

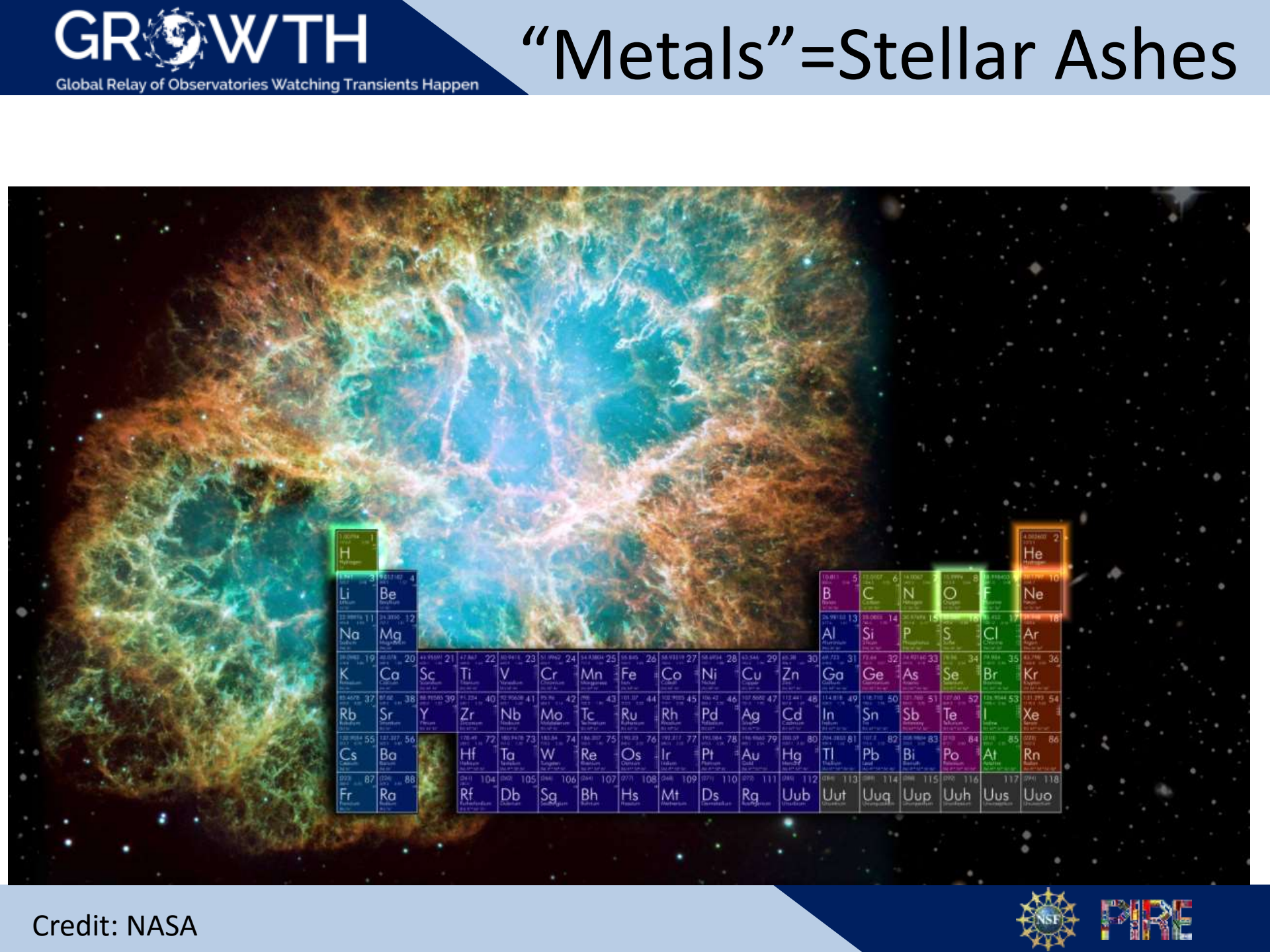
# Cosmic Explosions: Young & Energetic

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Caltech Optical Observatories



# “Metals”=Stellar Ashes



A periodic table of elements is overlaid on the bottom of the image. The elements are colored to match the colors of the nebula in the background. The colors are: Hydrogen (H) is green, Helium (He) is orange, Lithium (Li) is blue, Beryllium (Be) is blue, Boron (B) is purple, Carbon (C) is purple, Nitrogen (N) is purple, Oxygen (O) is green, Fluorine (F) is green, Neon (Ne) is orange, Sodium (Na) is blue, Magnesium (Mg) is blue, Aluminum (Al) is purple, Silicon (Si) is purple, Phosphorus (P) is purple, Sulfur (S) is green, Chlorine (Cl) is green, Argon (Ar) is orange, Potassium (K) is blue, Calcium (Ca) is blue, Scandium (Sc) is blue, Titanium (Ti) is blue, Vanadium (V) is blue, Chromium (Cr) is blue, Manganese (Mn) is blue, Iron (Fe) is blue, Cobalt (Co) is blue, Nickel (Ni) is blue, Copper (Cu) is blue, Zinc (Zn) is blue, Gallium (Ga) is blue, Germanium (Ge) is blue, Arsenic (As) is purple, Selenium (Se) is purple, Bromine (Br) is orange, Krypton (Kr) is orange, Rubidium (Rb) is blue, Strontium (Sr) is blue, Yttrium (Y) is blue, Zirconium (Zr) is blue, Niobium (Nb) is blue, Molybdenum (Mo) is blue, Technetium (Tc) is blue, Ruthenium (Ru) is blue, Rhodium (Rh) is blue, Palladium (Pd) is blue, Silver (Ag) is blue, Cadmium (Cd) is blue, Indium (In) is blue, Tin (Sn) is blue, Antimony (Sb) is purple, Tellurium (Te) is purple, Iodine (I) is orange, Xenon (Xe) is orange, Cesium (Cs) is blue, Barium (Ba) is blue, Lanthanum (La) is blue, Cerium (Ce) is blue, Praseodymium (Pr) is blue, Neodymium (Nd) is blue, Promethium (Pm) is blue, Samarium (Sm) is blue, Europium (Eu) is blue, Gadolinium (Gd) is blue, Terbium (Tb) is blue, Dysprosium (Dy) is blue, Holmium (Ho) is blue, Erbium (Er) is blue, Thulium (Tm) is blue, Ytterbium (Yb) is blue, Lutetium (Lu) is blue, Hafnium (Hf) is blue, Tantalum (Ta) is blue, Tungsten (W) is blue, Rhenium (Re) is blue, Osmium (Os) is blue, Iridium (Ir) is blue, Platinum (Pt) is blue, Gold (Au) is blue, Mercury (Hg) is blue, Thallium (Tl) is blue, Lead (Pb) is blue, Bismuth (Bi) is purple, Polonium (Po) is purple, Astatine (At) is orange, Radon (Rn) is orange, Francium (Fr) is blue, Radium (Ra) is blue, Actinium (Ac) is blue, Thorium (Th) is blue, Protactinium (Pa) is blue, Uranium (U) is blue, Neptunium (Np) is blue, Plutonium (Pu) is blue, Americium (Am) is blue, Curium (Cm) is blue, Berkelium (Bk) is blue, Californium (Cf) is blue, Einsteinium (Es) is blue, Fermium (Fm) is blue, Mendelevium (Md) is blue, Nobelium (No) is blue, Lawrencium (Lr) is blue, Rutherfordium (Rf) is blue, Dubnium (Db) is blue, Seaborgium (Sg) is blue, Bohrium (Bh) is blue, Hassium (Hs) is blue, Meitnerium (Mt) is blue, Darmstadtium (Ds) is blue, Roentgenium (Rg) is blue, Copernicium (Cn) is blue, Ununbium (Uub) is blue, Ununtrium (Uut) is blue, Ununquadium (Uuq) is blue, Ununpentium (Uup) is blue, Ununhexium (Uuh) is blue, Ununseptium (Uus) is blue, and Ununoctium (Uuo) is orange.

- The motivations to study cosmic explosions at early times
  - Supernovae without hydrogen
  - Supernovae with hydrogen
  - Supernovae which are driven by an engine

1. Determine what kind of stars explode as what kind of supernovae?
  - “mapping between types of supernovae and their progenitors”
2. Early studies is key
  - Early studies determine radius
  - Early studies allow us to probe circum-stellar environs (which is a clue to the state of star before it explodes)

3. Some supernovae are not simple explosions but are driven by an “engine”

- Engines are most active at early times and easily identified by X-ray observations (early times) and radio observations (early and late)

## **A. YOUNG SUPERNOVAE (WITHOUT HYDROGEN)**

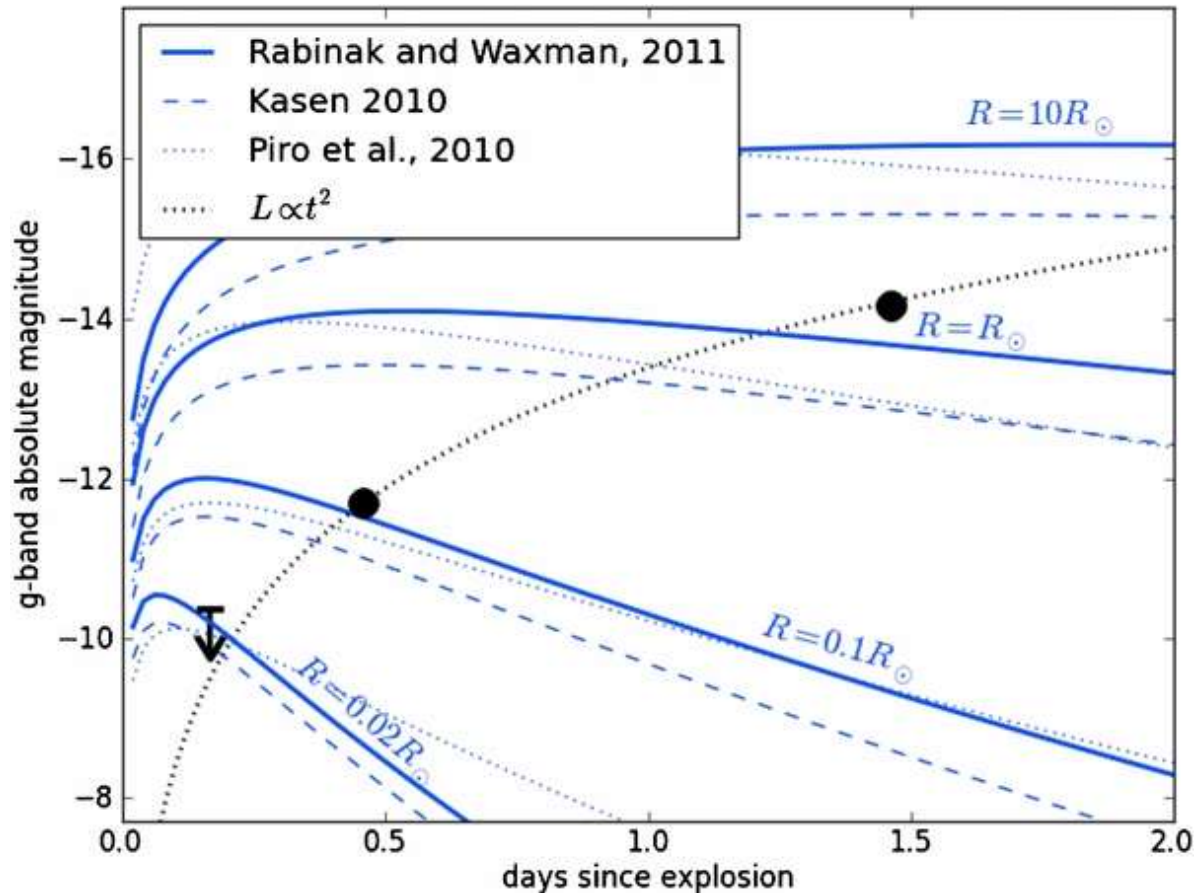
1. Two white dwarfs merge and the resulting merger explodes
  1. These are old systems and so no expectation of rich circum-stellar medium
2. One white dwarf is fed matter by a normal star, increases in mass and then explodes
  1. This is a “dirty” system and one expects lots of circum-stellar matter
  2. Blast wave interacts with the companion star!

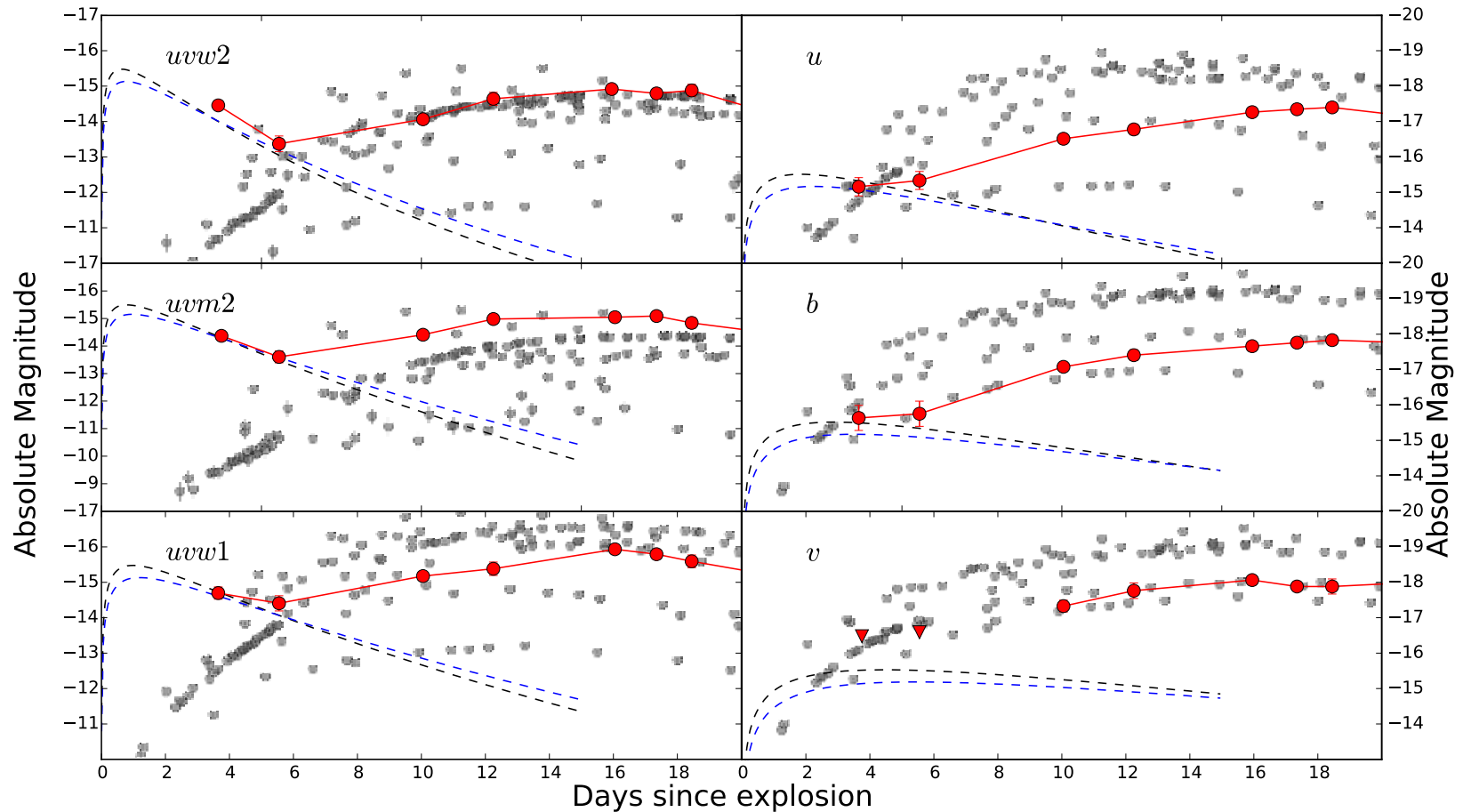




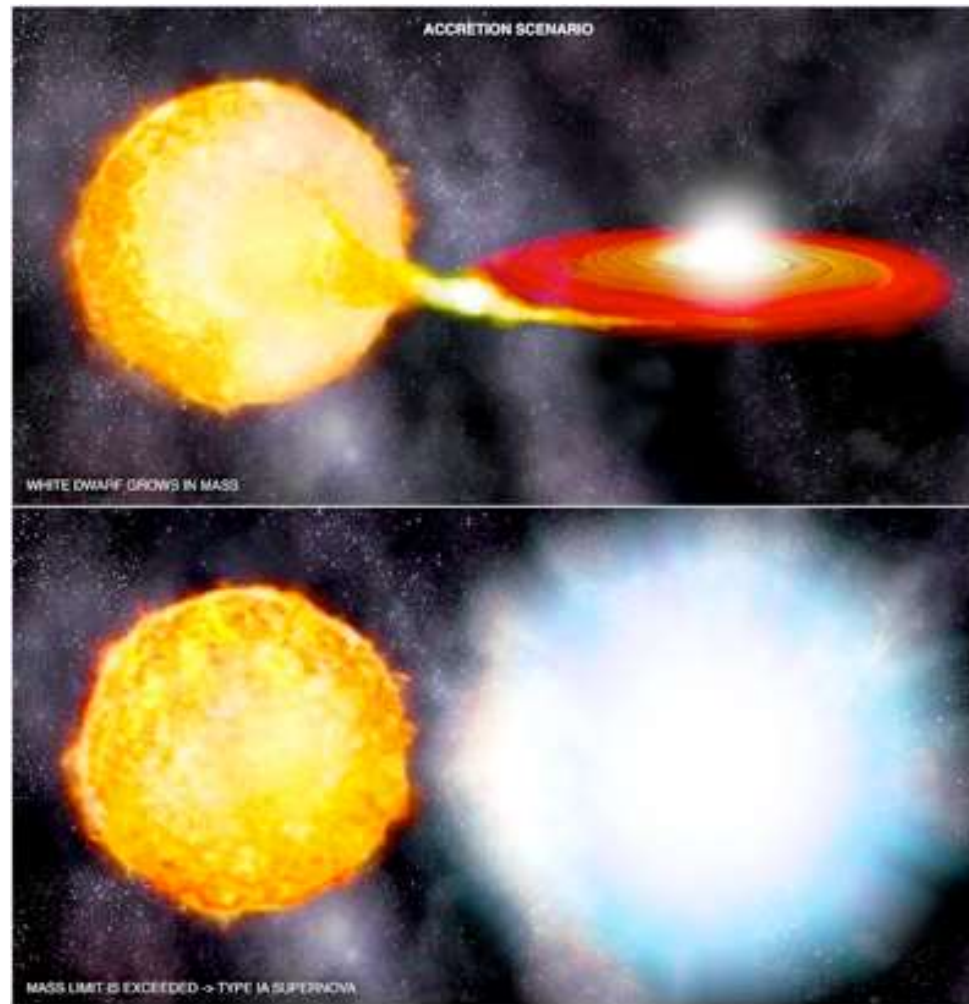


# Progenitor is small!





Yi Cao (PhD thesis)



Disappearance of the Progenitor of iPTF13bv

3

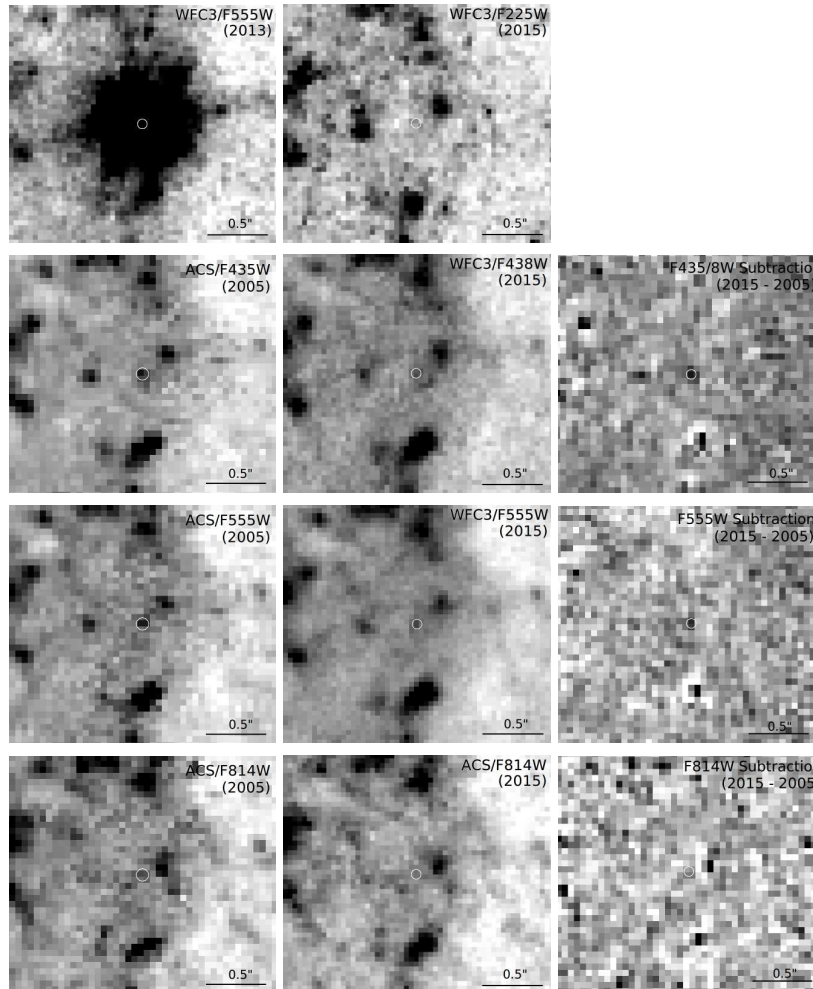
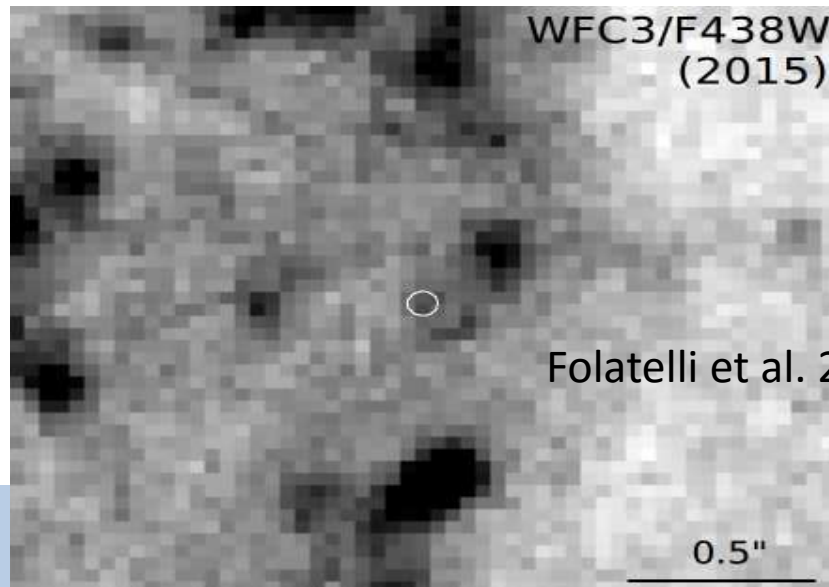
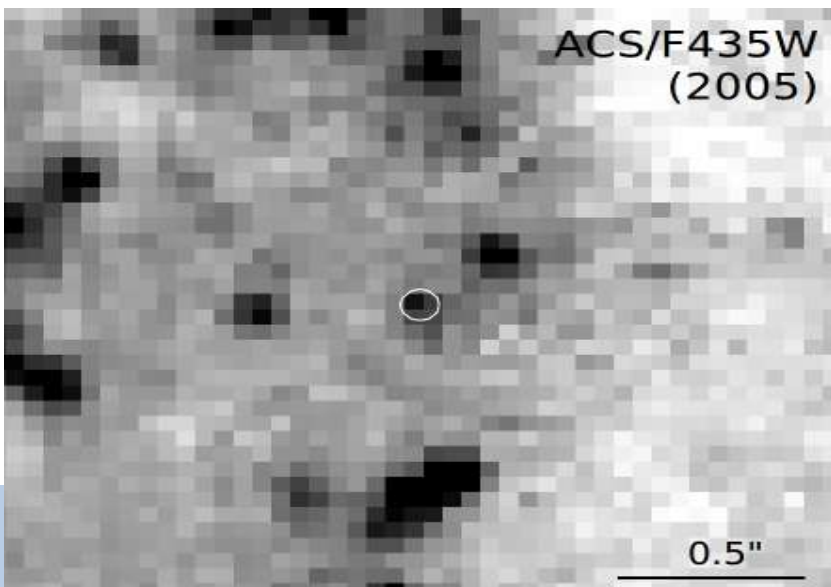
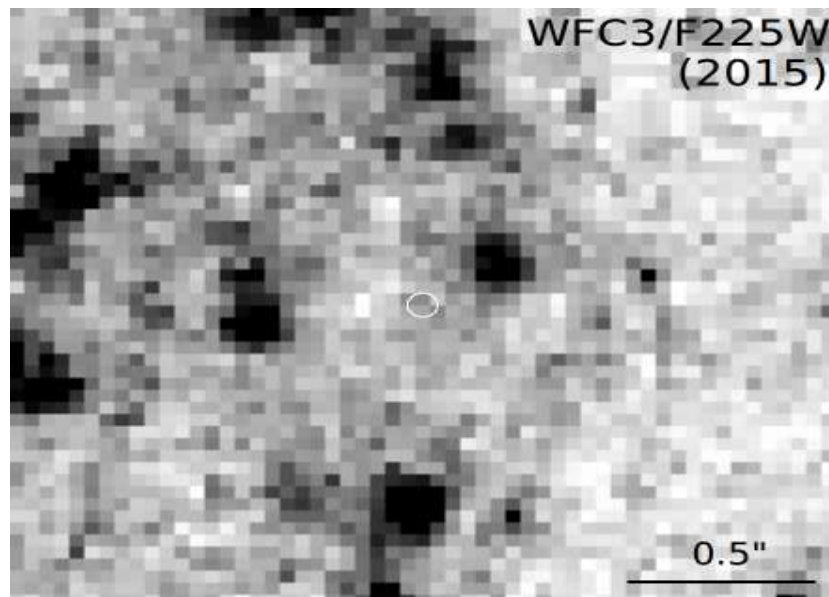
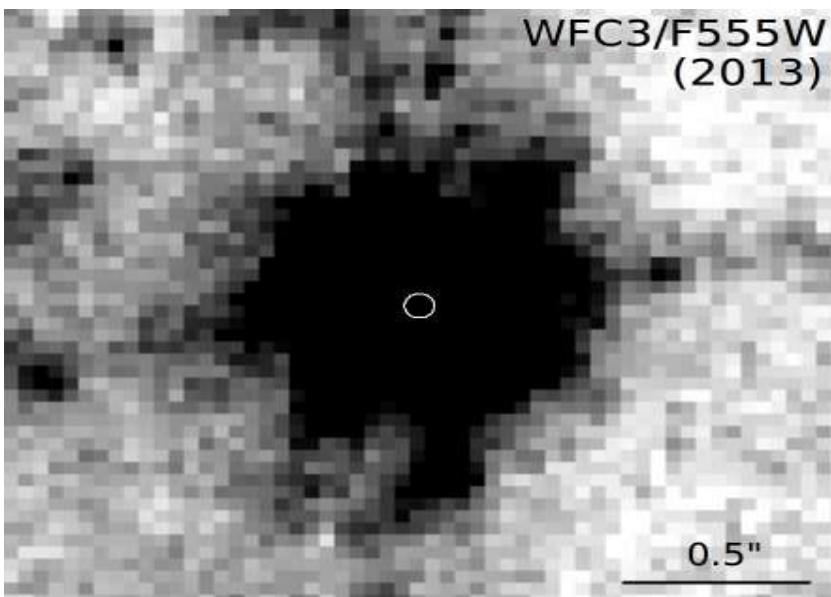


FIG. 1.— *HST* images of the site of iPTF13bv at different epochs. *Top left*: An image near maximum light to locate the SN. *Rest of left column*: Pre-SN images obtained in 2005. *Middle column*: New images obtained in 2015. *Right column*: Pre-SN minus post-SN images. The SN location is shown with a white circle of  $3\sigma$  radius. The image scale is indicated. North is up and east to the left.

Folatelli et al. 2016

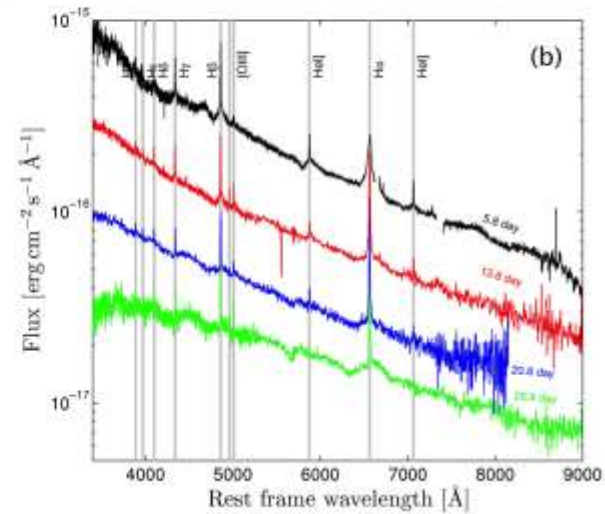
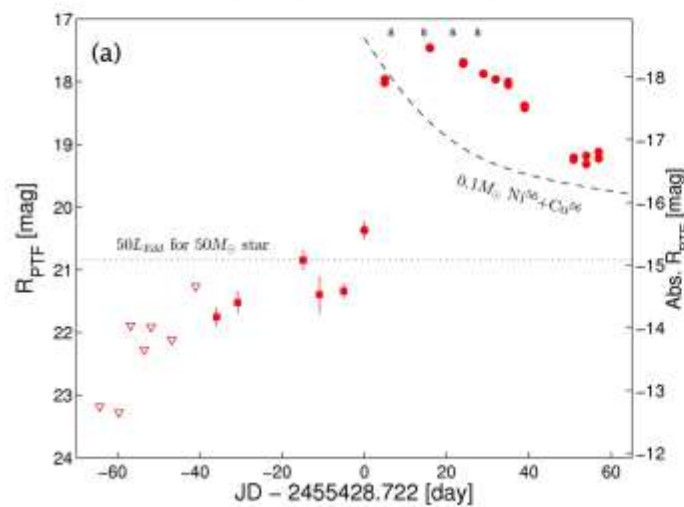
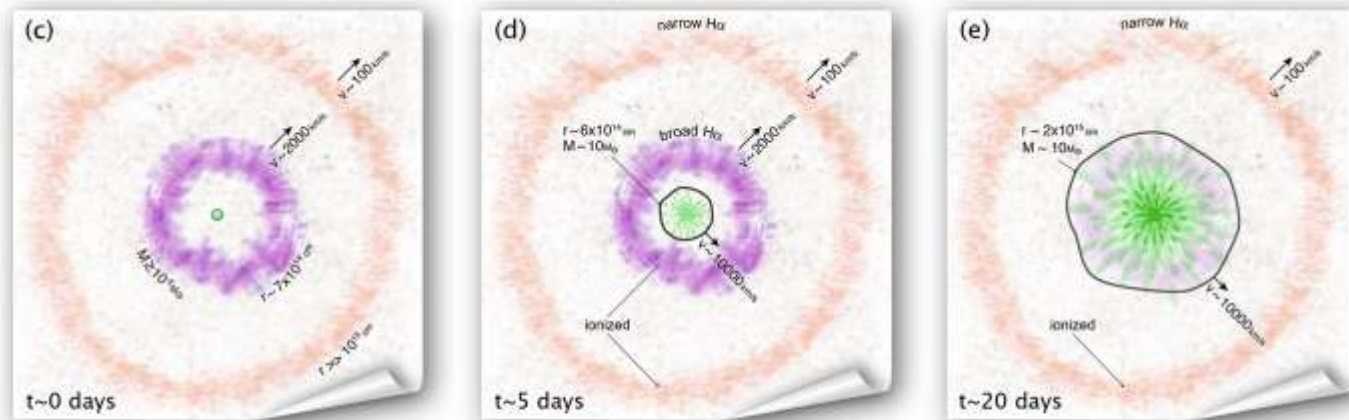


Folatelli et al. 2016

## **B. YOUNG SUPERNOVAE (WITH HYDROGEN)**

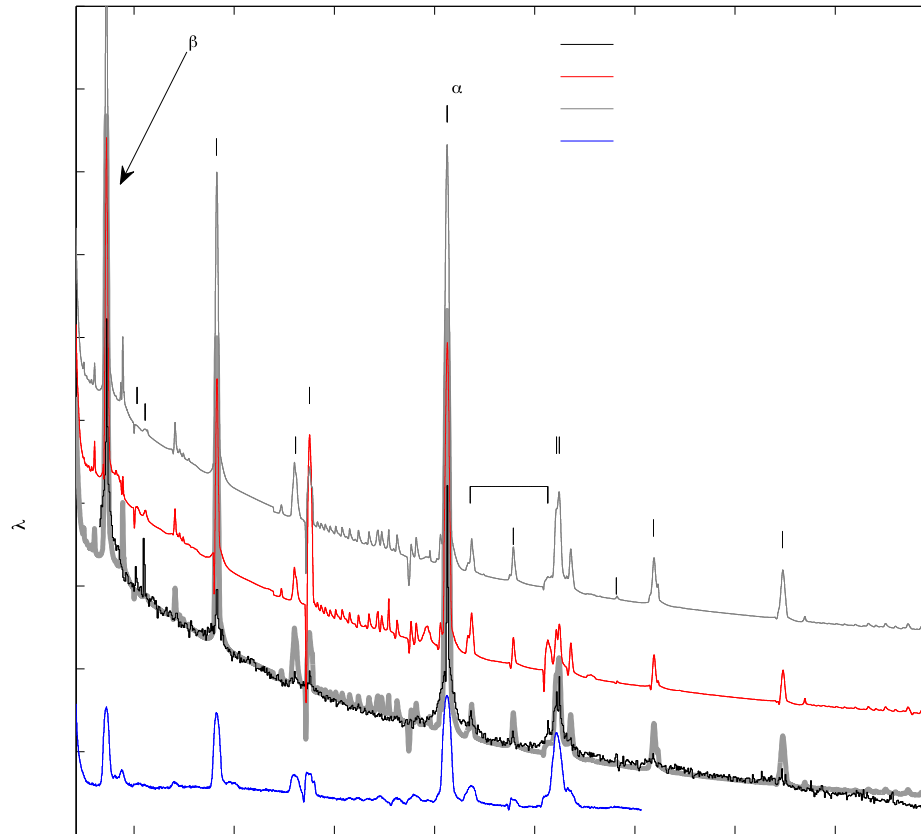


# Death Omen!

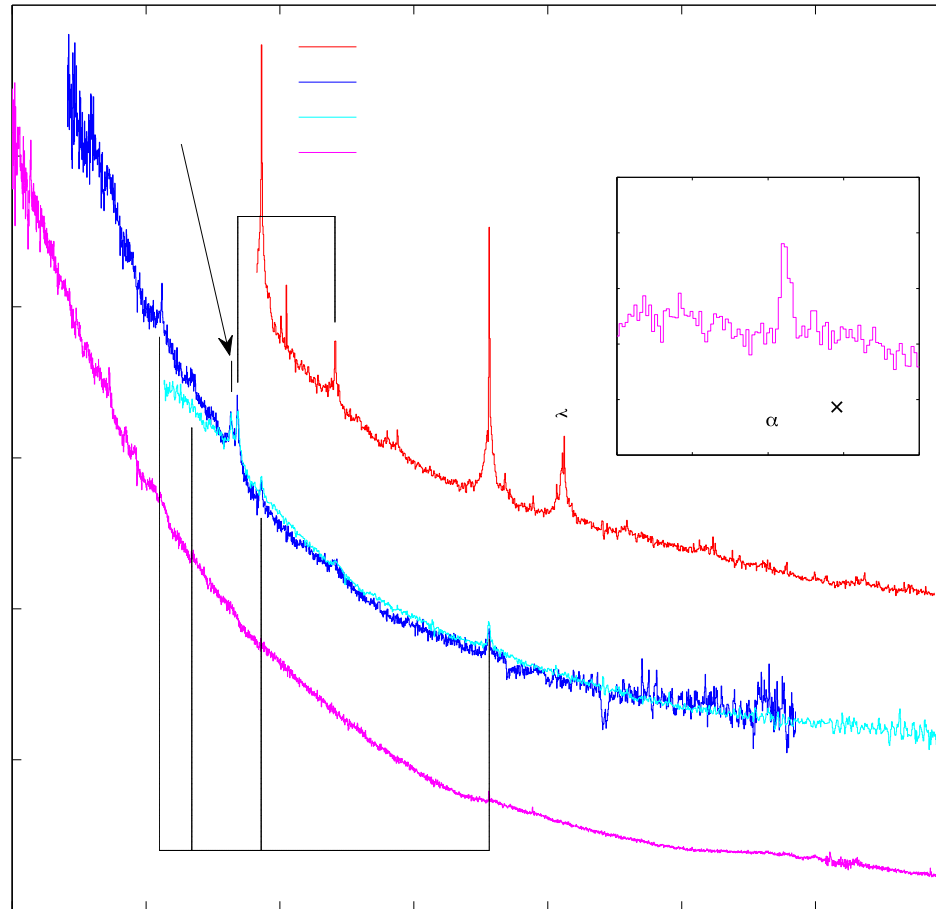


Ofek et al.



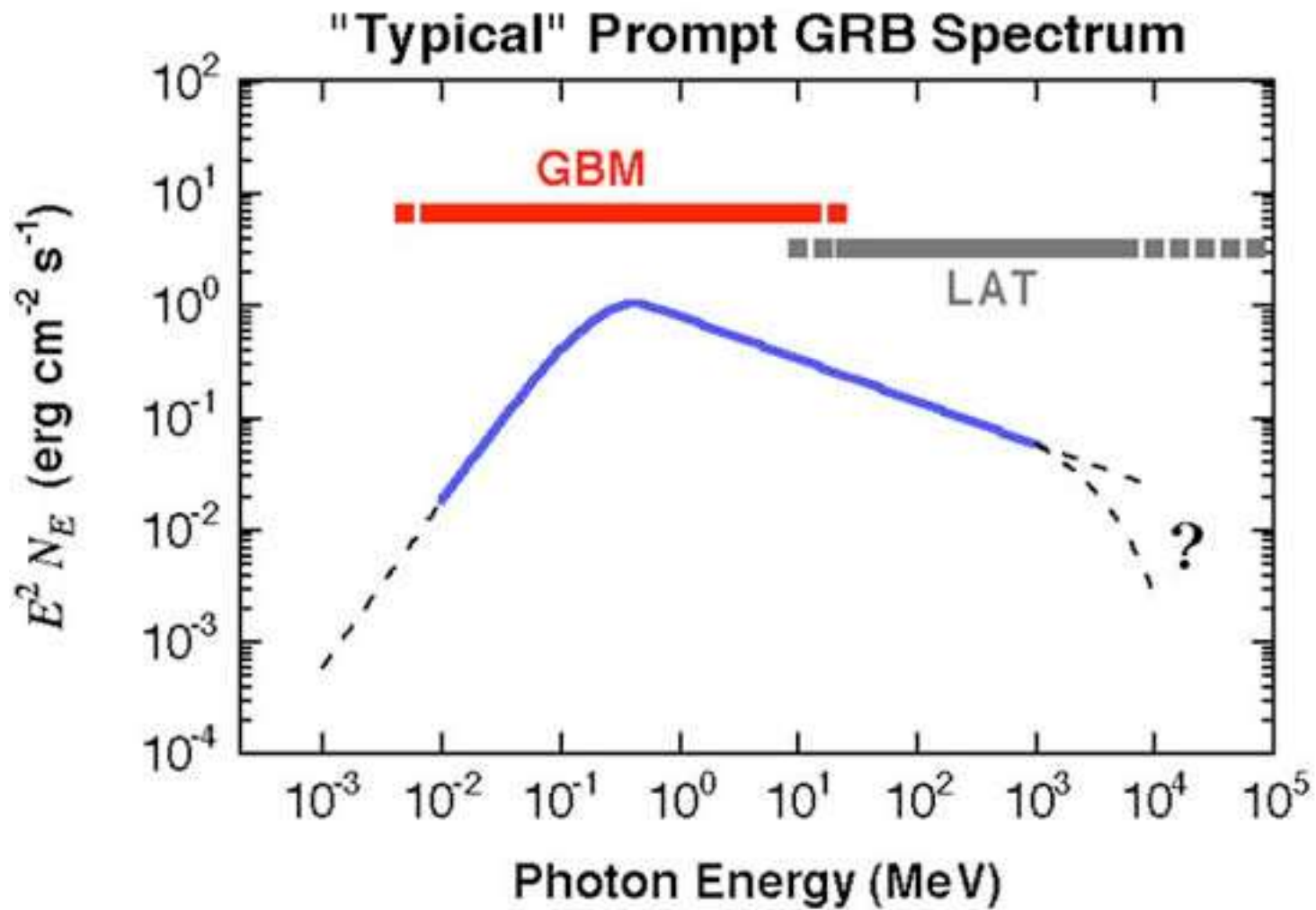


Gal-yam+

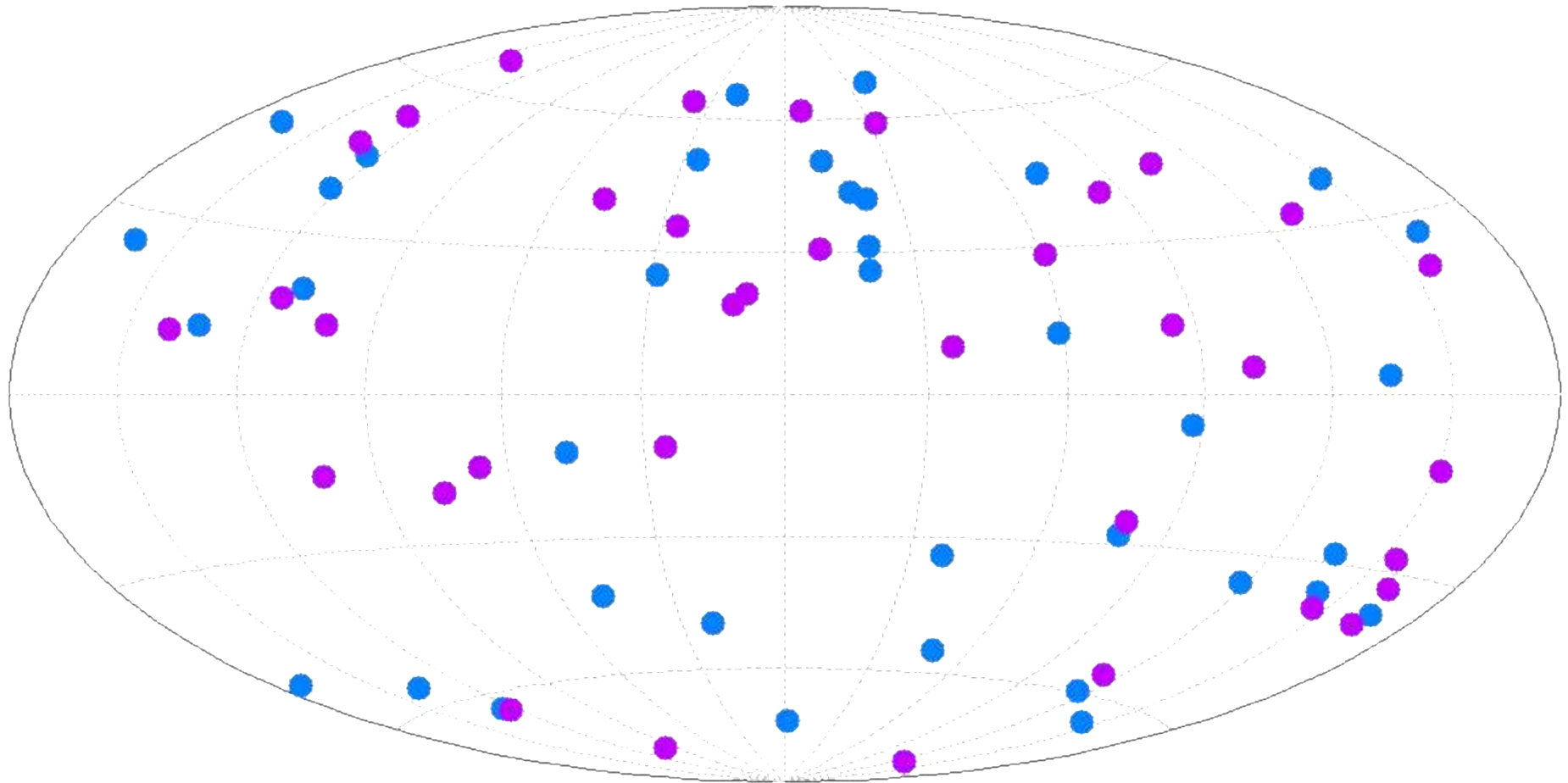


Gal-Yam+

## C. X-RAY FLASHES (XRF)





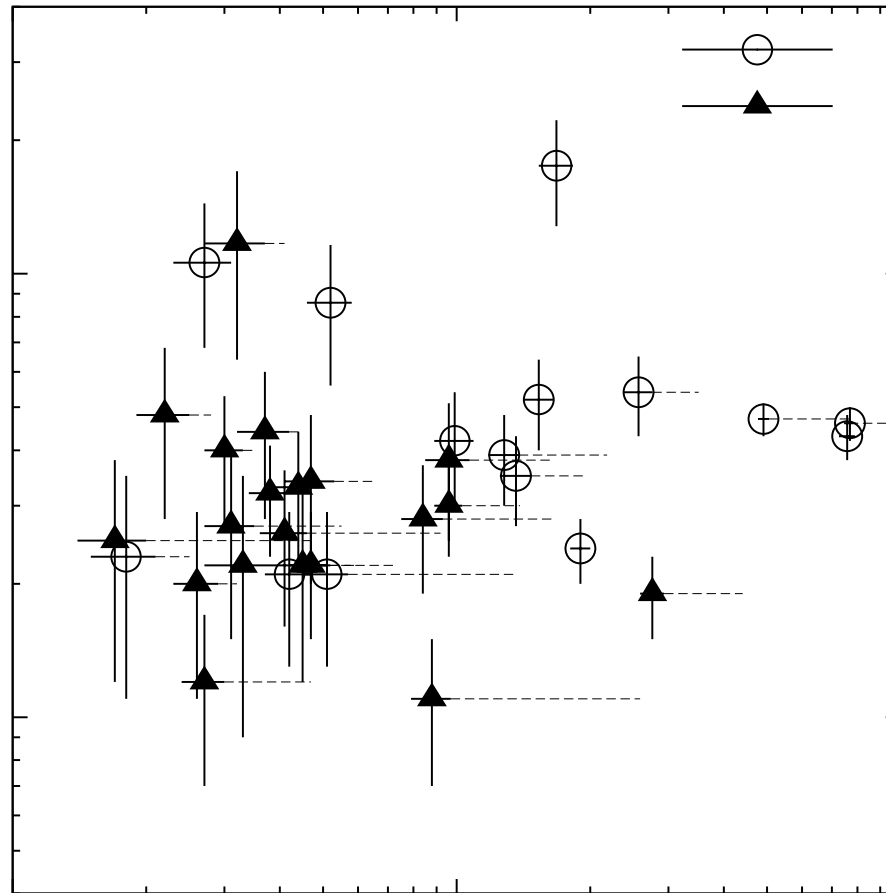


●: only MAXI (43)  
●: MAXI + other (39 prompt + 7 afterglows)

Serino et al. (2014)

<http://maxi.riken.jp/grbs/>



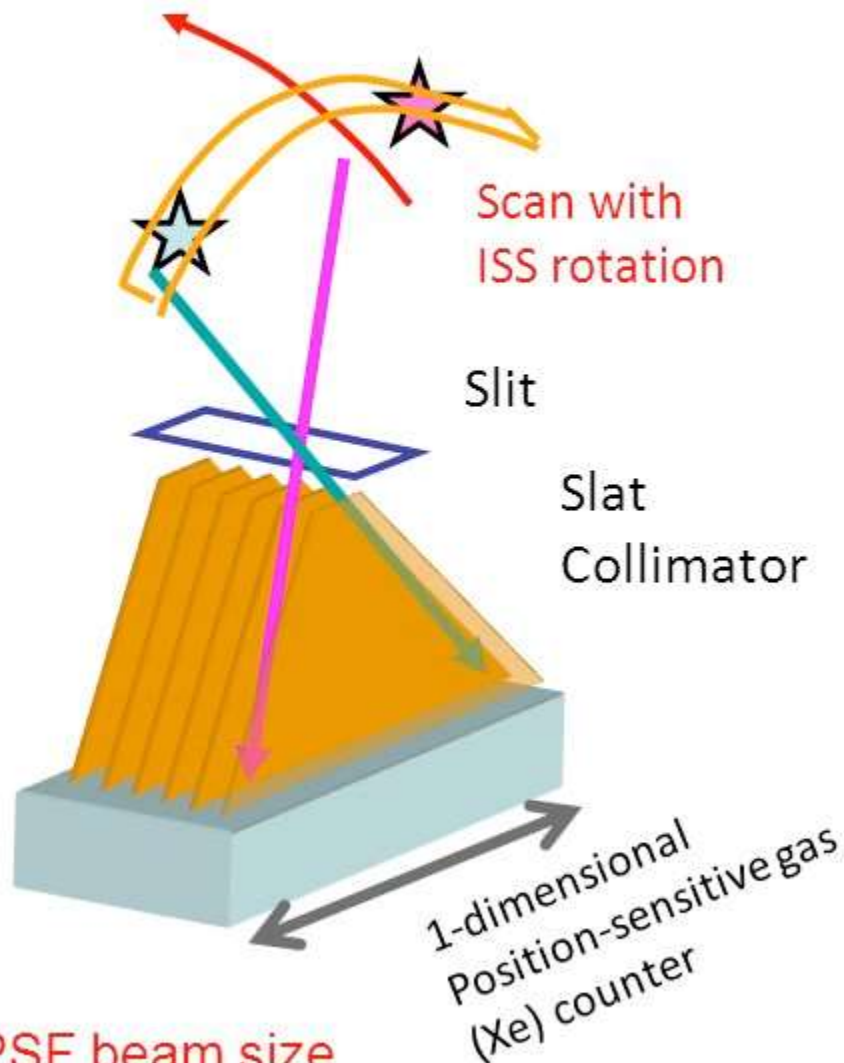


Serino+ 2014



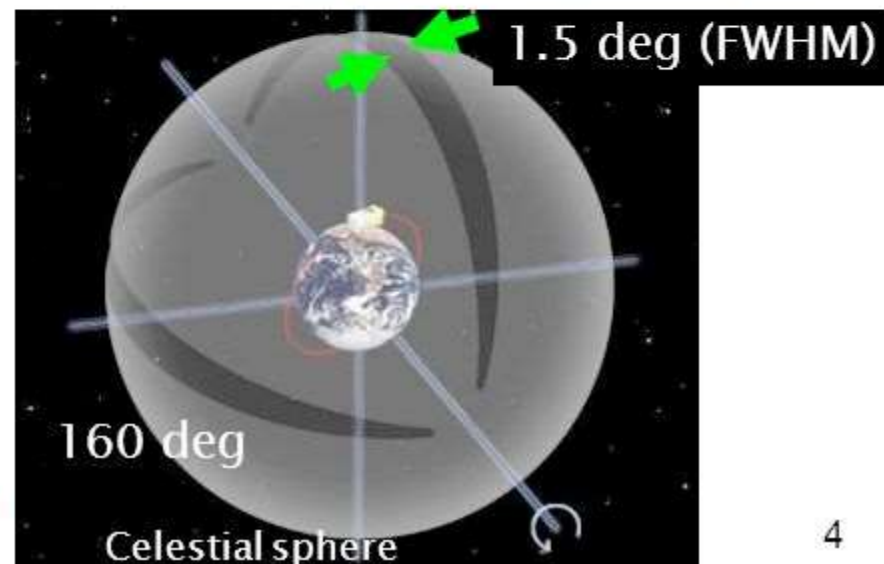
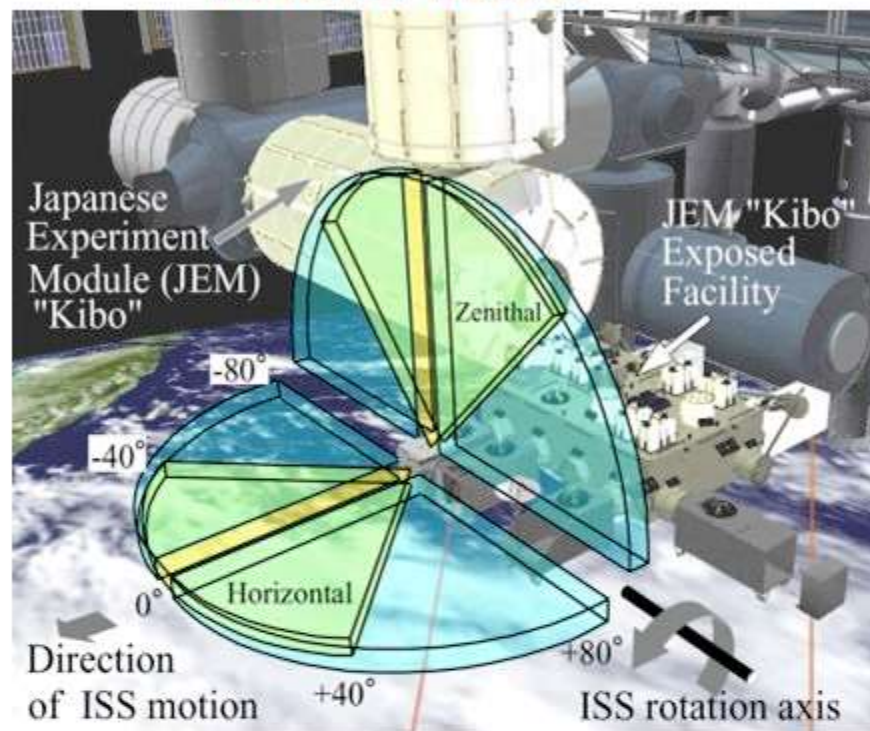
1. Rich in X-rays, so XRF
2.  $\log(n)$ - $\log(S)$  and peak flux suggests a closer distance than GRBs
  - Low luminosity GRBs?
  - A class of supernovae driven by underlying relativistic engine (GRB980425/SN1998bw)?
3. SN1998bw was particularly bright in radio
  - Search for radio and thence optical counterparts

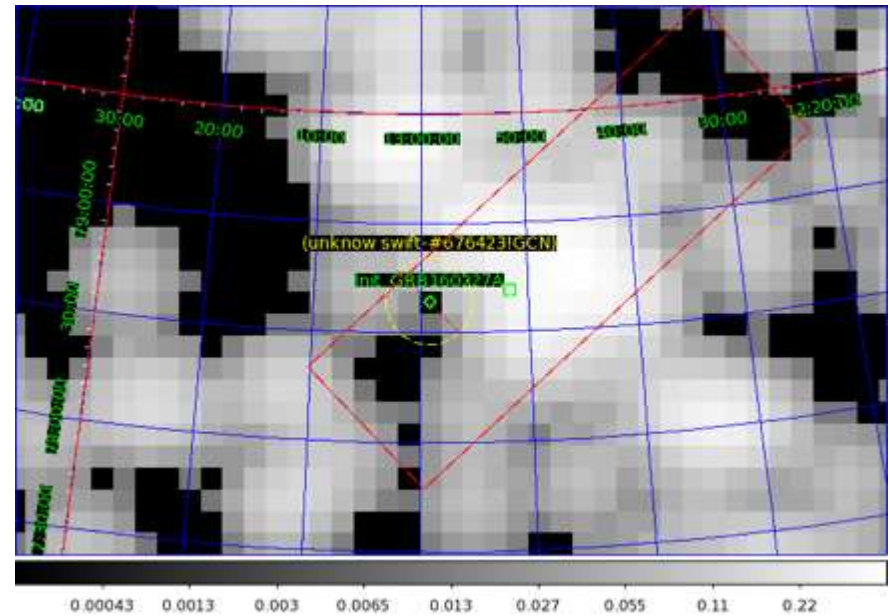
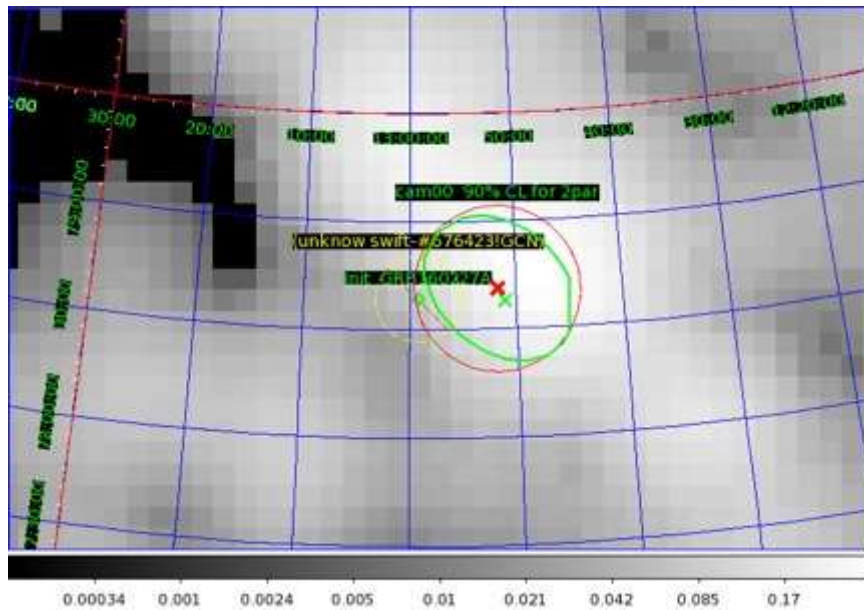
# Gas Slit Camera (GSC) on MAXI



PSF beam size  
~ 1.5x1.5 deg. Energy band: 2-30 keV

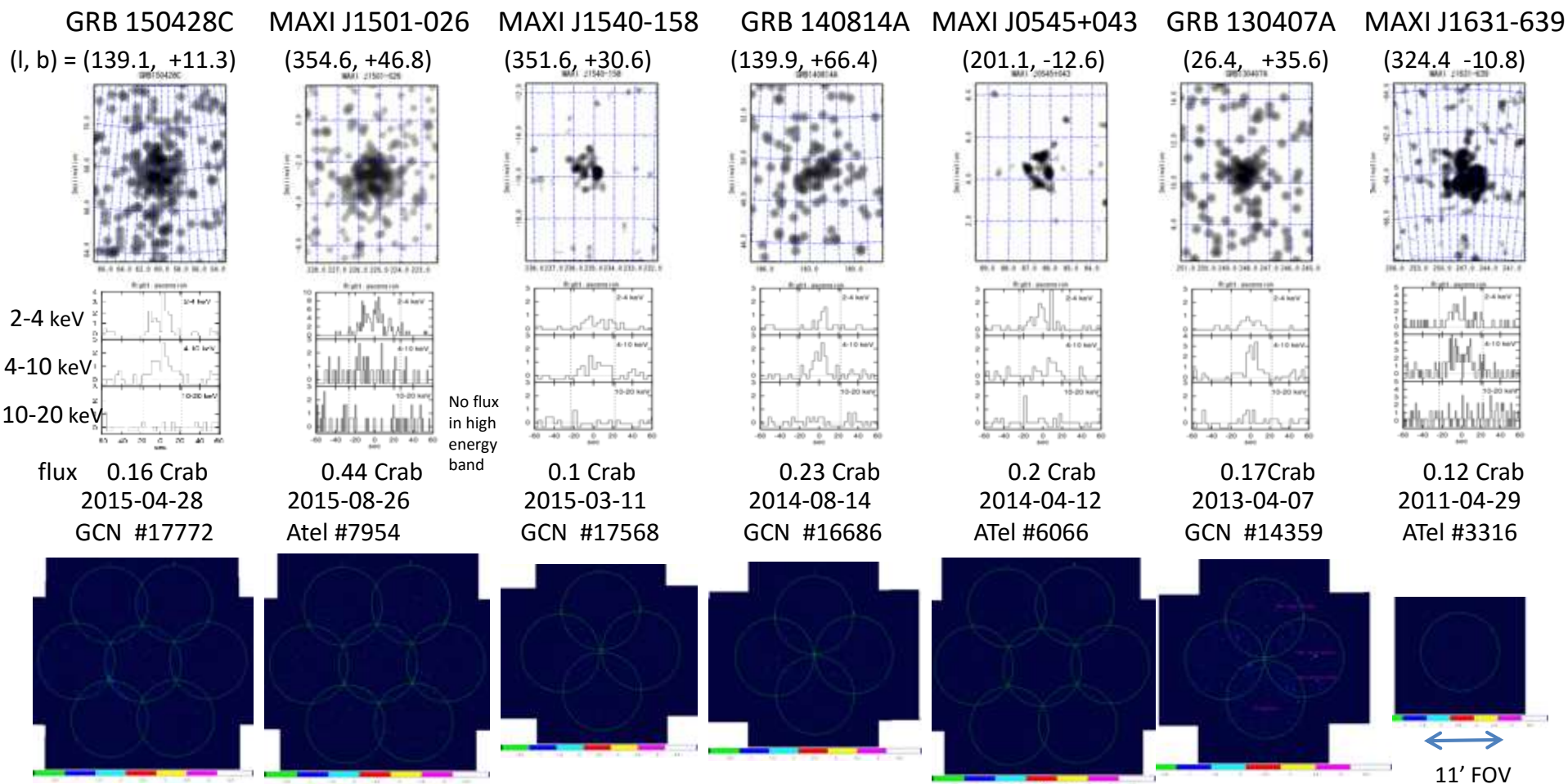
## Field of Views





Challenge is coarse localization: 1/2 degree x 3 degree





MAXI light curves not corrected for collimator transmission

1. ZTF has the capacity to identify *one young supernovae per night* (<24 hours old)
2. Between Palomar, Keck and Liverpool we are very well set up for both ultra-low & low spectroscopy and imaging
3. The MAXI rate of XRFs is one very two months
  - VLA imaging (using OTFM), ZTF imaging
  - Follow up world wide

1. MAXI: A collaboration between Caltech, Tokyo Tech and NRAO.
  - Good graduate student thesis project
2. Young supernovae: This constitutes two key projects within ZTF and is also a major project for the public use of ZTF. Expect considerable activity within the ZTF group and also by the US community.