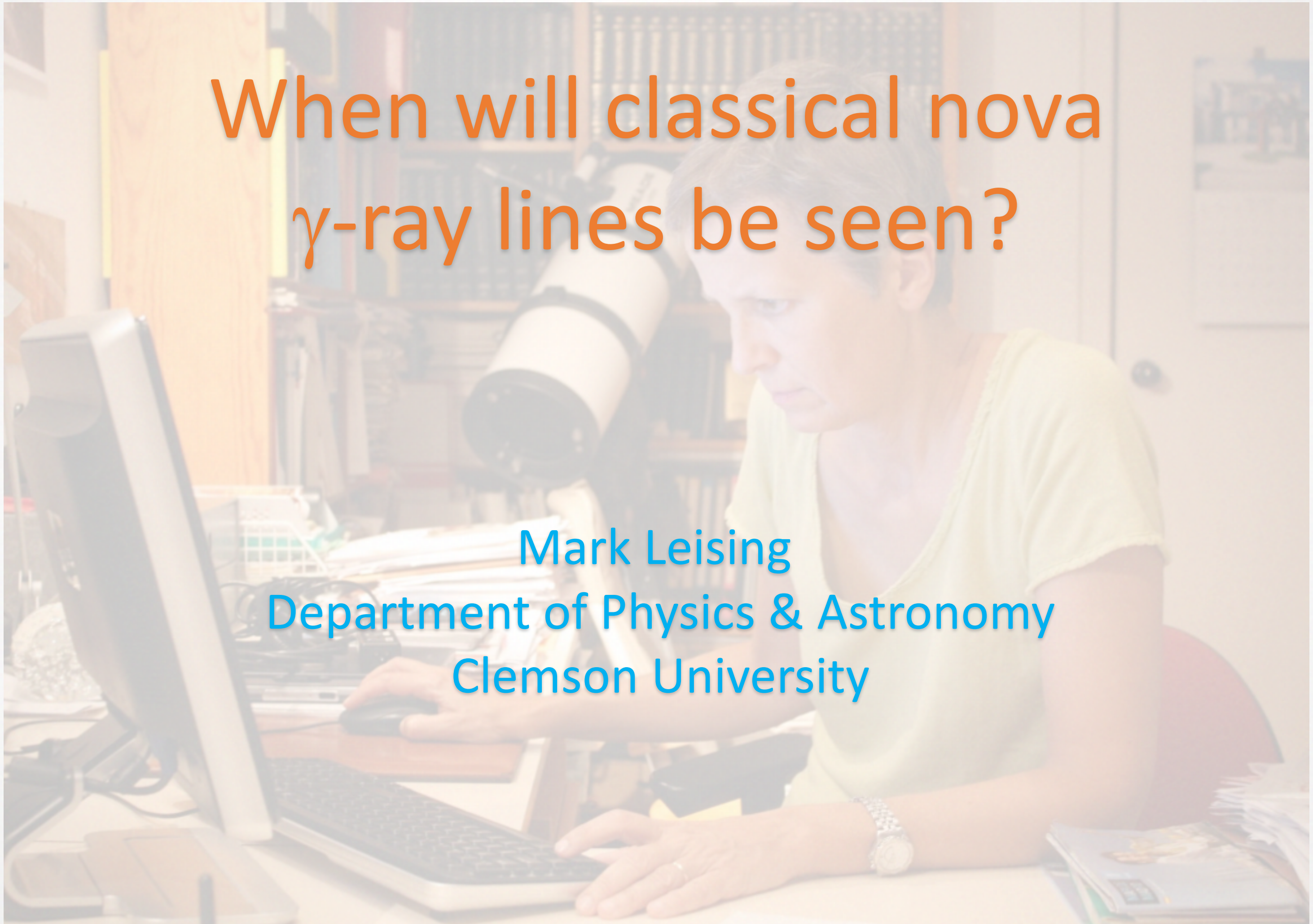


When will classical nova γ-ray lines be seen?

Mark Leising
Department of Physics & Astronomy
Clemson University

Gamma-ray lines from classical novae

Some of the history

Clayton and Hoyle 1974

Nova explosions may be accompanied by detectable levels of radioactivity. Positron annihilation and nuclear de-excitation following decays of ^{13}N, ^{14}O, ^{15}O, and ^{22}Na lead to gamma-ray line fluxes whose measurement will clarify the model.

Clayton 1981 ^{7}Be gamma-ray line

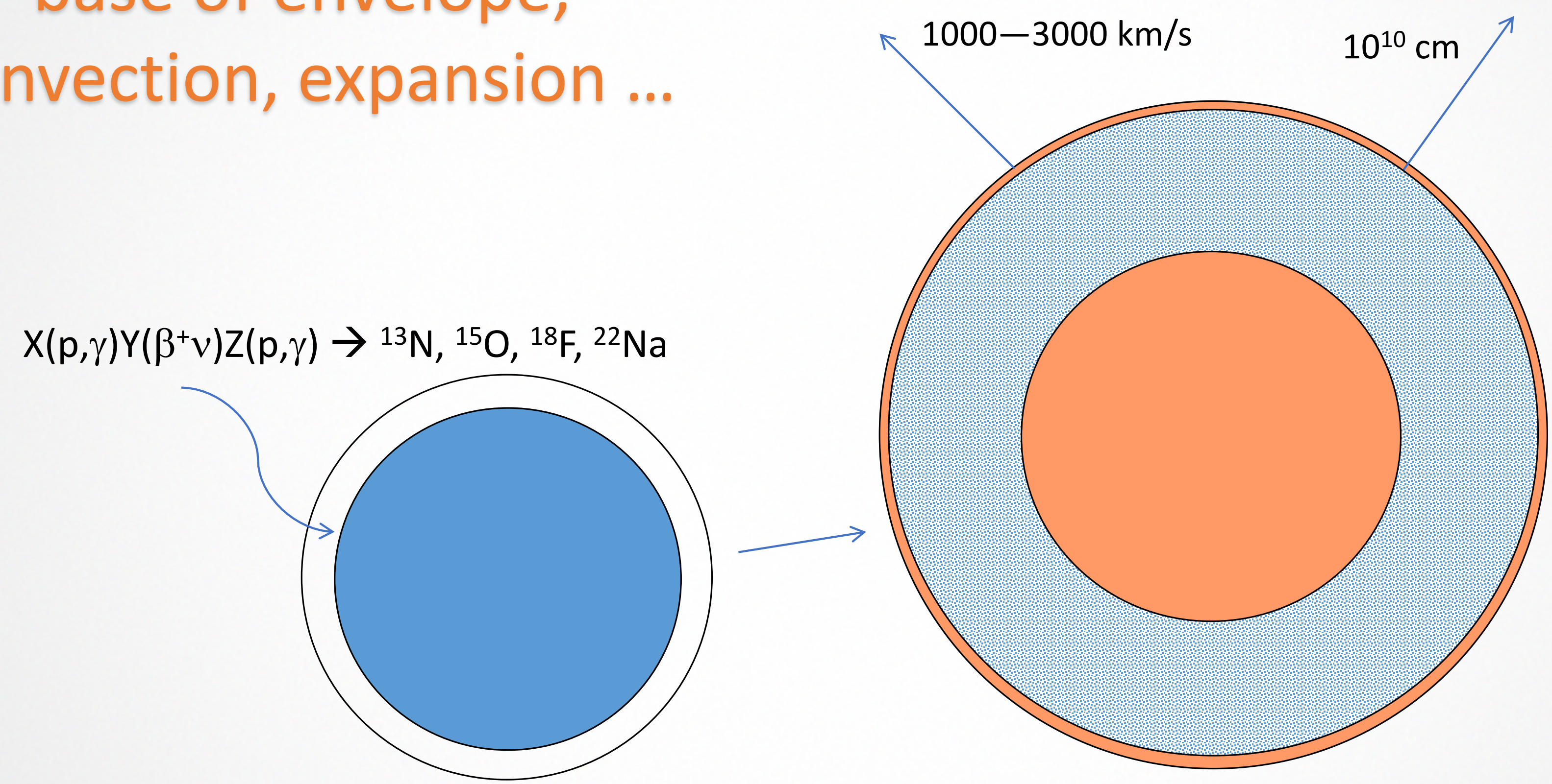
Leising and Clayton 1987 ^{18}F, ^{34m}Cl, monte carlo

Hernanz+ 1997a
Hernanz+ 1997b
Gomez-Gomar+ 1998
Hernanz+ 1999a
Hernanz+ 1999b
Hernanz+ 2000

Jean+ 2000
Hernanz+ 2001a
Hernanz+ 2001b
Hernanz+ 2002a
Hernanz 2002
Hernanz+ 2002b

Hernanz+ 2004
Hernanz+ 2005
Hernanz+ 2006
Senziani+ 2008
Hernanz 2012
Hernanz 2014

Thermonuclear runaway at base of envelope, convection, expansion …



e.g., Starfield, Truran, Sparks 1978

Uncertainties (*diagnostics!*)

Nucleosynthesis

- seeds
- cross-sections
- T_{peak}

Much great work

Convection

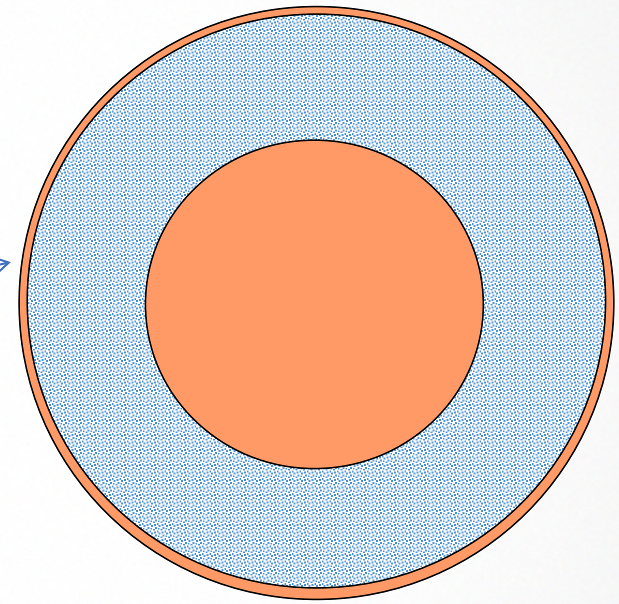
- must get e+ near surface
- might preserve some fragile e^+ emitters

Annihilation mode

- early – line: direct and singlet state Ps
- late – line and cont Ps

Asphericity

$$r = 10^{10}\ cm \quad M_\gamma \simeq 2 \times 10^{-11} M_\odot$$



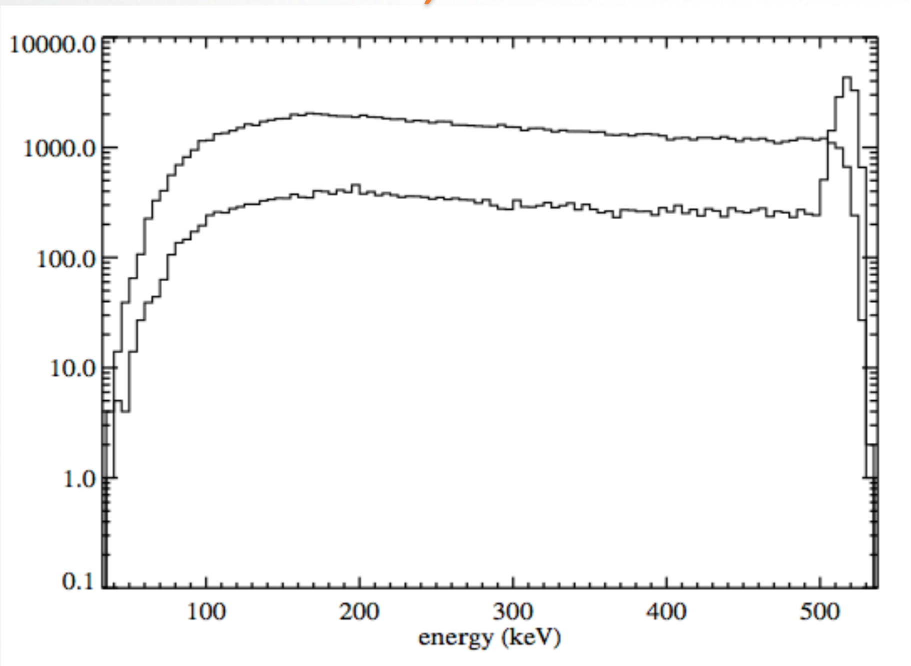
$$r = (3600\, s)(3000\, km/s) \quad M_\gamma \simeq 2 \times 10^{-7} M_\odot$$

Annihilation mode

early – 511 line

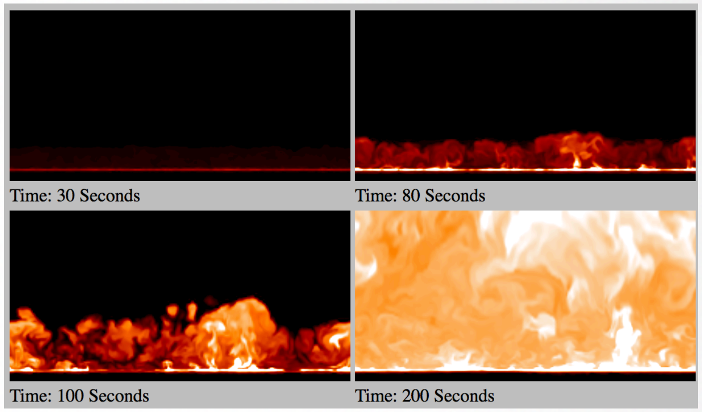
late -- line and Ps continuum

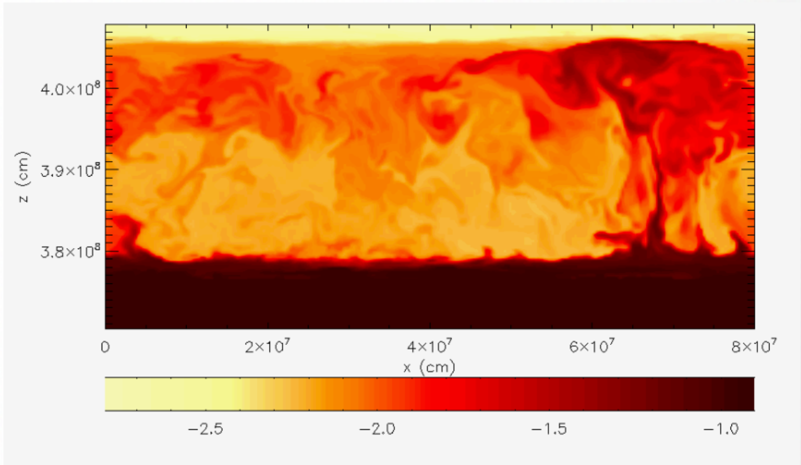
With ^{3}Ps, still thick



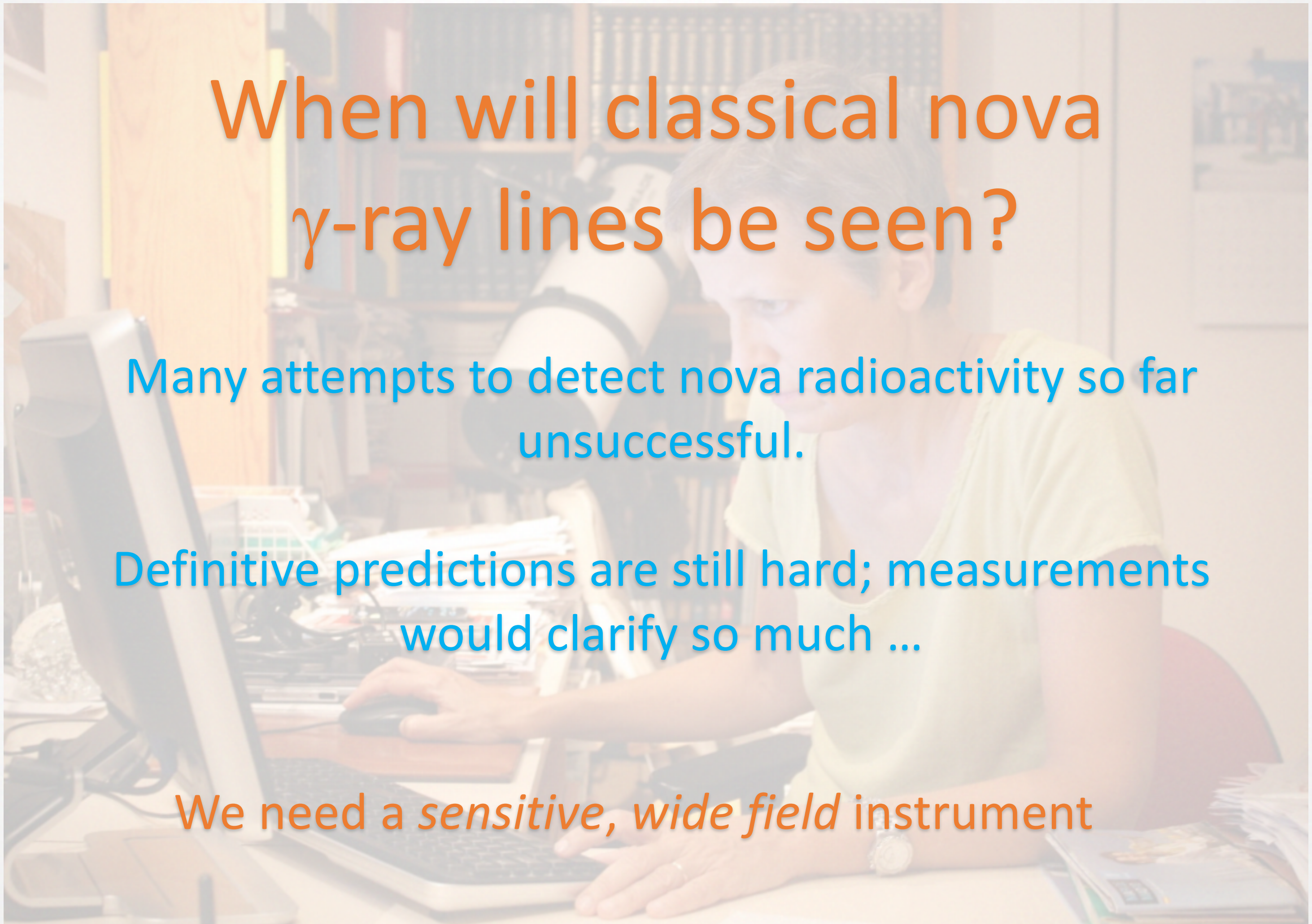
Convection/Asphericity

Kercek et al. 1998, ^{14}O





Casanova et al. 2016, ^{20}Ne

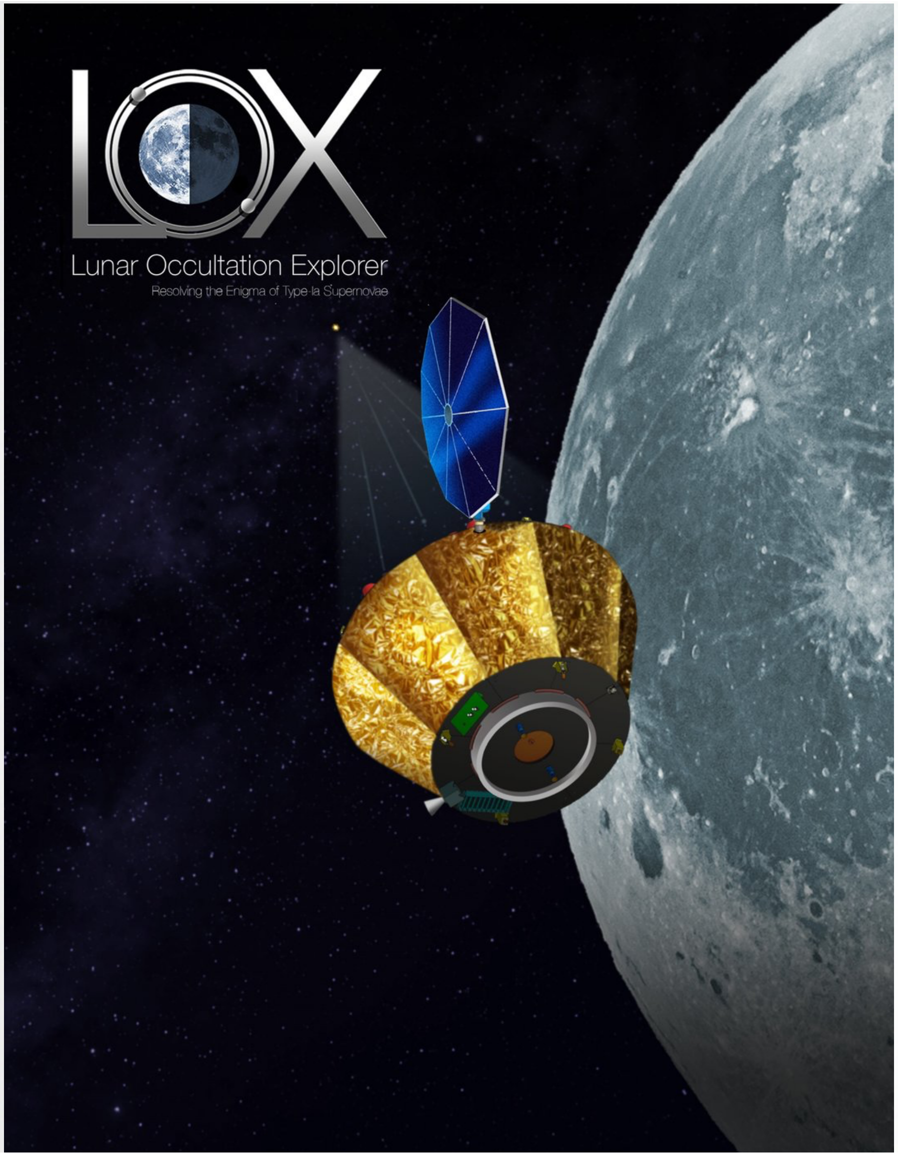


When will classical nova γ-ray lines be seen?

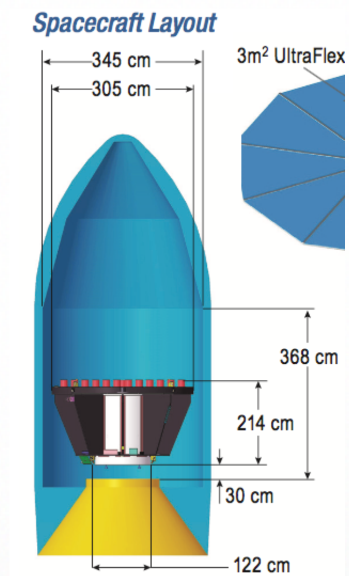
Many attempts to detect nova radioactivity so far unsuccessful.

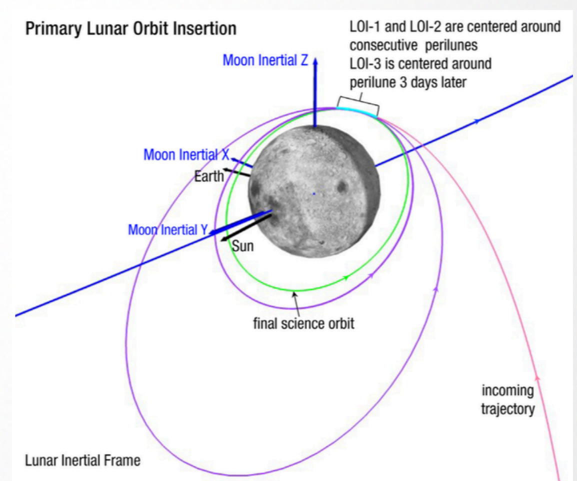
Definitive predictions are still hard; measurements would clarify so much …

We need a *sensitive, wide field* instrument



- Large array of simple detectors
- uses lunar occultations for background estimation
- *Lunar Prospector* heritage
- 2016 MIDEX proposal to NASA





LOX

Lunar Occultation Explorer

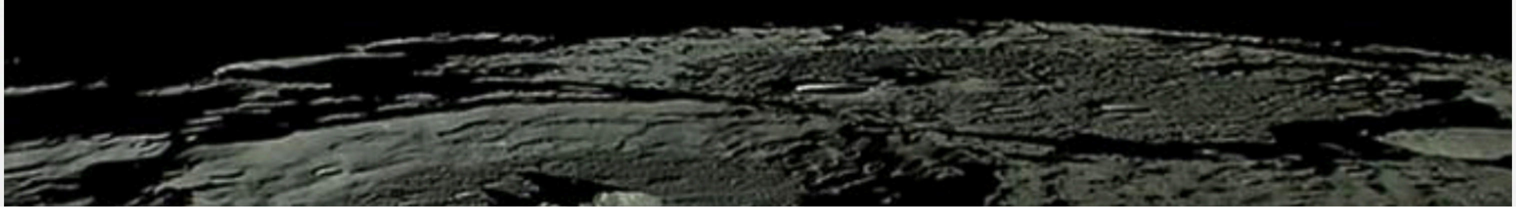
Resolving the Enigma of Type-Ia Supernovae

M. Ajello, J.F. Beacom, P.F. Bloser, A. Burrows, M. Errando, J.O. Goldsten,
D. Hartmann, P. Hoeflich, A. Hungerford, D.J. Lawrence, M.D. Leising, J.C. Leary,
R.S. Miller, P. Milne, P.N. Peplowski, E.L. Reynolds, L.-S. The

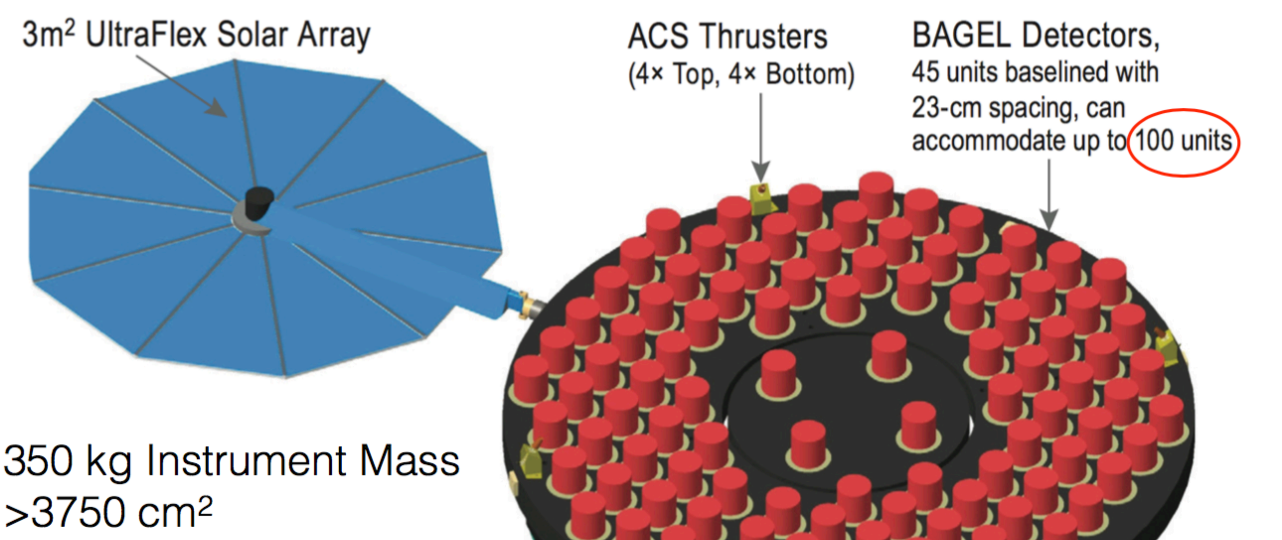
THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

JOHNS HOPKINS APPLIED PHYSICS LABORATORY

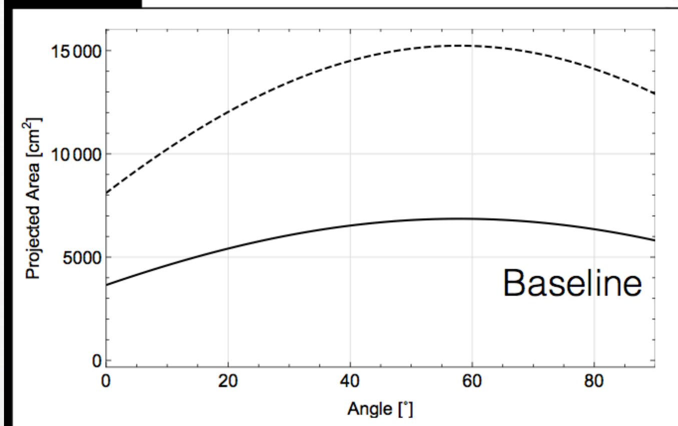
Los Alamos NATIONAL LABORATORY EST. 1943



Implementation: LOX is Low-Risk, High-Heritage



350 kg Instrument Mass
>3750 cm²



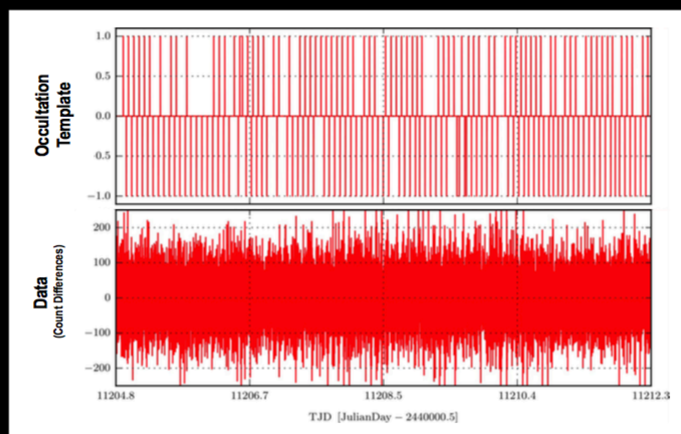
LOT: Validation

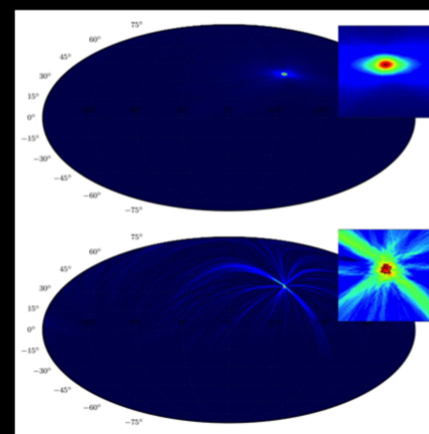
THE ASTROPHYSICAL JOURNAL LETTERS, 823:L31 (7pp), 2016 June 1
doi:10.3847/2041-8205/823/2/L31

CrossMark

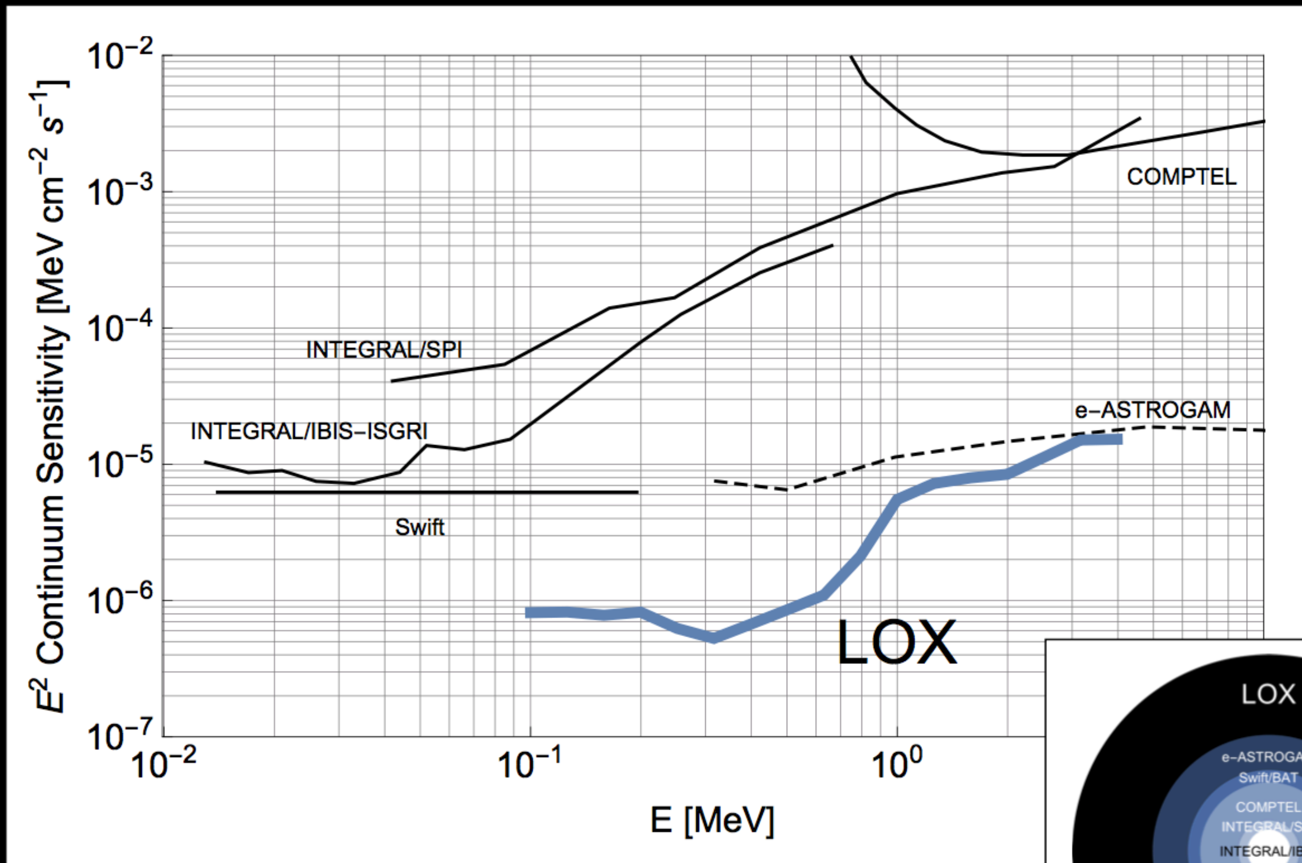
FIRST LIGHT: MeV ASTROPHYSICS FROM THE MOON

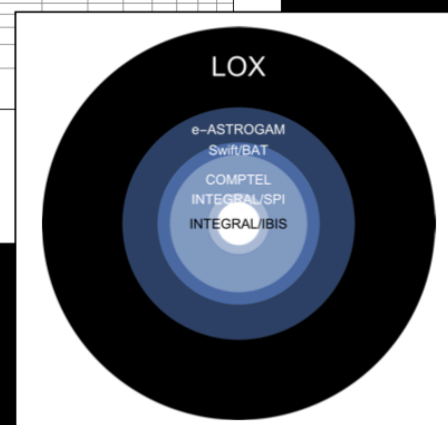
RICHARD S. MILLER[1] AND DAVID J. LAWRENCE[2]
[1] University of Alabama in Huntsville, 301 Sparkman Drive, Huntsville, AL 35899, USA; richard.s.miller@uah.edu
[2] Johns Hopkins University Applied Physics Laboratory, 11100 Johns Hopkins Road, Laurel, MD 20723, USA
Received 2016 May 4; revised 2016 May 12; accepted 2016 May 12; published 2016 May 26





- LP Gamma-Ray Spectrometer (Proxy)
- Broadband Spectrum Acquisition → Cadence
- 1.29×10^6 Spectra

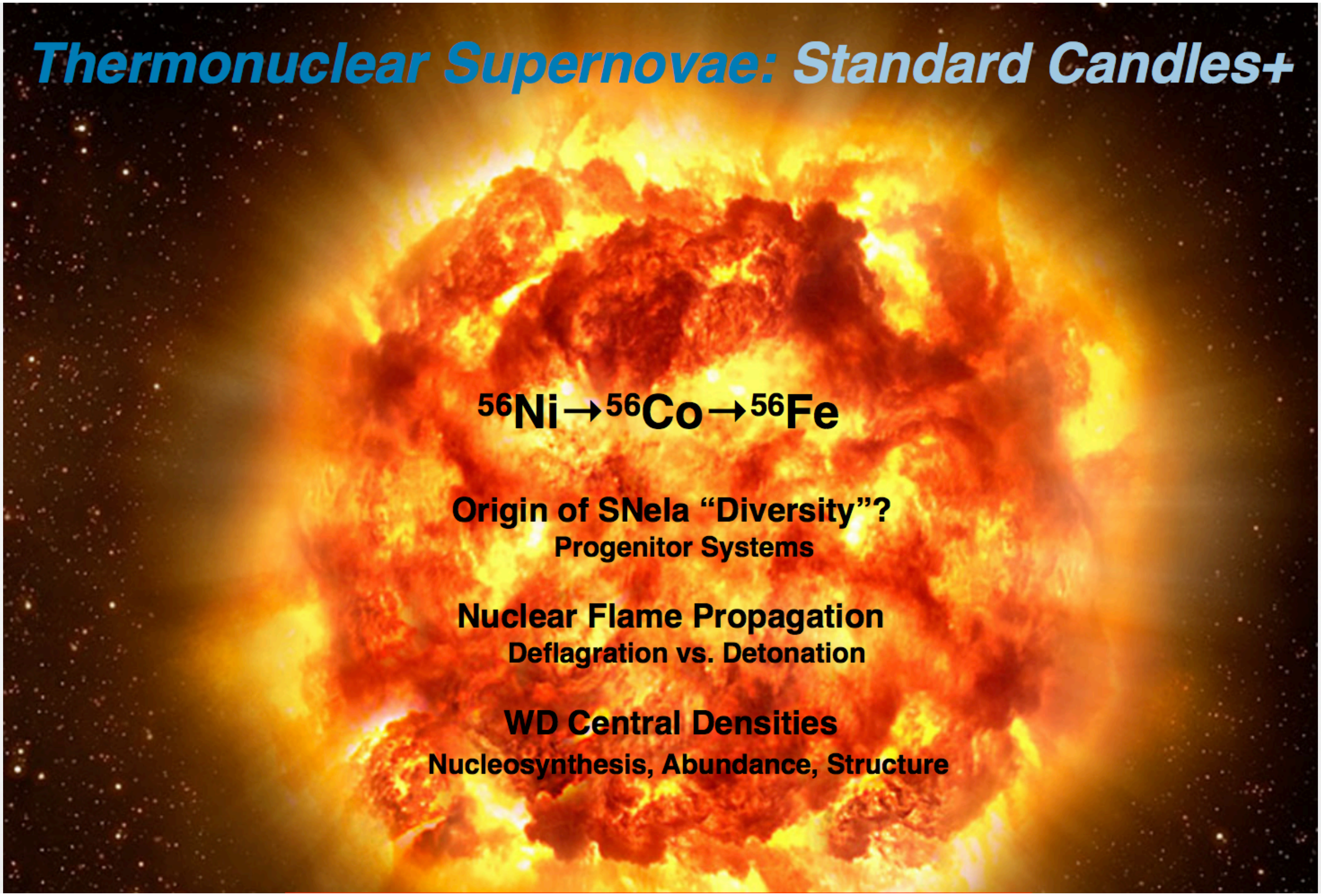




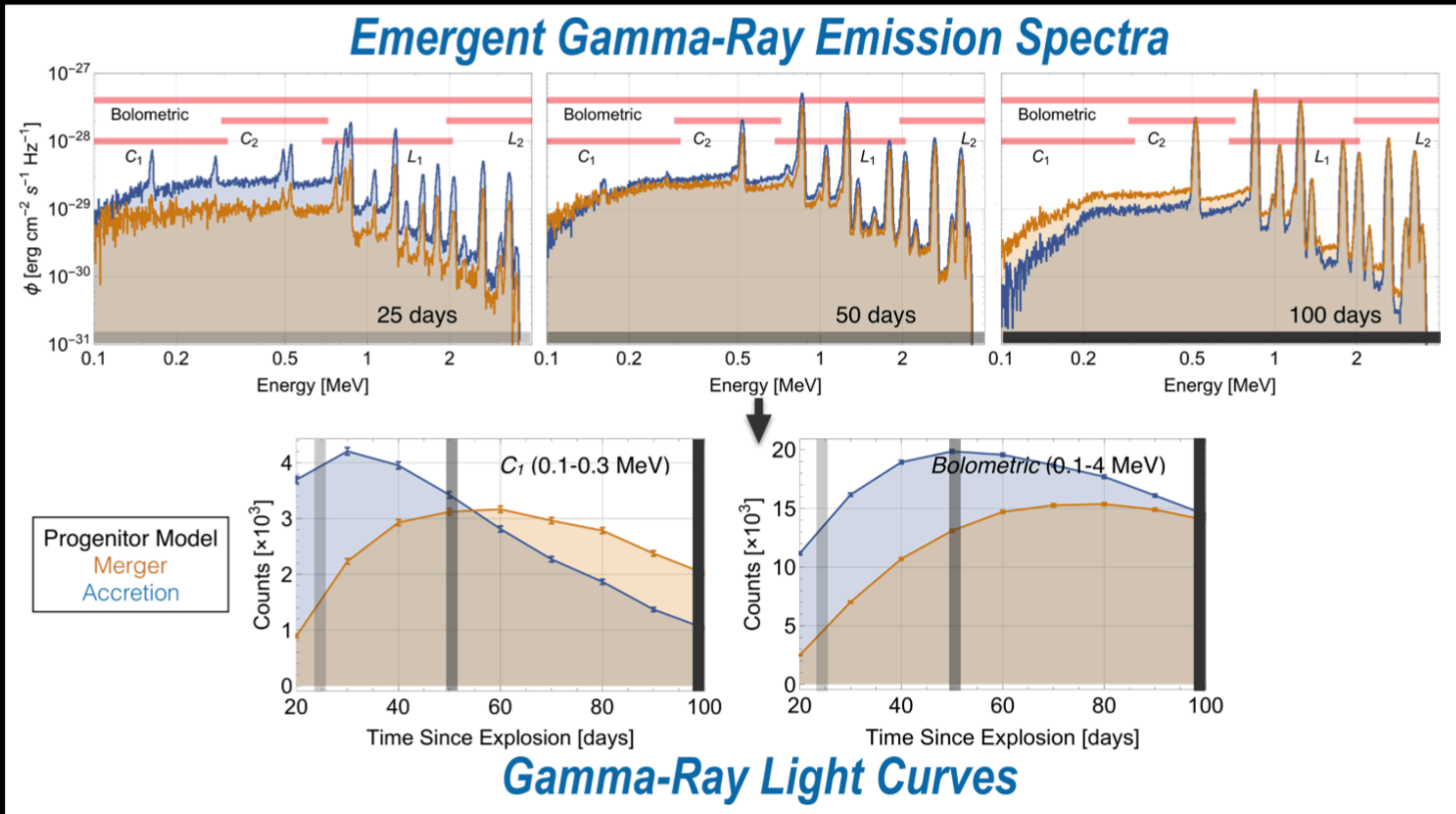
Enhanced Sensitivity w/ T_{obs}

(Cost to Light Curve Parameterization)

10^6 second
3σ Sensitivity
Baseline Configuration


Thermonuclear Supernovae: Standard Candles+
$^{56}Ni \rightarrow {}^{56}Co \rightarrow {}^{56}Fe$
Origin of SNeIa “Diversity”?
Progenitor Systems
Nuclear Flame Propagation
Deflagration vs. Detonation
WD Central Densities
Nucleosynthesis, Abundance, Structure

Strategy: SNela Light Curves



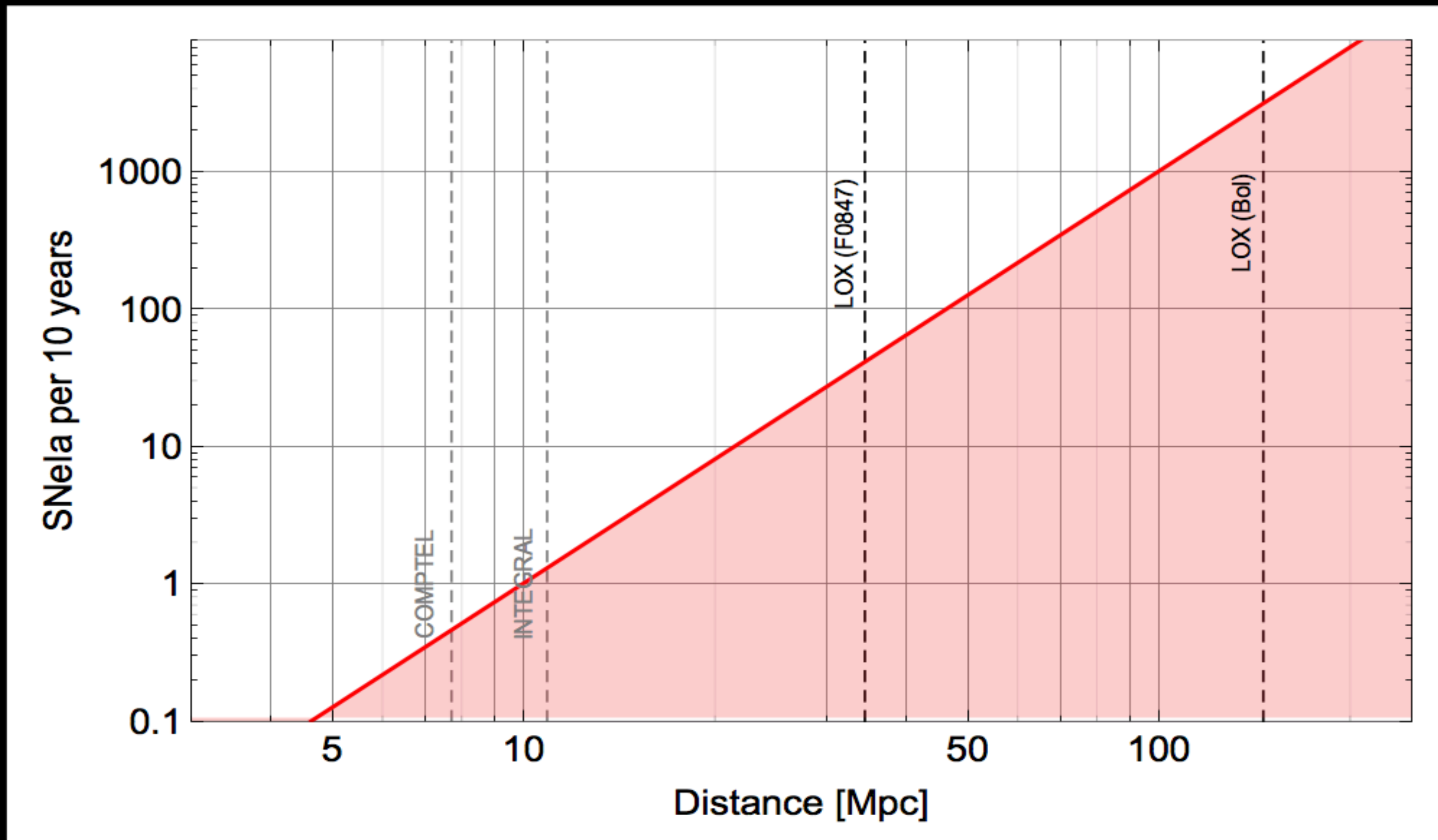
C_1 (0.1-0.3 MeV): Dominated by Compton continuum; ^{56}Ni lines early post-explosion

C_2 (0.3-0.7 MeV): Strong Compton continuum; some line emission including e^+-e^- annihilation

L_1 (0.7-2 MeV): Dominated by ^{56}Co lines; moderate Compton continuum

L_2 (2-4 MeV): Dominated by ^{56}Co lines; weak Compton continuum

Sensitivity Horizon: Event Rates



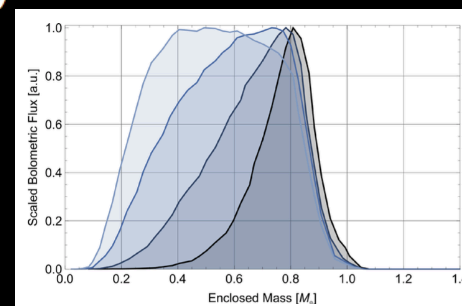
N100 (Seitenzahl, 2013) Model @ 50 days Post-Explosion

$$R_{\mathrm{SNeIa}} = 0.24 \times 10^{-4}\ \mathrm{yr}^{-1}\ \mathrm{Mpc}^{-3}$$

Horiuchi & Beacom (2010)

Strategy: SNeIa Light Curves

- Science Goal A: Probe Thermonuclear Physics of SNeIa
  - Fundamental Parameter Proxies: KE, Total Mass, ^{56}Ni Mass
  - Volumetric Distribution of ^{56}Ni (temporal evolution)
  - Nuclear Flame/Structure



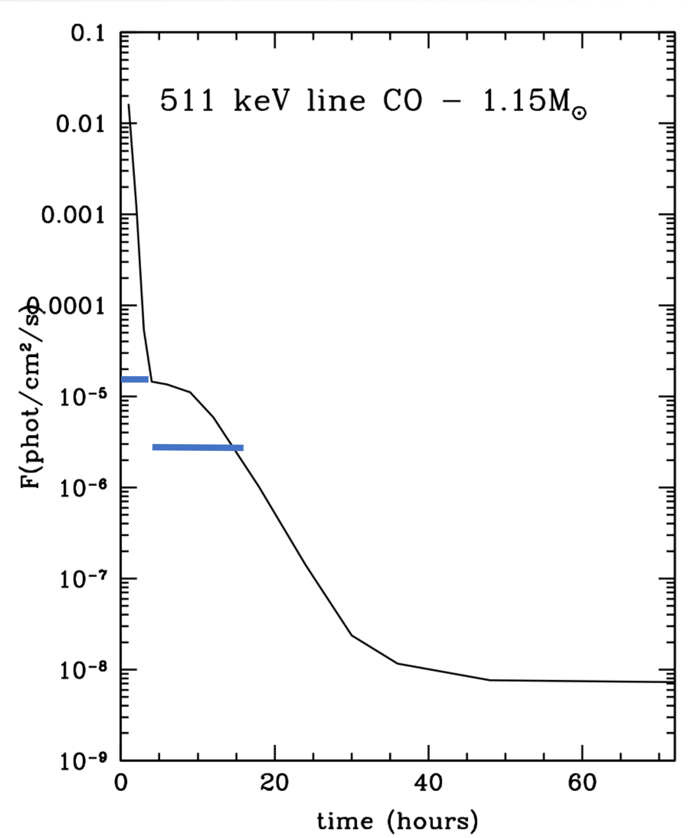
- Science Goal B: Diversity
  - Population Statistics of Fundamental Parameter Proxies
  - Census of SNeIa Sub-Classes → ^{56}Ni Mass, Total Mass, Explosion Energy
  - Census of SNeIa Environments (Galactic Age, Morphology)

Ensemble Population Studies

- Science Goal C: Standardize the Standard Candle
  - Nuclear Diversity ⟺ Optical Diagnostics
  - Gamma+UVOIR: Removal of Circumstellar & Interstellar Effects
  - SNeIa Core (nuclear), Atmosphere (optical/IR), External

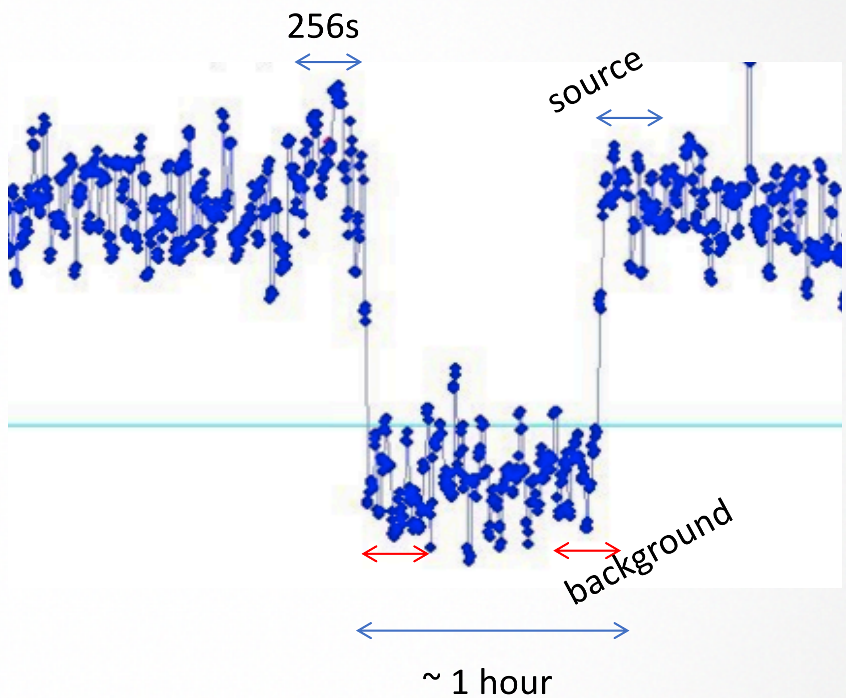
Multi-Wavelength Analyses

Nova LOX



Hernanz 2013

Quoted (SN Ia) sensitivities (10^6 s) are based on ~166 such differences

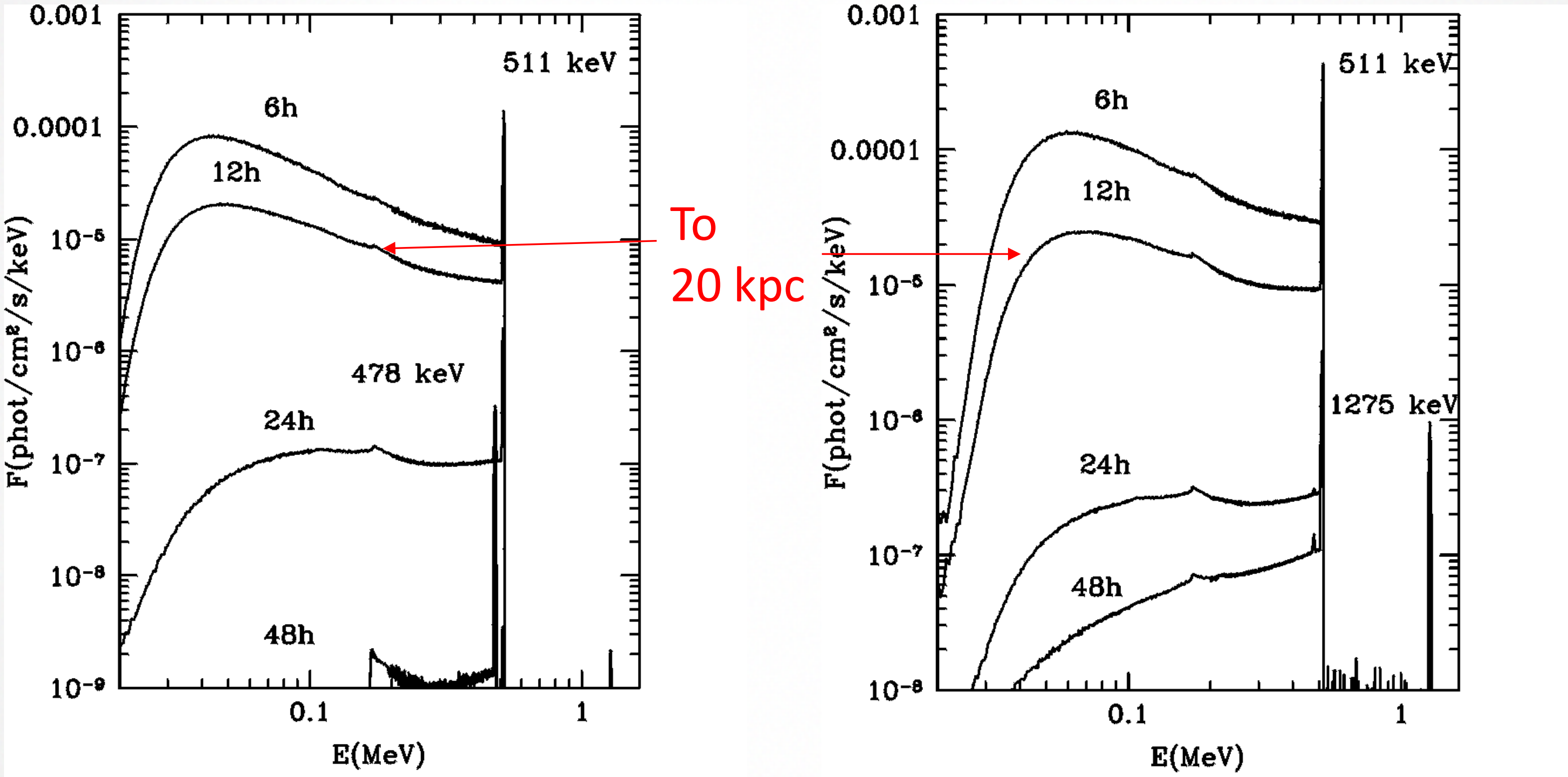


Persistent Lines

^{7}Be 478 keV $F_{lim} = 1.3 \times 10^{-6}$ cm^{-2} s^{-1}

^{22}Na 1275 keV $F_{lim} = 8 \times 10^{-7}$ cm^{-2} s^{-1}

LOX continuum



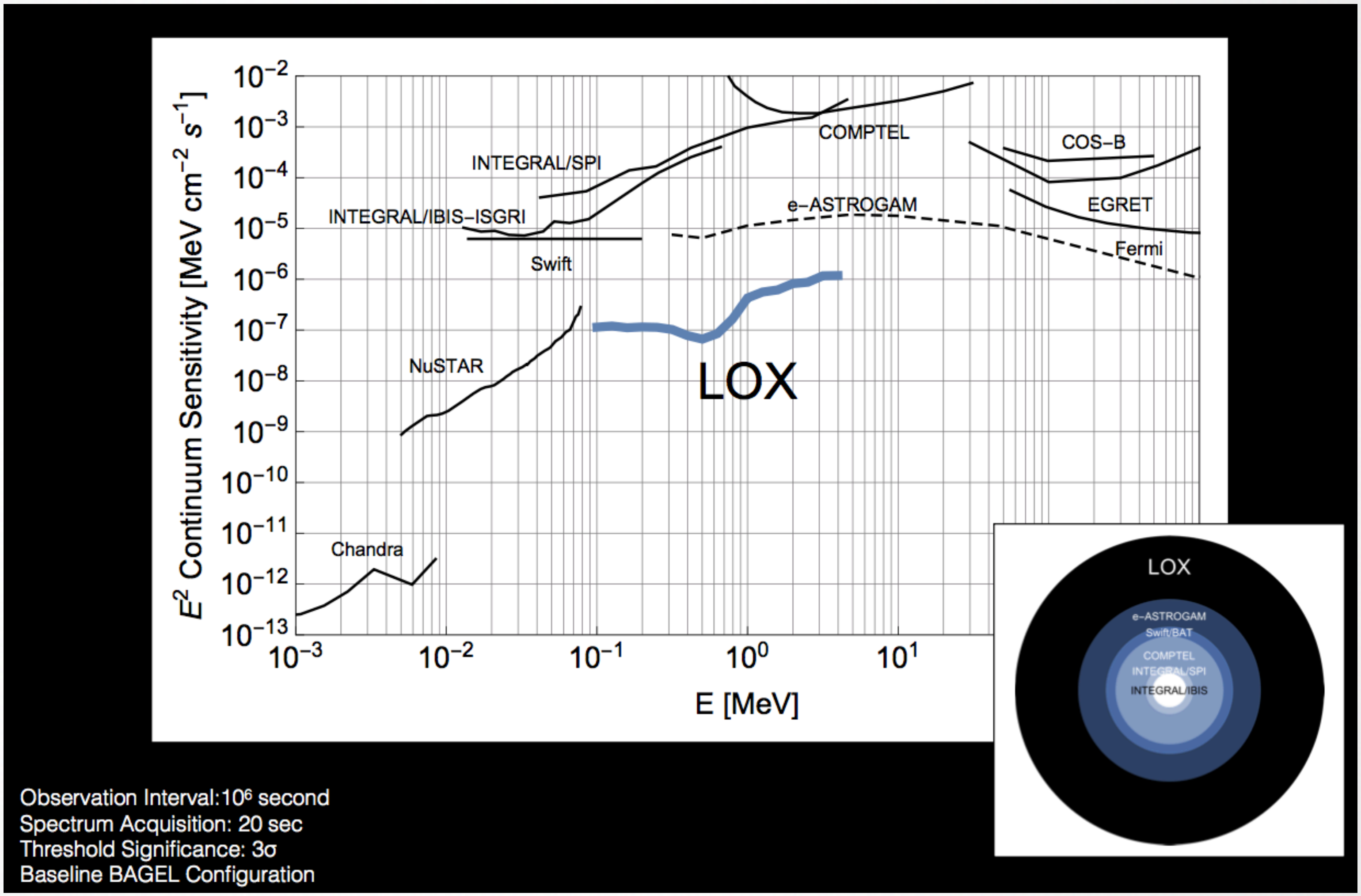
CO nova, 1.15 $M_{\odot}$, d=1kpc; Hernanz et al. 1999

ONe nova, 1.25 $M_{\odot}$, d=1kpc; Hernanz et al. 1999

Potential Improvement:

Global model of background and all sources

Also: AGN, Galactic hard X-ray sources, bright transients, …



21 August 2017

G dwarf occultation event