

What do we know of ULXs (But don't
even think I'm going to tell you everything!) & The
Cartwheel

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Ultra Luminous X-ray sources(ULX)

- dette anche
 - IXO = Intermediate Luminosity X-ray Object
 - SES = Super-Eddington Source
 - SLS = Super-Luminous Source
- Non risolte ($< 0.6''$ with *Chandra*)
- $L_x > 2 \times 10^{39}$ ergs/sec, 0.5-10keV

- Non corrispondono al nucleo della galassia

→ relazione tra la luminosità e la massa di un oggetto in accrescimento sferico da una nube di idrogeno ionizzato. E' il limite naturale alla luminosita' che puo' essere emessa per accrescimento su un oggetto compatto.

$$L = \frac{4\pi GMm_p c}{\sigma_T} \cong 1.3 \cdot 10^{38} \left(\frac{M}{M_*} \right) \text{erg} \text{ s}^{-1}$$

Luminosita' di Eddington

ULX

"Brillanti" $\rightarrow L_x > 2 \times 10^{38}$ erg/s
Luminosita' di Eddington per NS

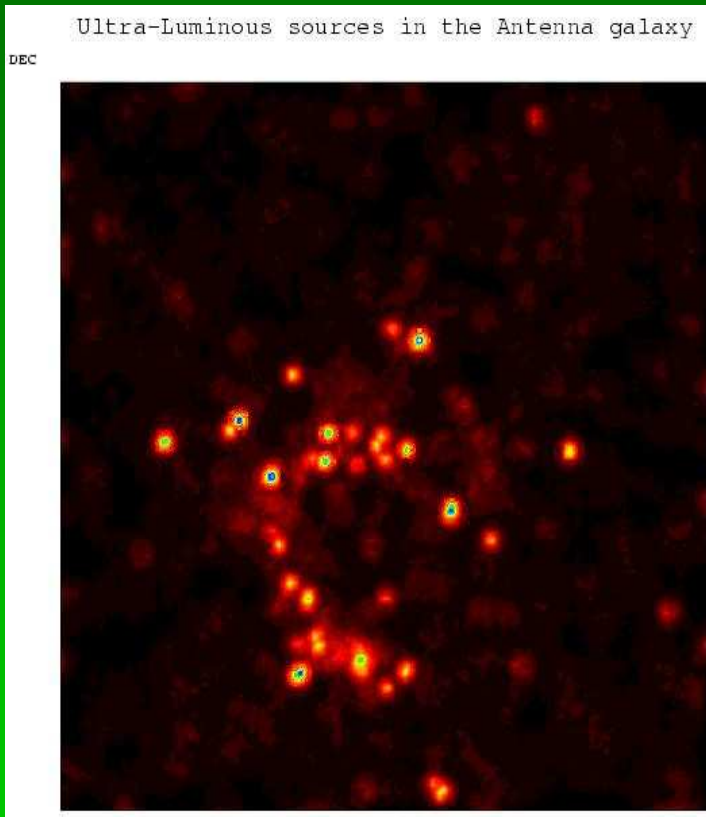
NGC4631



Per definizione -

ULX $\rightarrow L_x > 2 \times 10^{39}$ erg/s ($\sim 10 M_{\odot}$)
e fino a $L_x > \sim 10^{41}$ erg/s (\rightarrow Cartwheel; M81)

ULX



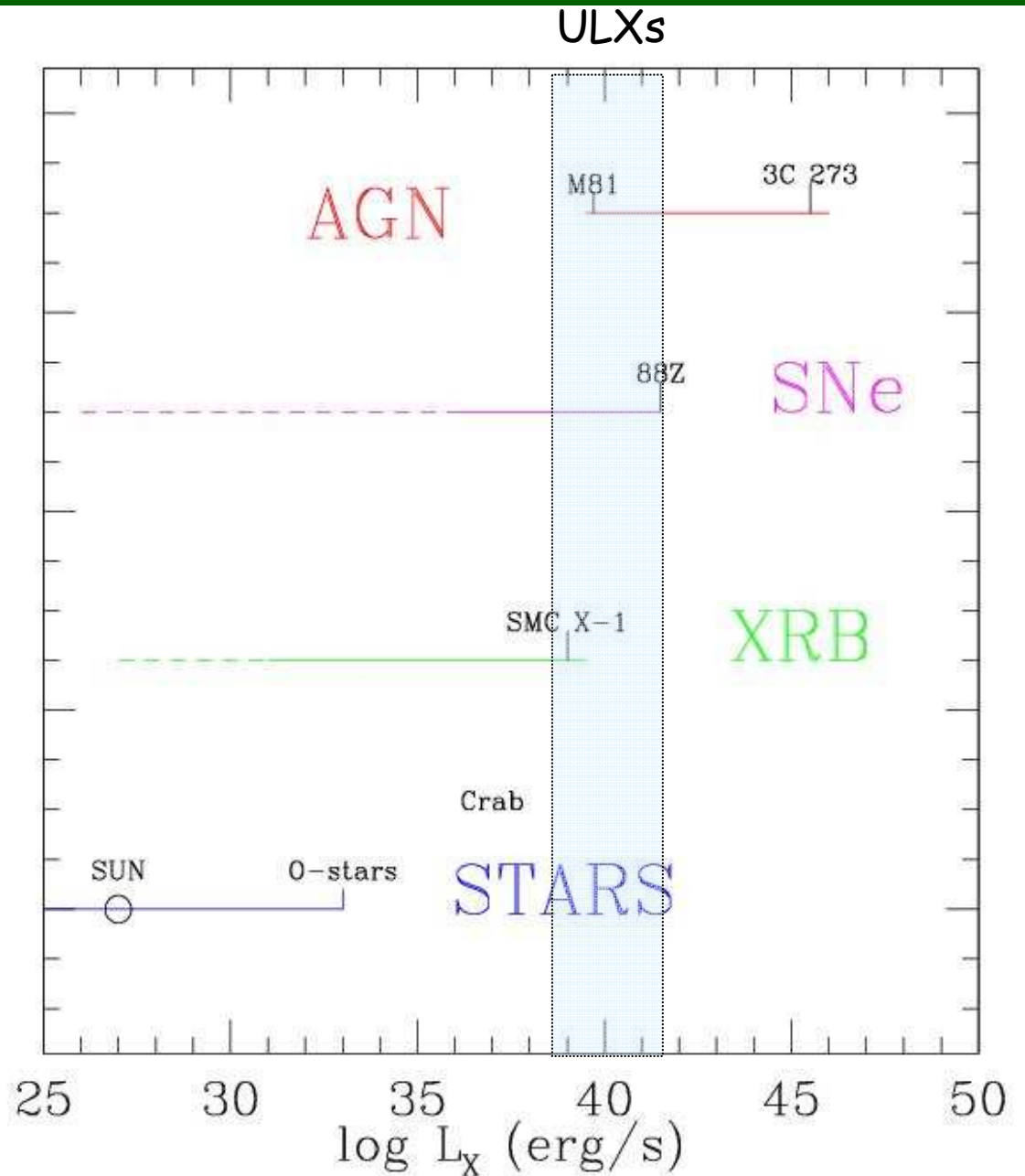
Perche' sono importanti?

Proprieta' non comuni ad altri oggetti noti

Se accrescono al limite di Eddington hanno una massa di qualche DECINA di masse solari.

Se invece accrescono sotto il limite di Eddington (come piu' normale) possono essere molto massicce, dell'ordine di 100-1000 Msun

Sorgenti X
"puntiformi"



ULX in galassie late type e in [regioni] starburst

- Relativamente comuni (1/4 di tutte le galassie?)
- Luminose: $L_x > 2$ ordini di magnitude fino a 10^{41}
- Variabili
- Spettri: legge di potenza / corpo nero
- Associazione con le zone di formazione stellare



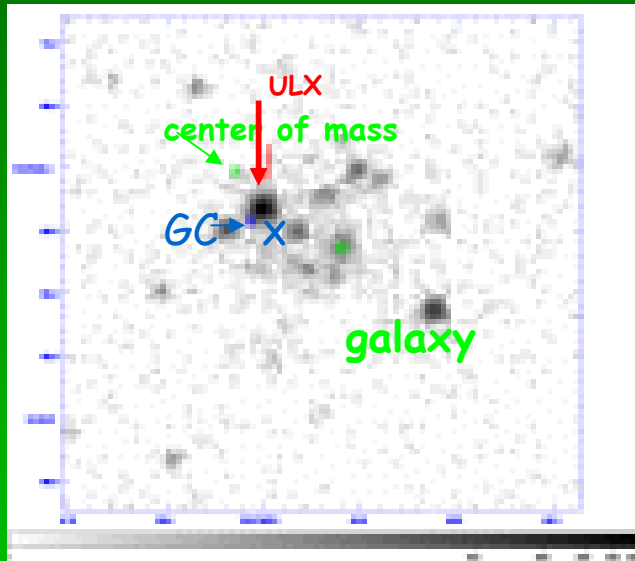
In galassie early type

- $L_x \sim 10^{39}$ erg/s
- solo in pochi sistemi sono associate alla galassia (Irwin et al 2004)



NGC 3379 con Chandra (Fabbiano et al 2006)

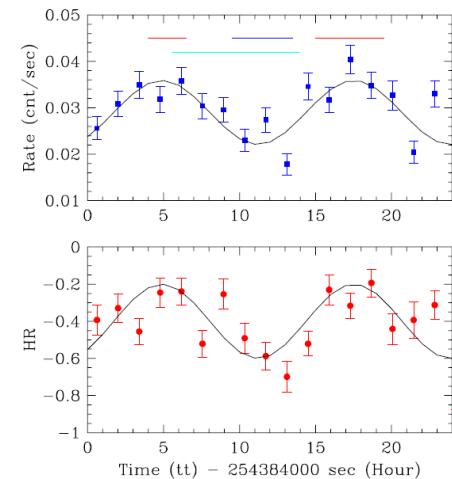
→ ULX binary in NGC3379



Popolazione
stellare vecchia:

9-10 Gyr

→ star @ ~ 1 M
+ BH @ ~ 30 M



- ✓ L_x $2-7 \times 10^{39}$ erg/s in una osservazione
- ✓ modulazione del flusso con periodo di ~12.6hr.
- ✓ piu' soft a basso flusso.
- ✓ Modello spettrale: multicolor disk (used for BH binaries); legge di potenza

Che cosa sono?

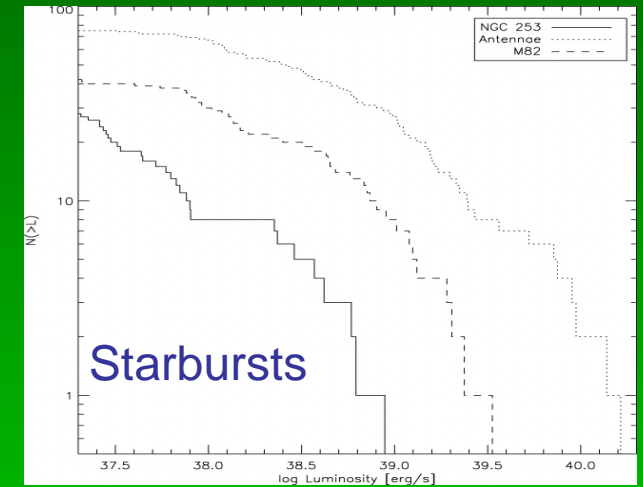
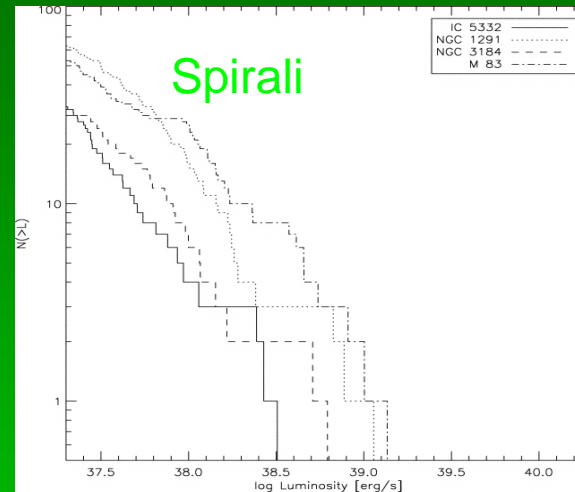
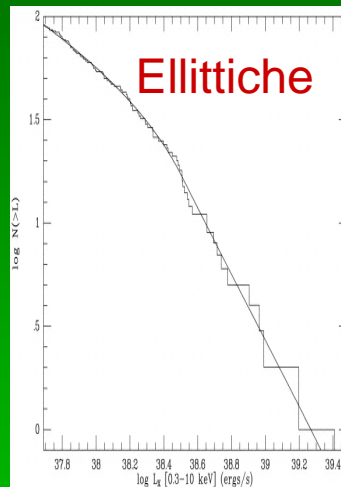
Caratteristiche oltre alla alta L_x !

- Non così rare!!! (ex: 229 in 85 galaxies, da Liu & Mirabel 2005; precedentemente 87 in 54 galassie Colbert & Ptak 2002)
- Variabili in L_x
- Variabili nello Spettro
- estensione di oggetti di più bassa L_x ?

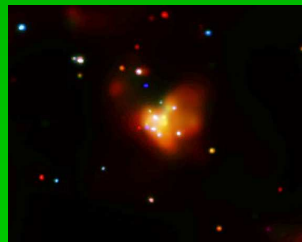
considerate sorgenti "esotiche":

- Una classe eterogenea → HMXB/SNR/IMBH/altro?
- Le più luminose sono associate generalmente con zone di formazione stellare: ma ...

Sorgenti puntiformi in galassie esterne: funzione di luminosita' (LF)



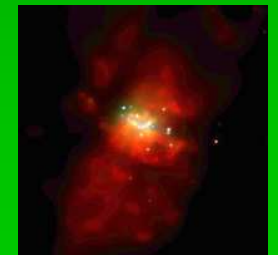
NGC 720



M83

LF simili a quelle delle XRB
per $L < 10^{39}$.

"Ginocchio" nella LF a
 $L \sim 10^{39}$?

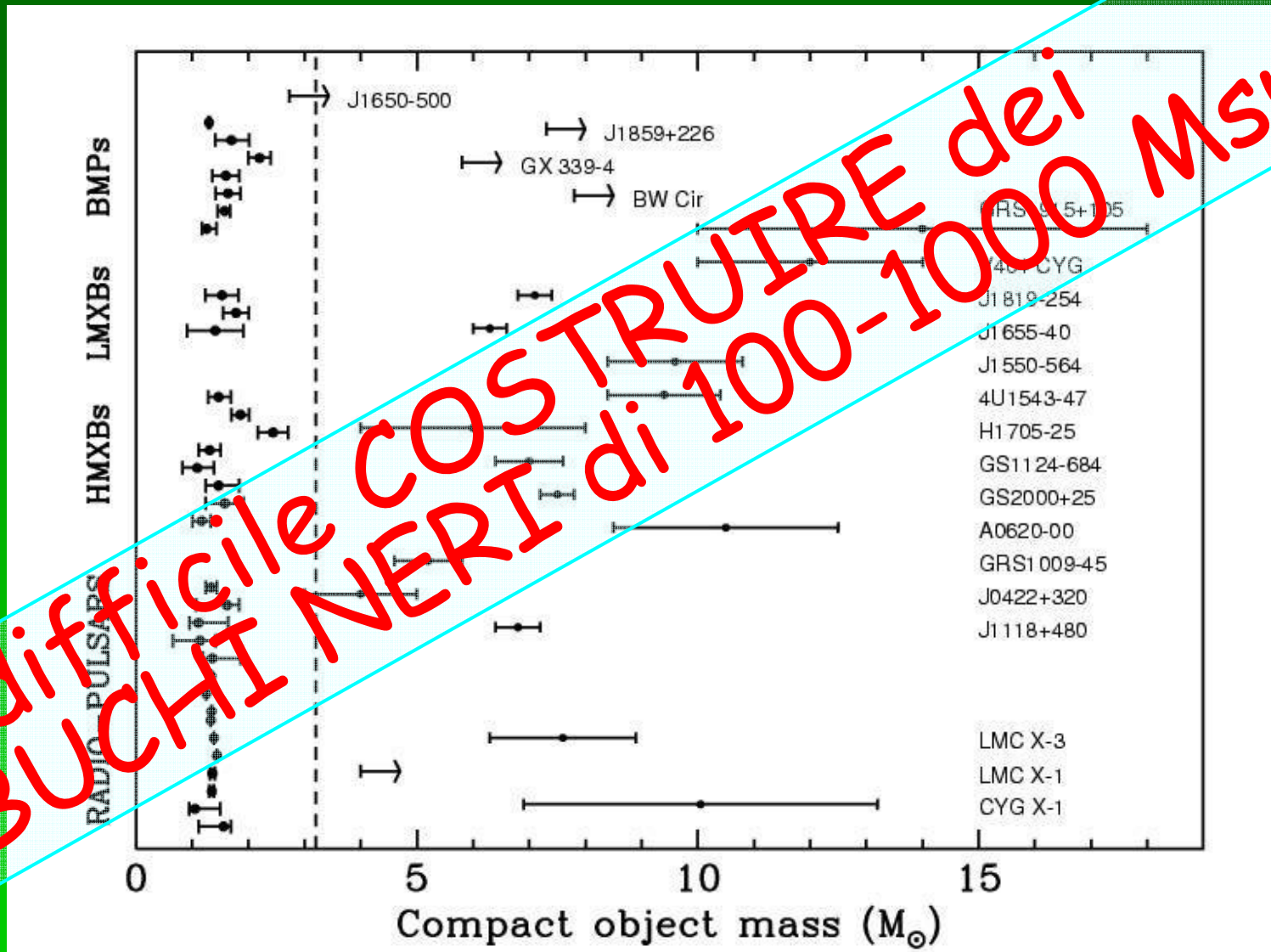


M82

ULX: identificate con...

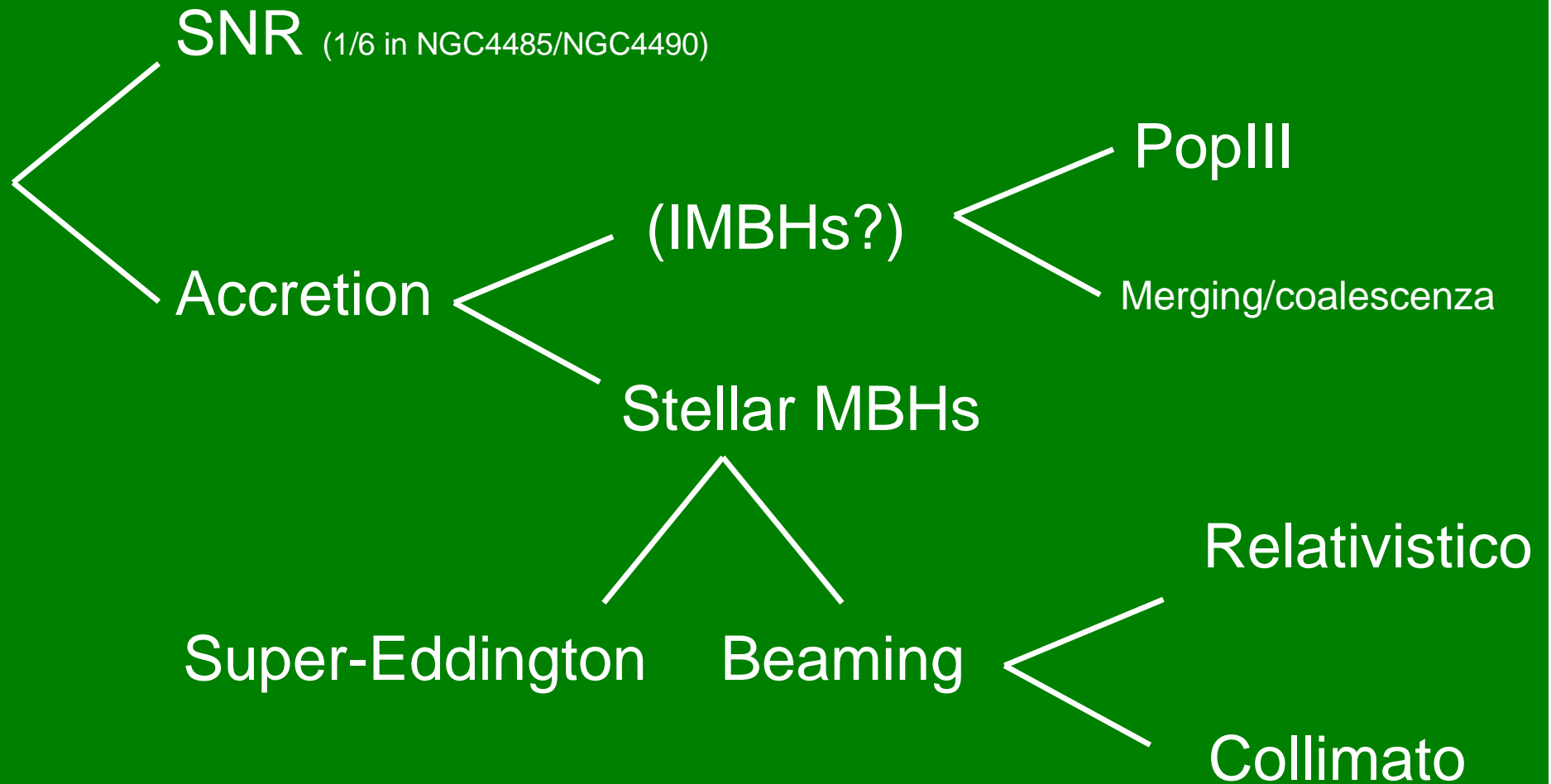
- Supernovae in ambienti densi (detettate $L_x \sim 10^{38}-10^{41}$ ergs/sec SN 1995N)
 - SNR
 - Pulsar wind nebula
- X-ray binaries non isotrope:
 - HMXB "Normali"
 - Micro-blazars (emissione a beam, getti relativistici)
- Accrescimento su oggetti molto massicci:
 - Intermediate-mass Black Holes (IMBH)
 - "Lost" LLAGN (Low-luminosity AGN)

Binarie nella Via Lattea

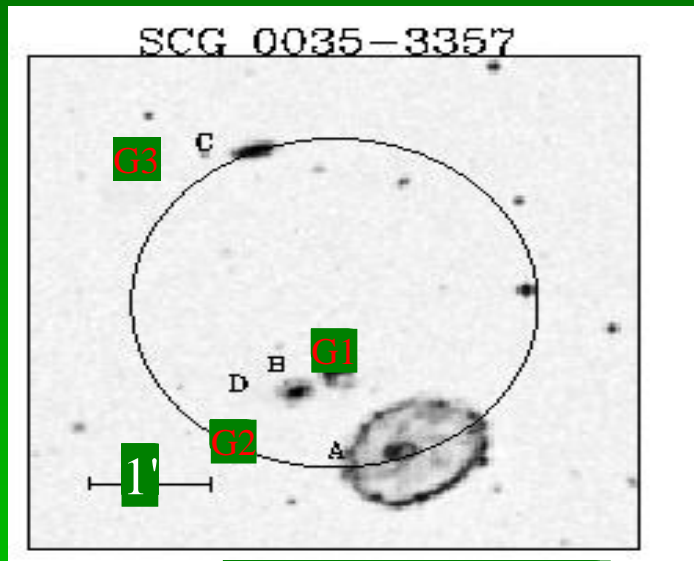


Schema riassuntivo

Collezione di src



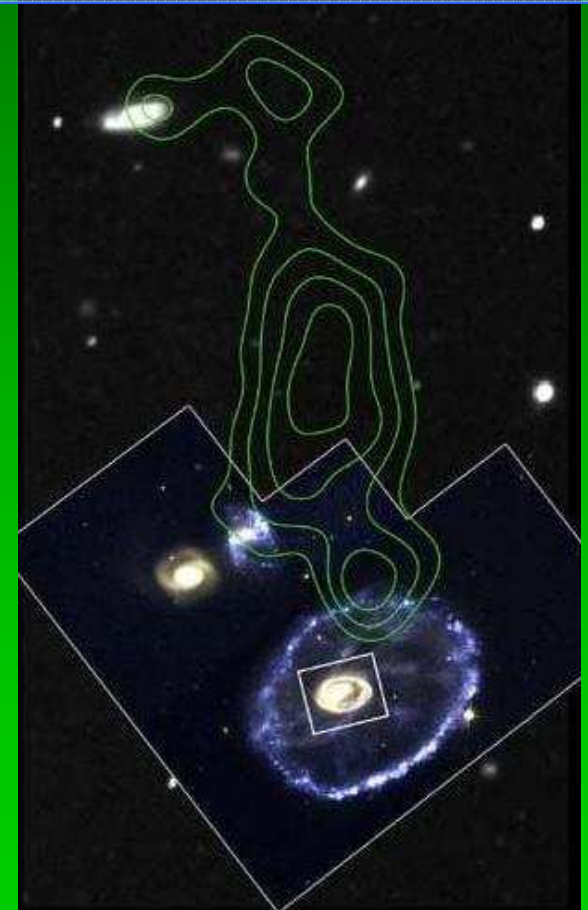
The Cartwheel group



courtesy of A. Iovino

Group (with G1, G2, G3)
Ring size 60" x 80"
 $D_L = 122$ Mpc

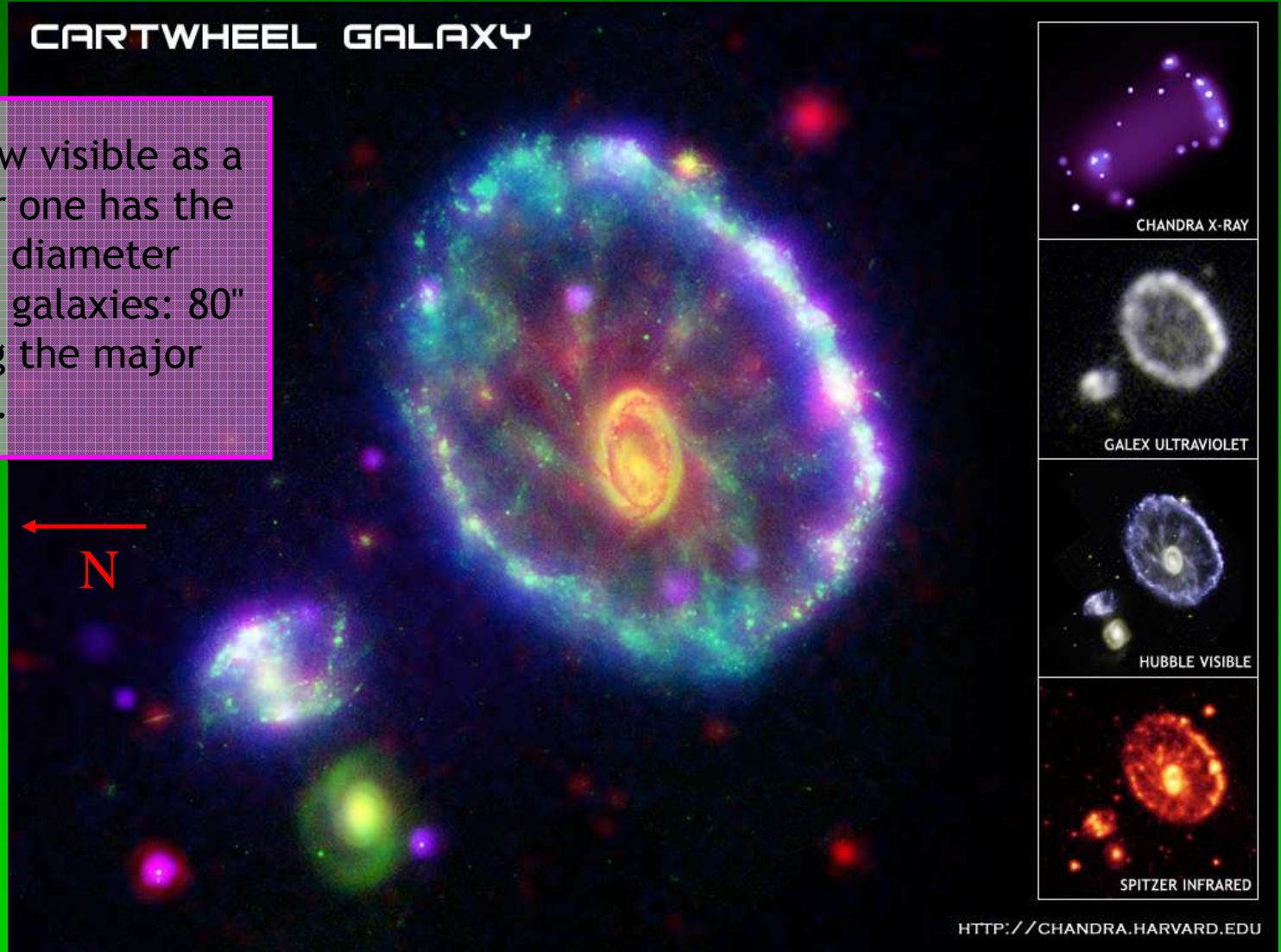
HST image + radio map (HI)
from Higdon et al 1996



The Cartwheel galaxy is a spectacular object, with the peculiar appearance reminiscent of a wheel (hence the name), most probably the result of an impact with one of the companion galaxies.

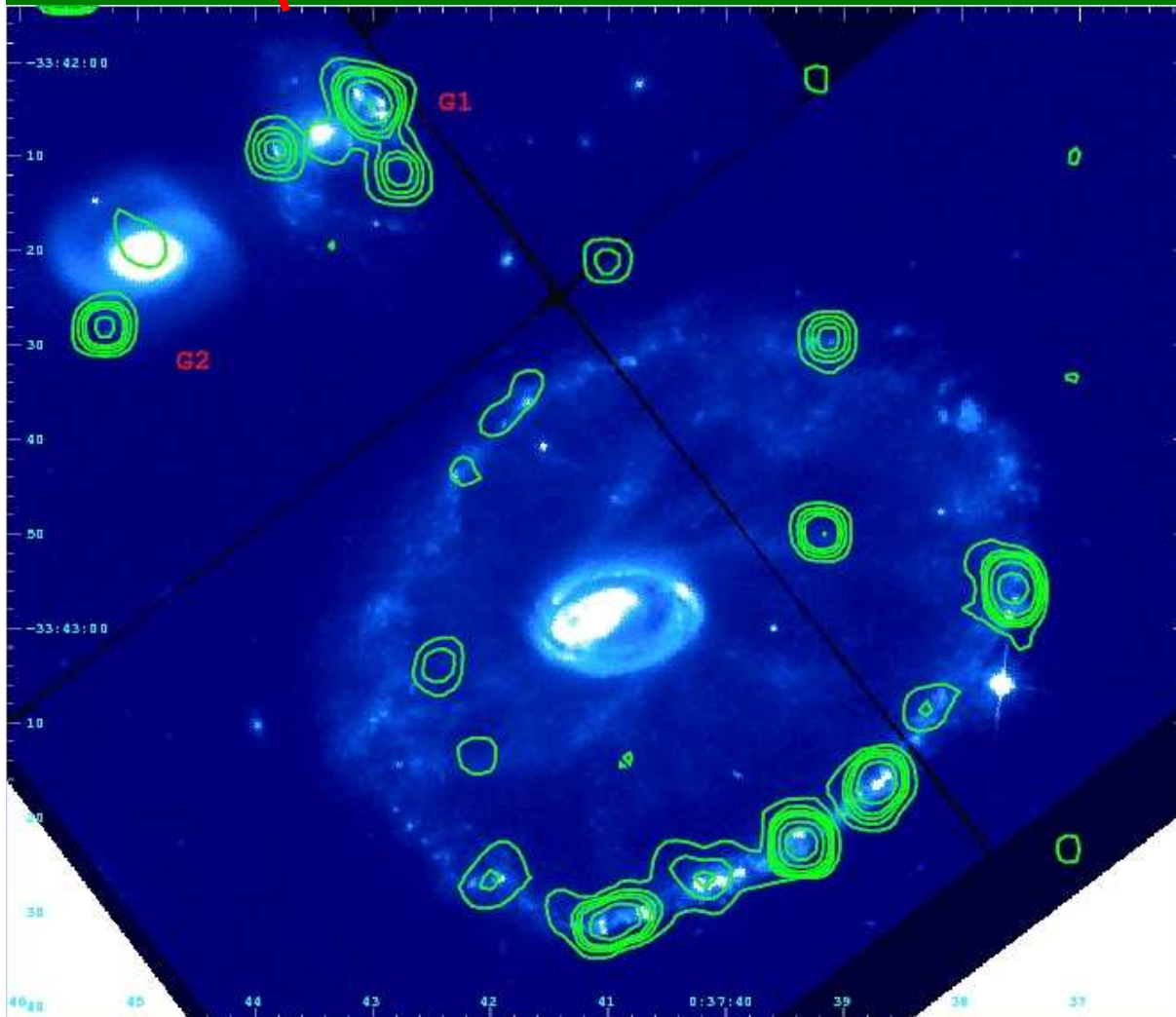
CARTWHEEL GALAXY

Two rings are now visible as a result: the outer one has the largest linear diameter measured in ring galaxies: 80" ~100 kpc along the major axis.



CHANDRA and HST

G3



F450W HST filter image and
0.3 - 7.0 keV CHANDRA
contours.

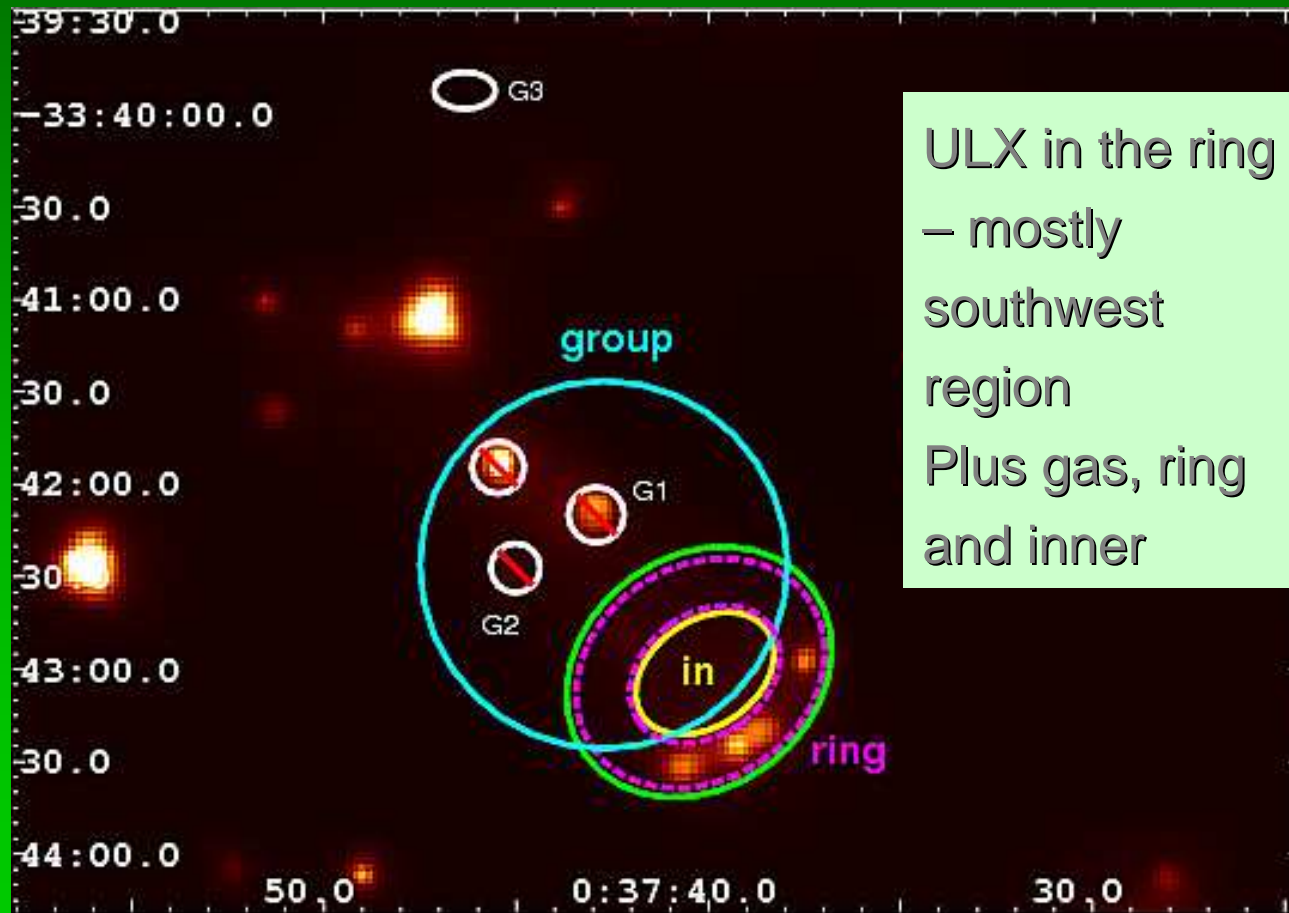
Large number of point
sources cospatial to the
outer ring.

Also G1 detected -
 $L_x = 1.6 \cdot 10^{40} \text{ erg s}^{-1}$

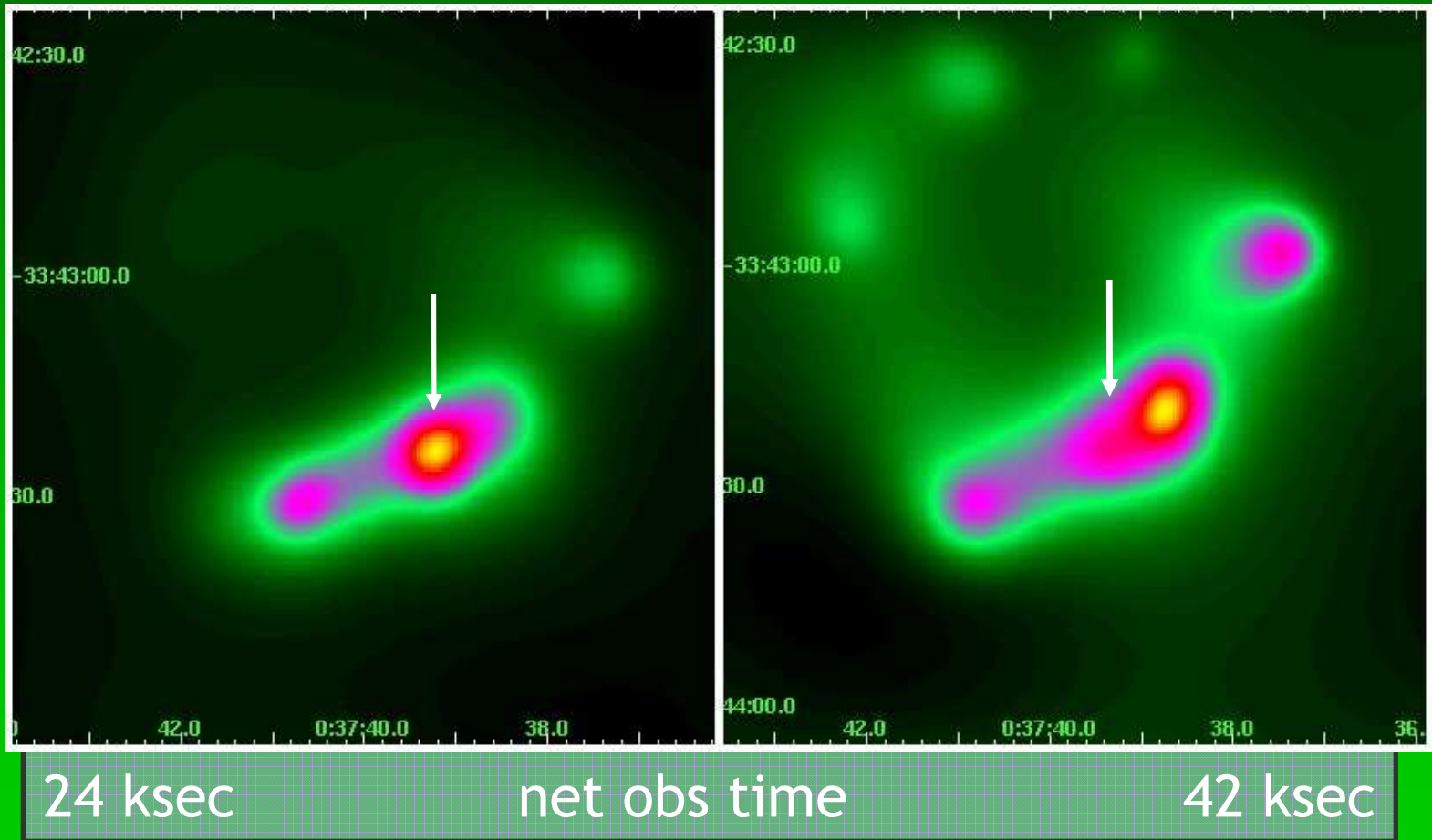
G3 detected at $L_x = 7 \cdot 10^{38} \text{ erg s}^{-1}$

CHANDRA resolution is $\sim 1 \text{ kpc}$

XMM – Newton data

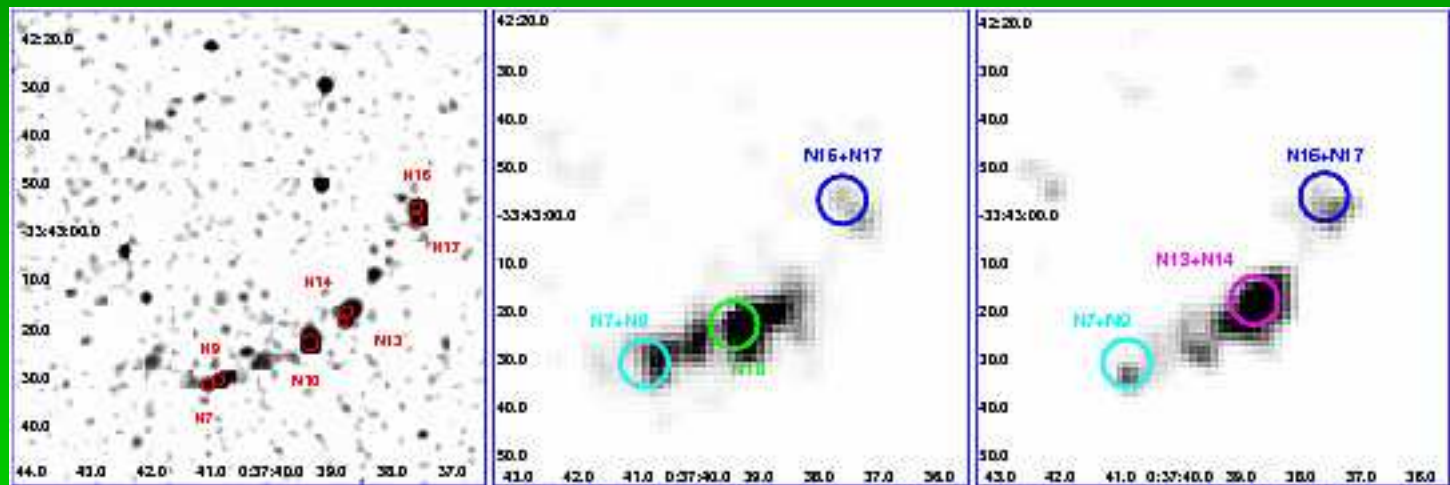


XMM-Newton data



XMM & Chandra sources

- 3 sources are detected in each of the two XMM observations. We know from Chandra that they are the superposition of at least 2 bright ULX each.



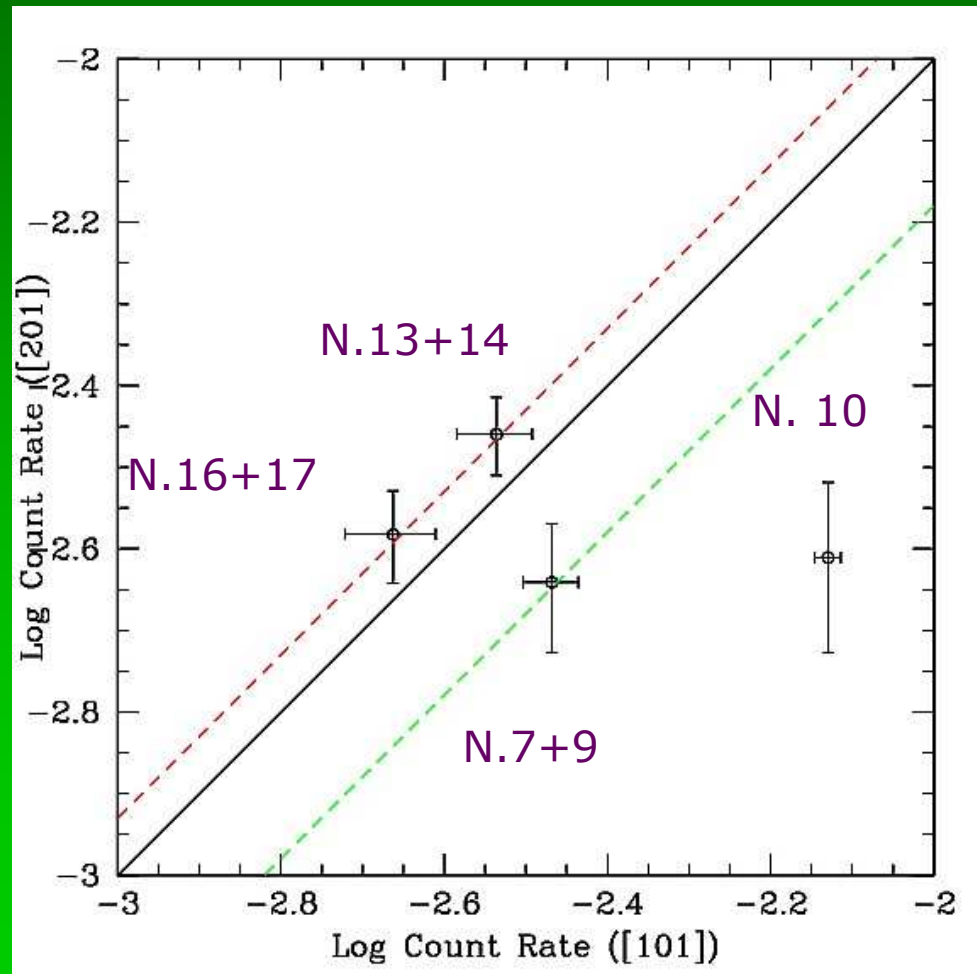
REMINDER: the resolution in XMM is > 3.5 kpc,
in Chandra ~ 0.6 kpc

XMM-Newton data

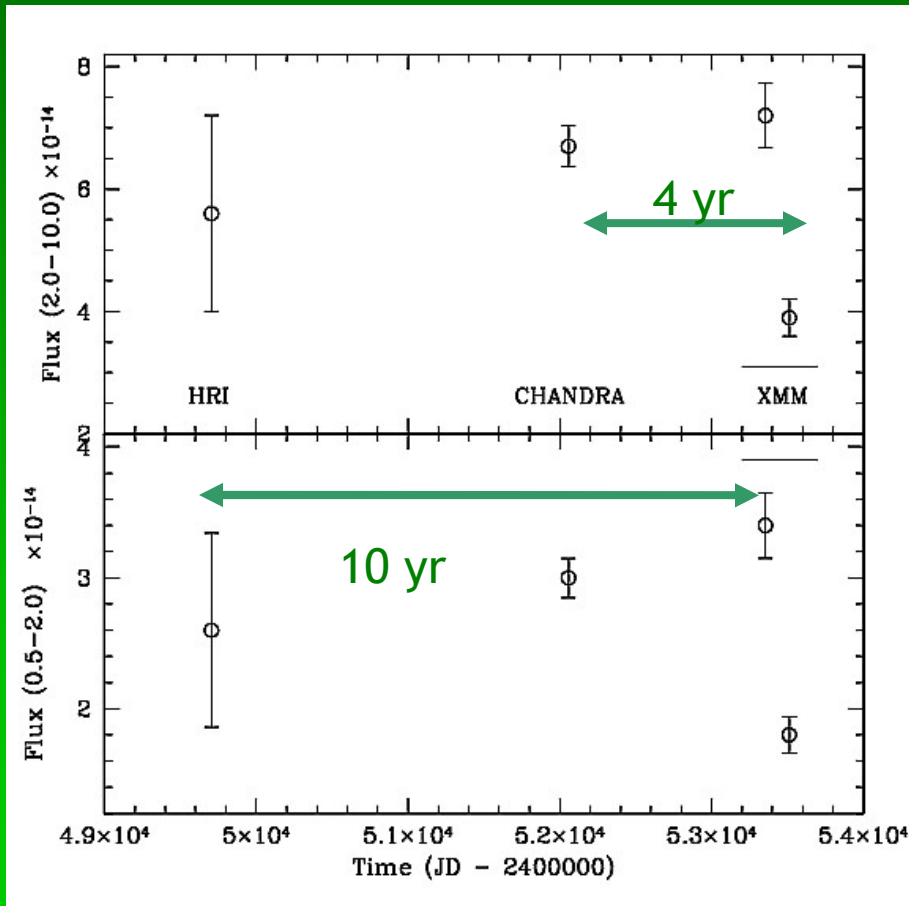
Comparison of the
count rates in the two
datasets

14-15 Dec 2004 [101]

21-22 May 2005 [201]



Long term Light-curve

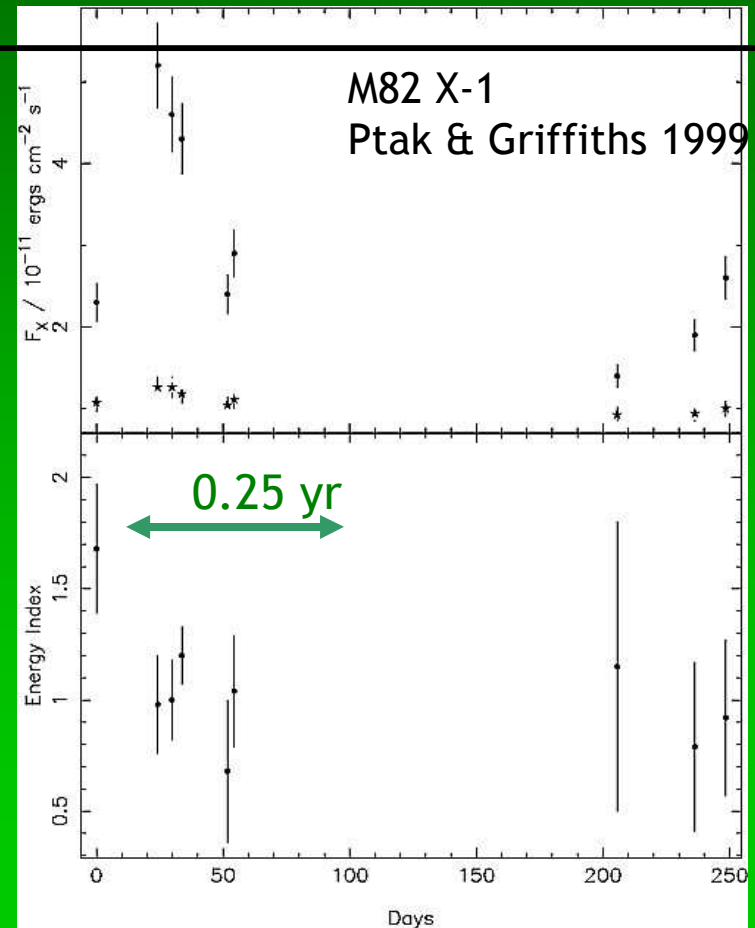


Counts from a 10'' region in each dataset.

The source was "ON" at least for 4 years, maybe for 10.

X-1 in M82

X-1 in M82 has been interpreted as Intermediate Mass Black Hole with $\sim 200 M_{\text{sun}}$ (QPO, PDS..)

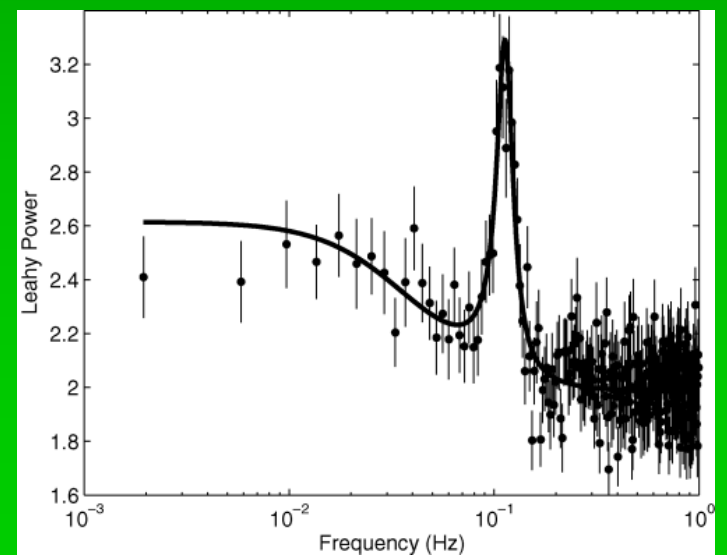


X-1 in M82

Parameter	Total observation	First half	Second half
ν_0 (mHz)	113 ± 2	120 ± 3	107 ± 4
FWHM (mHz)	26 ± 3	21 ± 4	19 ± 3
Fractional rms (%)	18.3 ± 1.0	17.5 ± 1.1	17.3 ± 1.1
Significance (σ)	8.9	8.3	8.2

Total power spectrum from the 2004 XMM observation (limited to the range 0.001–1 Hz).
The line represents the best-fitting model

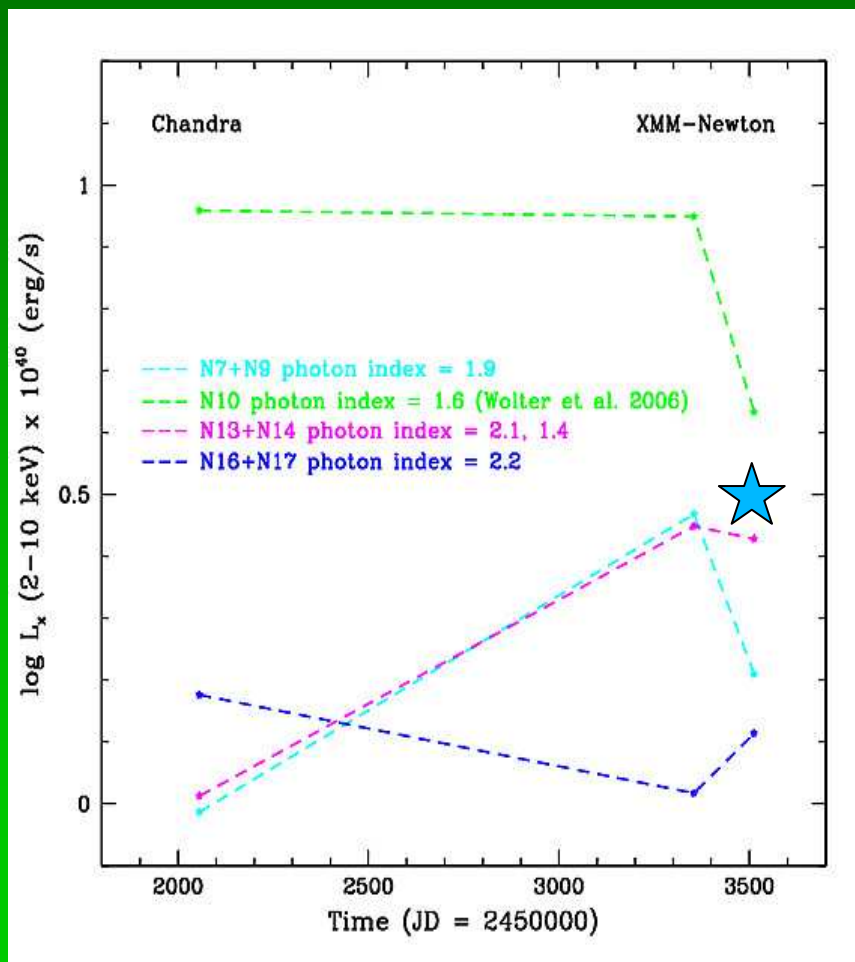
Mucciarelli et al 2006



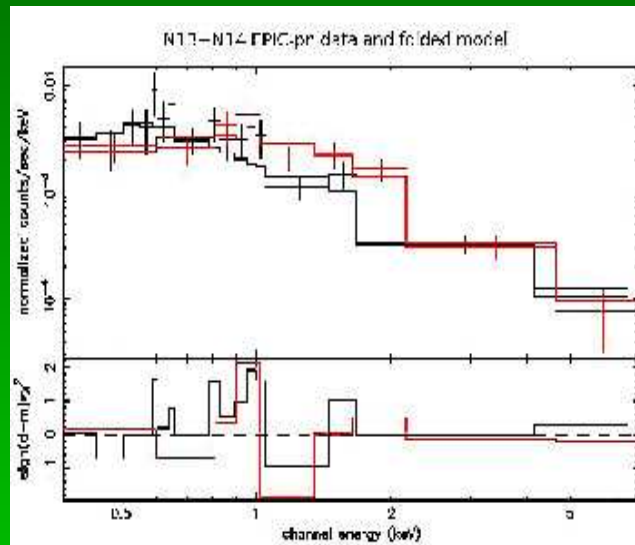
ULX variability

- We measure variability for N.10 and 3 other “sources” in XMM.
- The Chandra fluxes are the sum of the two sources.

★ N13+N14: small change in flux BUT...



Spectral variability or contamination?



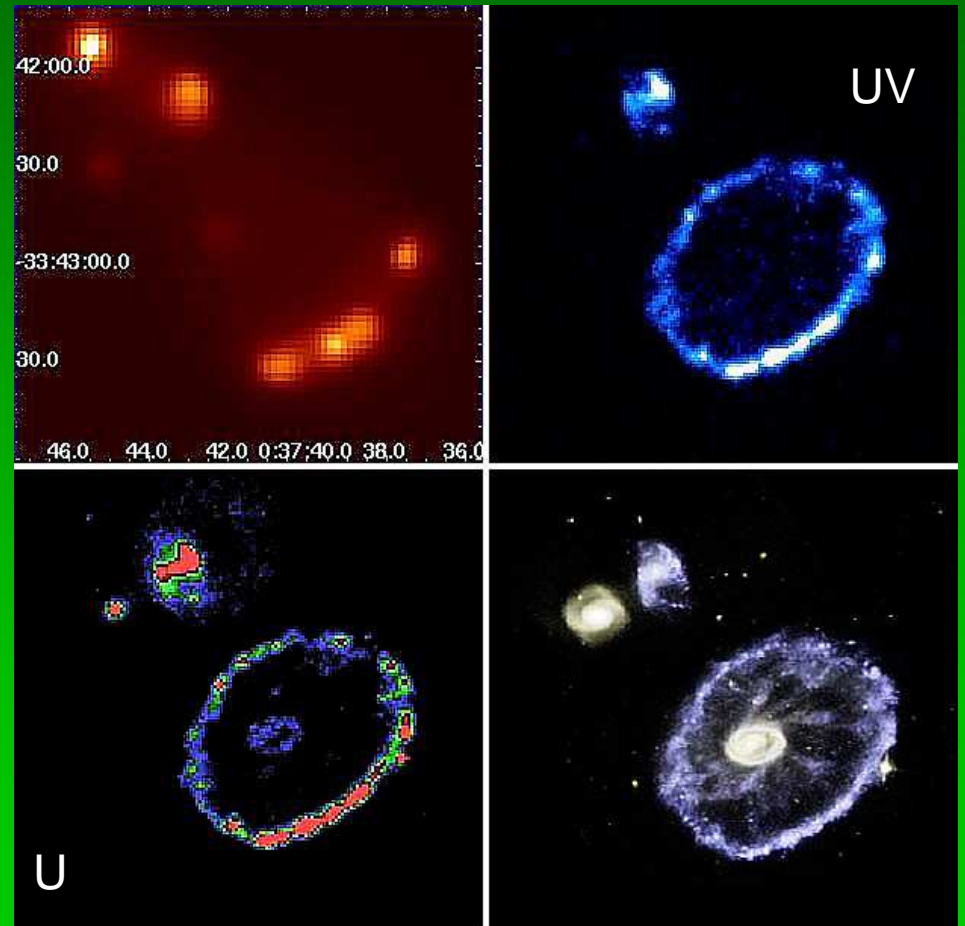
- The source “N13+N14” is close to N.10, so that the variation might be due to different amounts of “wings” from N.10?
- Although it seems to go in the wrong direction: source is softer ($\Gamma=2.1$) when N10 ($\Gamma=1.6$) is brighter

XMM and the OM filters

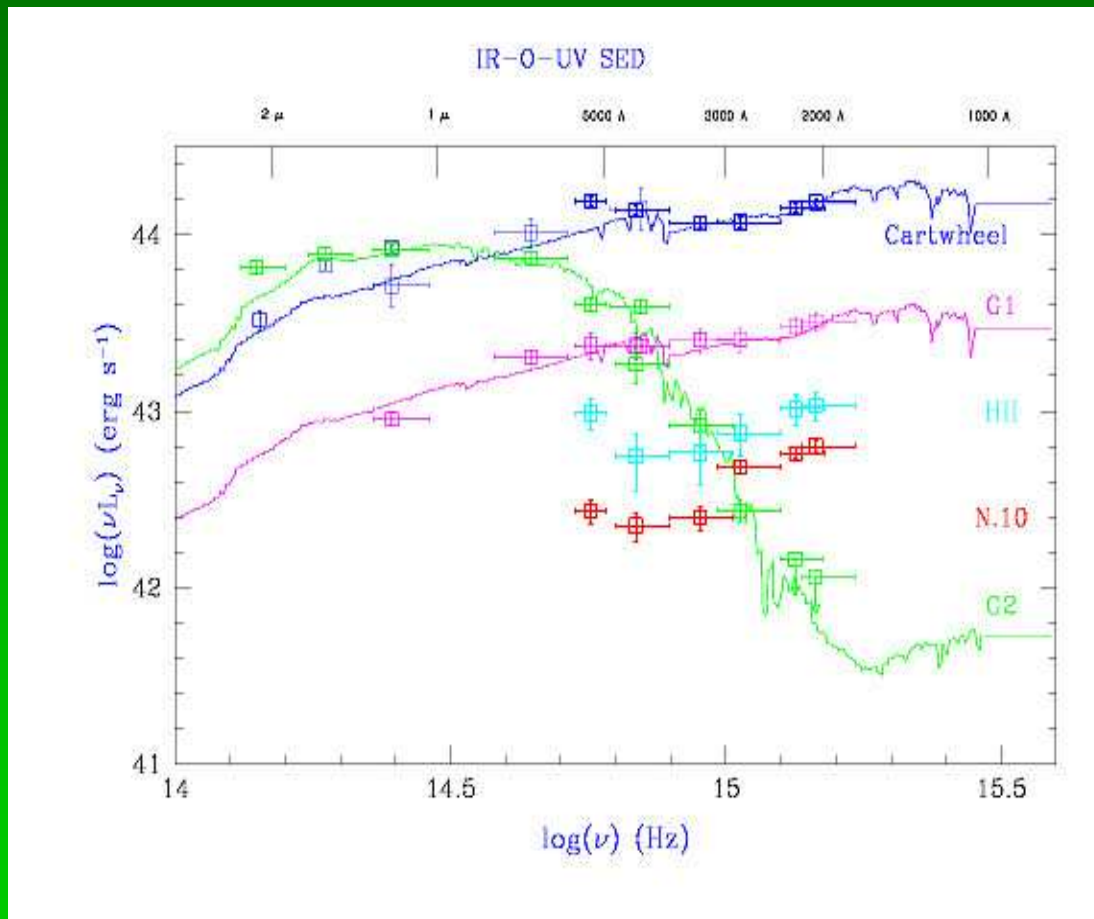
Optical (U V B) and UV
(UVW1 UVM2 UVW2)
filter data are available

(shown here with XMM and HST)

$i = 40^\circ$ Near side is NE!
(Fosbury & Hawarden 1977)



IR-UV SED for the ring, the companions and ULXs

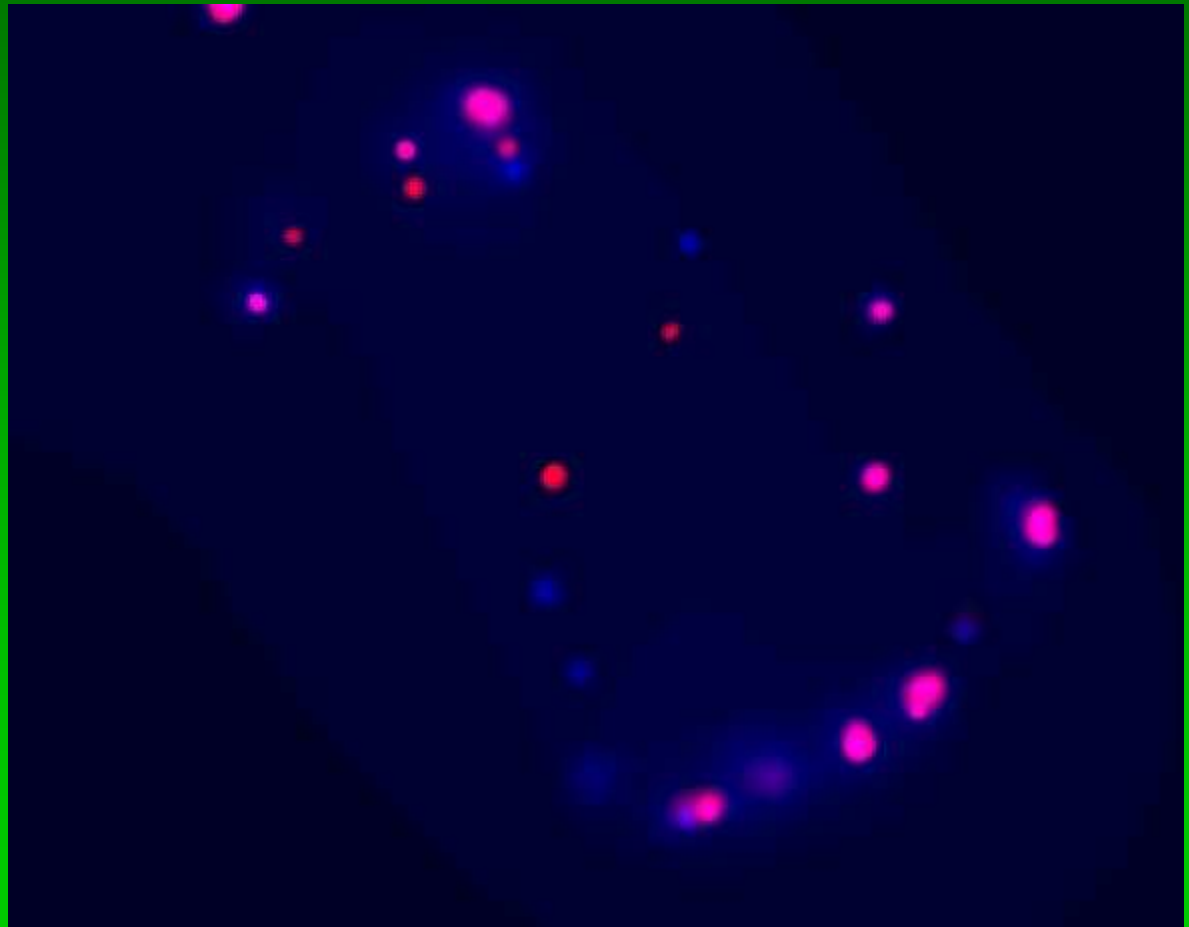


- Model for “Cartwheel” uses $M = 5 \cdot 10^9 M_{\text{sun}}$ age of the burst 400 Myr and $\text{SFR} = 23 M_{\text{sun}}/\text{yr}$ (PEGASE code)

(Old+)New Chandra data

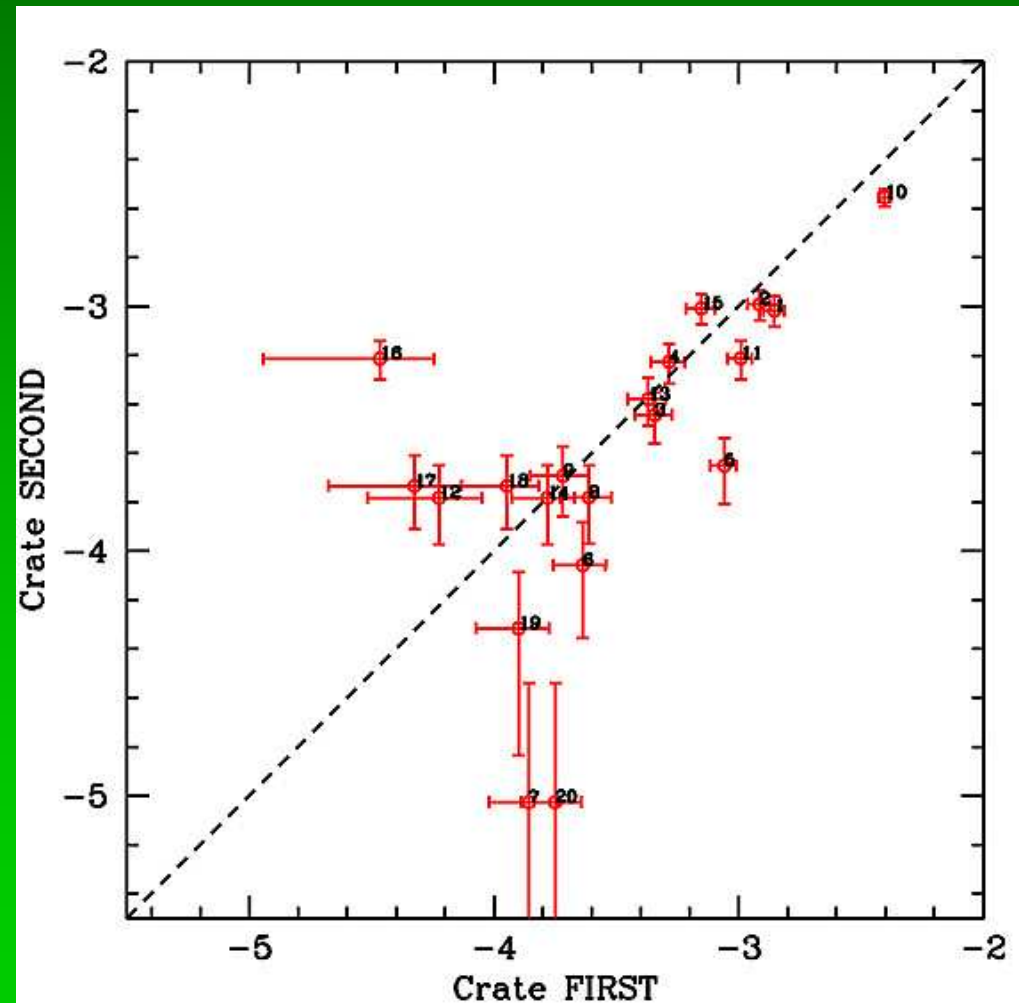
- Blue is the old one (2001), red is the new one (2008)
- A few sources have varied, both in the ring and in G1 (also G2?)

54 ksec; another
50 still to be done

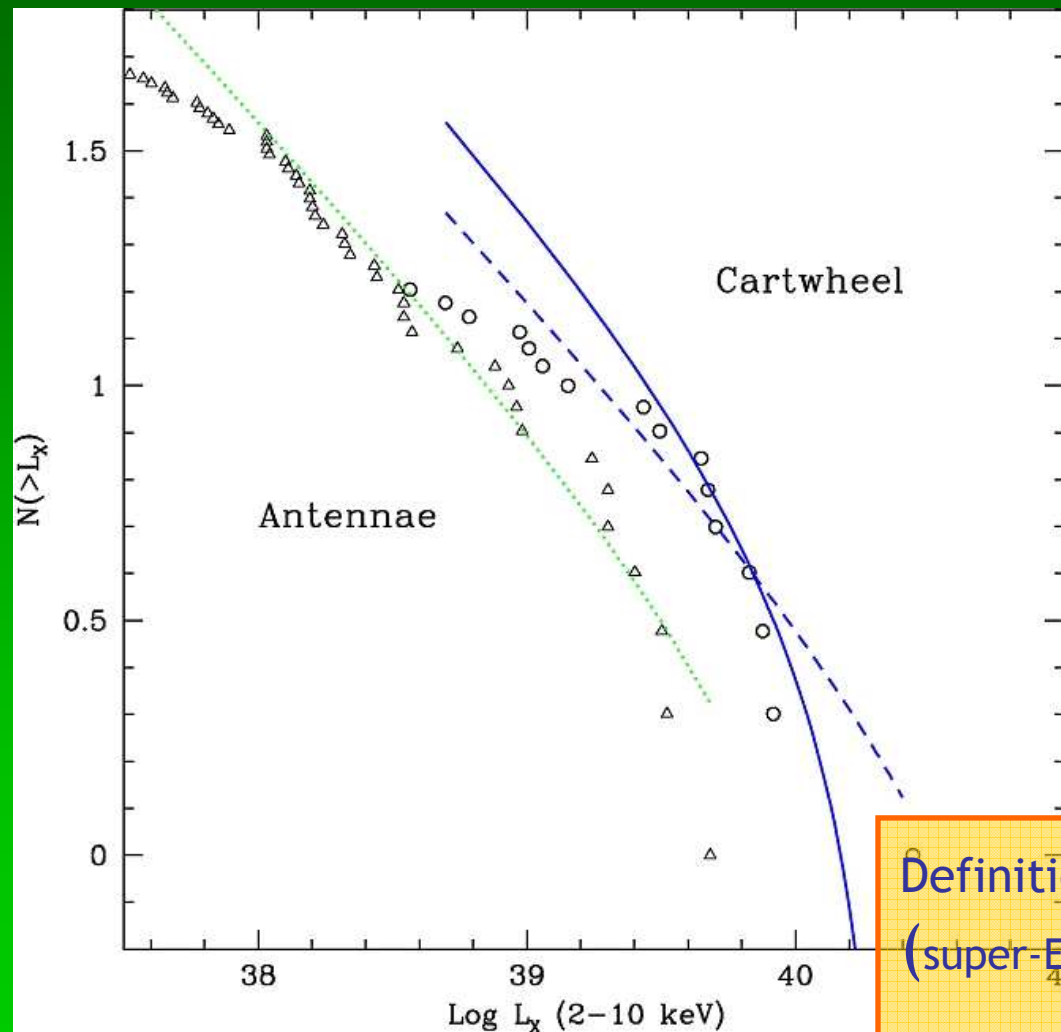


Flux comparison

- VERY PRELIMINARY!!
- In 7 years: CCD less sensitive
- FAINT vs VERY FAINT
- Needs a more accurate flux calculation.



Luminosity Function



Antennae:
SFR = 7 M_{sun}/yr

Cartwheel:
SFR = 20 M_{sun}/yr

or

SFR = 15 M_{sun}/yr

and $L_{\text{cutoff}} = 10^{41} \text{erg s}^{-1}$

(Wolter & Trinchieri 2004)

Definition: ULX has $L_x > 10^{39} \text{erg/s}$
(super-Eddington for a solar mass neutron star)

HLX has $L_x > 10^{41} \text{erg/s}$

CONCLUSIONS

Variability for many ULX in the Cartwheel

Most probably extension of HMXB

They are ALL very bright: link with low metallicity? With high SFR?

Sum of 2 (or 3) Chandra dataset to get spectra

Different epochs LF & comparison

Cosa vorremmo sapere

- MASSA
 - Non ci sono misure dinamiche di massa
 - Forse 1 o 2 candidati disponibili
 - Oggetti vicini piu' facili da studiare
- COME FARE $50 \times L_x$ PER MASSA STELLARE
- COM'E' FATTO IL BUCO NERO ?

