Knowable Transients

S. R. Kulkarni
California Institute of Technology

An age old refrain:
Explore Phase Space!

Twinkle, twinkle, little star,
How I wonder what you are.
Up above the world so high,
Like a diamond in the sky.
Variable, variable, little star,
How I wonder what you are!

Jane Taylor 1806

Another Approach

The advent of spaceborne instrumentation necessitated a new approach in which new equipment had to be designed to solve specific quantifiable observational problems, much as one designed experiments in physics. Serendipity was always hoped for but did not set the experiment parameters.

R. Giacconi (Nobel Laureate)

Explosive Transients

- Stellar flares (impressive but not explosive)
- Novae
- Supernovae
- Afterglow (forward/reverse relativistic shocks)
  - GRB
  - Magnetar Flares

The total heat of the system is due to the electrons (density, n_e), ions (density, n_i) and photons:

$$E/V = \frac{3}{2}n_i(Z+1)kT + aT^4, \tag{2}$$

where $V = 4\pi/3R^3$, $N_i = M_{\rm ej}/(Am_H)$, $n_i = N_i/V$, $n_e = Zn_i$ and m_H is the mass of a hydrogen atom. For future reference, the total number of particles is $N = N_i(Z+1)$. This heat store has gains and losses described by

$$\dot{E} = \varepsilon(t) - L(t) - 4\pi R(t)^2 P v(t) \tag{3}$$

where $L(t)$ is the luminosity radiated at the surface. P is the total (electron, ion and photon) pressure and is

$$P = n_i(Z+1)kT + aT^4/3. \tag{4}$$

As explained earlier, the ejecta gain speed rapidly from expansion (the $4\pi R^2 P v_s$ work term). Thus, following the initial acceleration phase, the radius can be expected to increase linearly with time:

$$R(t) = R_0 + v_s t; \tag{5}$$

With this (reasonable) assumption of coasting we avoid solving the momentum equation.

Pure explosion

Photon dominated explosion:

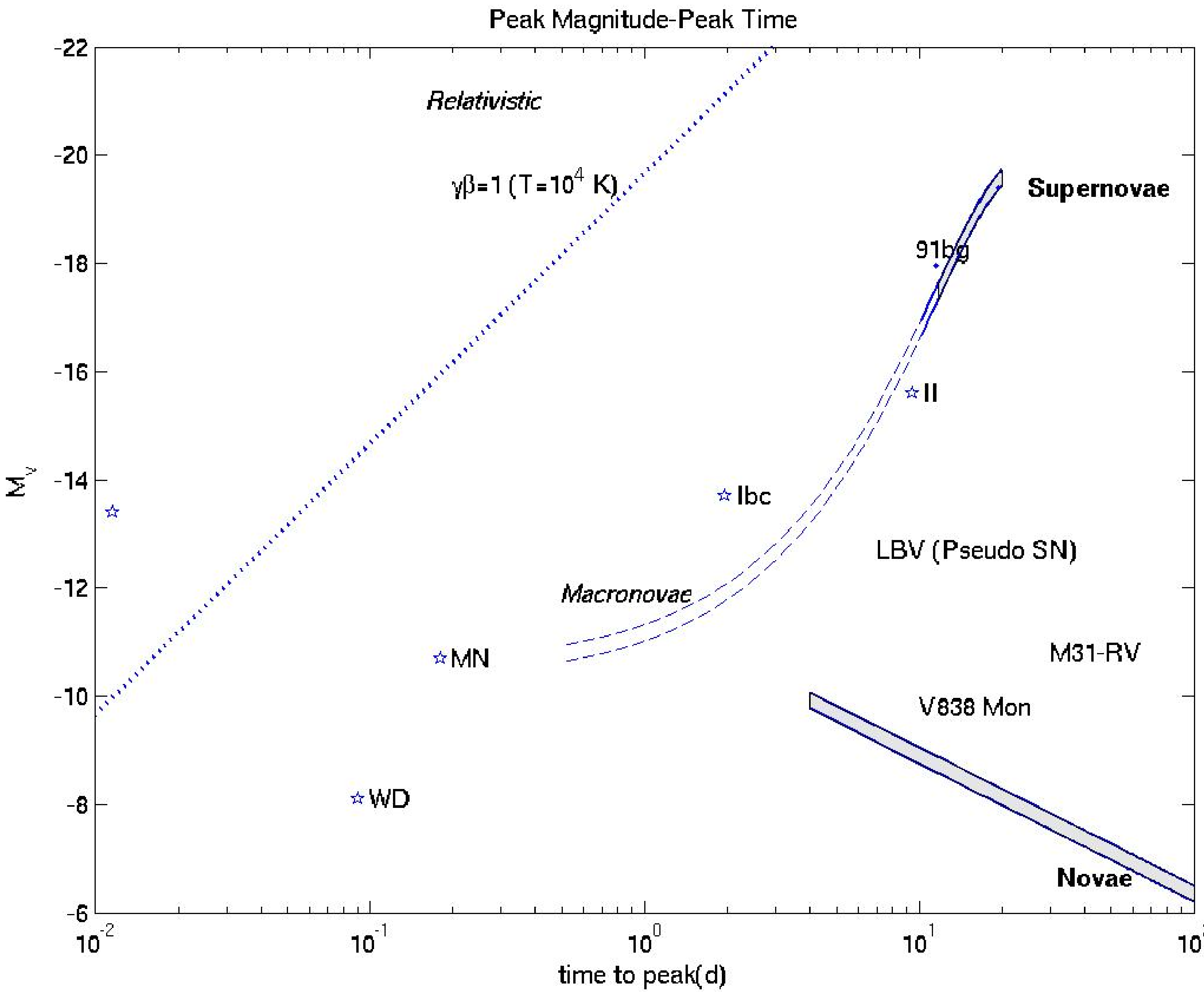
$$L(t) = L_0 \exp\left(-\frac{t_h t + t^2/2}{t_h t_d(0)}\right);$$

Gas-pressure dominated explosion

$$L(t) = \frac{L_0}{(t/t_h + 1)} \exp\left(-\frac{t_h t + t^2/2}{t_h t_d(0)}\right).$$

Explosions with long lasting emission

- Supernova family (radioactive decay)
- Nova family (central heating)
- Afterglow family (non-radiative shocks)


Peak Magnitude-Peak Time
-22
-20
-18
-16
-14
-12
-10
-8
-6
M_V
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
time to peak(d)
Relativistic
γβ=1 (T=10^4 K)
Supernovae
91bg
II
Ibc
LBV (Pseudo SN)
Macronovae
MN
M31-RV
V838 Mon
WD
Novae

Black Hole-Neutron Star (Rupert, Janka)

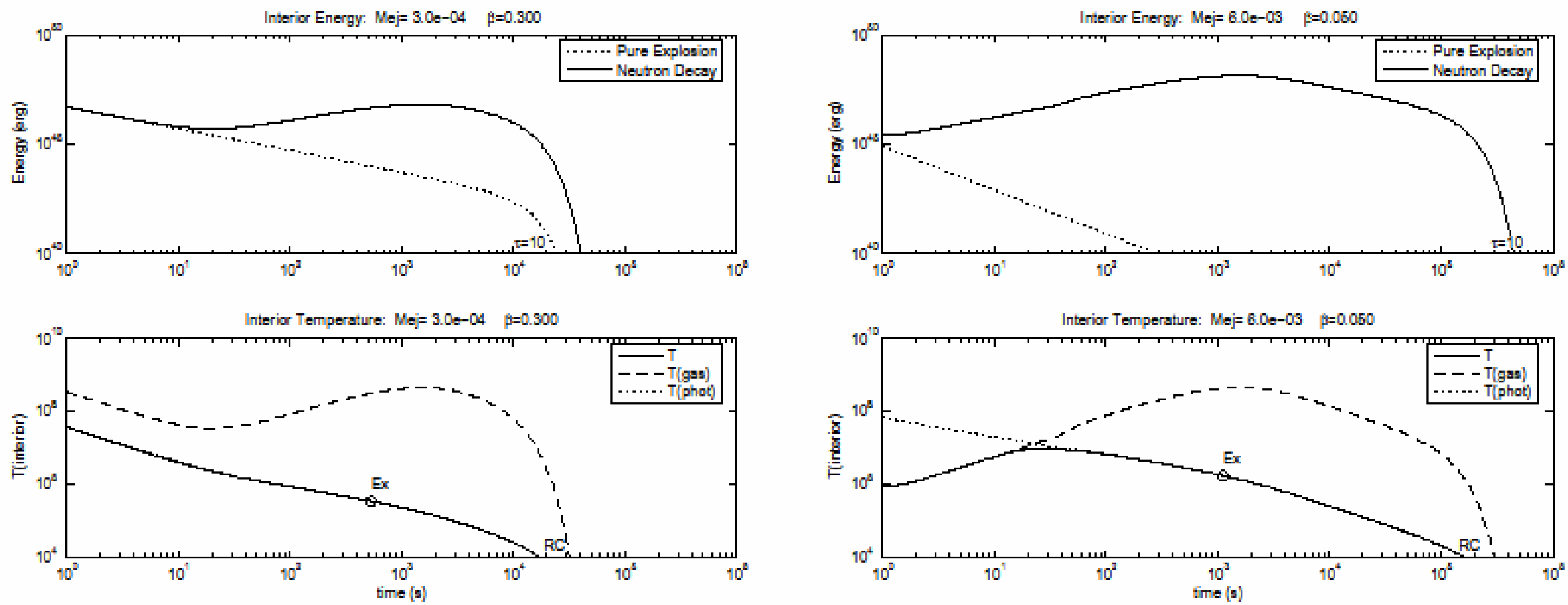
QuickTime™ and a
YUV420 codec decompressor
are needed to see this picture.

Macronova Model: An example

- Parameters: M_{ejecta} & $v=\beta c$
- Composition
  - Free Neutrons
  - Radioactive Nickel
  - Neutron Rich Material (non-radioactive)
- Injection of energy essential for macronova to shine and be detectable

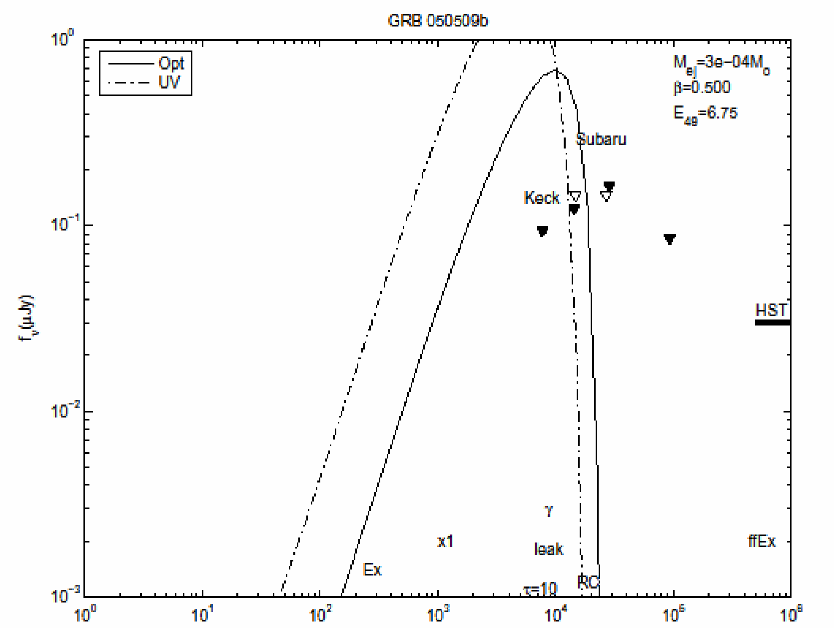
Heating by Neutron Decay

8 *Kulkarni*

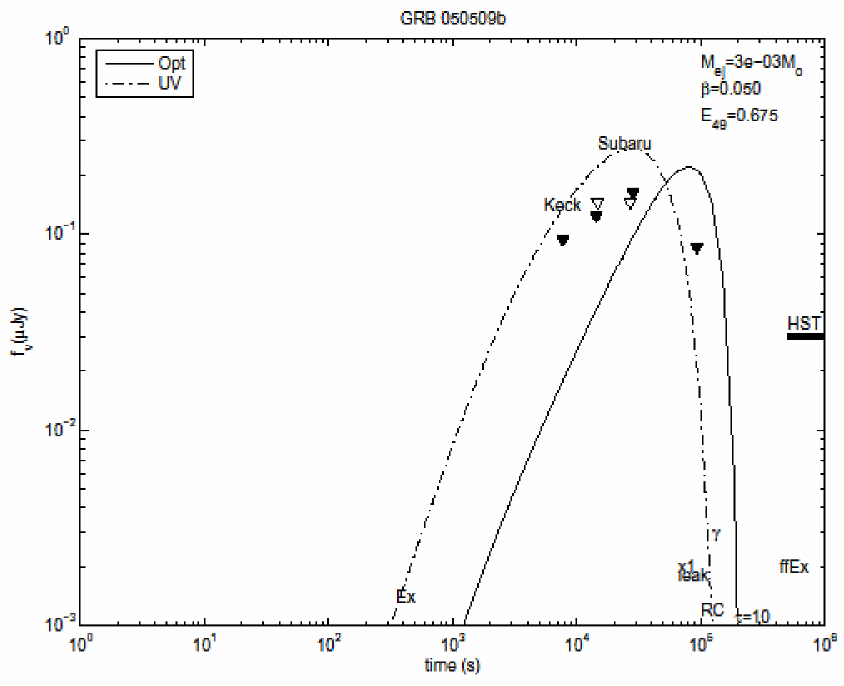


Problem: Initial photons radiated away

Comparison to Data (GRB 050509b)



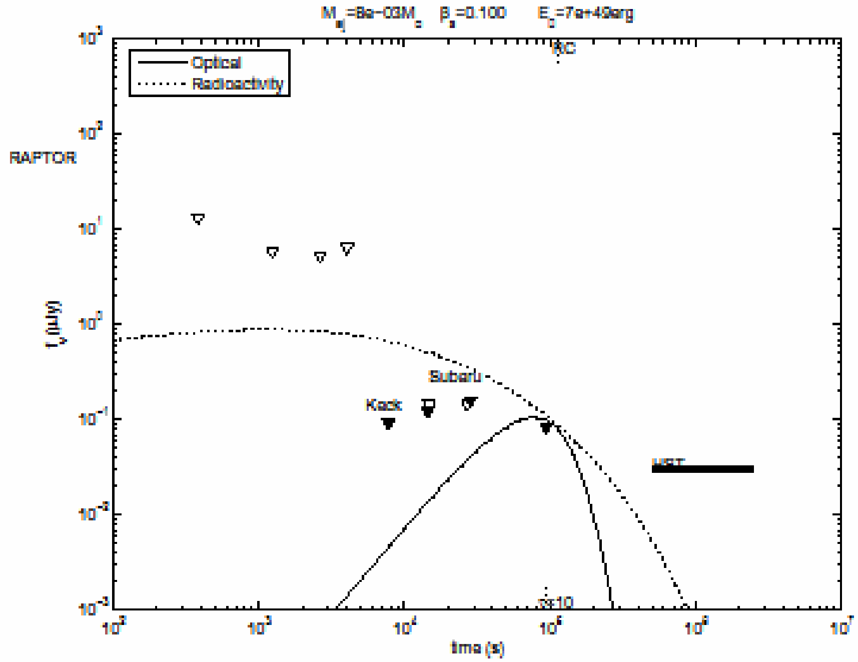
β=0.5



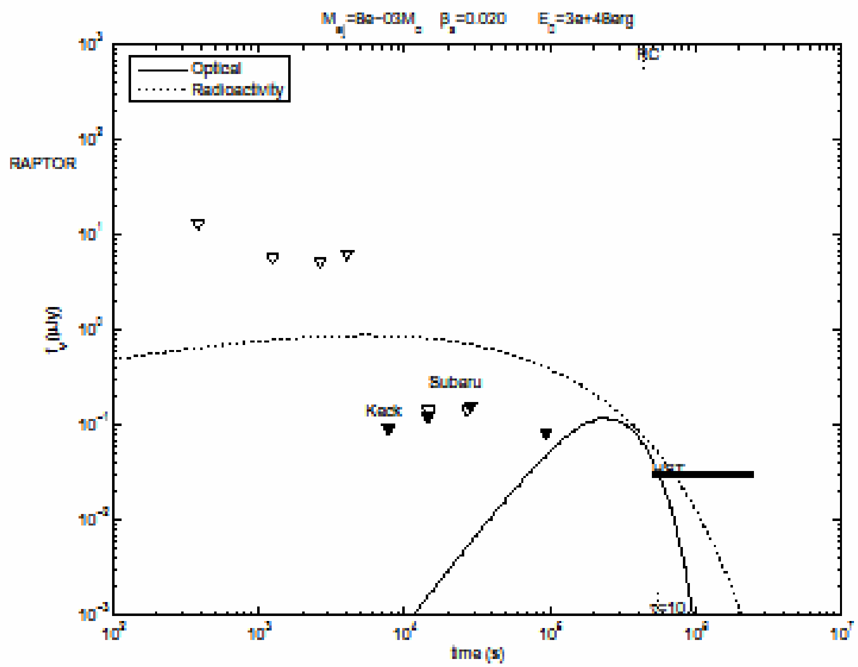
β=0.05

Heating by Decay of Ni^{56}

- Nickel decay results in 1.72 MeV gamma-rays.
- A few scatterings are needed to transfer bulk of the energy to electrons
- Unlike ordinary SN, the ejecta become transparent to gamma-rays before 6 days.


Optical
Radioactivity
RAPTOR
Keck
Subaru
HST
time (s)

β=0.1


Optical
Radioactivity
RAPTOR
Keck
Subaru
HST
time (s)

β=0.05

Brachynova: Nova model for coalescence

•Long lived central soure (e.g. magnetar)
•Long lived accretion disk

There are already indications of tremendous late time activity in short hard bursts.

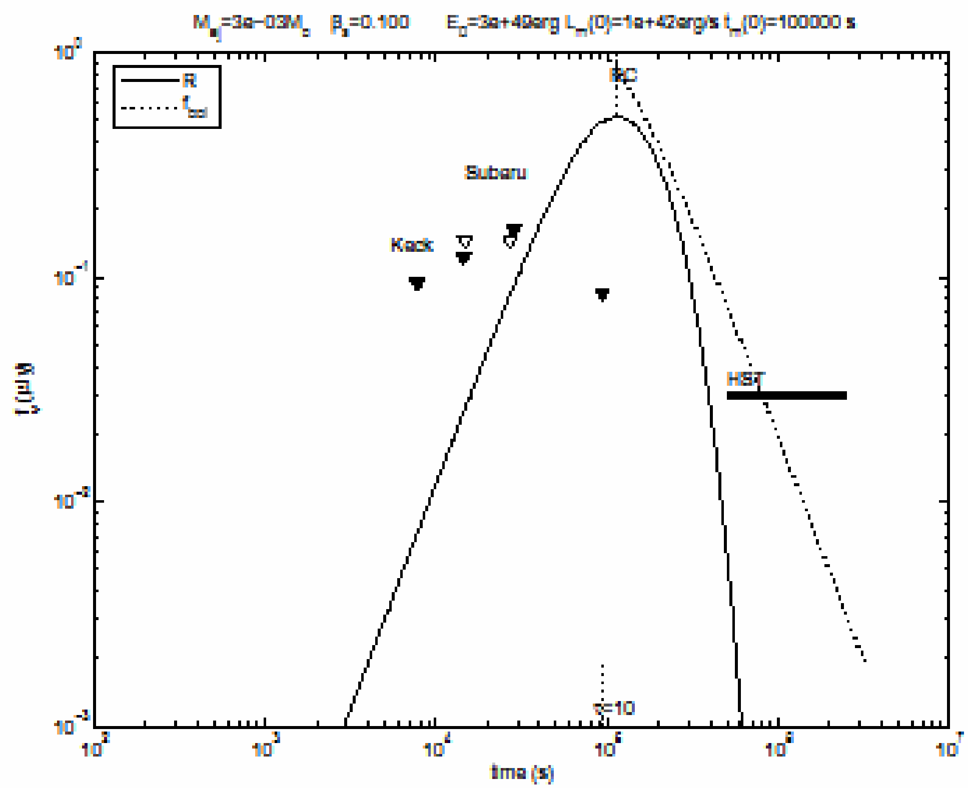


Figure 8.

angular frequency and P is the rotation period. For $B = 10^{15}\,\mathrm{G}$, $R_n = 16\,\mathrm{km}$ we obtain $dE/dt \sim 10^{42}(P/100\,\mathrm{ms})^{-4}\,\mathrm{erg\ s^{-1}}$ and the characteristic age is $5 \times 10^4\,\mathrm{s}$ (Fig. 8).

Dolichonova

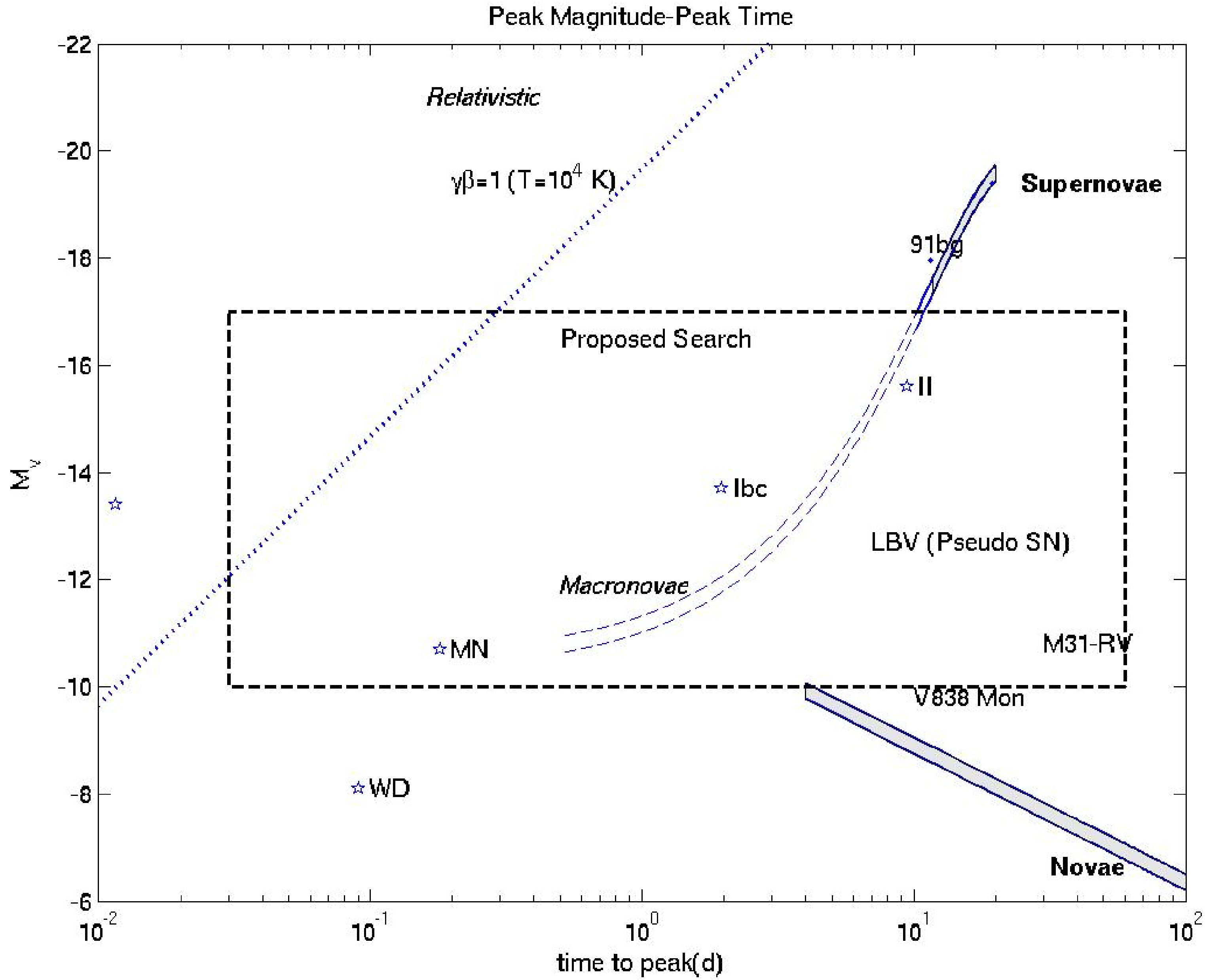
A New Class of Transients

LUMINOUS M GIANTS IN THE BULGE OF M31

R. MICHAEL RICH[1]
Department of Astronomy, Columbia University
JEREMY MOULD AND ALAIN PICARD
Palomar Observatory
AND
JAY A. FROGEL AND ROGER DAVIES
Kitt Peak National Observatory[2]
Received 1988 October 17; accepted 1989 March 14

ABSTRACT

We report on spectroscopy of luminous red stars in the central bulge of M31. A number of these are shown to be late-type M giants similar to those in the Baade's window field of the bulge of the Milky Way. Among the M31 stars, we serendipitously discovered an exceptionally luminous M0 Ie red supergiant which has brightened by more than 5 mag in the last 2 yr. At peak brightness, this star was the most luminous red supergiant in the local group, with $M_{\rm bol} = -10$.



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Relativistic
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Proposed Search
II
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Macronovae
MN
M31-RV
V838 Mon
WD
Novae
-22
-20
-18
-16
-14
-12
-10
-8
-6
M_V
10^-2
10^-1
10^0
10^1
10^2
time to peak(d)

New classes?

- Macronova (weaker versions of SN)
  - eg short hard bursts
- Brachynova (super fast novae)
  - eg variable central engine
- Dolichonova (super slow novae)
  - eg M31 RV, V838 Mon

It is all Greek to me

"It's somewhere between a nova and a supernova ... probably a pretty good nova."