M31: X-ray sources and search for SNe Ia progenitors

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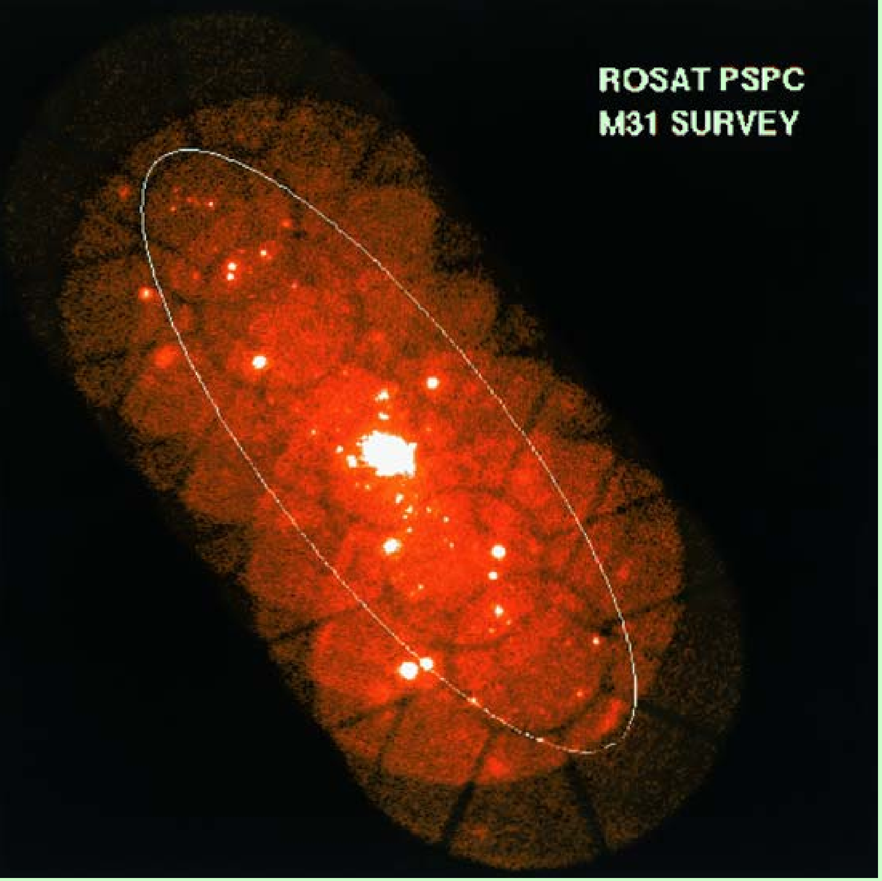
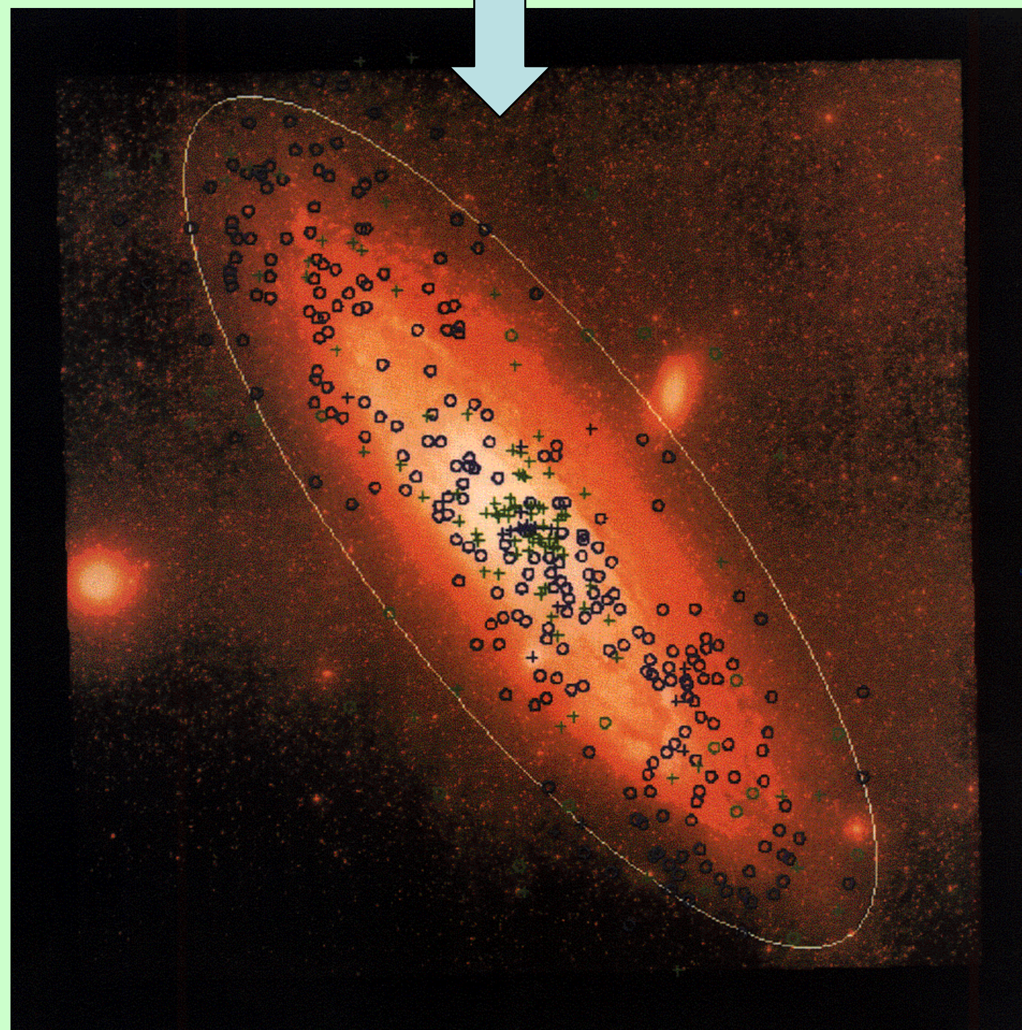
A brief history of M31 X-ray studies

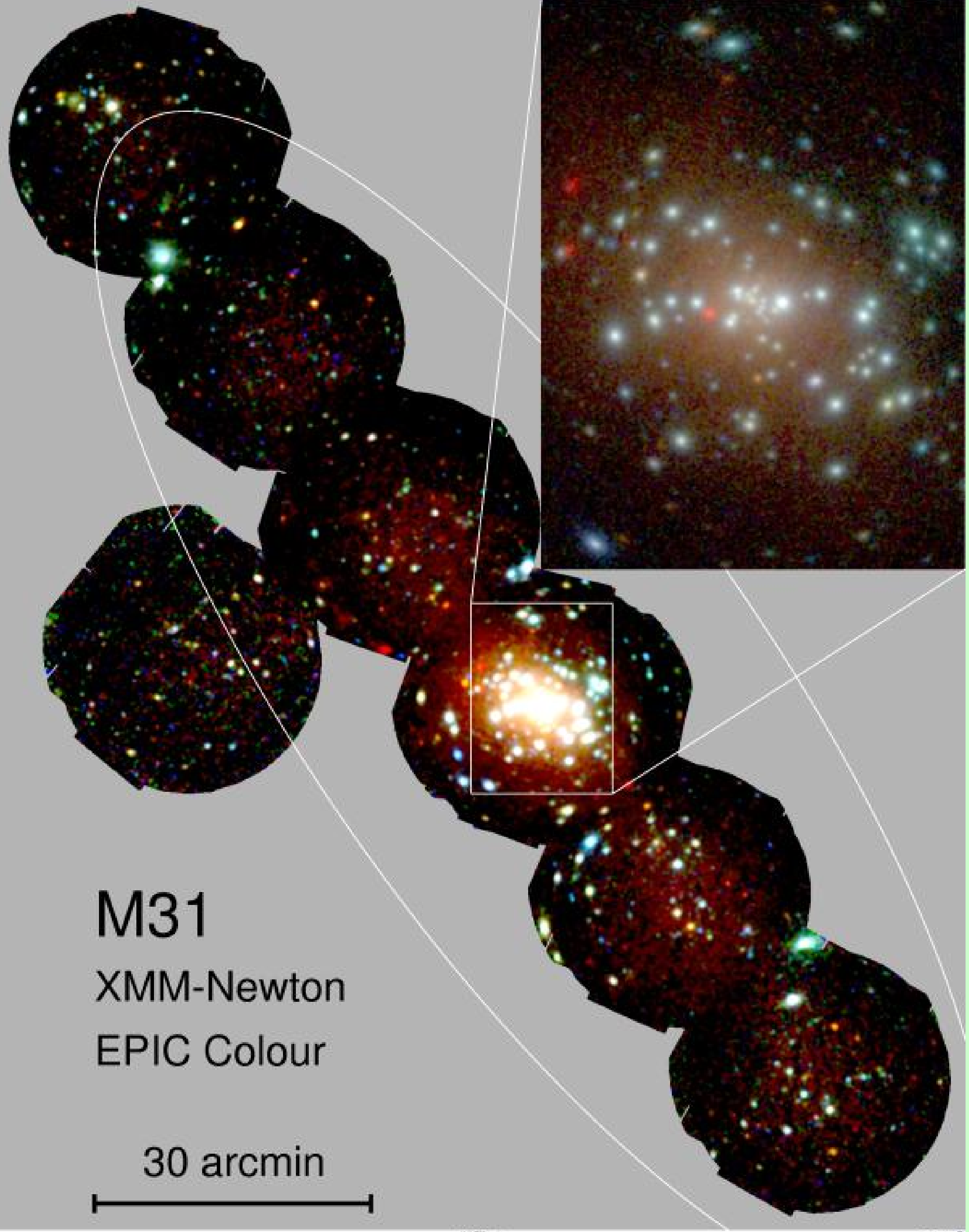
- *Trinchieri & Fabbiano (1991): 108 sources detected with Einstein, limit only >=5x10(36) erg/s. 14 variable sources, 3 arcsec positions, optical follow up by Crampton et al. (1994) . Several sources intrinsic to M31 !*
- *ROSAT PSPC, 1.3 D(25) , PSPC>200 ksec, limit 10(36) erg/s. 396 sources of which only 43 FG, 27 belonging to GC, 17 SNR, 11 SSS. At least 22 bulge sources, of them 16 most likely belong to M31.   (Supper et al)*
- *On average: 20% AGN, 20% FG, 60% of detected XRS belong to M31*
- *Today <~1000 sources known*



6 square degrees coverage

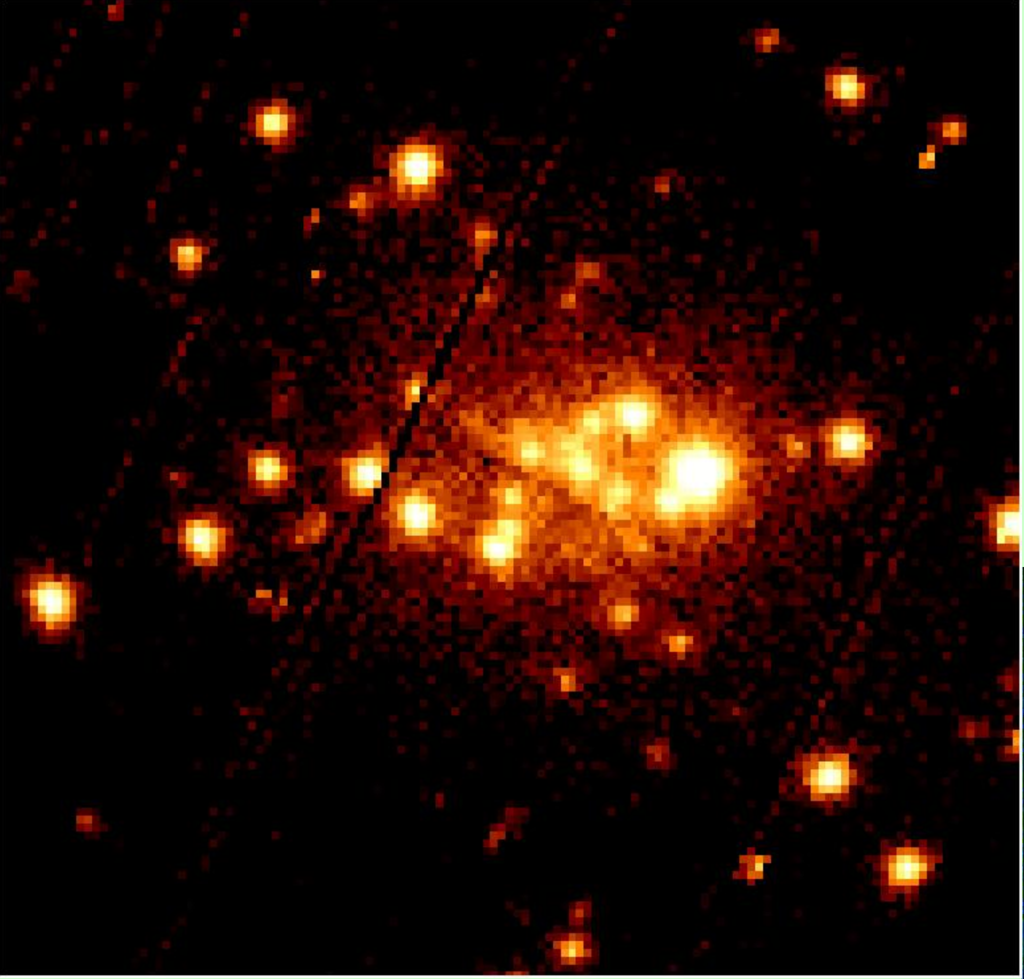
All ROSAT sources





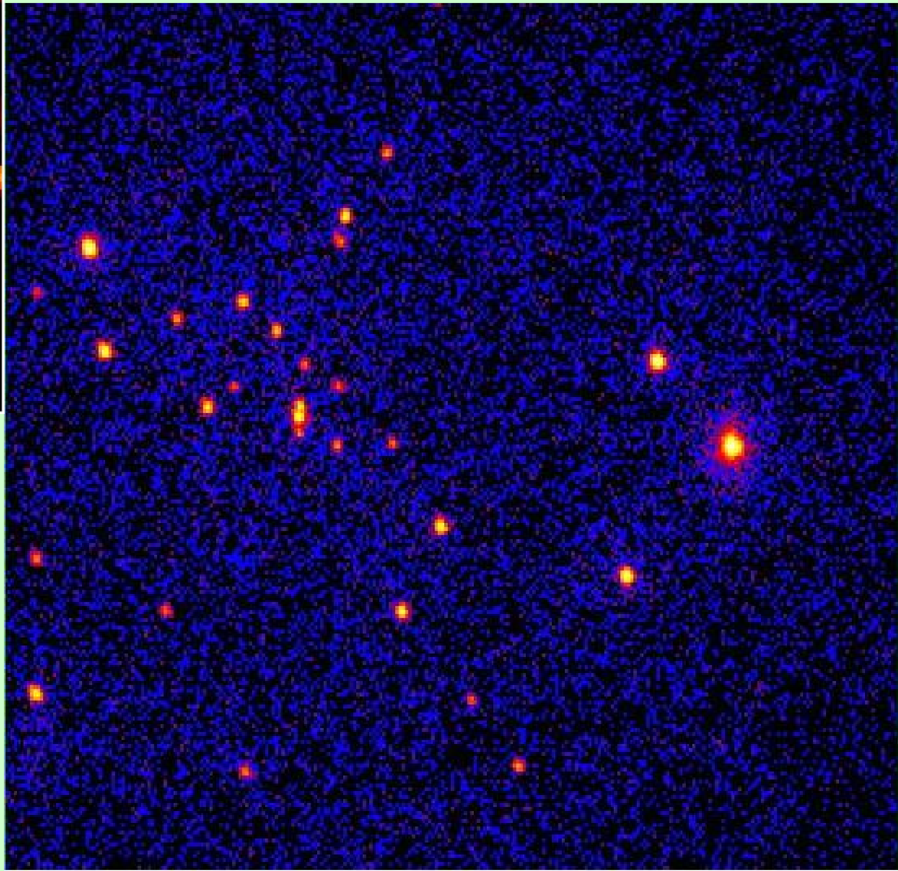
*The lower limit on the X-ray luminosity is 10**(34) -10**(35) erg/s in the existing Chandra and XMM-Newton images: too high to detect quiescent LMXB, but well below outburst luminosity.*

M31 is still monitored with XMM-Newton (no more soft spectra with Chandra ACIS-S), however… no “background limited” exposures have been done or will be done soon.

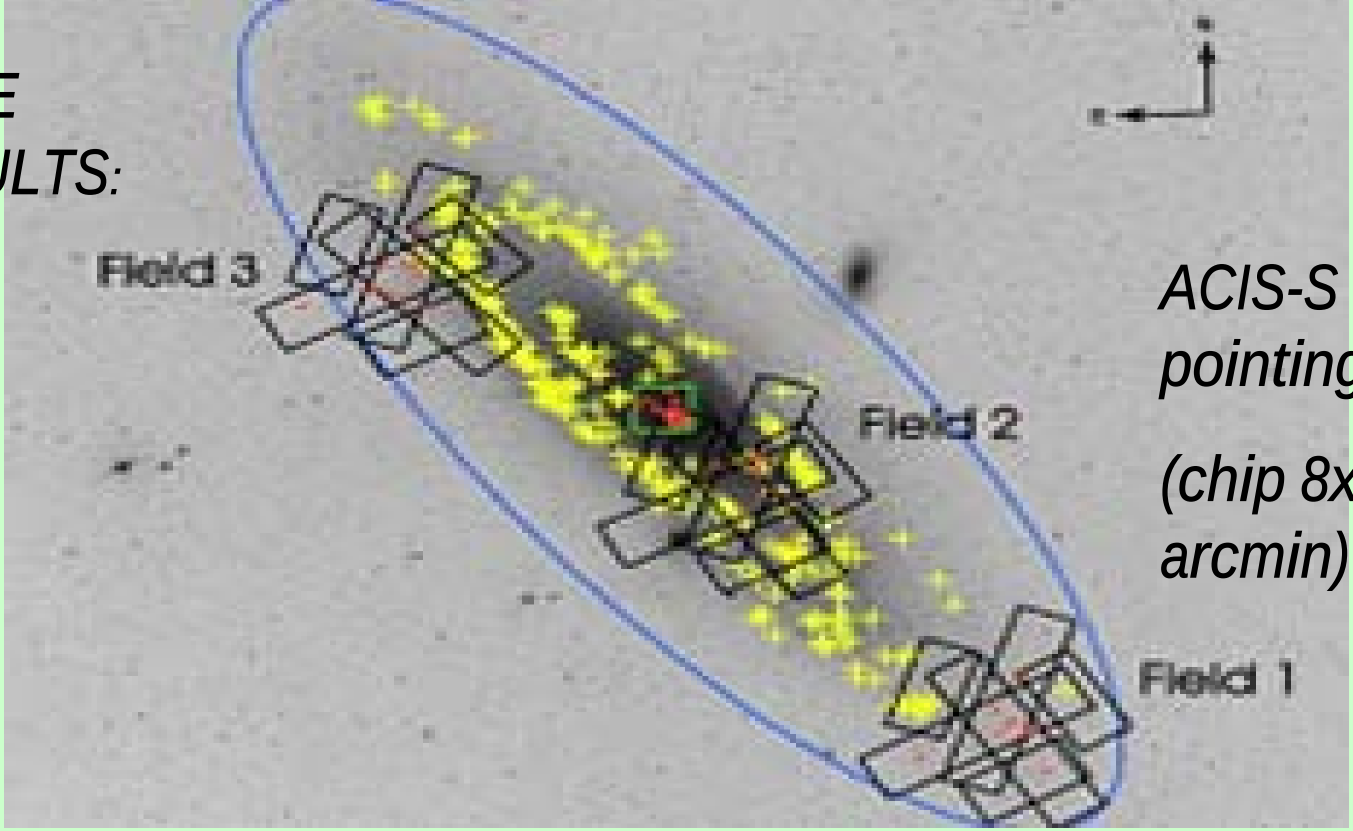


Example of the inner 8 arcmin(2) of the M31 thick disk observed with EPIC-pn (XMM-Newton)

Example of inner 2 arcmin(2) observed with ACIS-S . 17% of XRS (and stars) are here



SOME RESULTS:



ACIS-S deep pointings

(chip 8x8 arcmin)

*** Center studied with HRC: in 17 pointings in 2.5 years 166 objects, 25% variable, 2 transients with variable optical c. At B~22.3 and V=18.8 (Williams et al. 2006). N(NS)/N(BH)~1?***

The most luminous XRB are in globular clusters

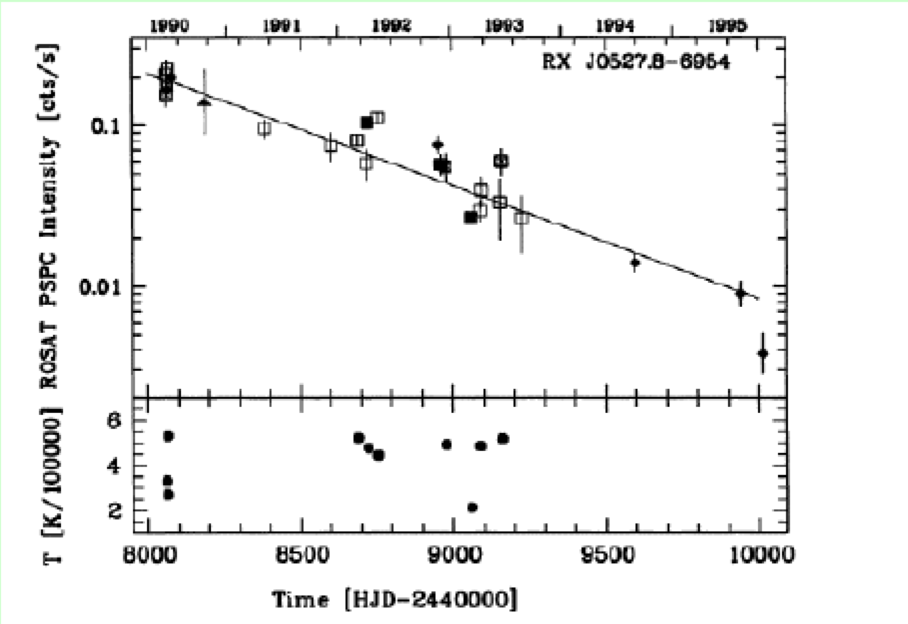
- ***Northern disk: 37 bright sources, 19 likely counterparts, only 5 of them FG stars, 3 SNR.***

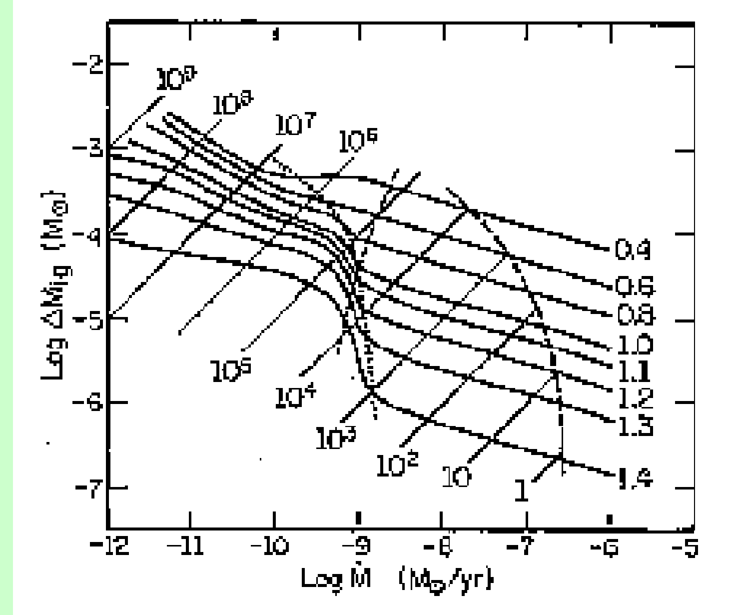
*** Some SNR resolved with Chandra, they are also very soft***

The nature of supersoft X-ray sources:

- Supersoft X-ray sources (SSS) are X-ray sources whose luminosity peaks in the EUV. Due to absorption, most flux is actually detected in supersoft X-rays (<0.8 keV).
- A large part of SSS are thought to be "single degenerate" systems with a WD accreting and burning H in shell at the high rate (Mdot>10(-8) Msol/yr) necessary for type Ia SN progenitors.
- Also many classical novae (CN), 3 (4?) recurrent novae (RN) and a few symbiotic stars have been observed as SSS.
- Other SSS are associated with non-bursting sources, but a large fraction (>20%) seem to be transient.
- Following SSS evolution, determining WD masses, temperatures and abundances we want to learn about the secular evolution of type Ia SN progenitors.

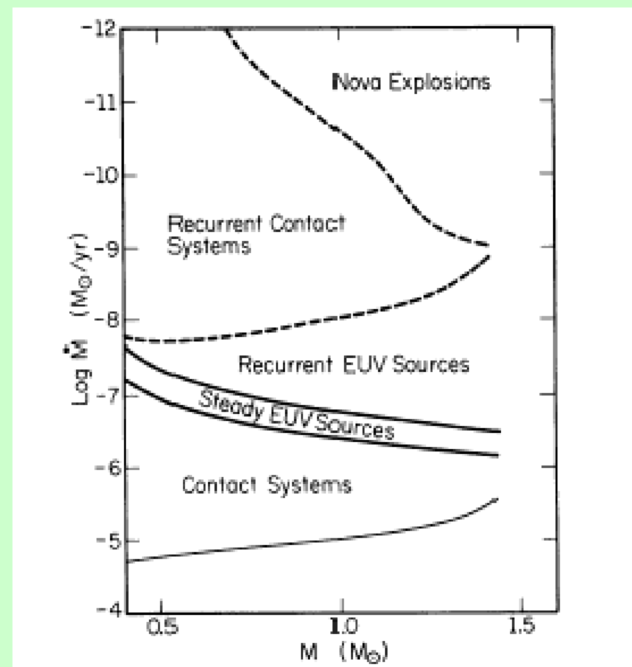
Accreting and H-burning WD:





Recurrent or transient X-ray sources.
Hydrogen shell flashes are indeed recurrent

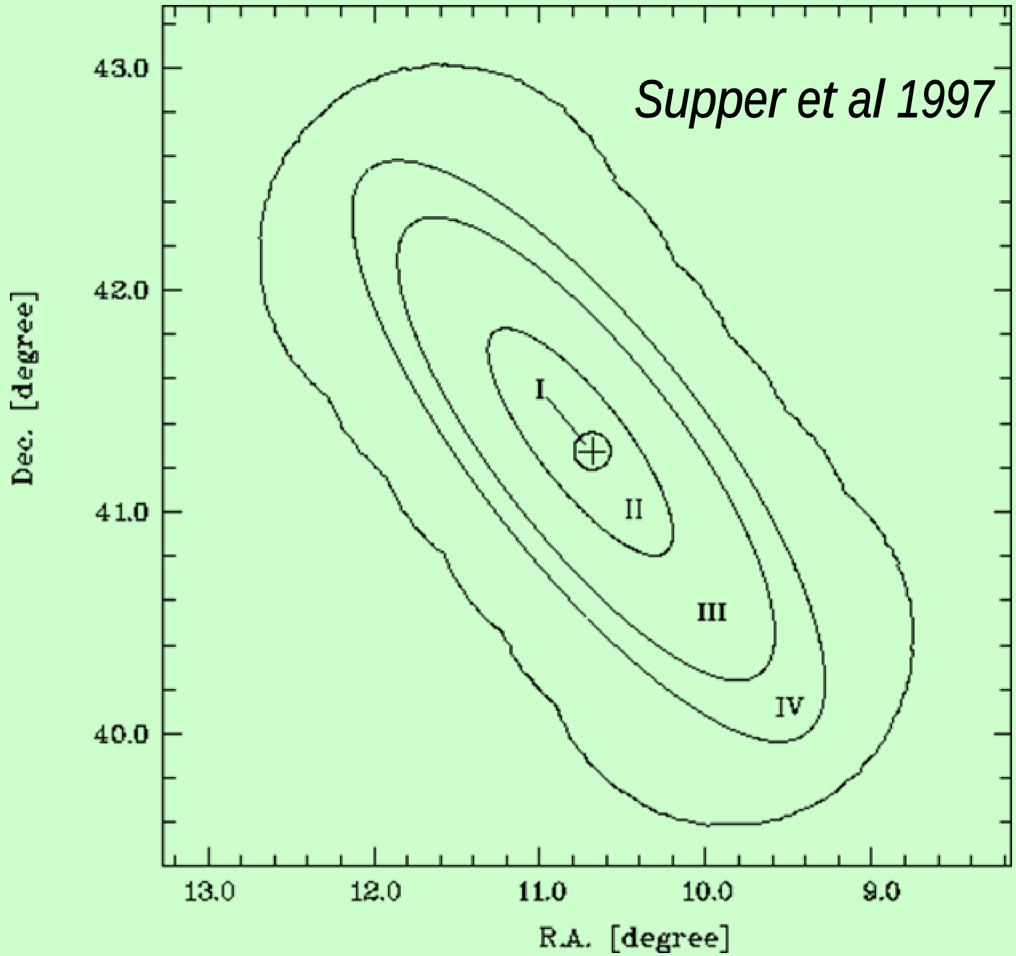
Time scales are f(m(WD),mdot).
Prialnik et al. 1976, 1984, Fujimoto 1982 …
Recent: Yaron et al. (2004), Townsey & Bildsten 2002-2005: T(WD)=f(mdot)



A range of high mdot allows steady burning

Facts of life about all SSS in general:

- *Definition of SSS is instrument and author-dependent, no clear agreement*
- *No WD masses have ever been determined directly.*
- *The only WD mass estimates based on radial velocity show small WD mass, ~0.6 M(sol) (or too large for a WD…).*
- *Only a handful of WD grating spectra, 2 systems observed with gratings do not show the WD`AT ALL (MR Vel, Cal 87).*
- *Only two massive WD, the RN RS Oph and Cal 83, show high mass based on indirect proofs including WD atmospheric fits.*

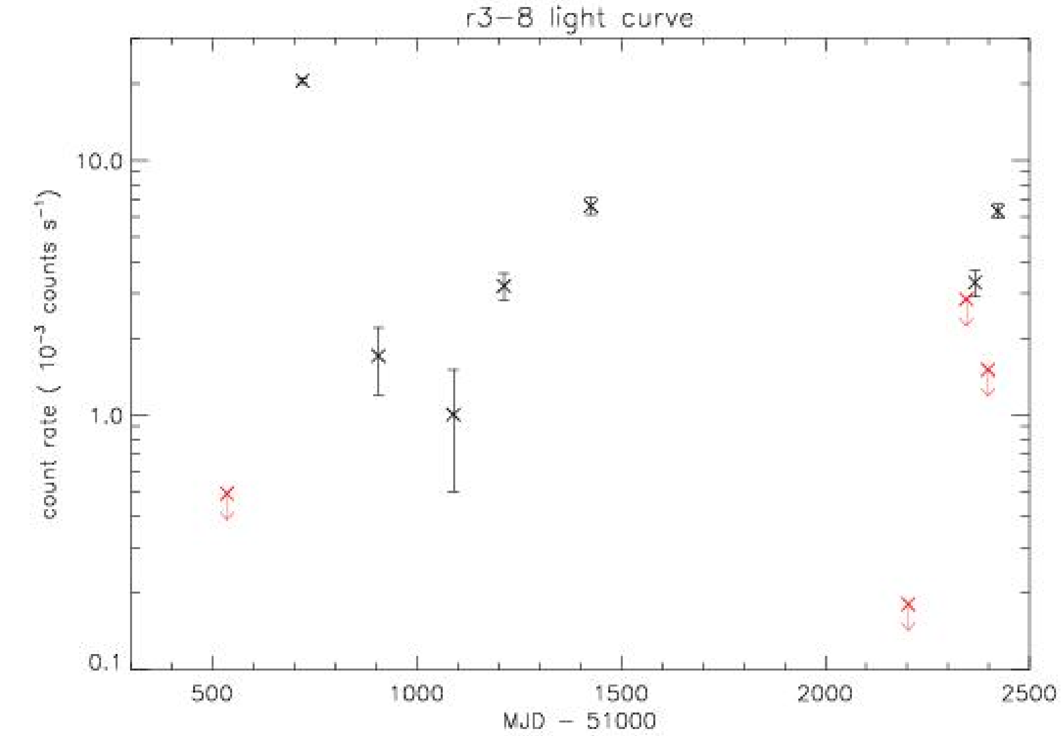


N(H) ~7x10(20)/cm(2)in the core,
~1.1 x10(21) in II, ~1.7x10(21) in region II and IV,
7.7x10(21)/cm(2) in reg III
⇒No SSS found in reg III, even if very hot and massive WD would still be detected

Selection effect in comparison with other galaxies:
SMC, dwarf ellipticals and dwarf spheroidal
Metallicity effect secondary to this selection effect?

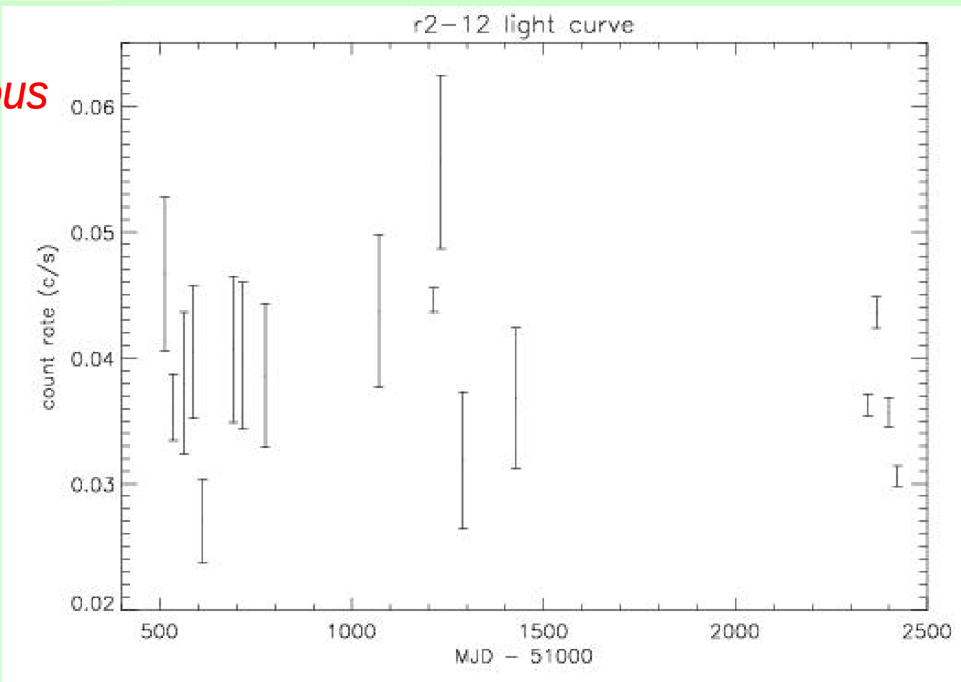
Supersoft X-ray sources in M31:

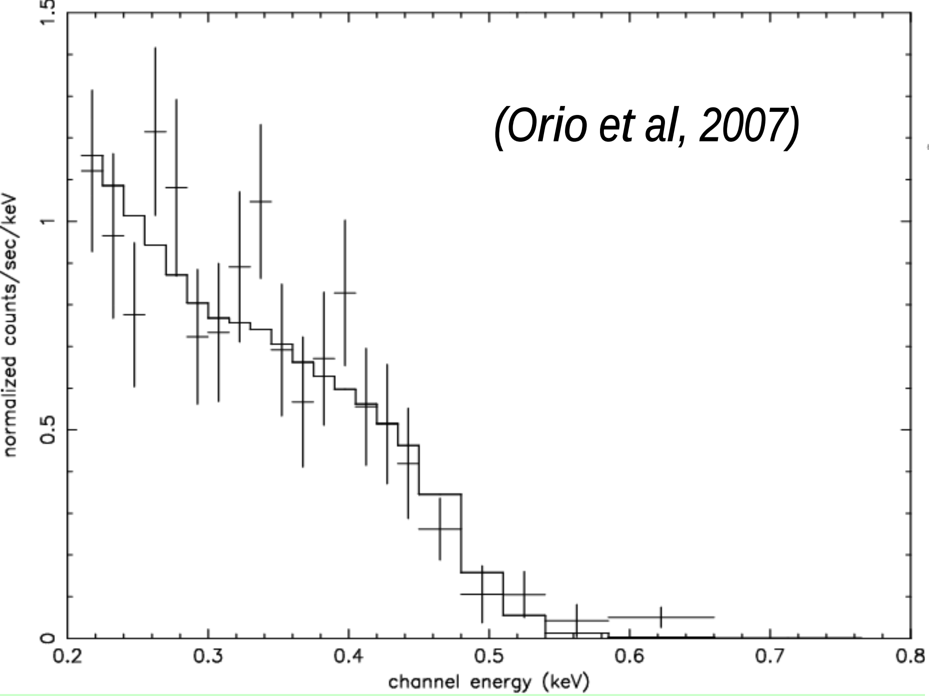
- *61 observed with ROSAT+first 3 years of M31 monitoring with Chandra and XMM. Probably ~100 at a given time in all M31 (~10% of all XRS)*
- *30% of these sources are classical novae (with some BHT included by mistake) and emit X-rays for up to 10 years*
- *At least 2 likely black hole transients also included in the search for SSS or in novae*
- *Only 20% clearly variable*
- *2 luminous, variable sources in the bulge…r3-8 ad r2-12*

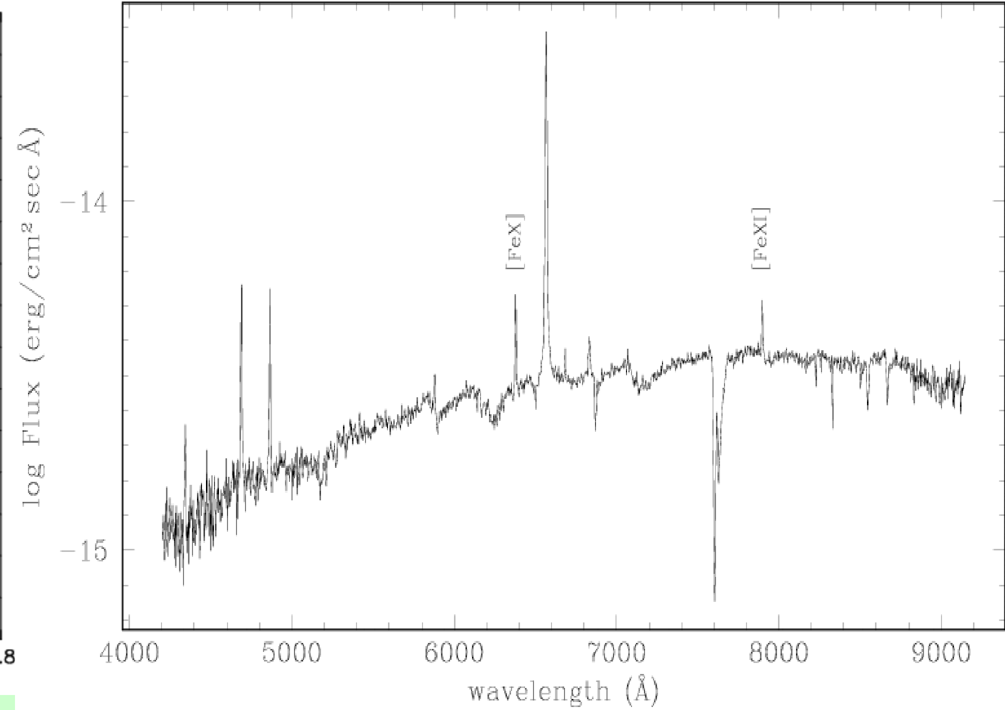


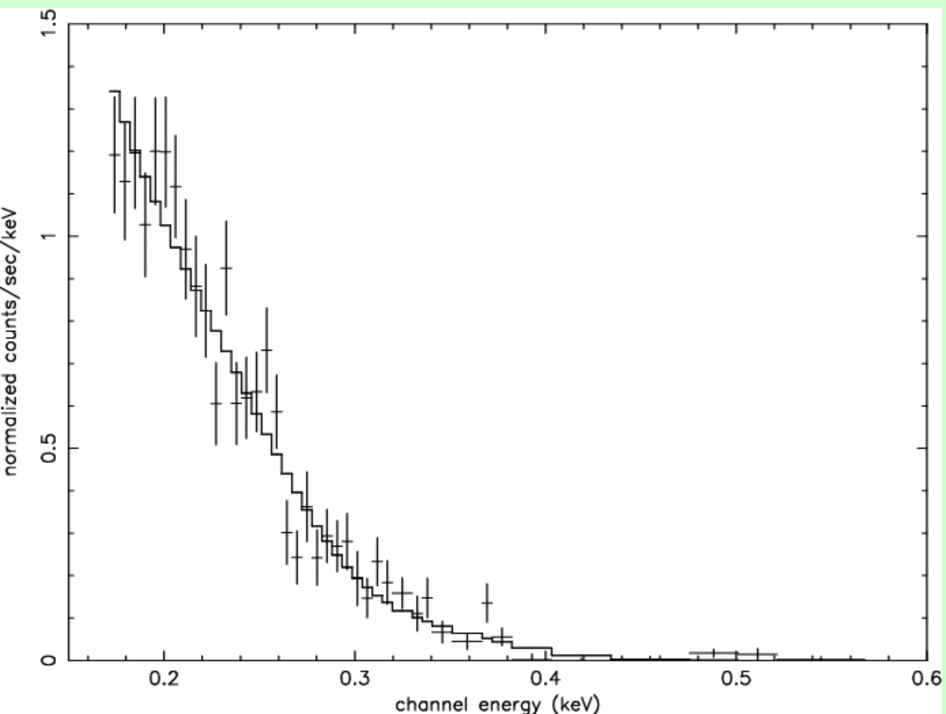
r3-8 is a very variable source with Tbb)~45-80 eV , softer at lower luminosity, perhaps obscured while It cools => a wind?
Accreting and cooling NS? Why so Variable?
AM Her system?
But nothing with B<23.5… !
Black hole or WD?
L>=10(38) in M31

r2-12 is a much less variable, even more luminous source wit T(bb)60-65 eV,
There are possible red counterparts in error box => is it a ymbiotic in M31?
Or FG AM Her???









Above: XMM-Newton broad band EPIC-pn spectrum and optical Spectrum of SMC 3 (T(eff)~450,000 K), and below, XMM-Newton EPIC-pn spectrum of Lin 358 (T(eff)~200,000 K). Both are symbiotic stars in the SMC that showed no indications of cooling In ~15 years => type Ia progenitors?!

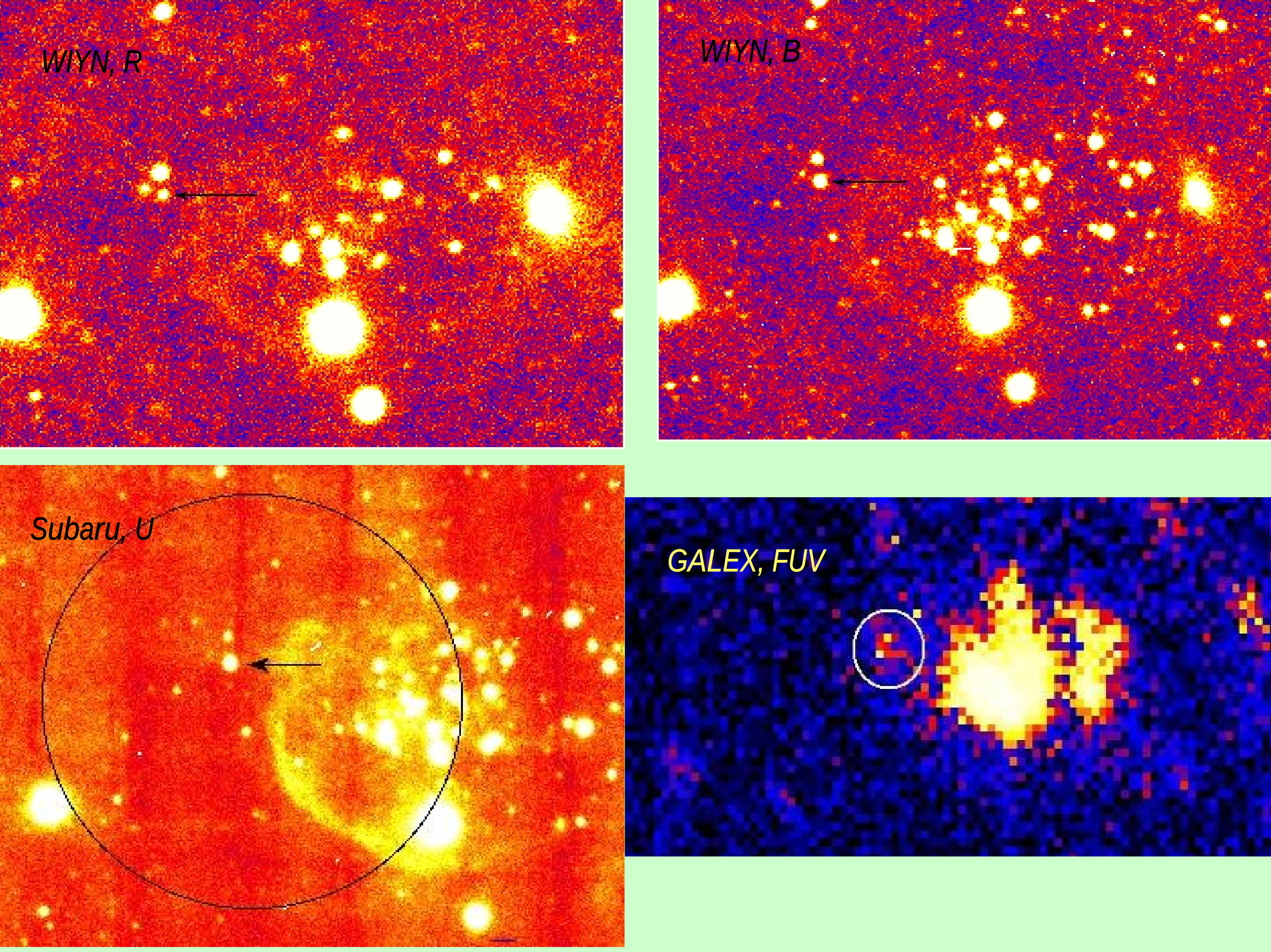
Search for novae:

- *Nedialkov et al. (2002): first SSS identified with a classical nova.*
- *Pietsch et al. 2005, Orio 2006, Pietsch et al. 2007: novae <=10 years after the outburst appear as SSS, >30% of all novae become SSS (probably all novae, even if for a short time)*
- *Novae account for ~30% of all SSS in M31 (depending on cut off on Temp and L)*
- *~10% of “novae” are BHT included in nova surveys (need to have R images before and after to select them)*

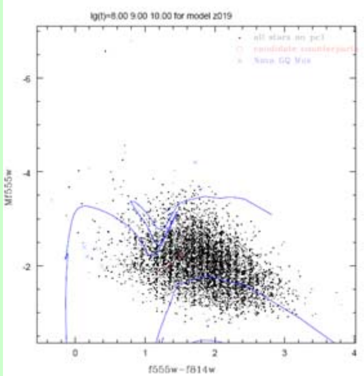
Optical and UV search for non-nova counterparts:

- *Very time-consuming!*
- *Outside the core, ~50% of all SSS in error box of bright GALEX sources (Nelson et al., in prep).*
- *Found a ROSAT SSS with ~5 hours period counterpart.*
- *No orbital variability for another, almost certain counterpart: now checking months time scales*
- *No emission lines (Greiner et al., in prep) for "very blue" possible counterparts (SUBARU spectra).*
- *Archival project using HST data (WFPC2 done, ACS in progress): SSS in the core belong to OLD populations*

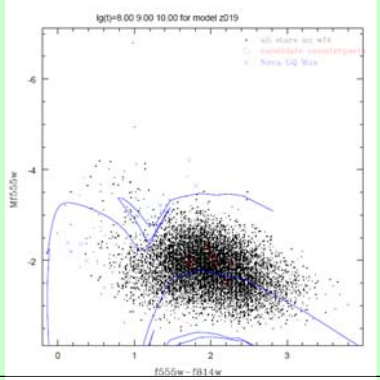
=> Implications for delay time?


WIYN, R
WIYN, B
Subaru, U
GALEX, FUV

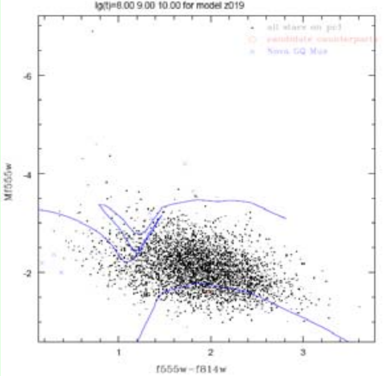
Colo-Color Diagrams by Scoles et al, WFPC2 images: OLD pop!



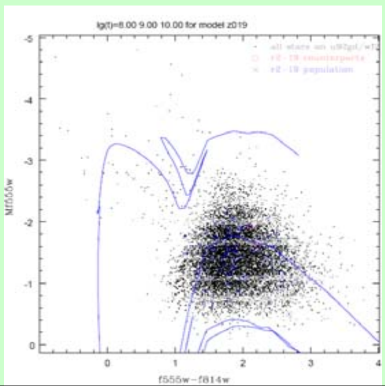
a) r1-9, dataset u2lg020



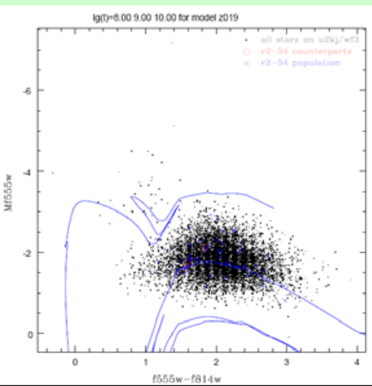
b) r1-25, dataset u2lg020



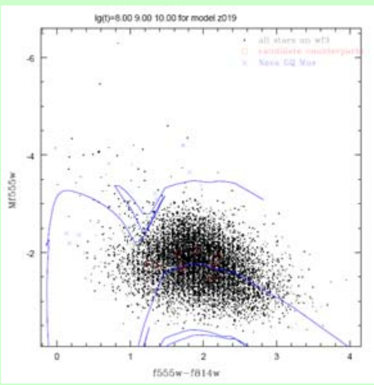
c) r1-35, dataset u2e201



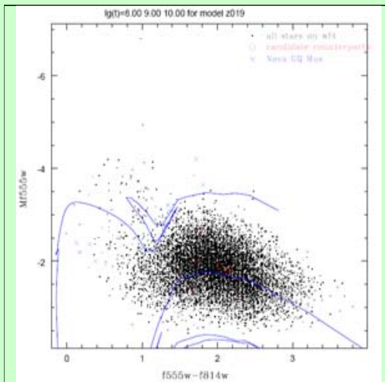
d) r2-19, dataset u92gd



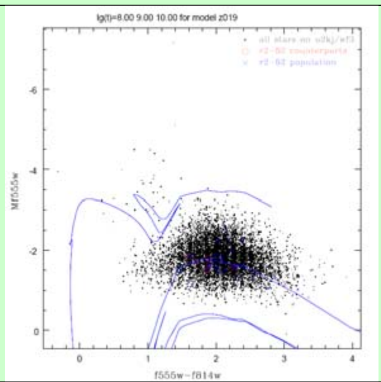
e) r2-54, dataset u2kj



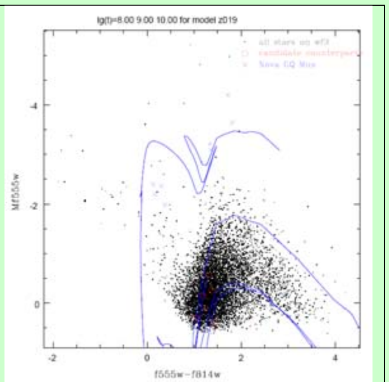
f) r2-56, dataset u2lg020



g) r2-61, dataset u2lg020



h) r2-62, dataset u2kj



i) s1-18, dataset u92gb90

Summary and highlights:

- ***Novae are an important fraction of SSS, but by no means the majority.***
- ***Possible important component are symbiotic (should be verified soon as optical ID are becoming feasible).***
- ***BHT may be included in the SSS census.***
- ***LMC sources are more transient and have shorter duty cycles than M31 sources, of which only 20-30% of non-novae are clearly variable .***
- ***However, the M31 sources seem to be associated with an older population (work in progress).***
- ***M31 can teach a lot about SSS, but we loose the softest, coolest WD… observed in SMC and other small old Local Group galaxies.***