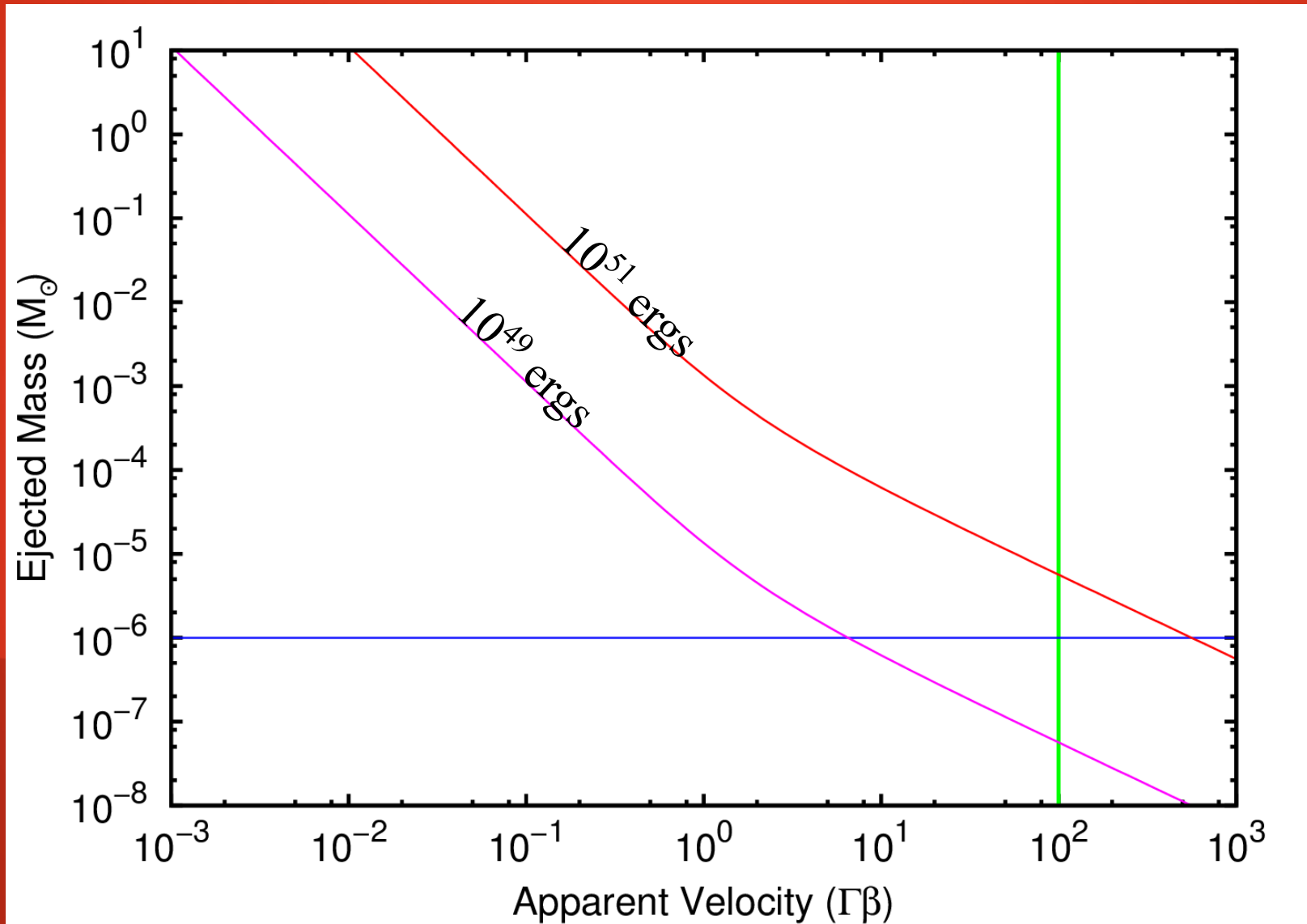
---

Sayan Chakraborti  
(Society of Fellows and ITC, Harvard University)

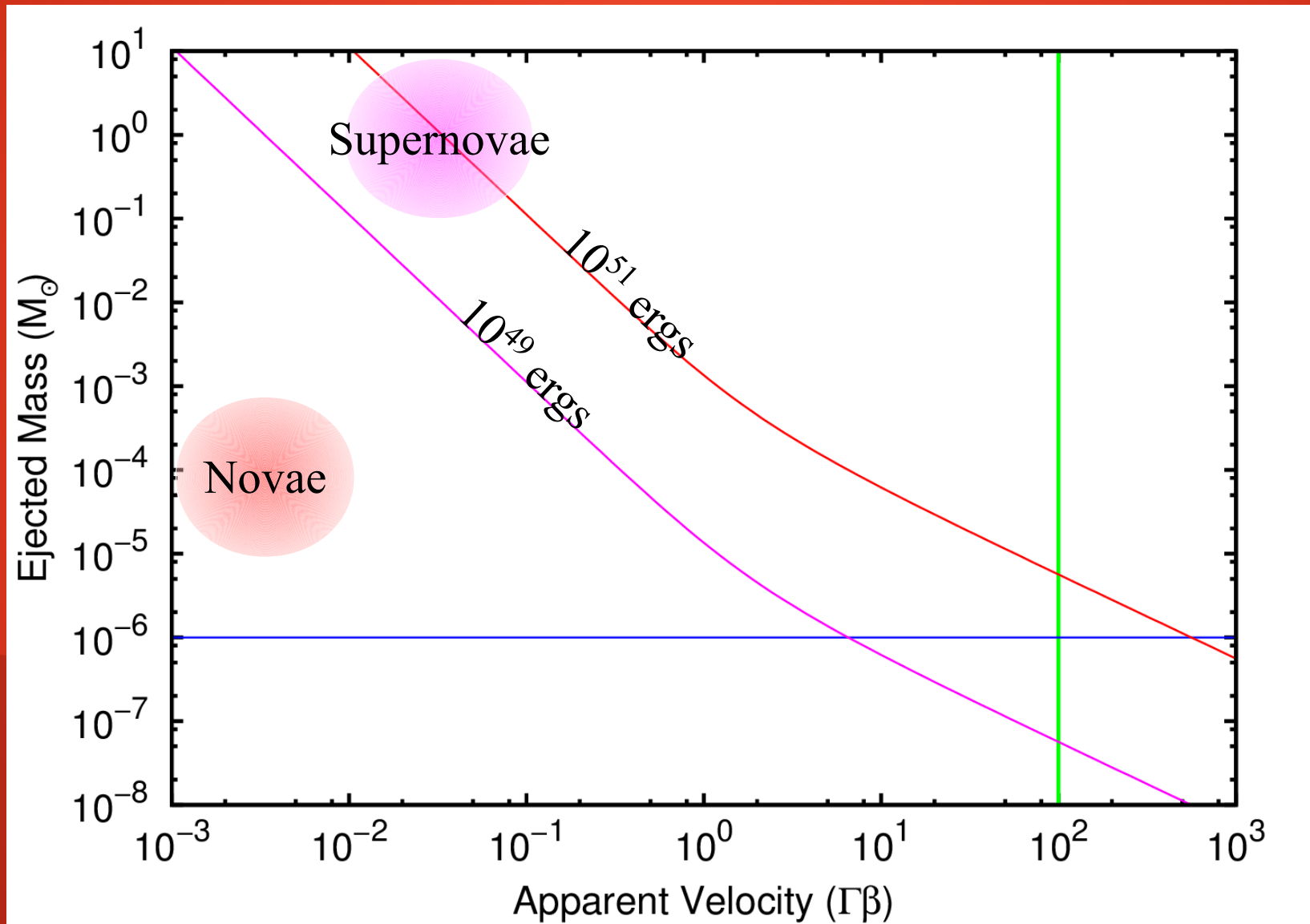
# History: The Supernova-GRB Connection

- GRBs localized with satellites
- Type Ic supernovae in their error boxes
- Radio emission from relativistic outflows

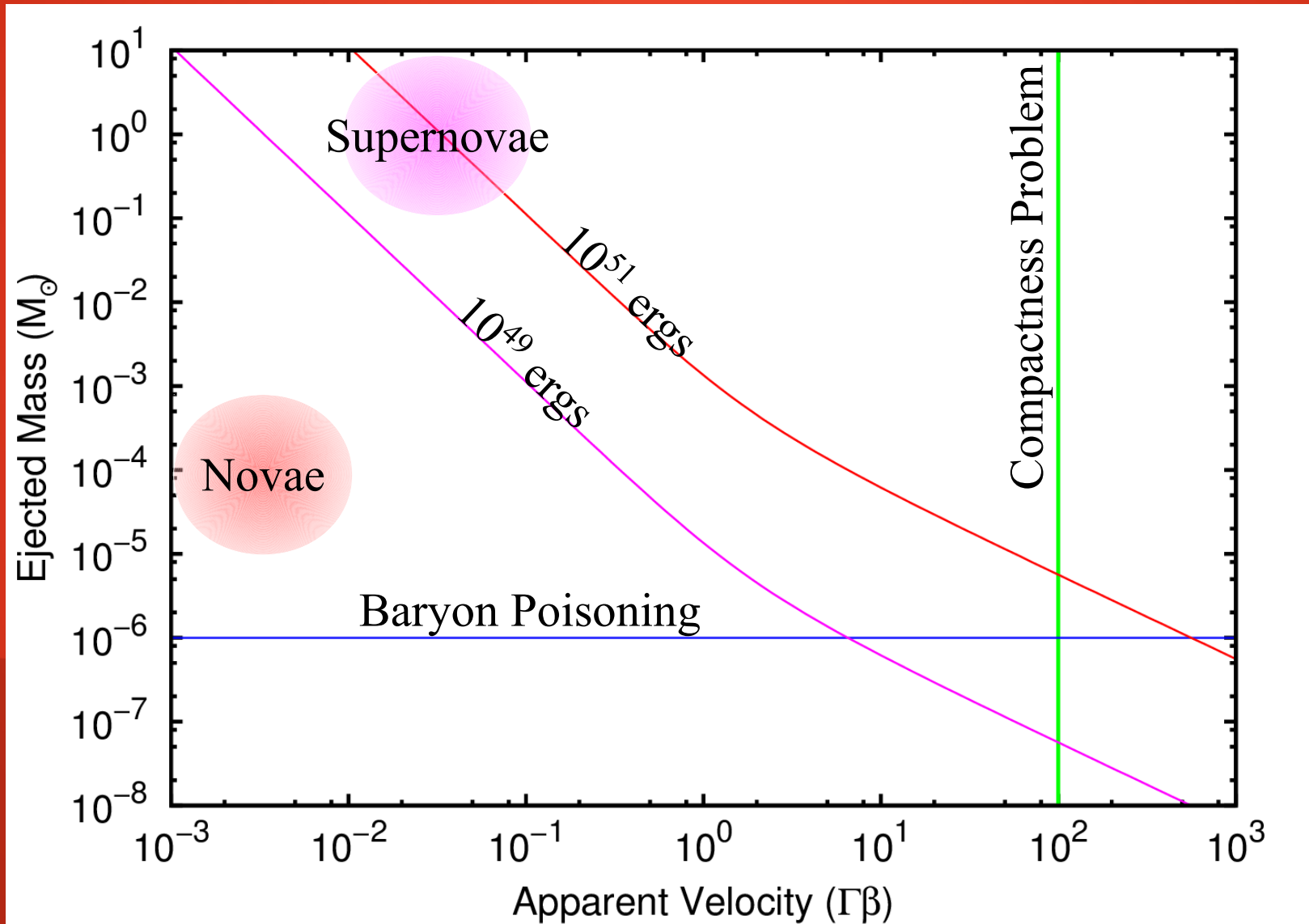
# A cartoon map for explosions



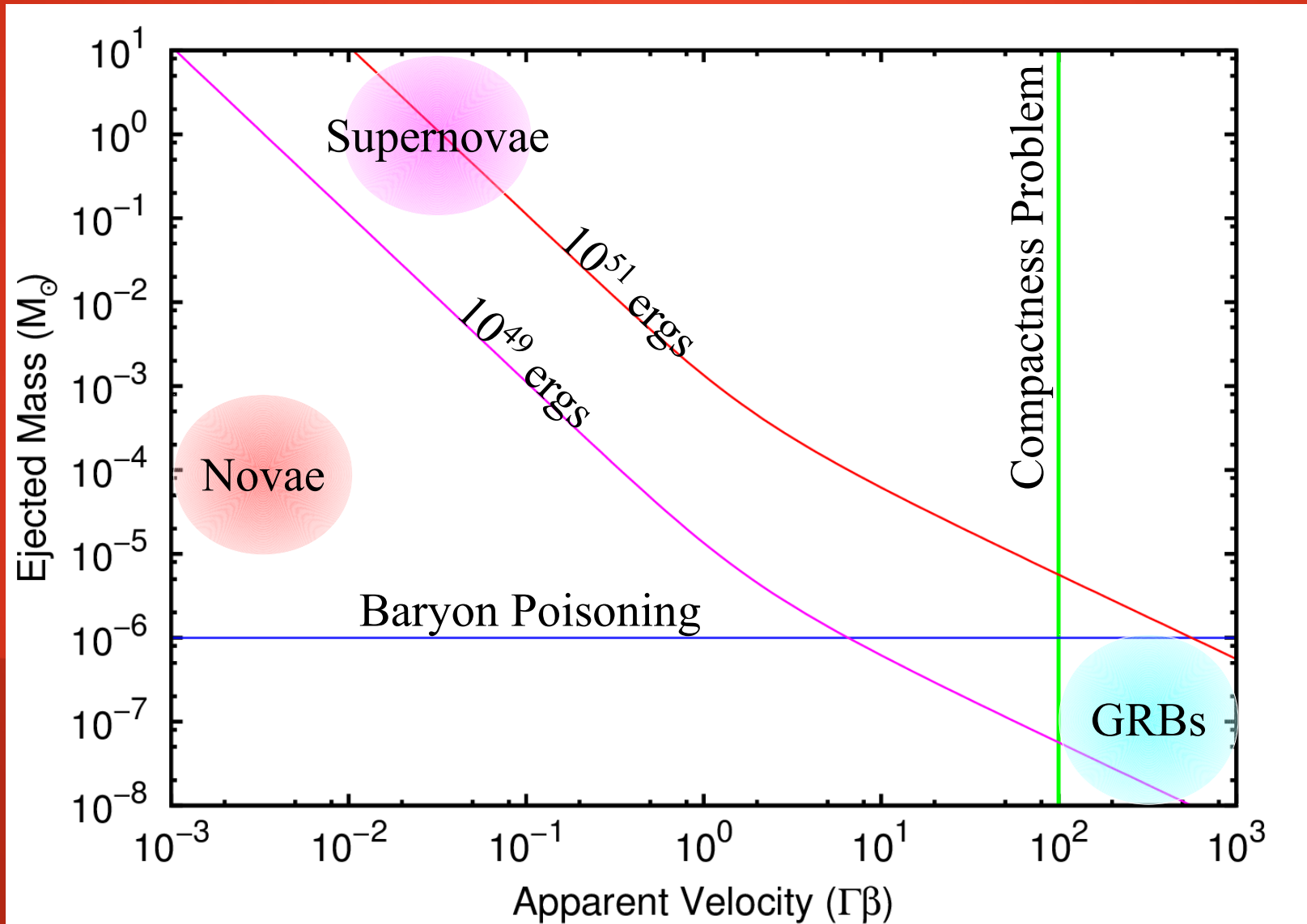
# Where are the Supernovae?



# Where are the GRBs?



# The gap





# Exploring the gap with radio observations

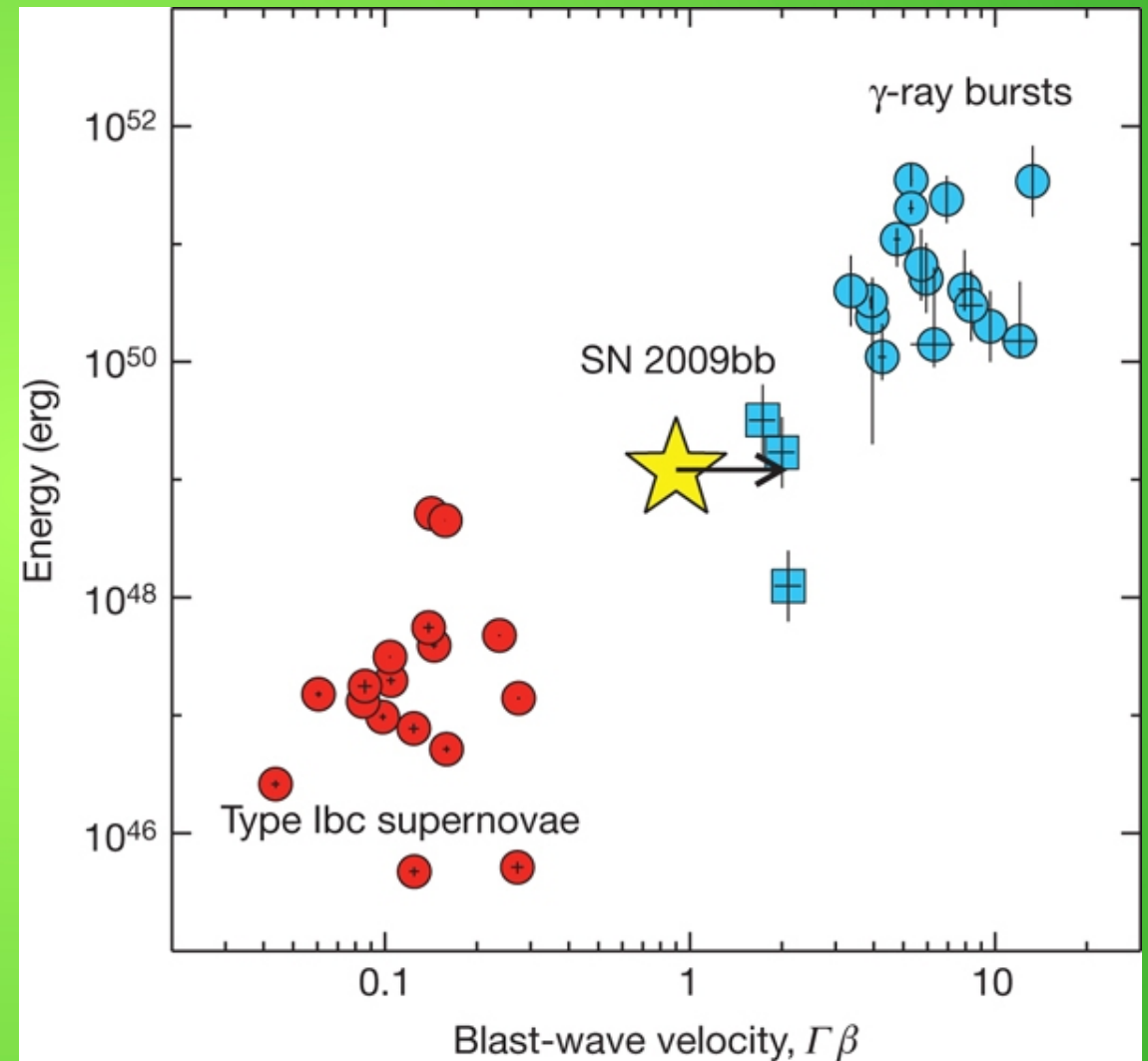
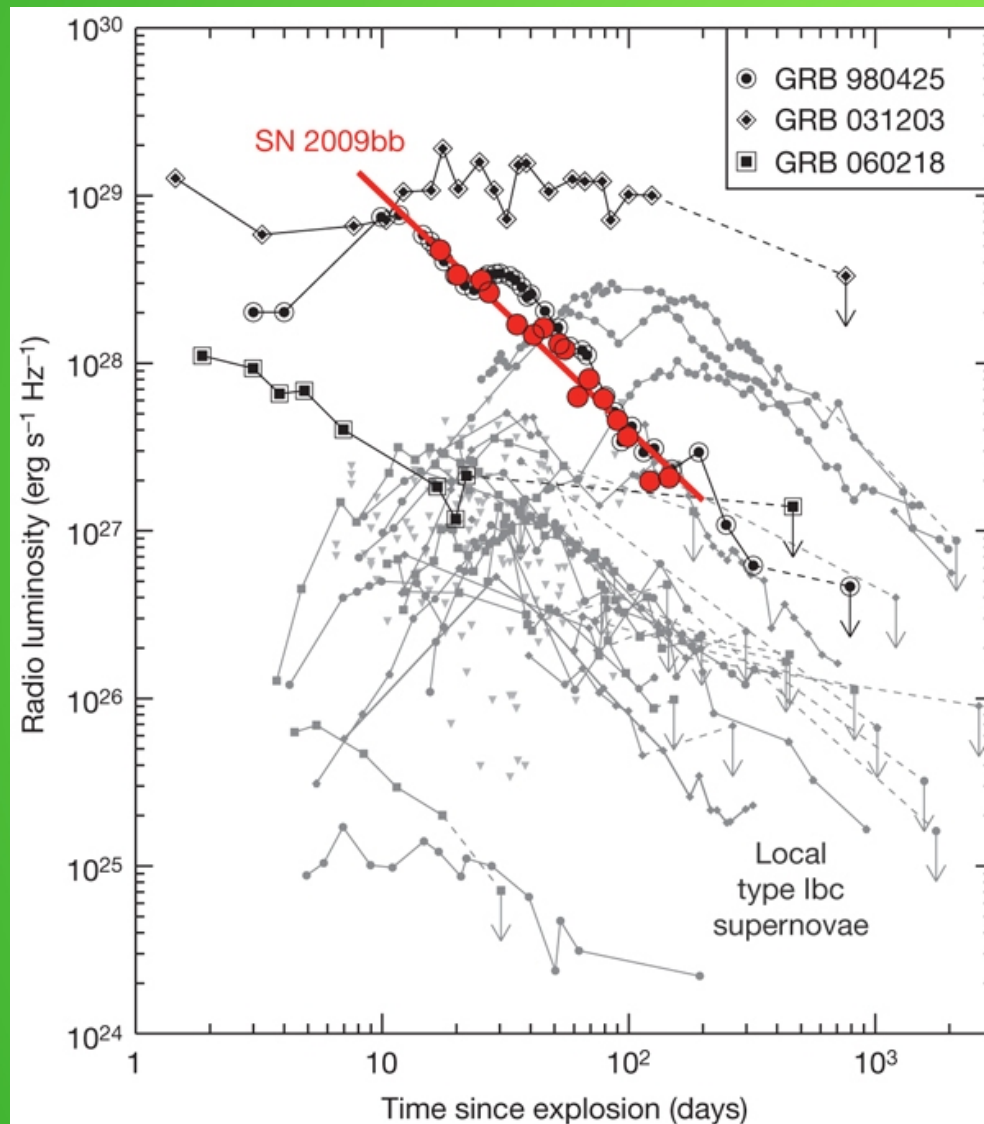


# Exploring the gap with radio observations



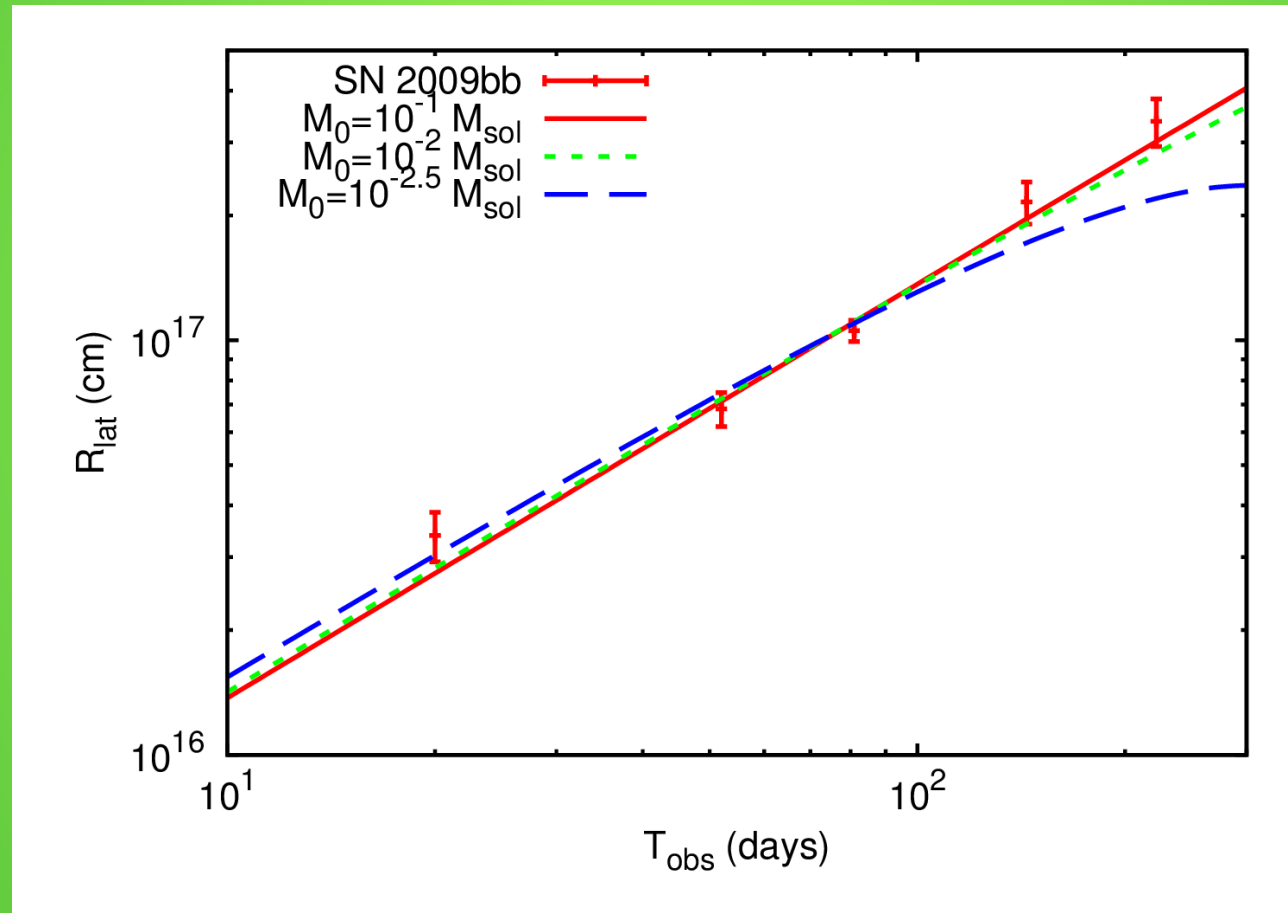


# Past: Relativistic outflow from SN 2009bb



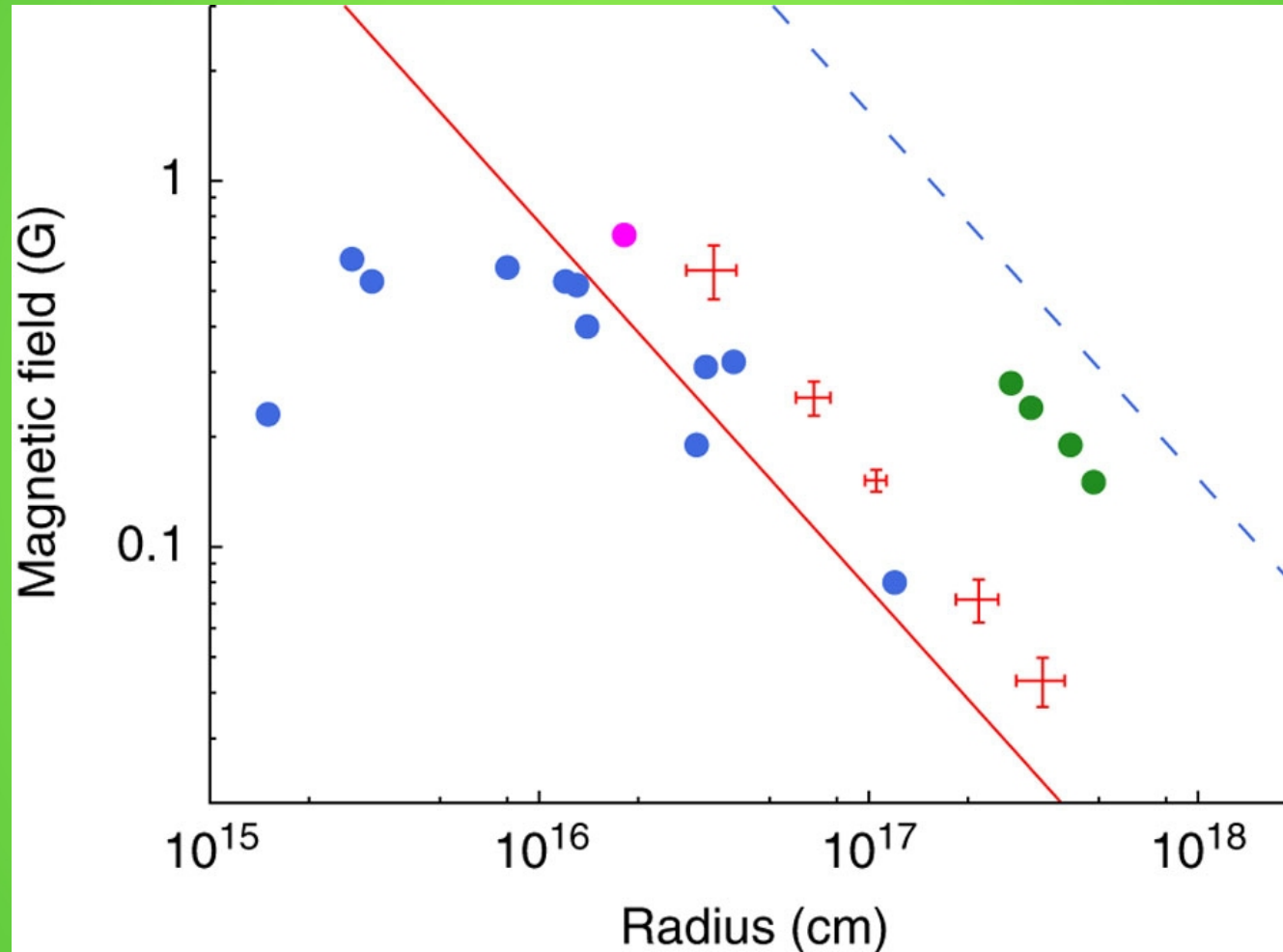
Soderberg, Chakraborti et al. 2010 Nature 463, 513

# Nearly free expansion in SN 2009bb, baryon loading



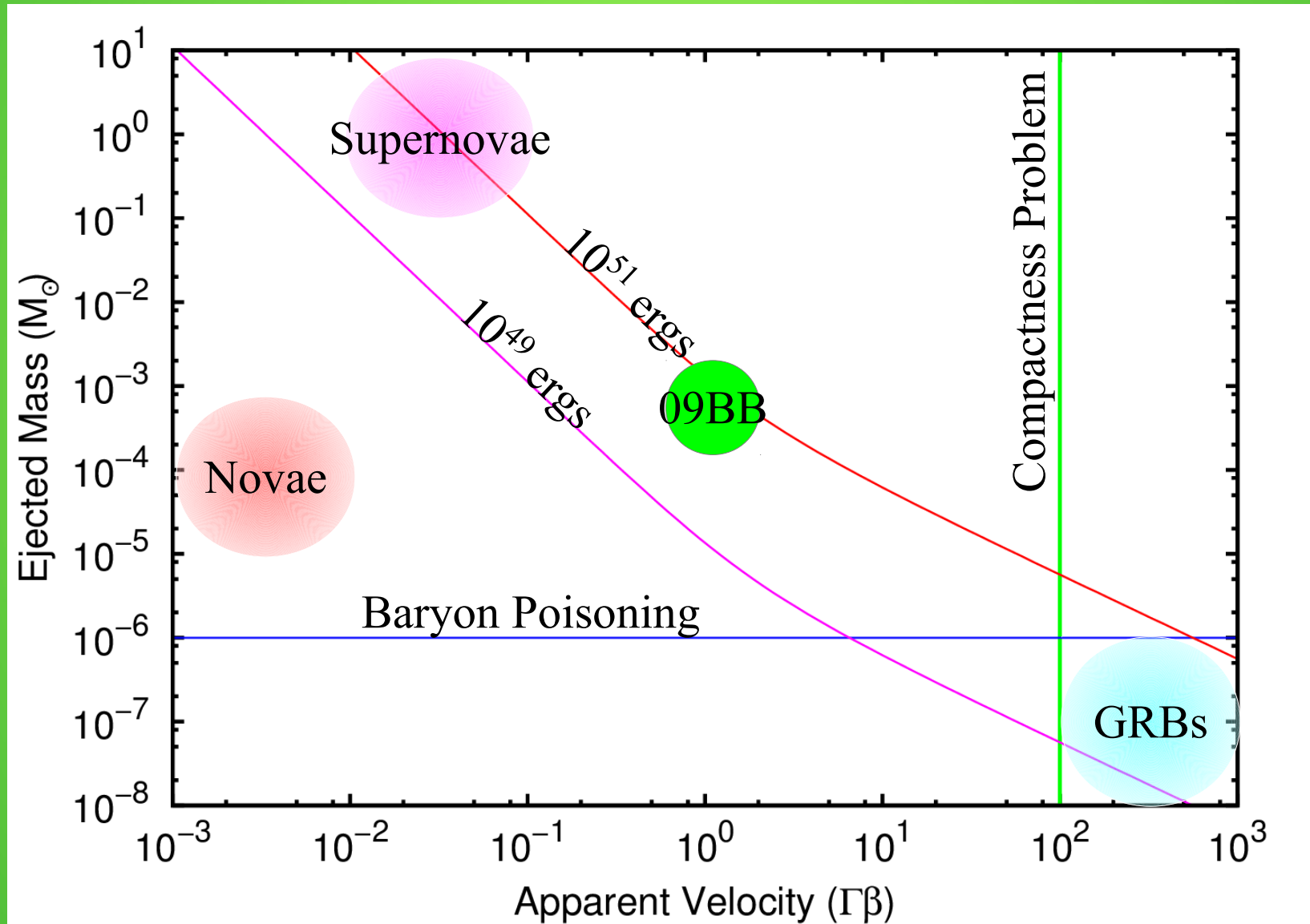
Chakraborti and Ray, 2011 ApJ 729, 57

# SN 2009bb as a particle accelerator



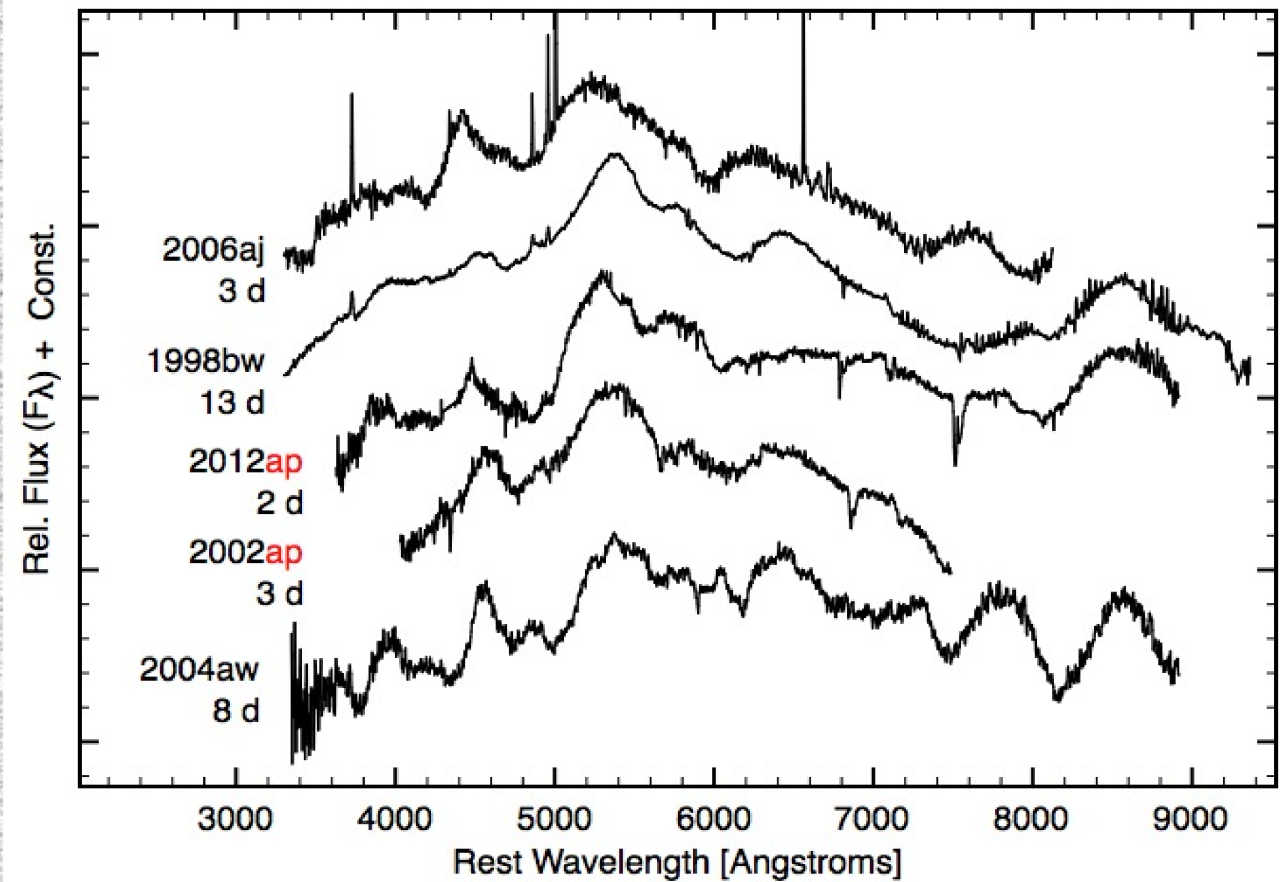
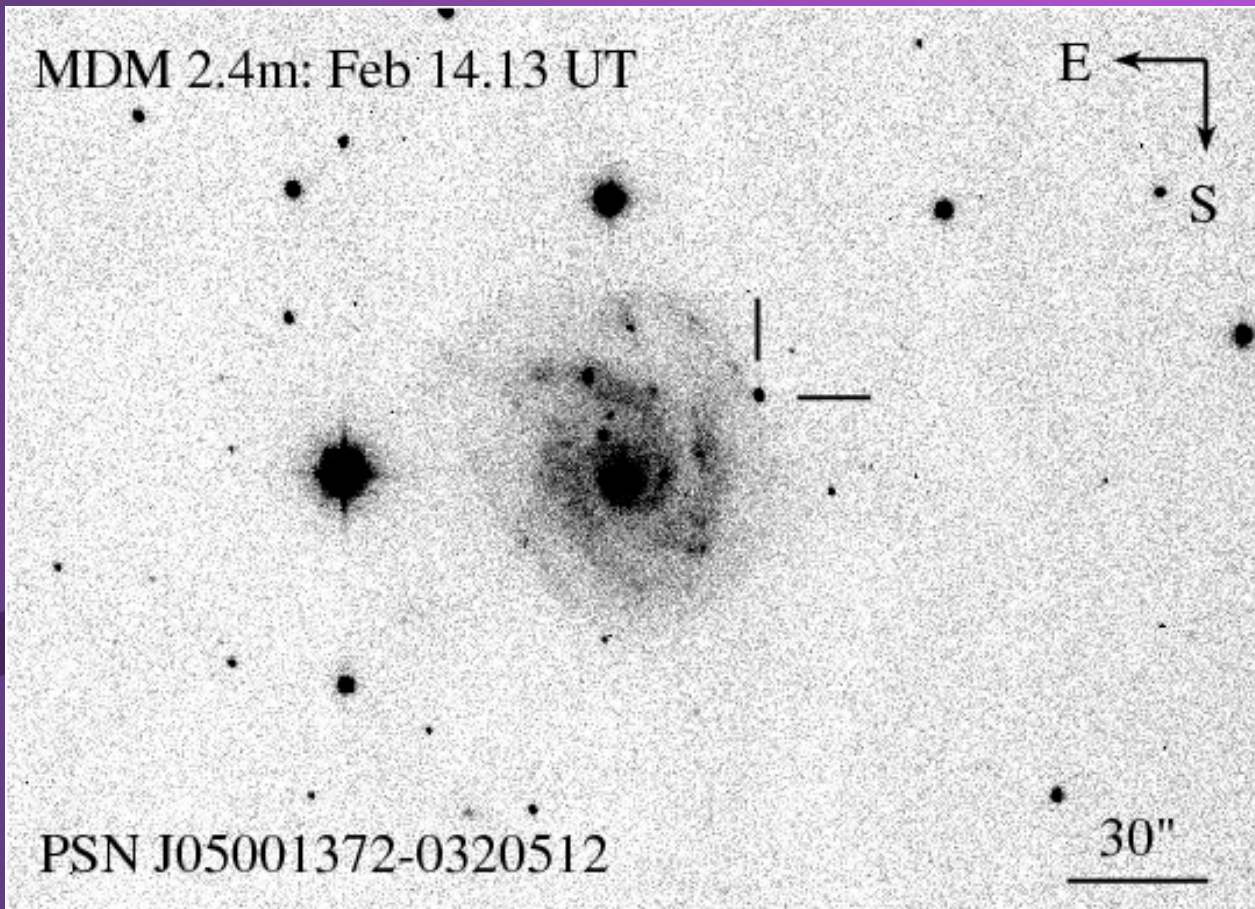
Chakraborti et al., 2012 Nature Comm. 2, 175

# SN2009bb, relativistic but baryon loaded



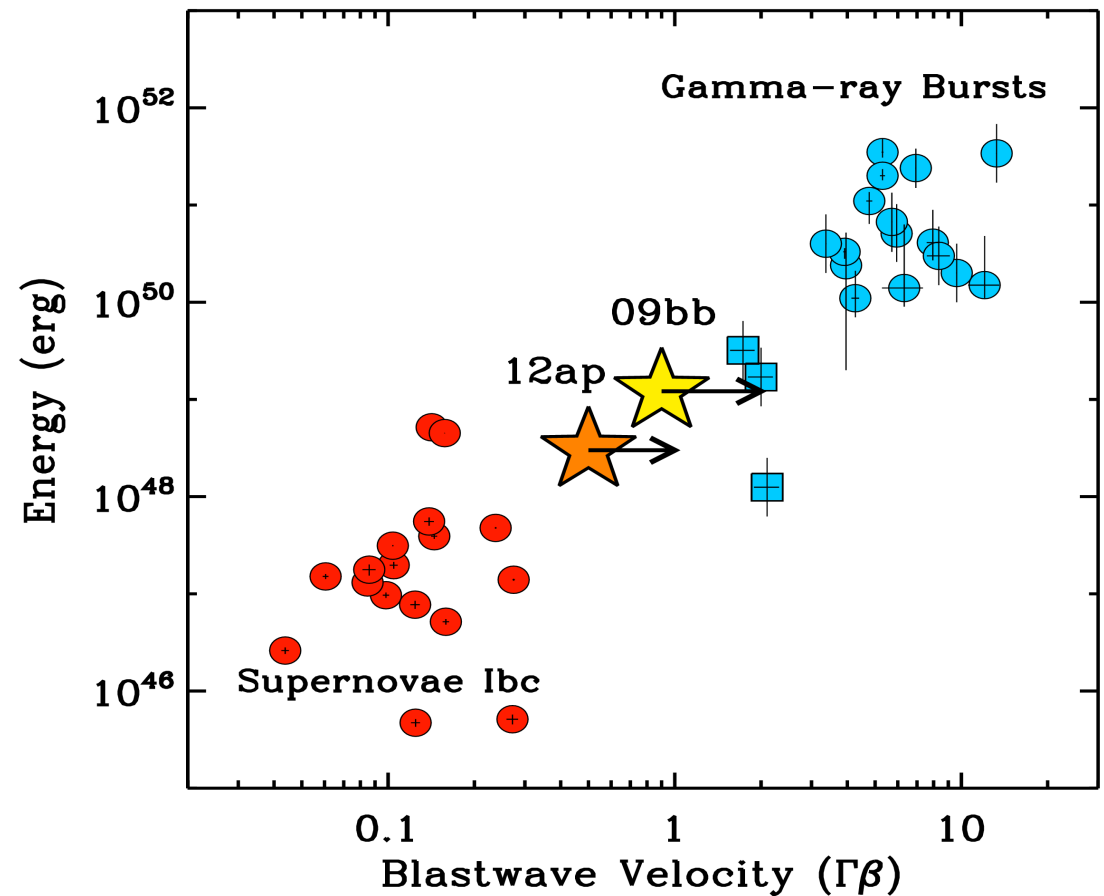
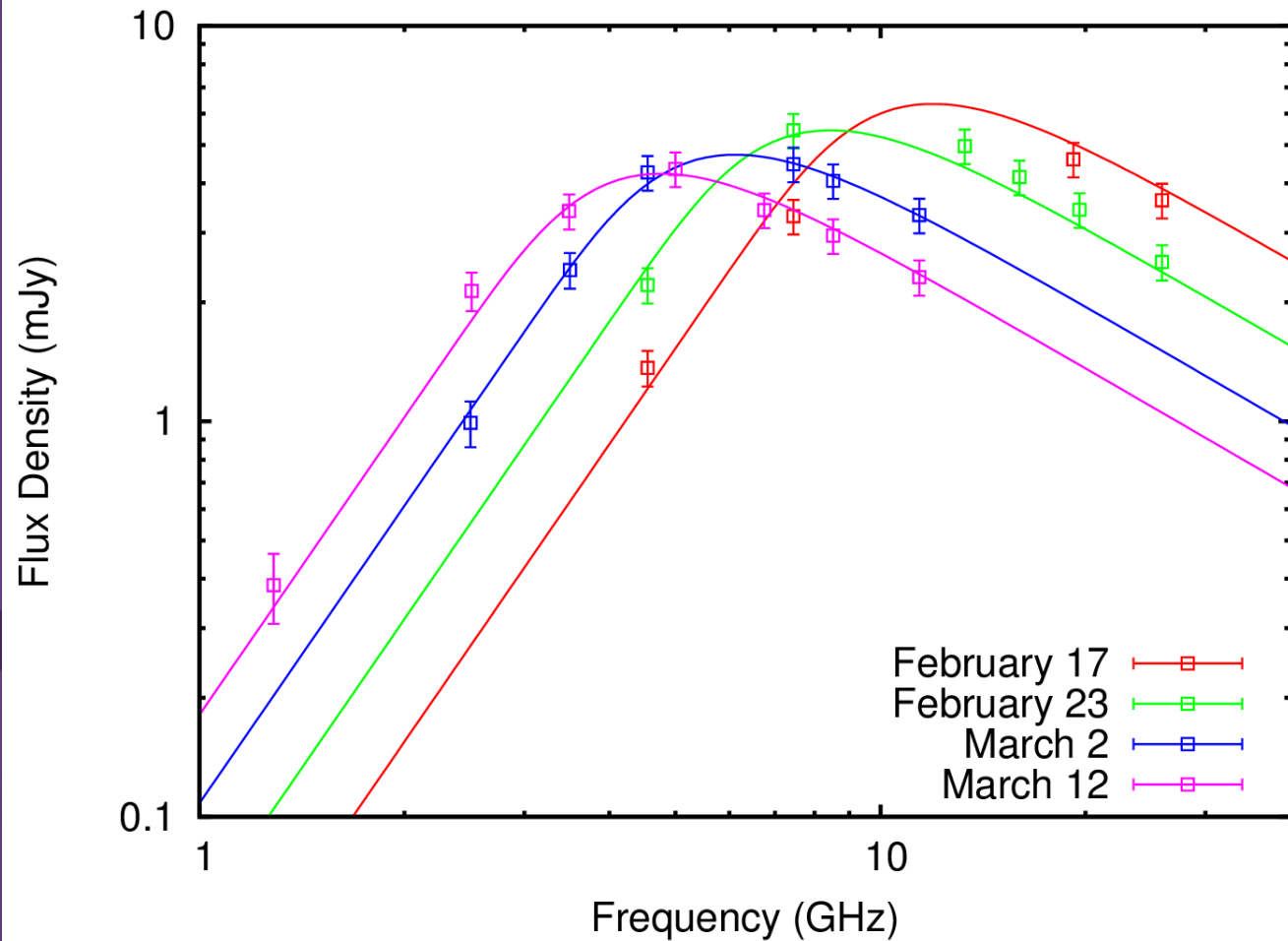


# Present: The Type Ic SN 2012ap

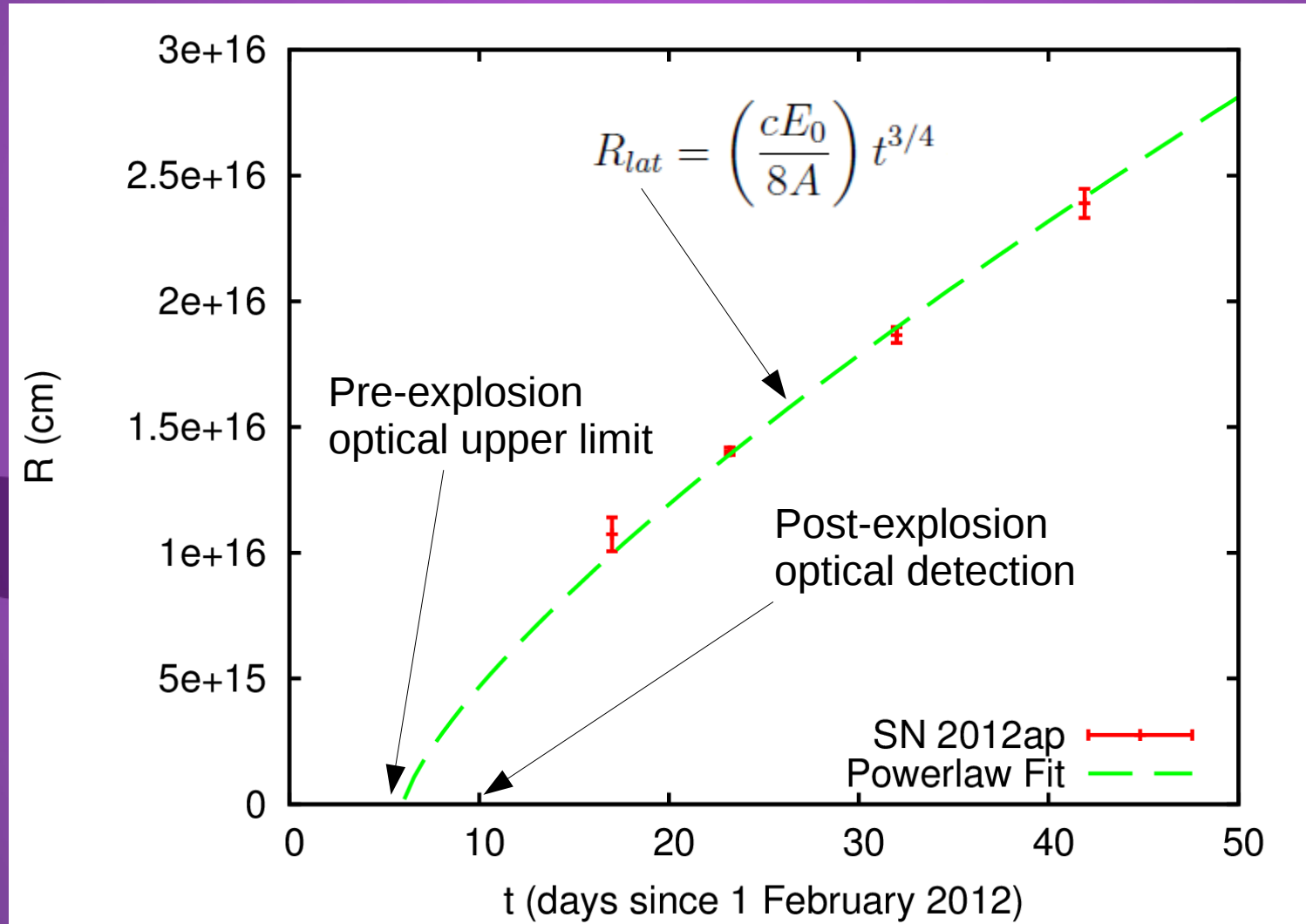




# Relativistic outflow from SN 2012ap



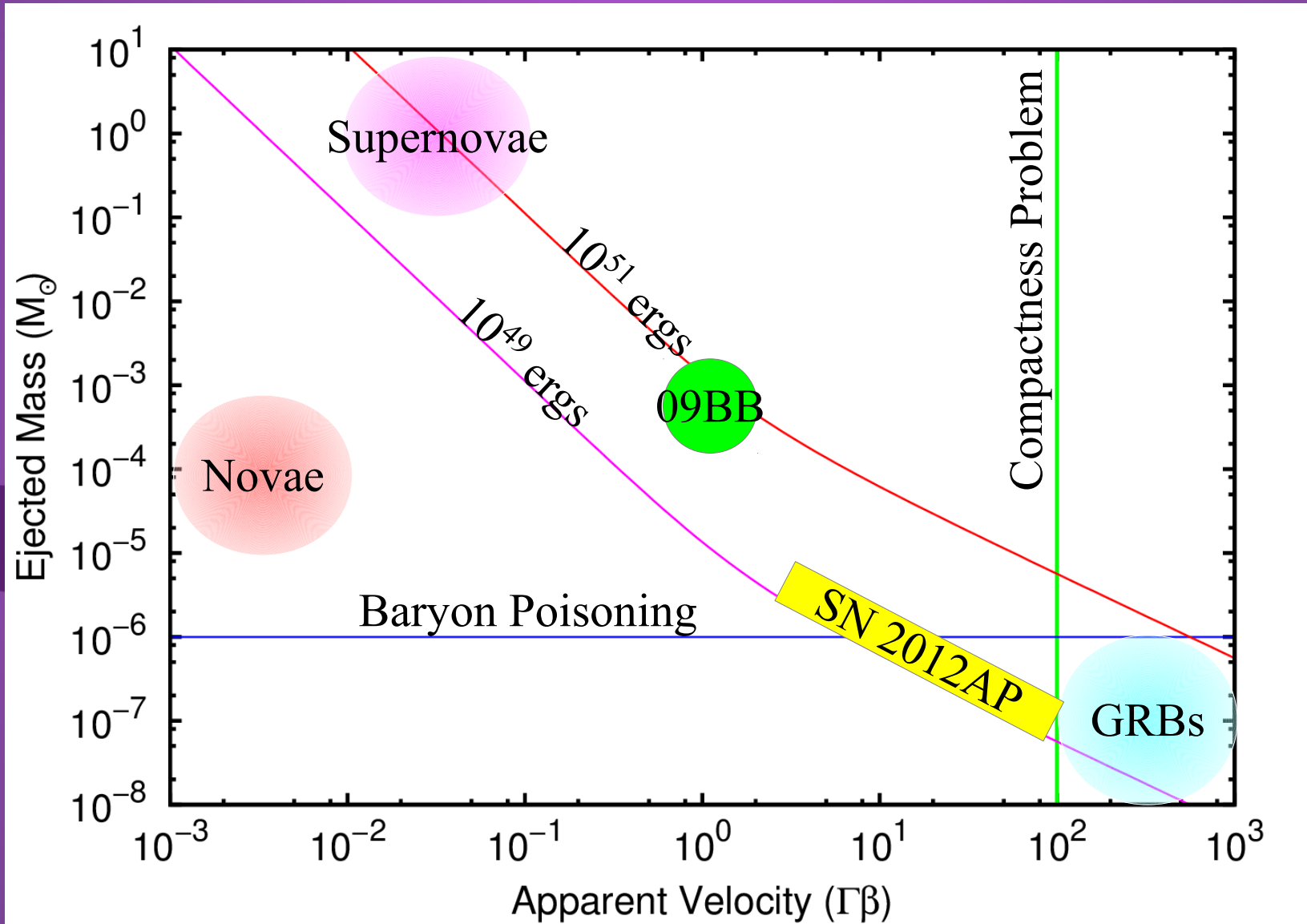
# Decelerating expansion in SN 2012ap, light ejecta



# Is it a GRB?

- Its radio afterglow is reminiscent of a GRB-SN
- Its mildly relativistic and decelerating
- $10^{49}$  ergs of energy, in less than  $10^{-5}$  solar mass
- So we looked for a GRB counterpart
- Did not find anything in IPN, BAT, GBM, etc
- Definitely  $<10^{47}$  ergs in gamma rays (from IPN)
- Maybe an off-axis GRB?
- Maybe not fast enough?

# Where is SN 2012ap?



# Future:

## The way forward, for models

- Produce explosions which make a broad line Type Ic SN
- Also drive a mildly relativistic outflow
- Put  $10^{49}$  ergs of energy, in less than  $10^{-5}$  solar mass
- Magnetars / quark stars ?



# Future:

## The way forward, in the radio

- Ongoing radio follow up
- Every announced local type Ic supernova
- Dependent upon optical surveys

# Future:

## The way forward, in X-rays

- Large (extrapolated) magnetic fields at early times
- Synchrotron cooling time shorter than age
- Possibly produce X-Ray flashes (like XRF 060218)
- Find with all sky X-Ray monitors and follow up in radio

# Thanks!

- Comments, suggestions, questions?
- Send them to [schakraborti@fas.harvard.edu](mailto:schakraborti@fas.harvard.edu)