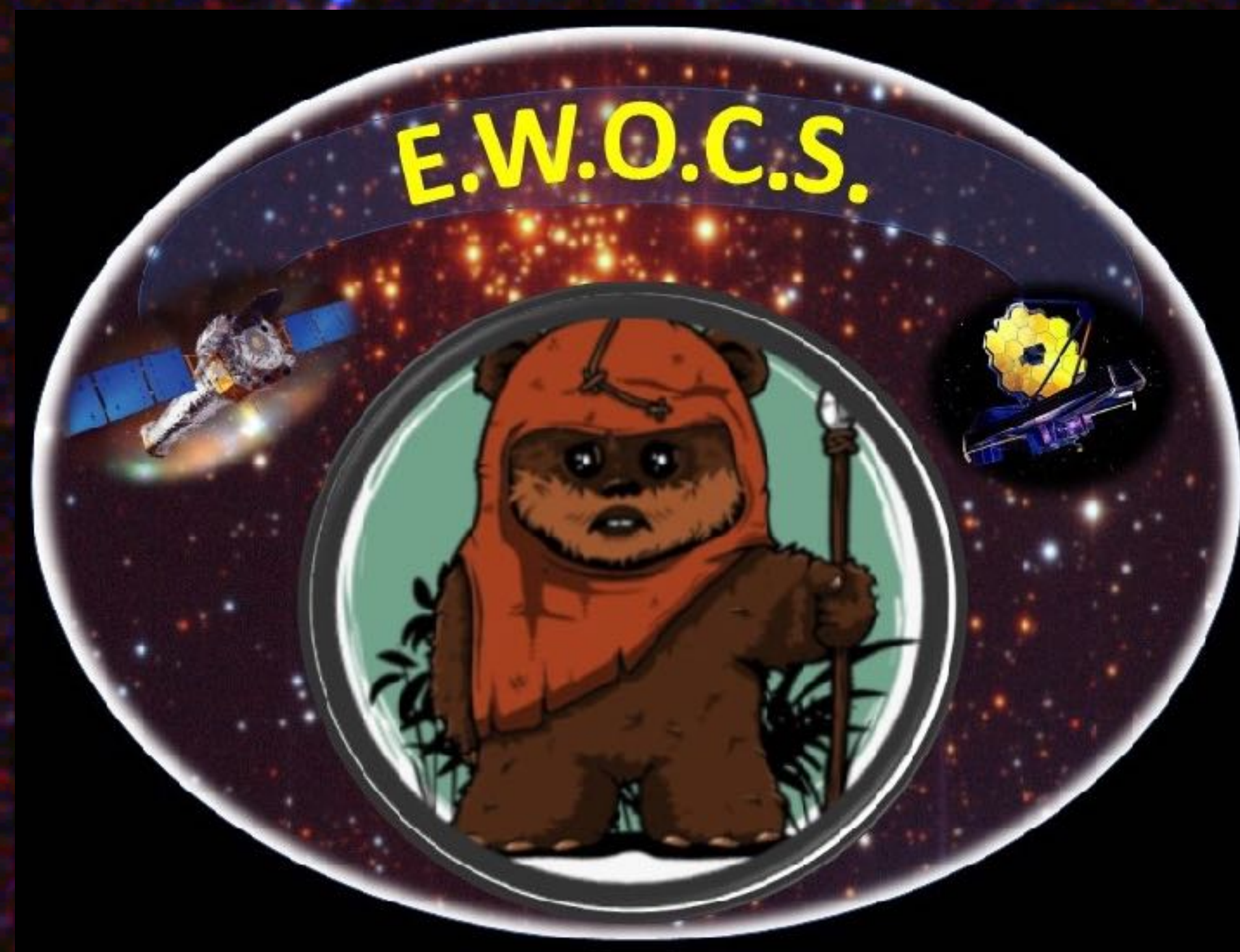


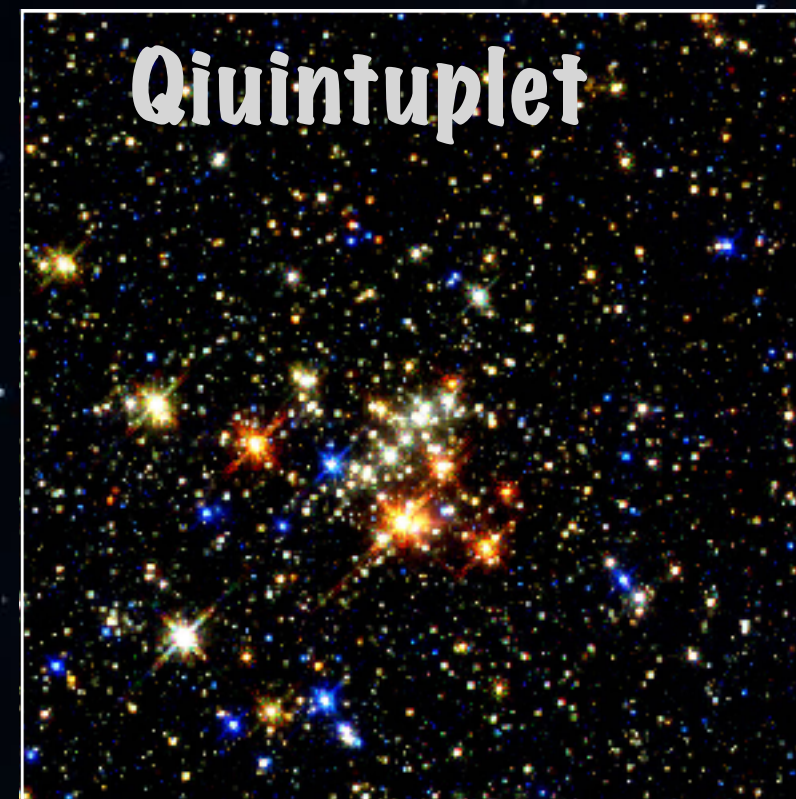


The EWOCs project: an X-ray view of young supermassive star clusters

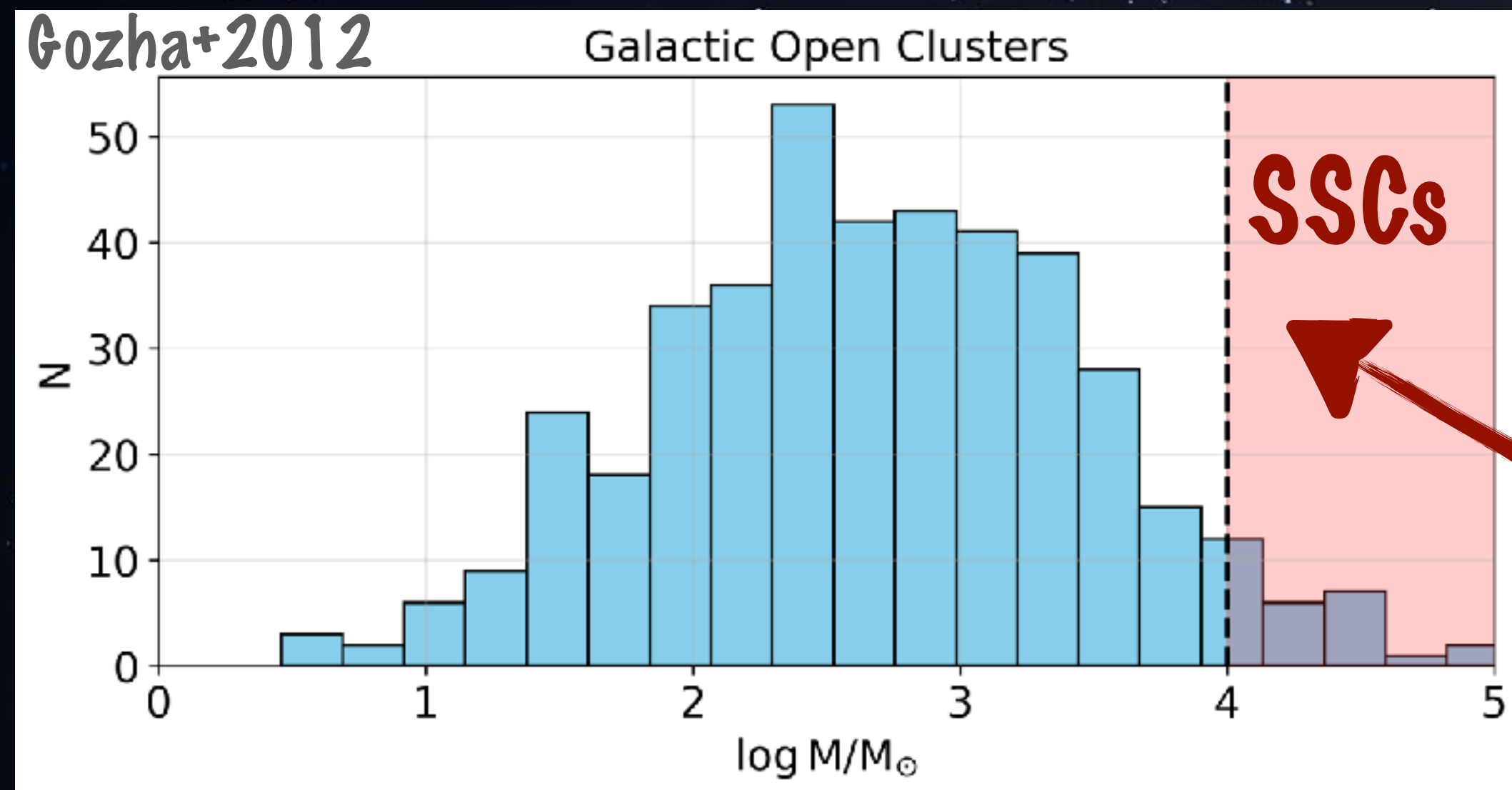
PI: Mario Giuseppe Guarcello
INAF, Osservatorio astronomico di Palermo

Presenter: Konstantina Anastasopoulou
Center for Astrophysics, Harvard & Smithsonian

Young Supermassive Star Clusters (SSCs)



Credit: NASA

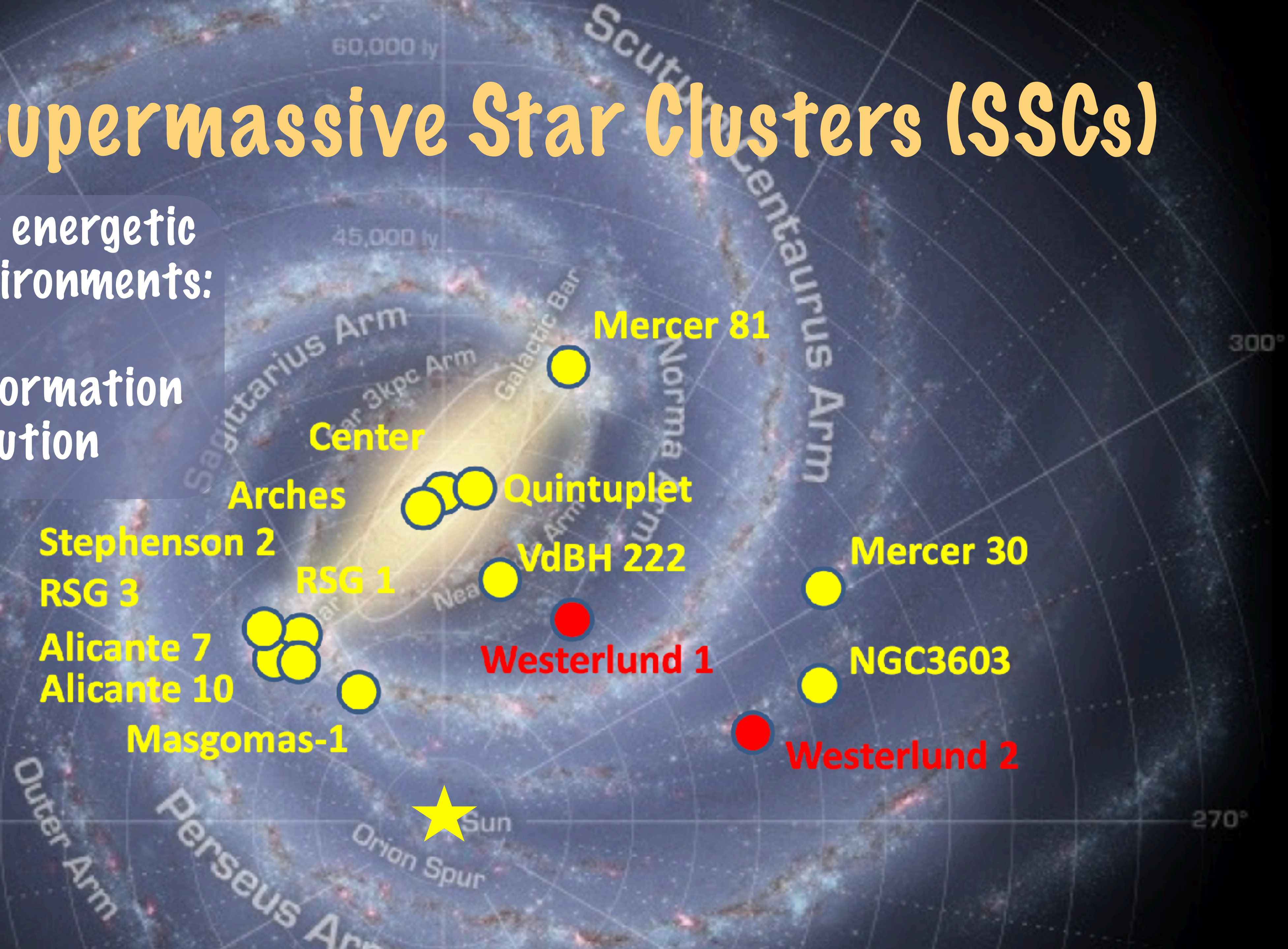


- $M > 10^4 M_{\odot}$
- Ten of thousands of members
- Hundreds of massive stars
- SSCs are very rare!

Young Supermassive Star Clusters (SSCs)

Probe in the most energetic
star forming environments:

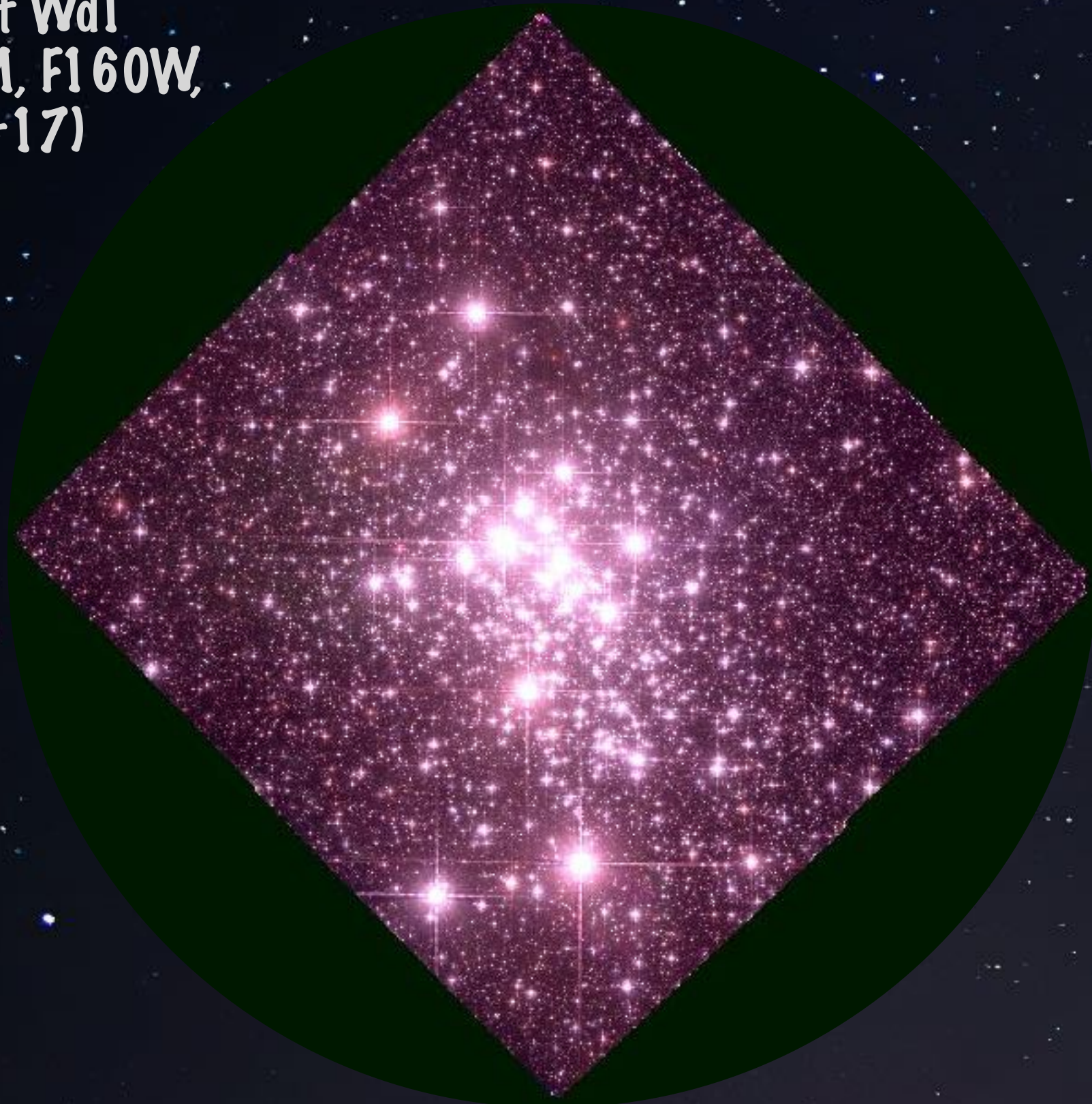
- Star and planet formation
- Early stellar evolution



Westerlund 1 (Wd1) and Westerlund 2 (Wd2)

Best targets to study star and planet formation and early evolution in supermassive star clusters

HST image of Wd1
(F125W, F139M, F160W,
Andersen+17)



HST image of Wd2
(F555W, F814M, F125W,
Vargas Alvarez+13)



Westerlund 1 (Wd1) and Westerlund 2 (Wd2)

Best targets to study star and planet formation and early evolution in supermassive star clusters

- Relatively nearby (Wd1: 2.6-5 kpc, Aghakhanloo+19, Clark+05; Wd2: 4.2 kpc, Vargas Alvarez+13)
- The most massive young clusters known in the MW (several $10^4 M_{\odot}$; Andersen+17, Zedler+17)
- Richest population of massive stars in clusters (many authors)
- Young enough to host protoplanetary discs (Wd1: 3.2-10.4 Myrs; Wd2: 1-2 Myrs)
- Wd1 hosts compact objects (at least two; Munro+05, Borghese+ in prep, Israel+ in prep)

EWOCs project

P.I. Mario G. Guarcello and 50+ researchers

Extended **W**esterlund 1 and 2 **O**pen **C**lusters **S**urvey

OBJECTIVES

Protoplanetary
disks

Wd1 : Magnetar

Planet formation

Stellar content

Lifecycle of SSCs

Lifecycle of massive
stars

Compact objects

Cluster IMF



<https://westerlundsurvey.wordpress.com/>



The EWOCs project: main datasets



1 Msec ACIS-I Chandra (**Wd1**)



JWST MIRI/NIRCam
23.6h + 1.9h DD (**Wd1**)
24.7h (**Wd2**)



Together with

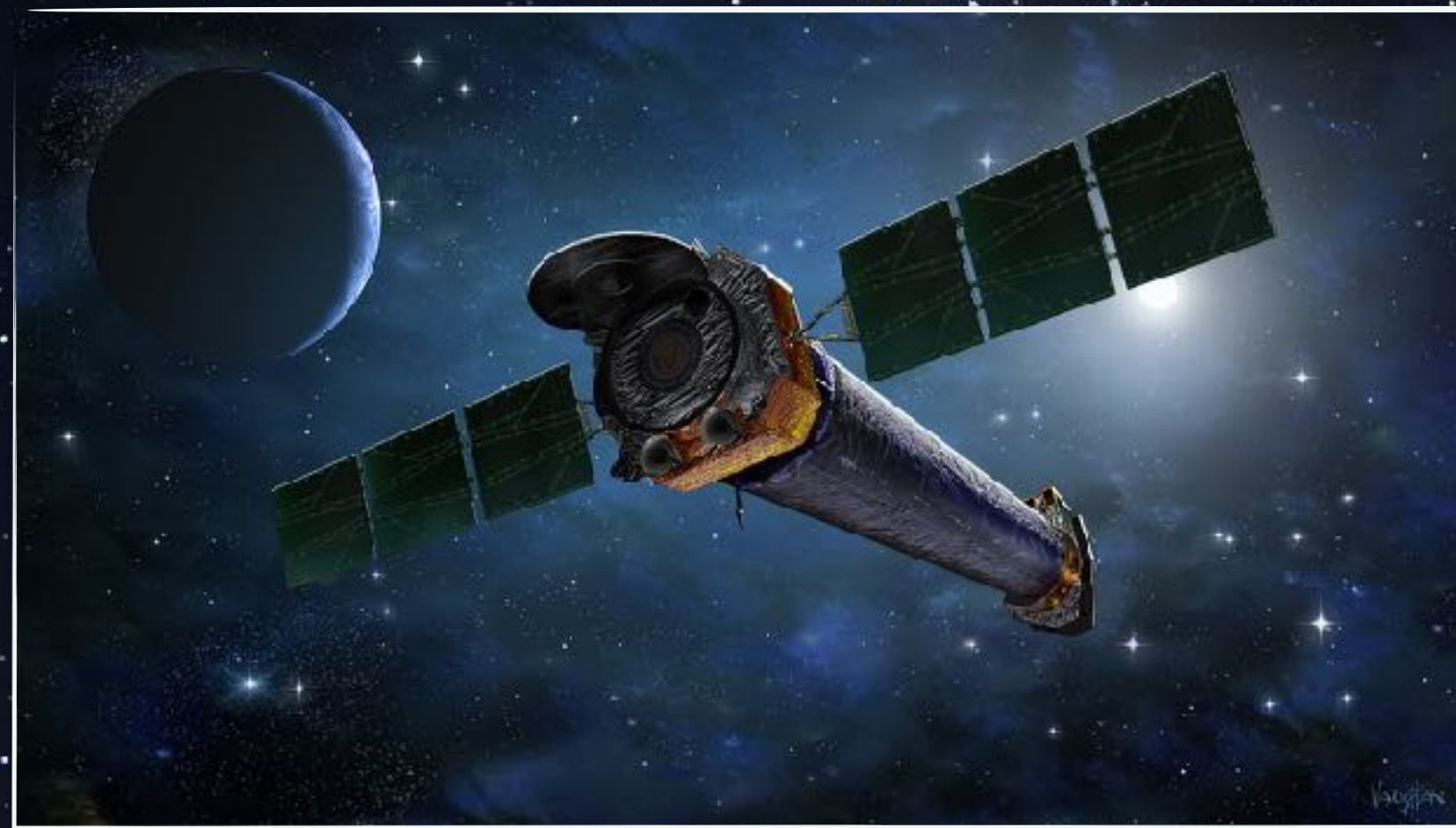
- HST
- NICER
- KMOS
- ALMA
- MeerKAT
- VVVx
- Gaia
- MUSE
- Swift

...and others in the future



The EWOCs project: First results

1 Msec ACIS-I Chandra **Westerlund 1**



Stellar content

The most massive stars

Compact objects

Diffuse emission

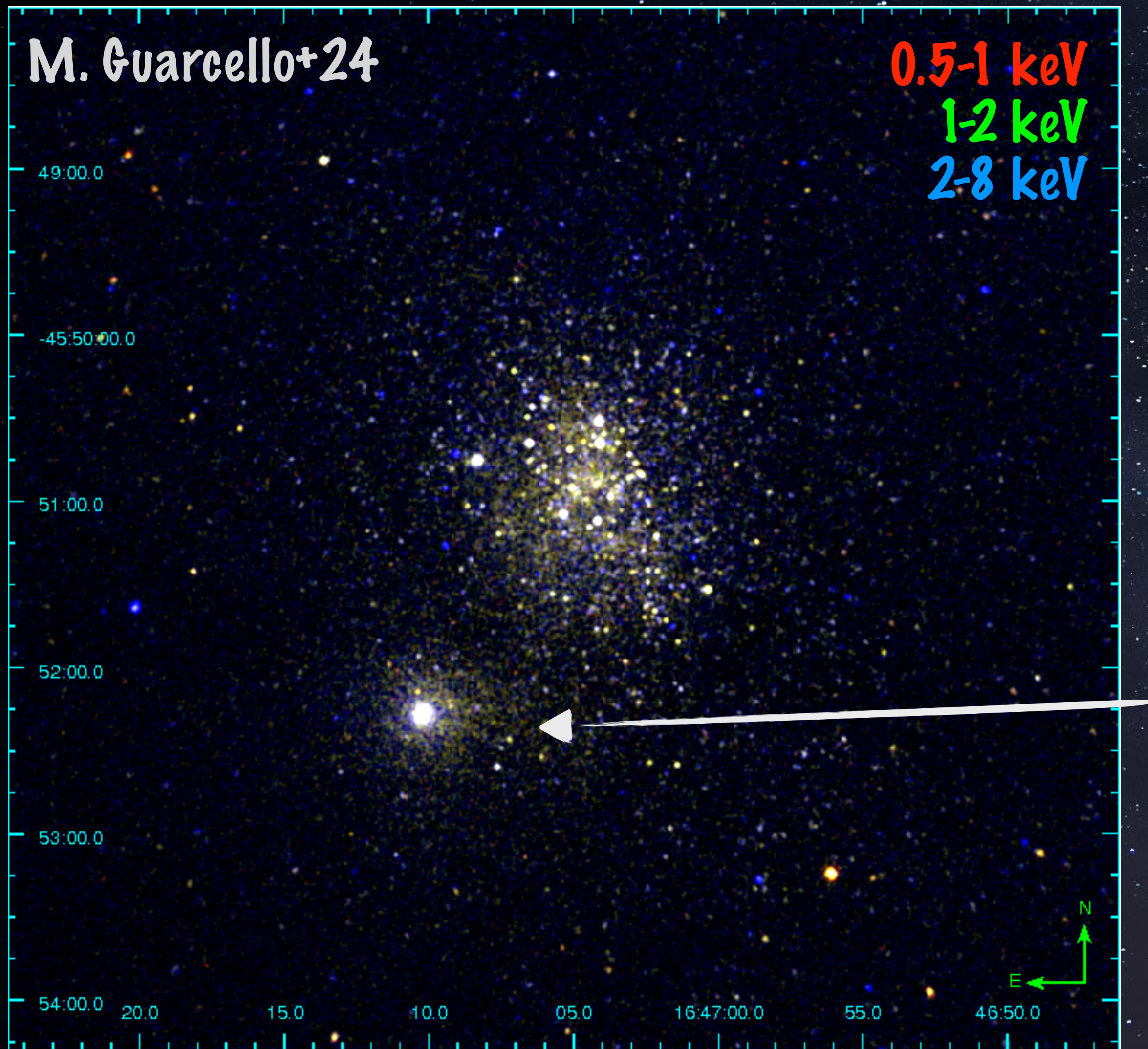
EWOCs -Westerlund 1 Stellar X-ray content

1Ms Chandra ACIS observations

Chandra catalogue:

- 5963 validated sources
- Magnetar
- 126 (out of 166) massive stars

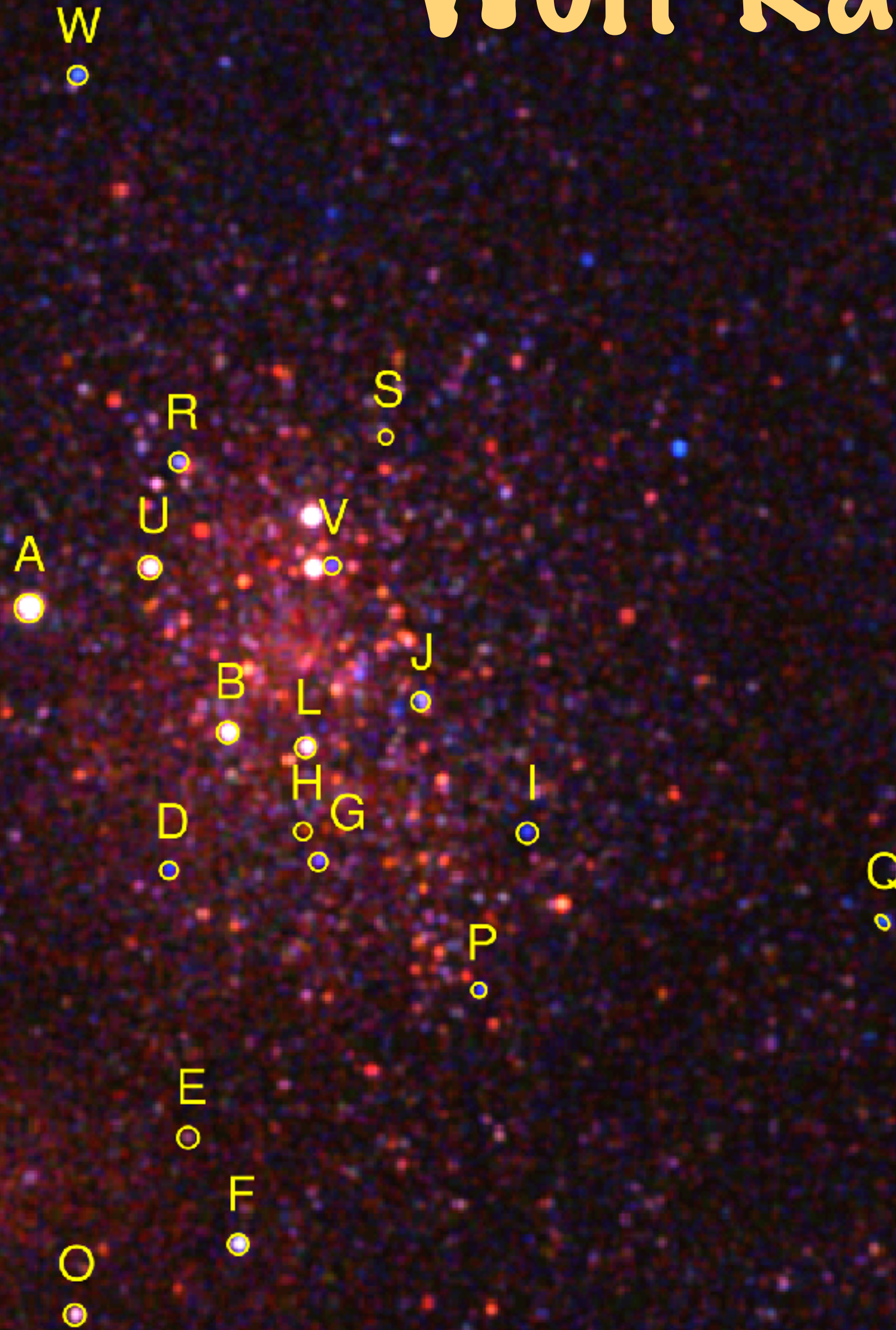
Guarcello+24



S: 0.5-2 keV M: 2-4 keV H: 4-8 keV

Wolf-Rayet stars in Wd1

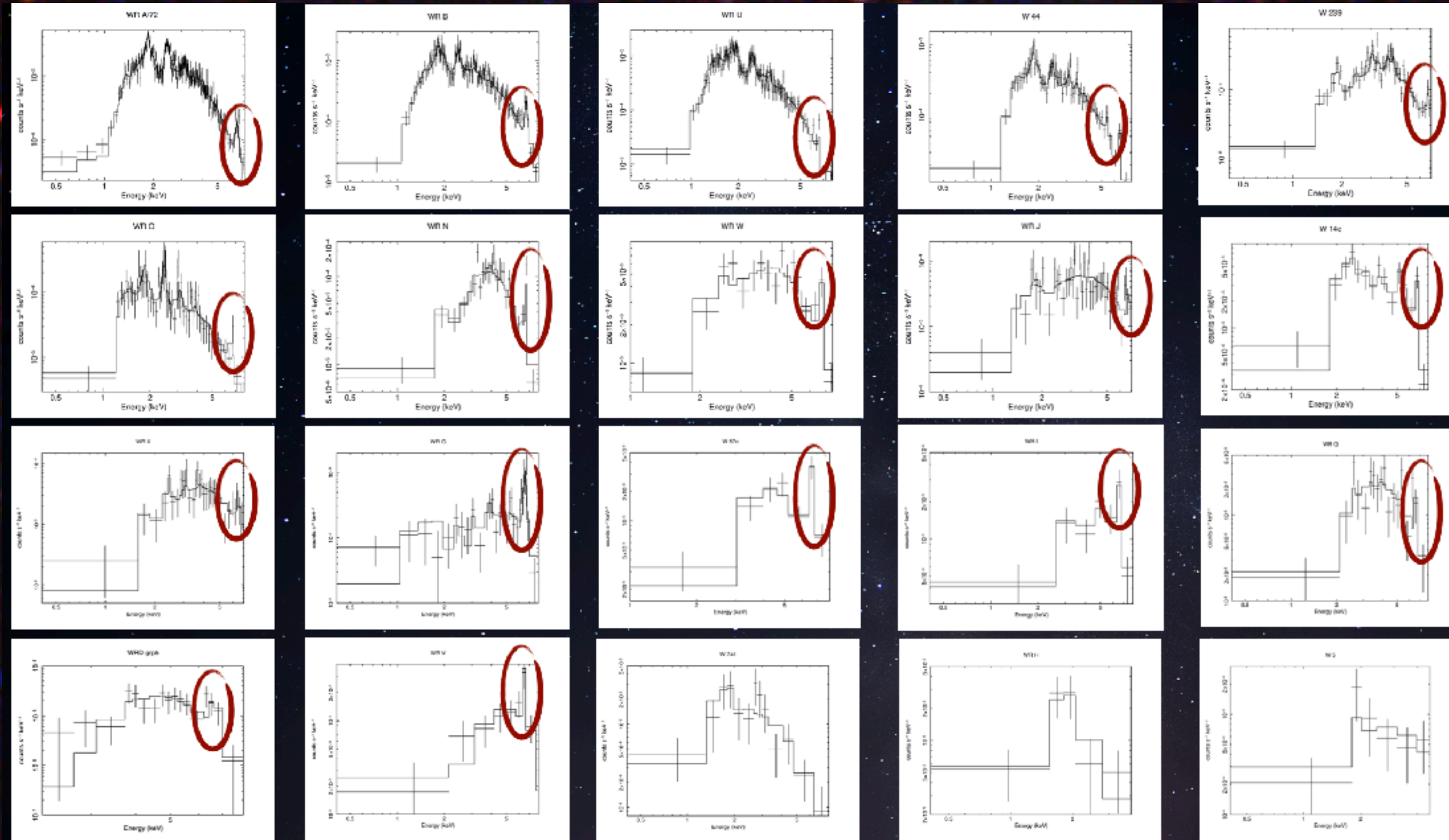
- Detected 20 out of the 24
- Lx range: $2e30$ to $5e32$ erg/s



S: 0.5-2 keV M: 2-4 keV H: 4-8 keV

W
○

Wolf-Rayet stars in Wd1



- Detected 20 out of the 24
- Lx range: $2e30$ to $5e32 \text{ erg/s}$

- Thermal spectra:
kT approx 2-4 keV
FeXXV line 6.7keV

Q
○

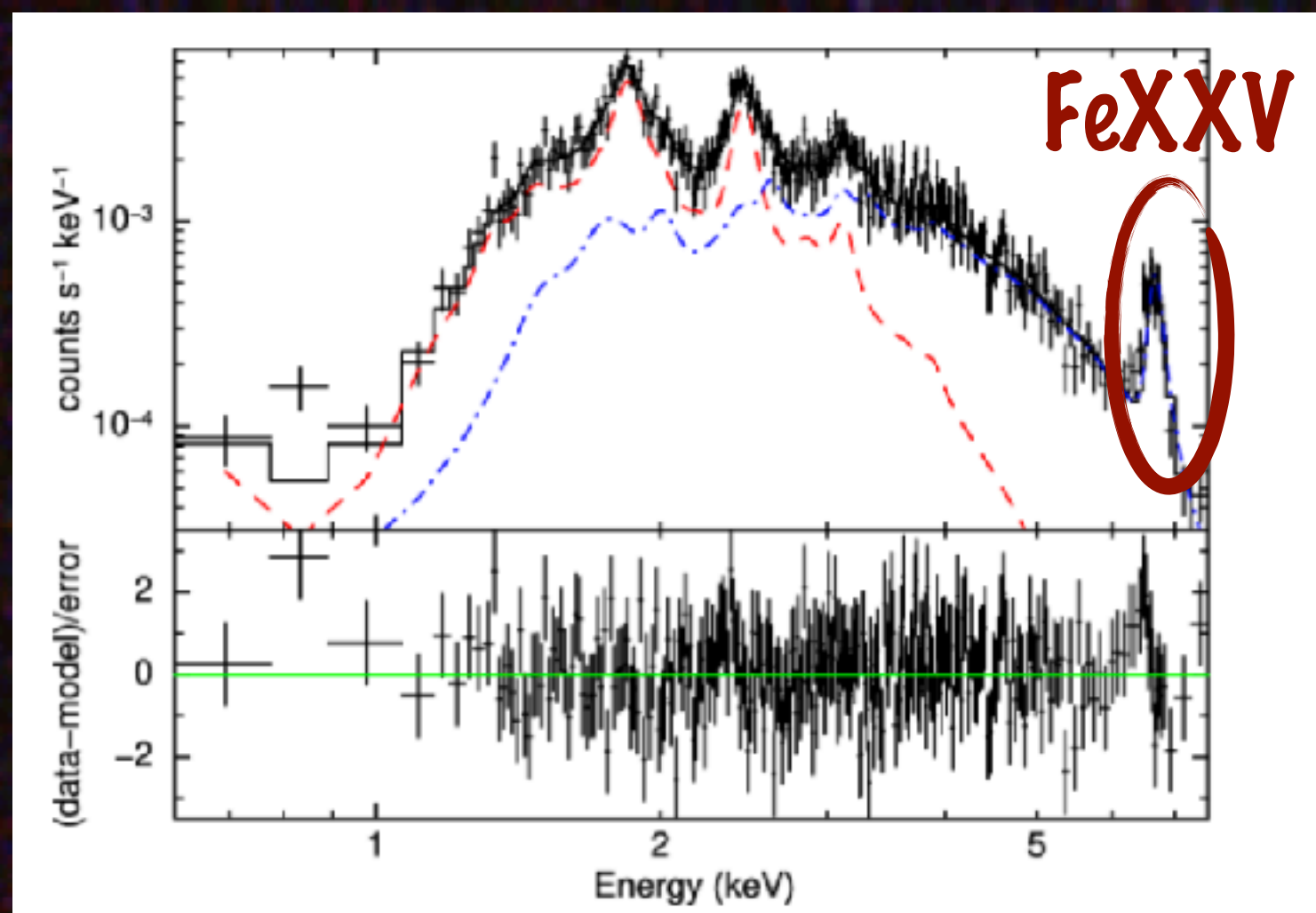
↓
Hot gas $T > 10\text{-}20 \text{ MK}$

For more details: Anastasopoulou+24
Check out poster 26

92-100% of the WR stars
colliding wind X-ray
binaries

Interesting massive stars in Wd1

S: 0.5-2 keV,
M: 2-4 keV
H: 4-8 keV

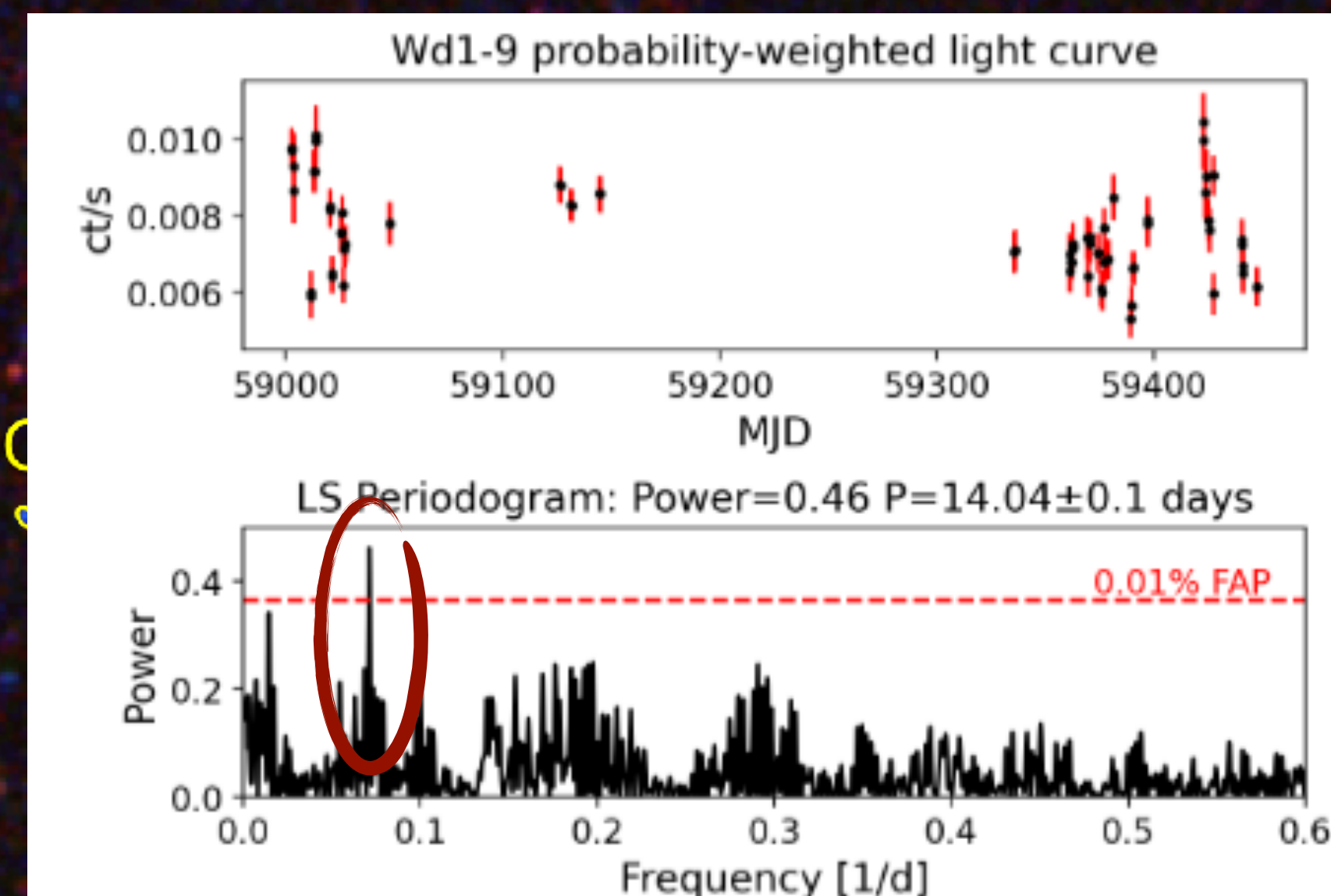


- Spectrum indicative of colliding wind X-ray binary



Anastasopoulou+in prep

Wd1-9: Supergiant B[Oe] Star
Binary system buried in a
circumstellar disc (Clark+13)



- 14 days period

Compact objects in Westerlund 1

S: 0.5-2 keV,

M: 2-4 keV

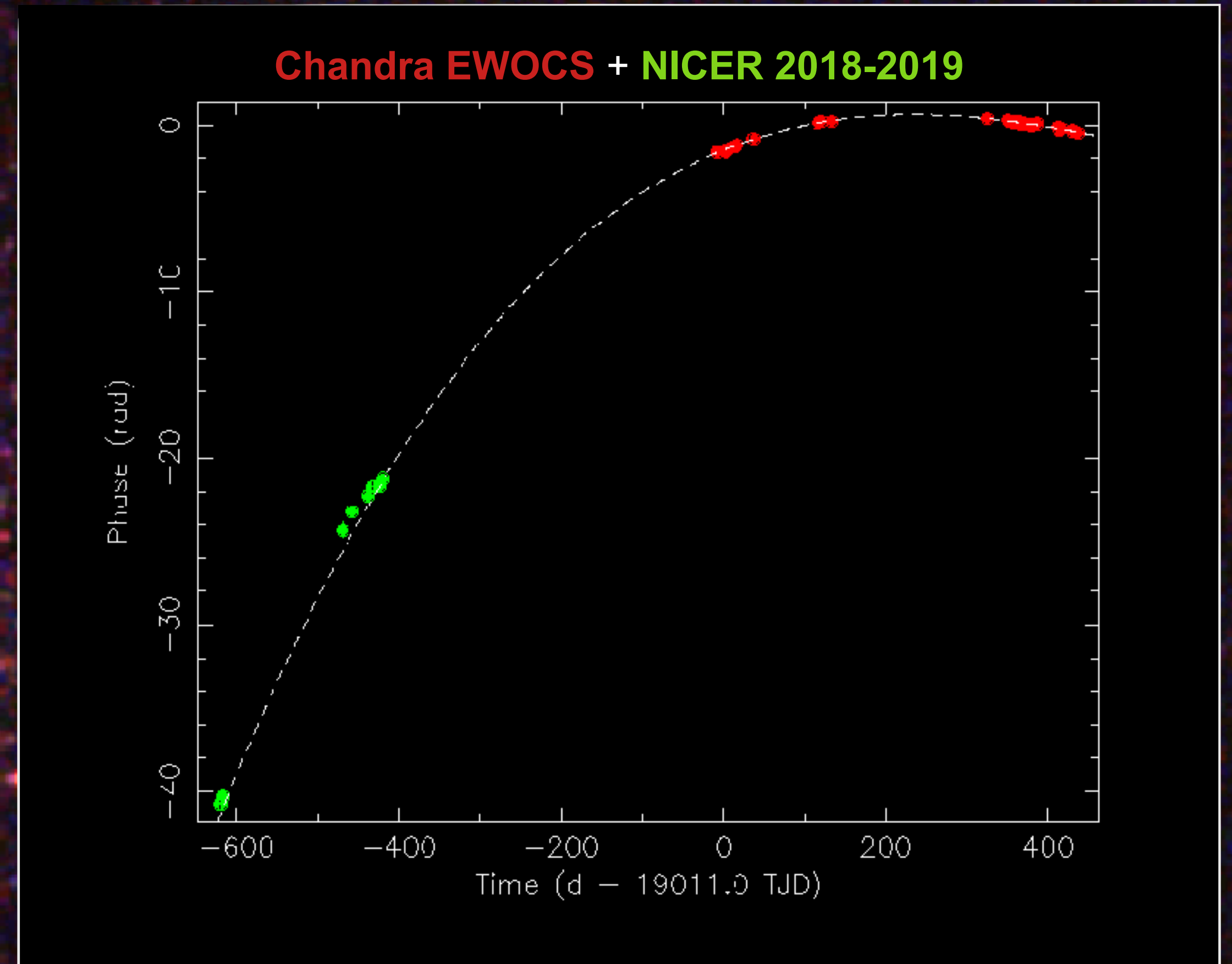
H: 4-8 keV

10.6s magnetar

Outbursts: 2006 2011 2017 2018

EWOCS epochs are far from glitch/
burst (good for timing)

A. Borghese+in prep CXO J164719.2-455216
Wessy

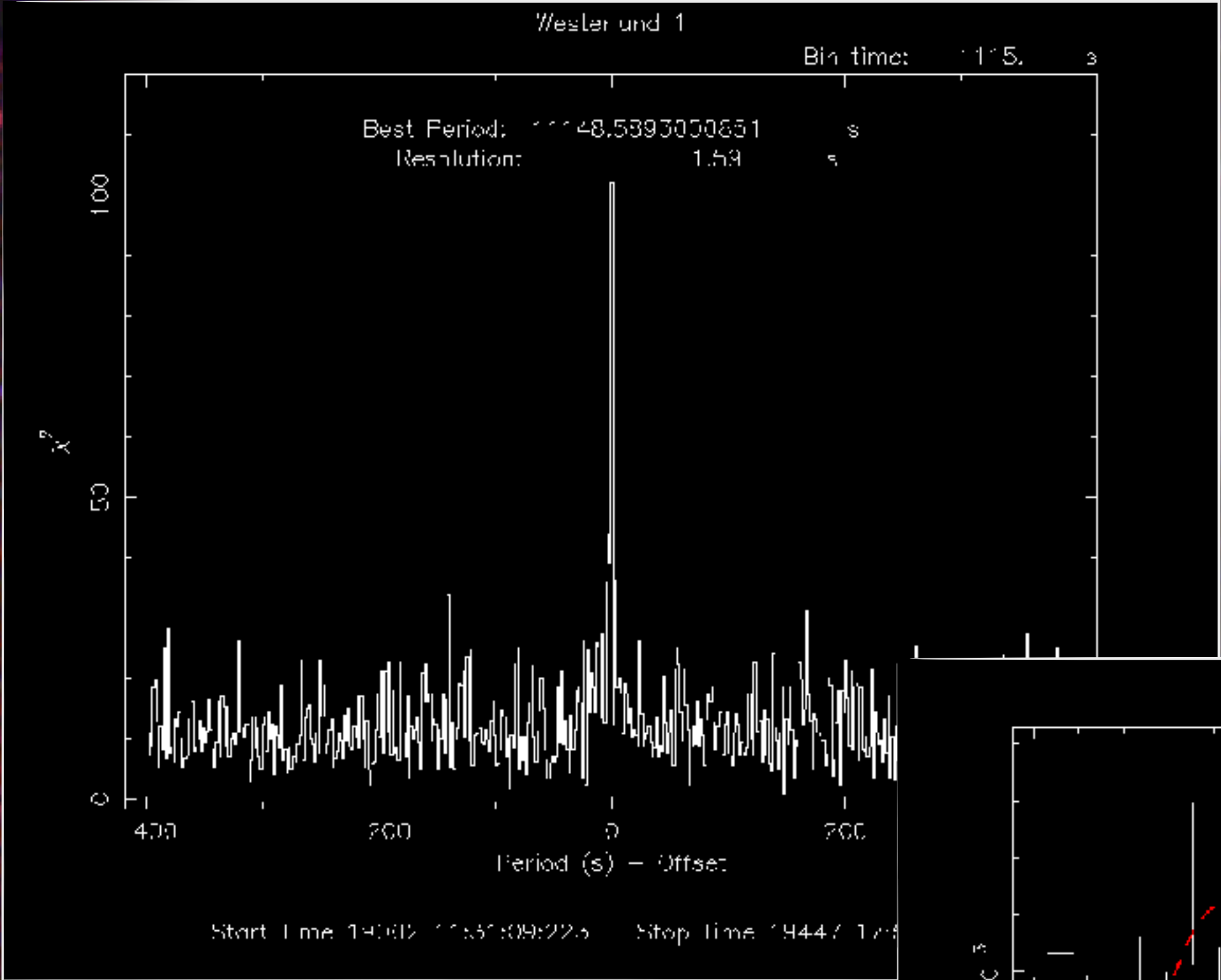


New Timing Solution from EWOCS data:
 $P=10.6107\text{s}$; $\dot{P}=2.5\text{e-}13\text{ s/s}$, $\ddot{P}=4.9\text{e-}21\text{ s/s}^2$
 $B_{\text{dip}} \sim 5 \times 10^{13}\text{ G}$; $T \sim 0.7\text{ Myr}$

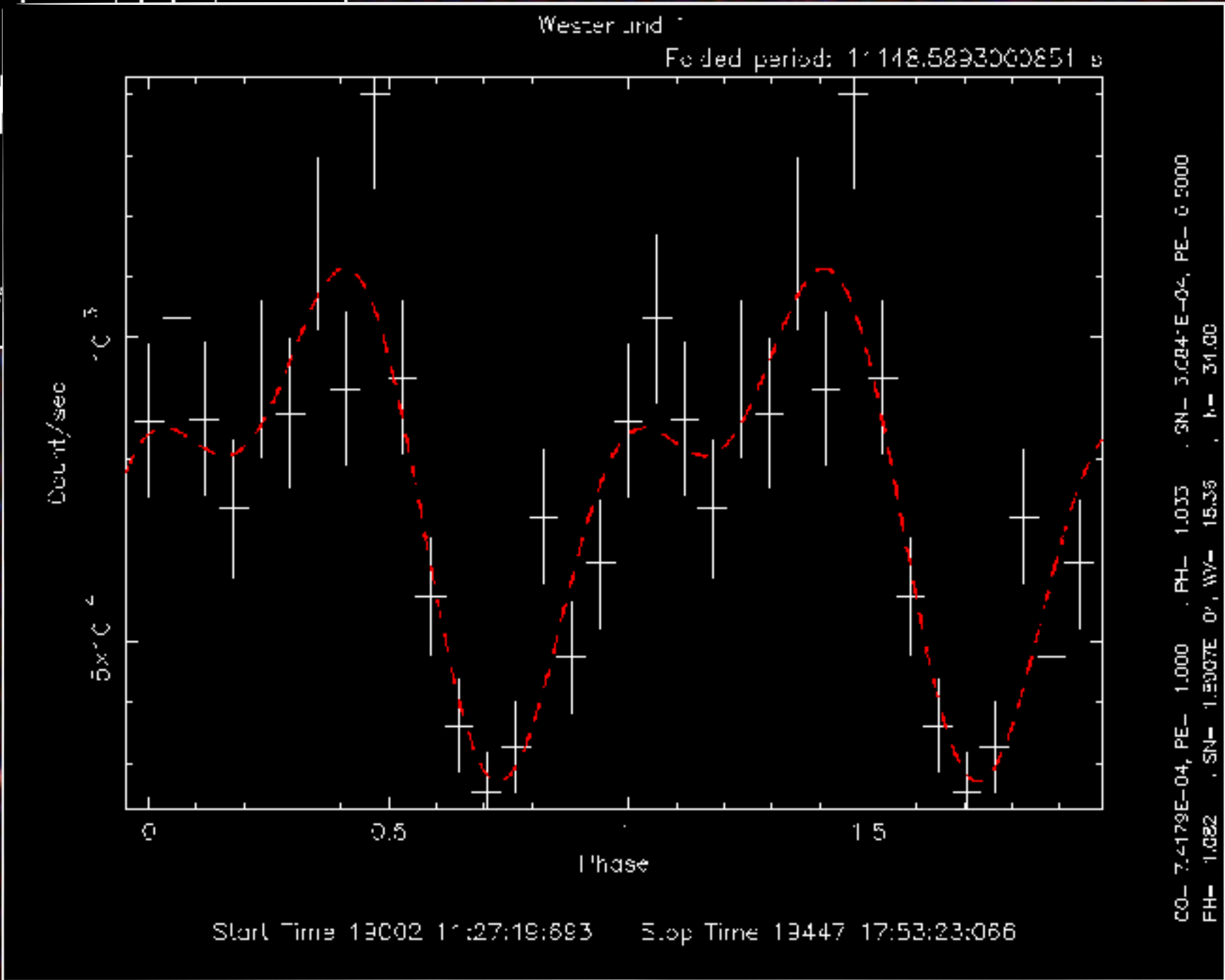
Compact objects in Westerlund 1

S: 0.5-2 keV,
M: 2-4 keV
H: 4-8 keV

New pulsator
found



PSD and
Light curve

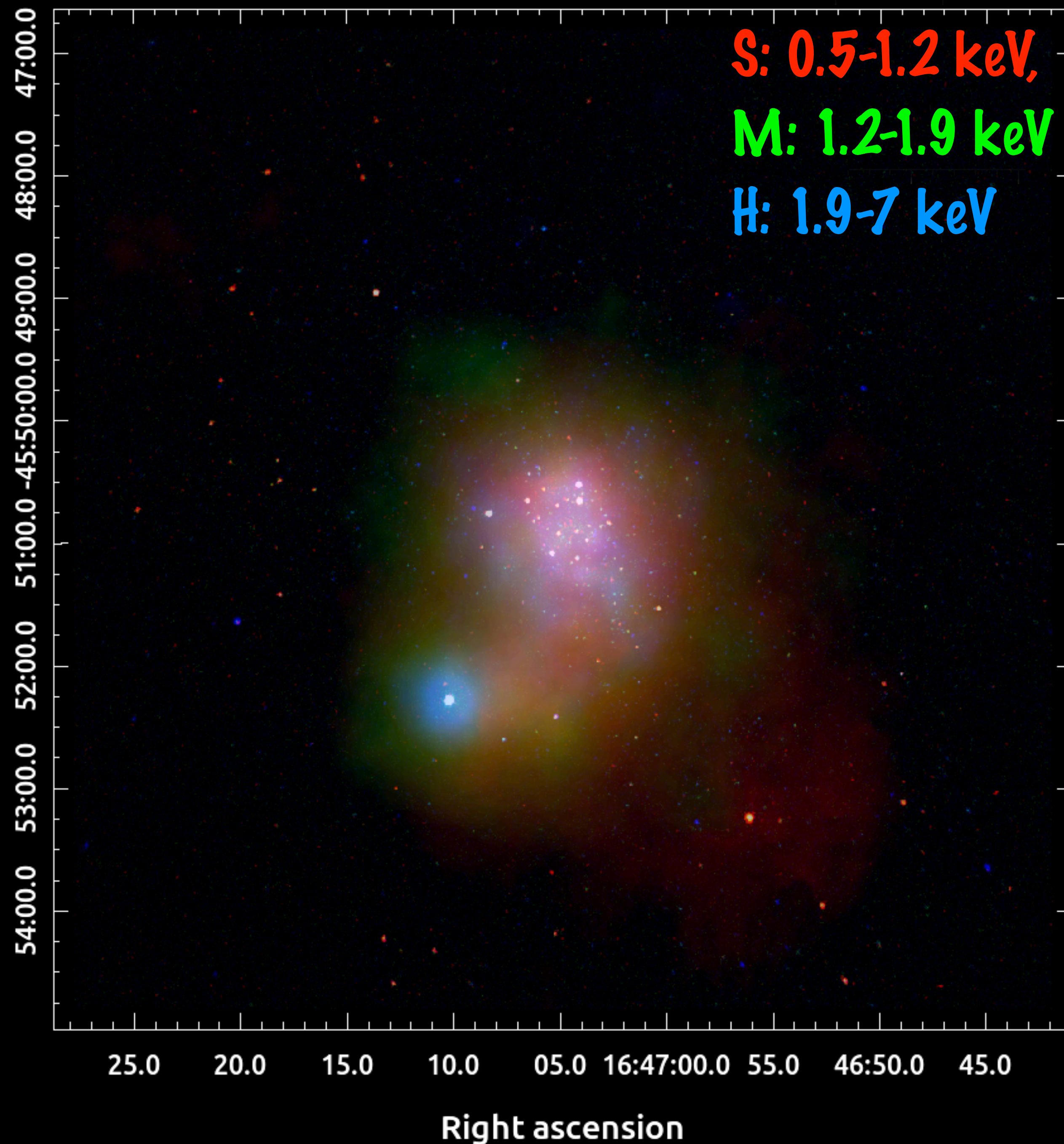


G. Israel+in prep



Pulsation
P=11150s
3.1h

Declination



Diffuse emission in Wd1

Not all detected X-ray
photons are associated with
sources.

Cluster Diffuse emission
main sources should be:

- Unresolved sources
- Winds from massive stars
- Hot intracluster gas

F. Albacete Colombo+ in prep

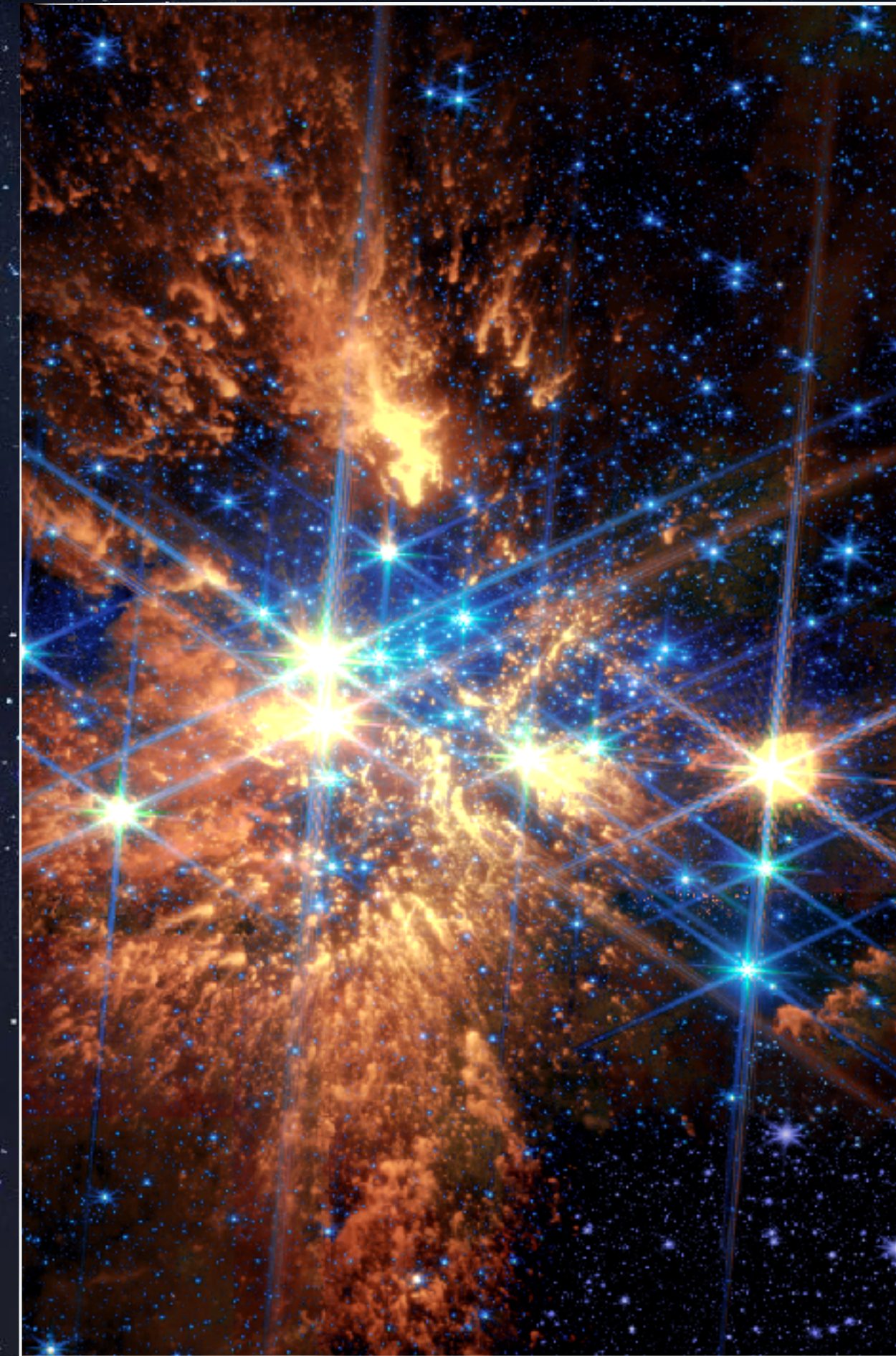


JWST NIRcam and MIRI: Wd1



F150W+F277W+F444W

V. Almendors Abad, K. Muzic, T. Rom



K.Monsch, J.Lovel, J.R. Martinez
Galarza

First publication:
Guarcello+24



W237

Take away remarks

Young supermassive star clusters probe star and planet formation and early evolution in starburst conditions

!!This science can only be done by Chandra!!

<https://westerlundsurvey.wordpress.com/>

Objective of the EWOCs project focused on Westerlund 1 and Westerlund 2 with Chandra/ACIS and JWST

Amazing X-ray results:
source content
massive stars; diffuse emission and compact objects

Thank you...

