Optical studies of an ultraluminous X-ray source: NGC1313 X-2

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in collaboration with
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OUTLINE

- background: ultraluminous X-ray sources
- a case study: NGC1313 X2
    - X-ray observations
    - optical observations
        - astrometry
        - photometry
        - color-magnitude diagram
        - spectral energy distribution
    - discussion
        - IMBH formation
        - period?
        - radial velocity

ultraluminous X-ray sources

ULTRALUMINOUS X-RAY SOURCES

- ULXs are non-nuclear X-ray point sources with Lx > 2 X 10^{39} erg/s, i.e., more luminous than the Eddington luminosity for stellar mass black holes, and could be intermediate mass black holes of 30 - 10^5 Ms

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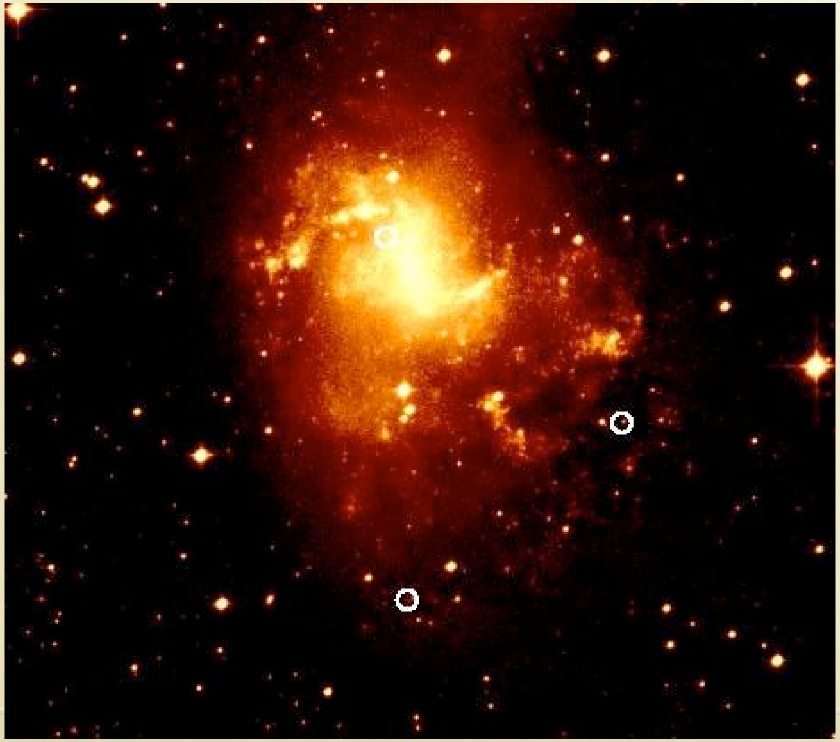
  - how do they form if IMBH?
  - how do they radiate if stellar mass black holes?

ULXs in NGC1313

- a barred SB(s)d galaxy at 3.7Mpc
- low metallicity of 0.1-0.2 Zs
- irregular SW satellite regions - a tidally disrupted companion galaxy? a collision of huge HI clouds with the disk?
- ULXs: X1, X2, and SN1978K



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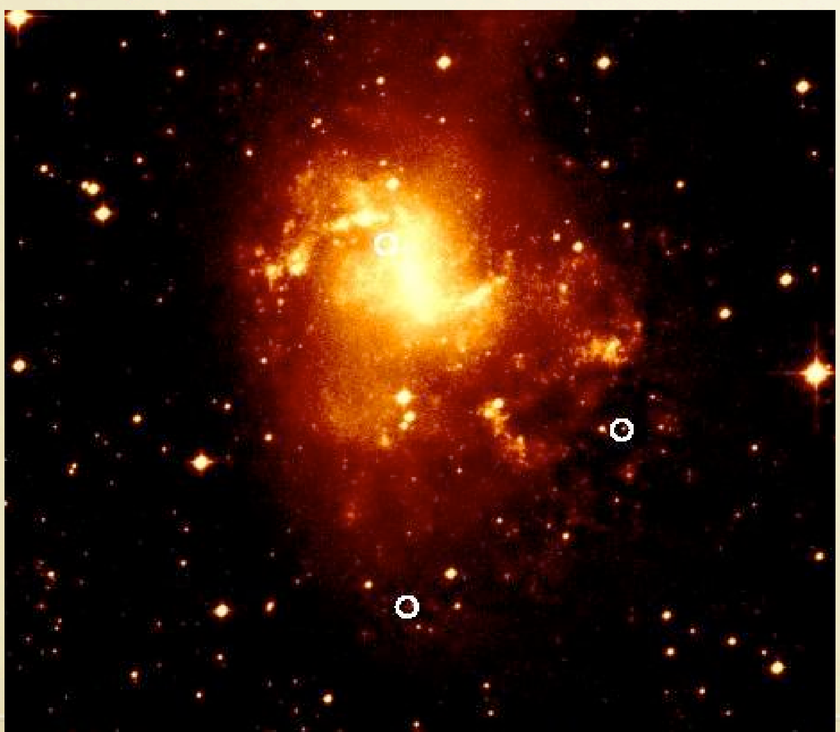
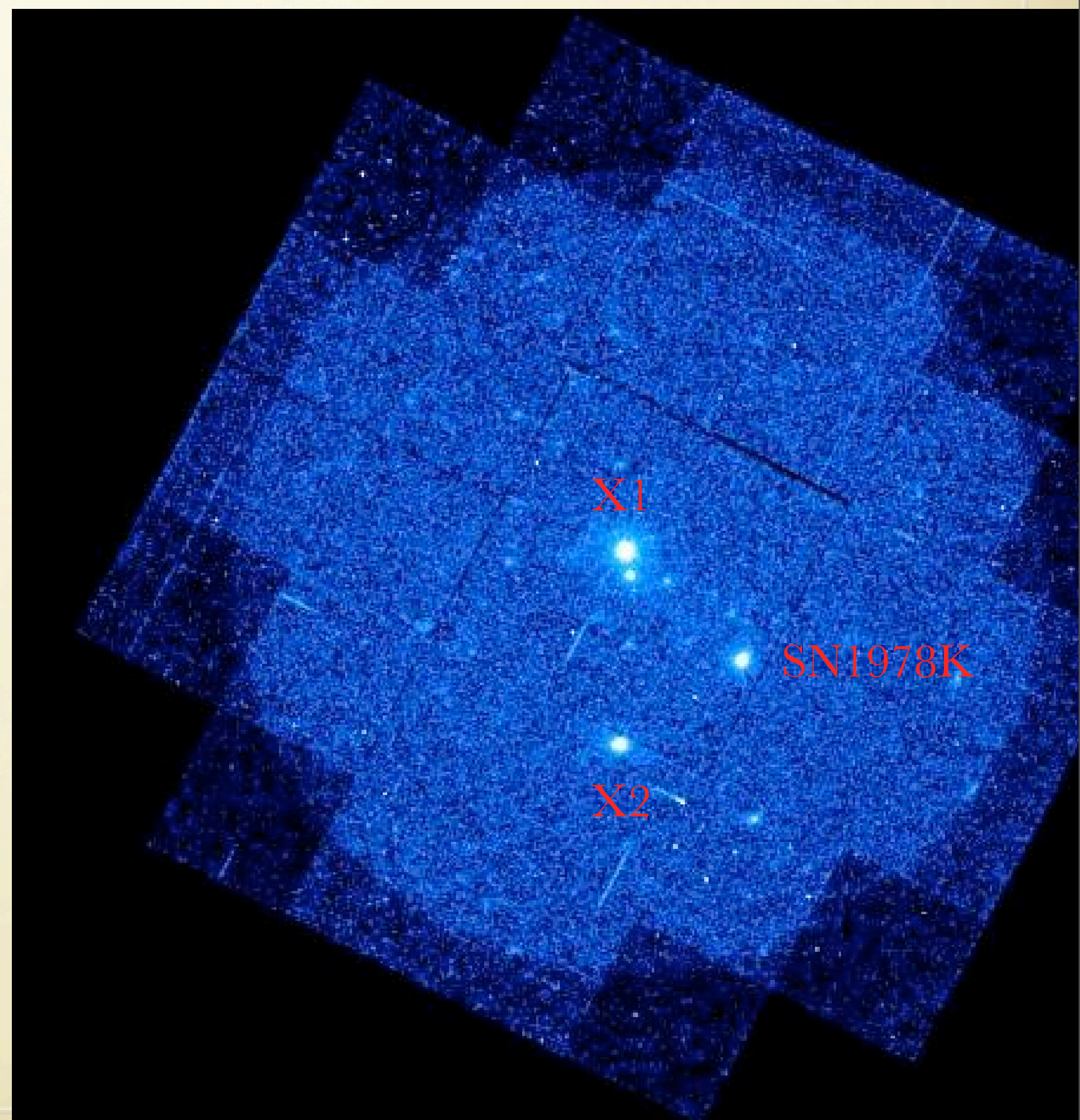
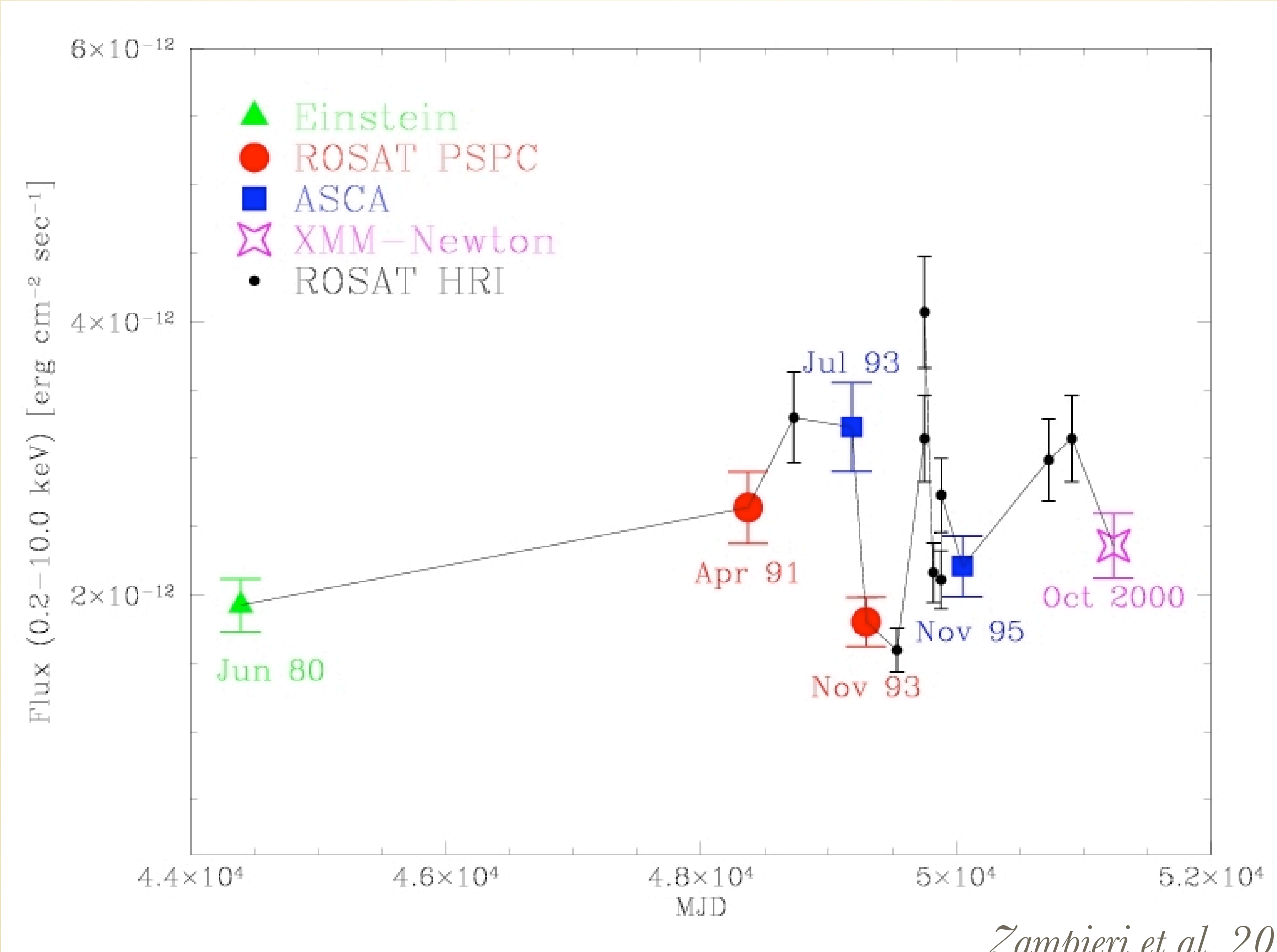




X-ray observations: light curves



Zampieri et al. 2004

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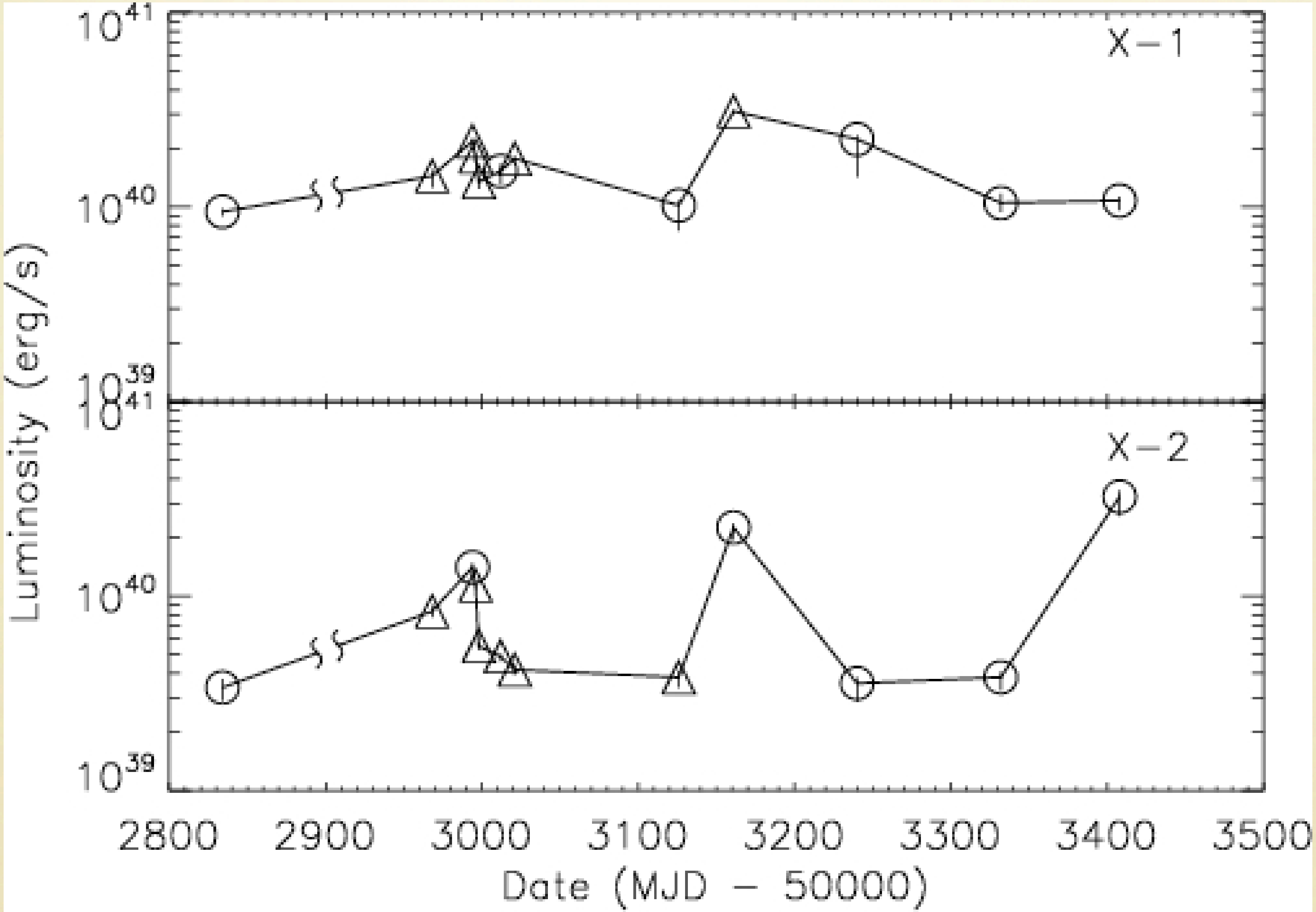
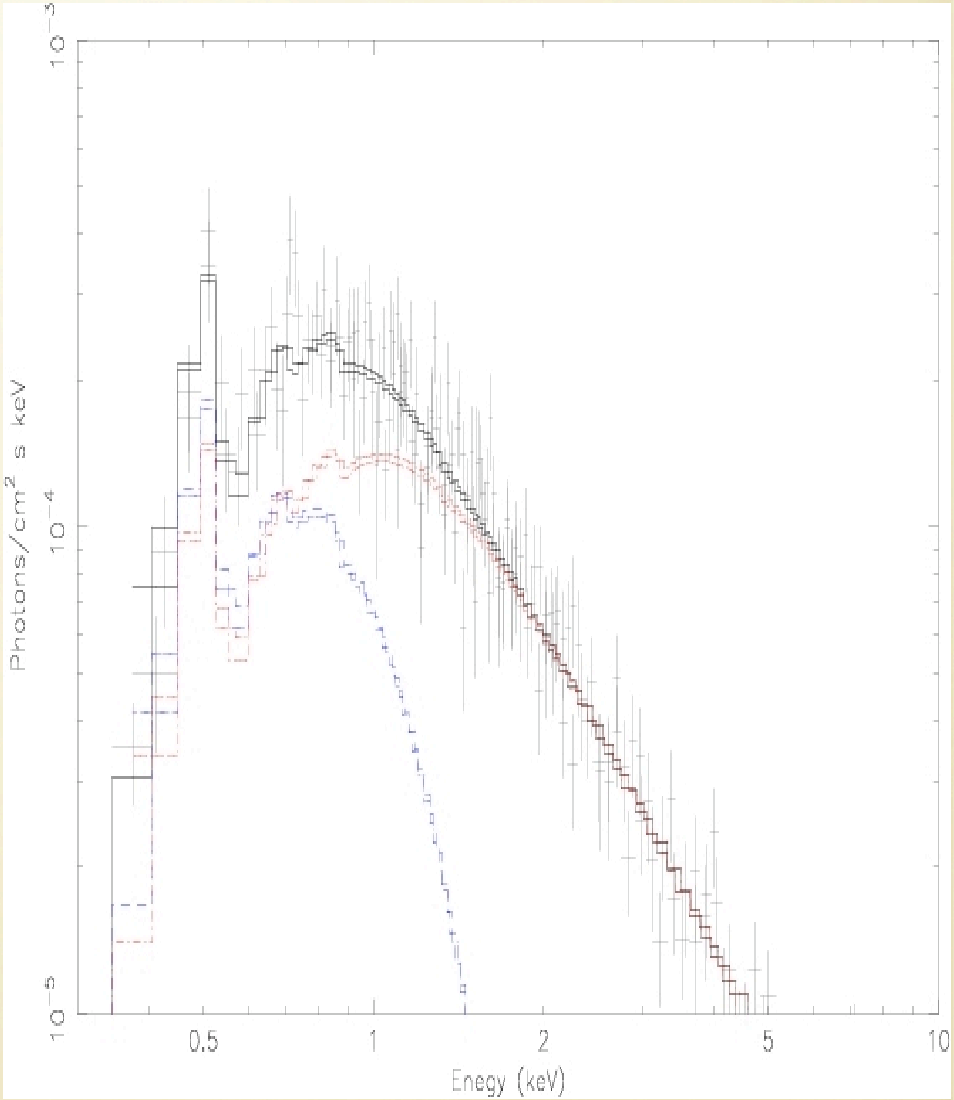


XMM

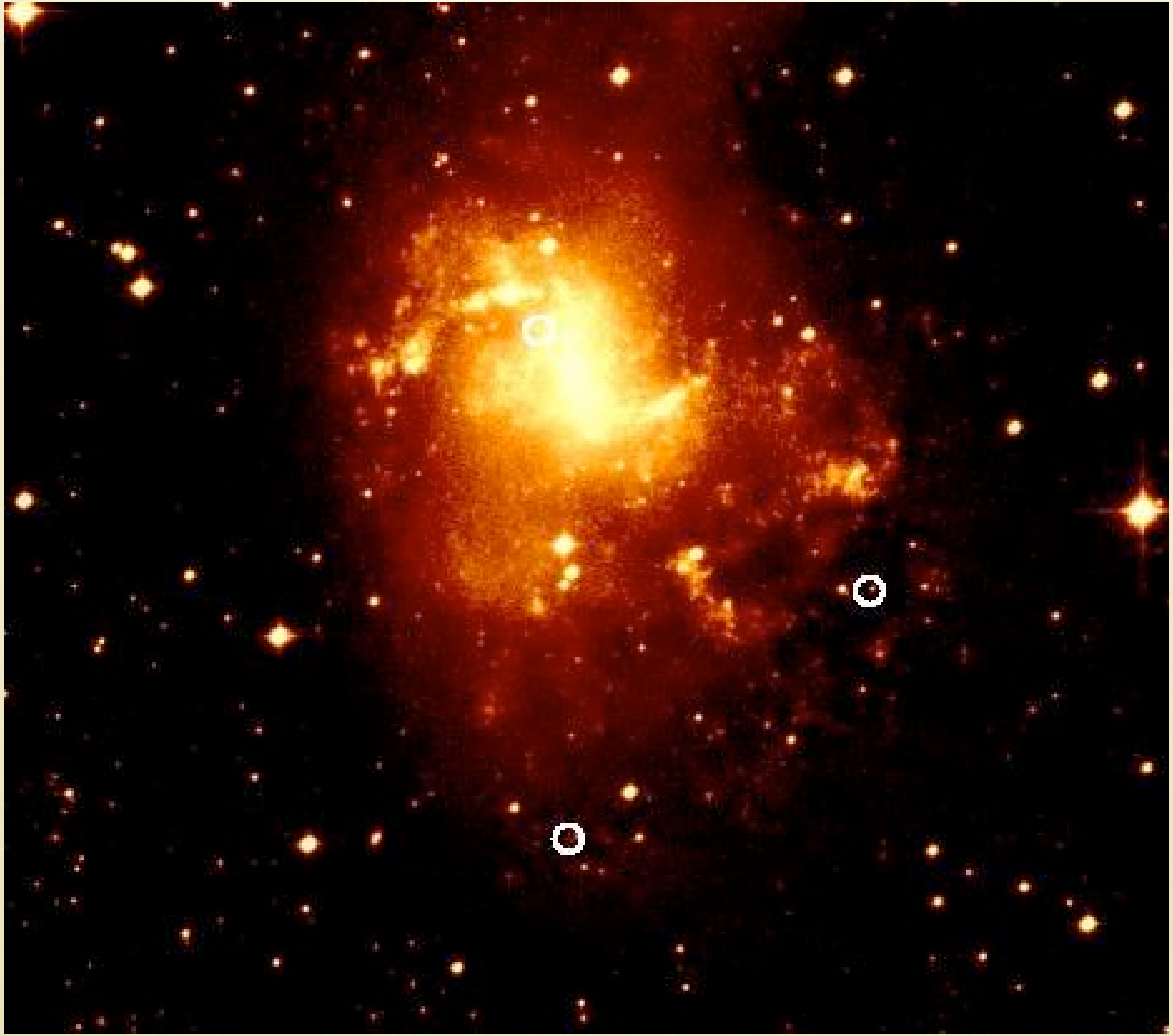
Feng & Kaaret 2006

X-ray observations: spectroscopy

- light curves
  - observed since EINSTEIN
  - variability on time scales from days to months to years
  - maximum Lx up to 3×10^{40} erg/s
- X-ray spectra
  - can be fitted with a power-law (Γ~2.3, 63%) plus a cool accretion disk (~160 eV, 37%) suggestive of a IMBH of ~10^3 Ms (Miller et al. 2003)
  - but the cool accretion disk component is dominated by the power-law component, and the fit is not unique
  - it can also be fitted with a power-law (Γ~2.9,64%) plus a hot disk (~2.7 keV, 36%). (Stobbart et al. 2006)



OPTICAL OBSERVATIONS



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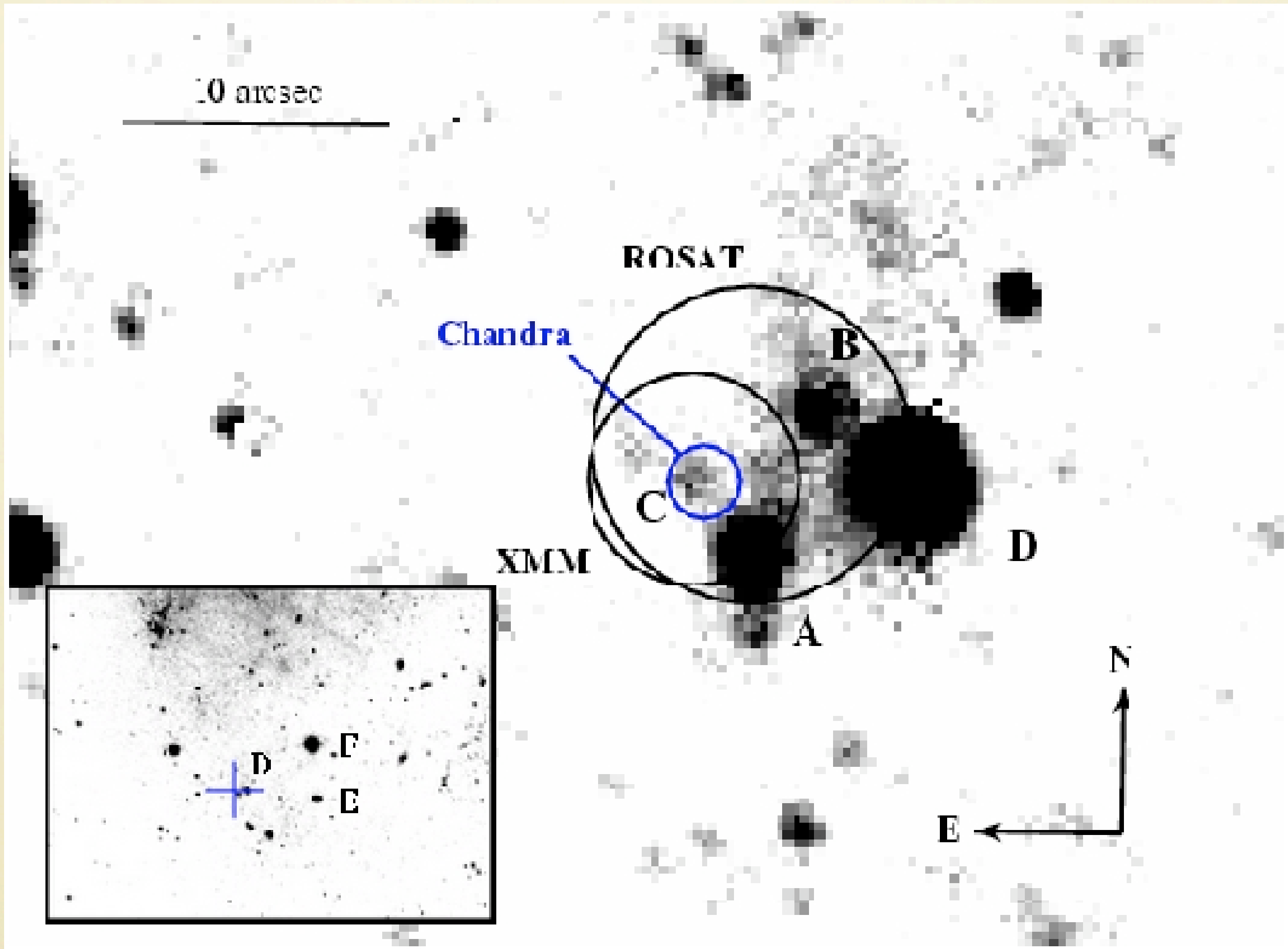
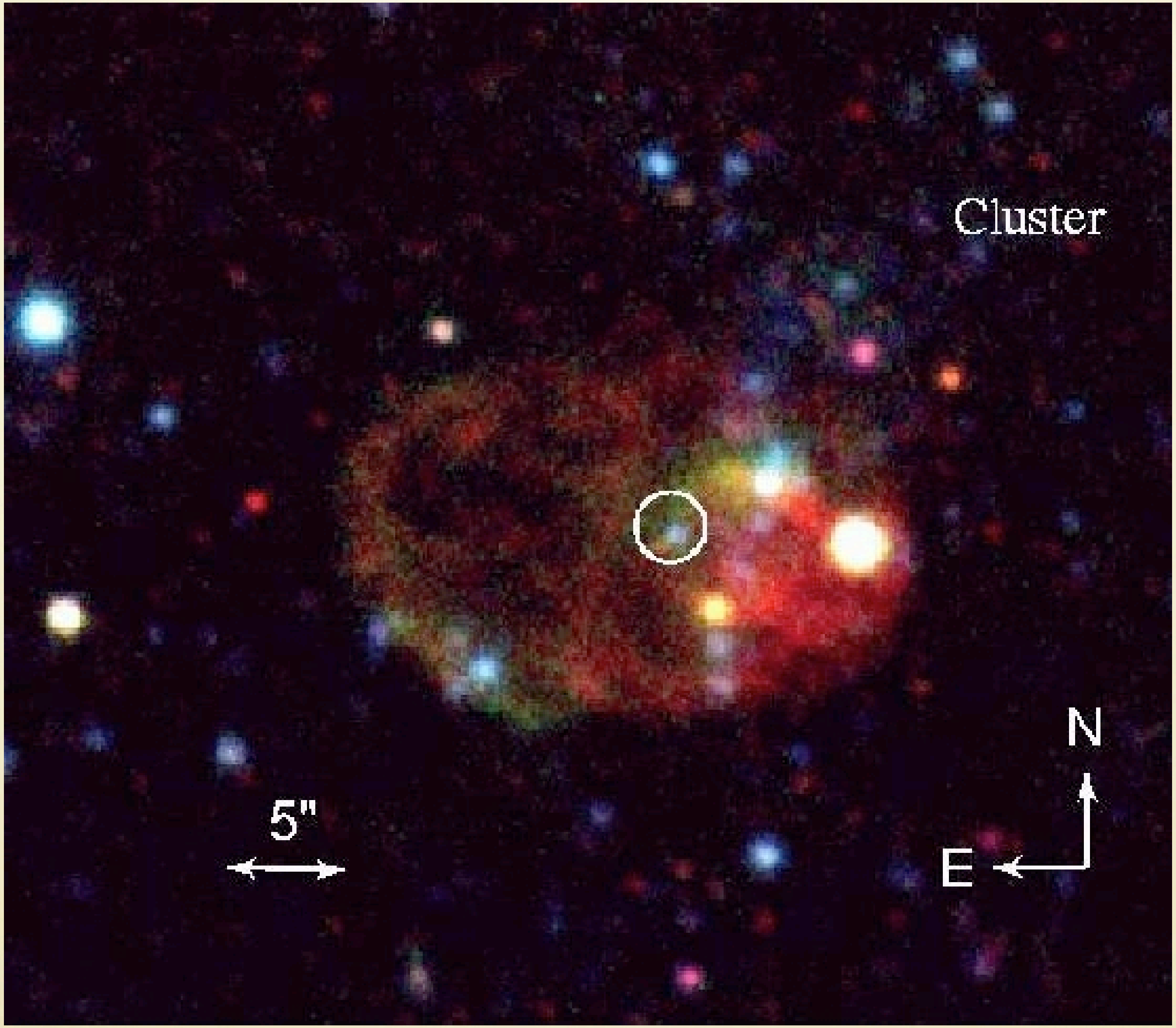


ESO 3.6m R

Zampieri et al. 2004

counterpart: C (later resolved to C1 and C2)

OPTICAL OBSERVATIONS



ESO VLT true-color image

Pakull et al. 2006

OPTICAL OBSERVATIONS

Table 1. The HST ACS observations for NGC1313 X-2

ID	Filter	ExpT	DATE	ACor	Z_{VEGA}	Z_{ST}	VEGAmag
j8ola2010	HRC/F330W	2760	2003-11-22	0.420	22.904	23.026	22.037±0.021
j8ol02040	WFC/F435W	2520	2003-11-22	0.277	25.779	25.157	23.470±0.017
j8ol02030	WFC/F555W	1160	2003-11-22	0.249	25.724	25.672	23.625±0.026
j8ol02010	WFC/F814W	1160	2003-11-22	0.292	25.501	26.776	23.640±0.043
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Note. — The columns are (1) exposure ID, (2) filter, (3) total exposure in seconds, (4) observation date, (5) aperture correction in magnitude, (6) zeropoint for VEGAmag, (7) zeropoint for STmag, and (8) VEGAmag for the counterpart.

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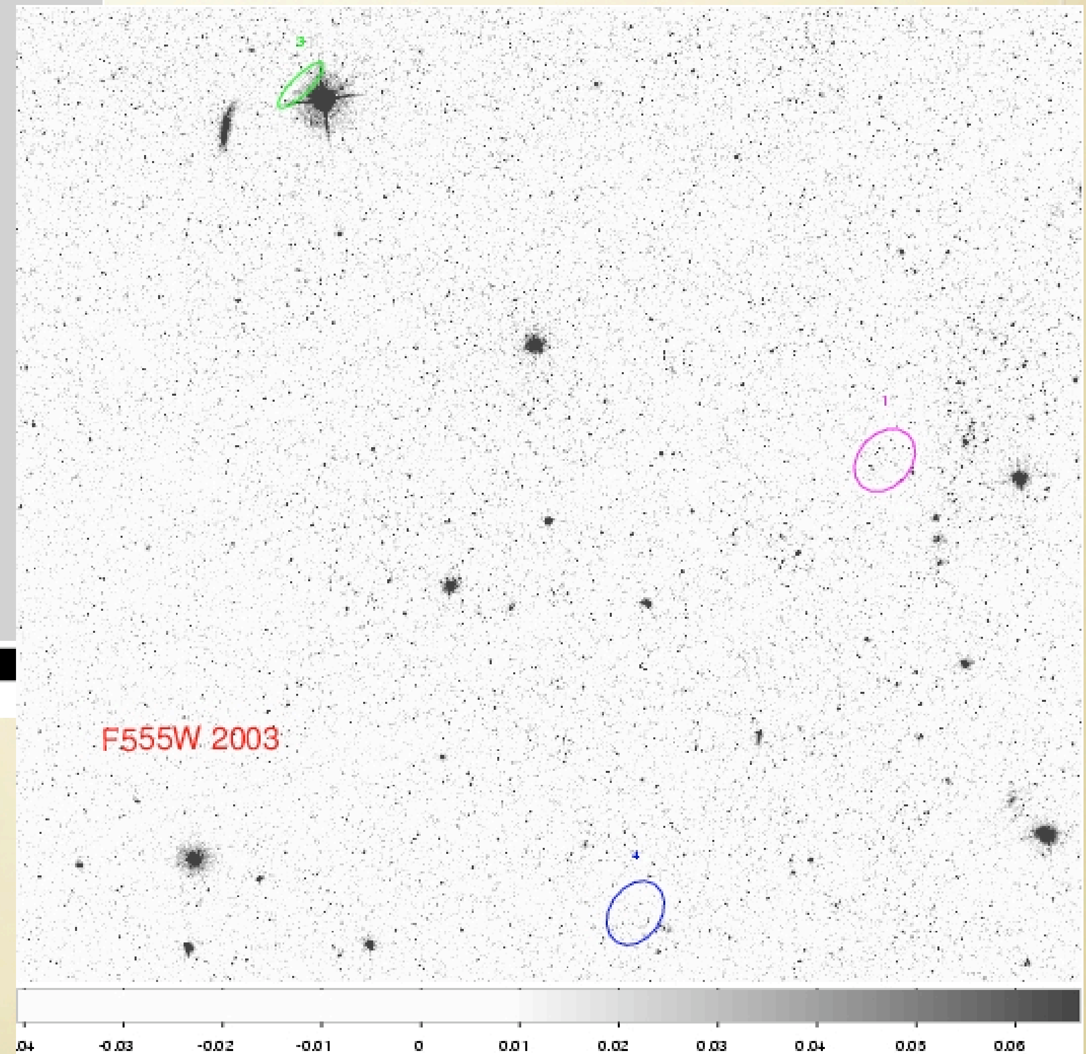

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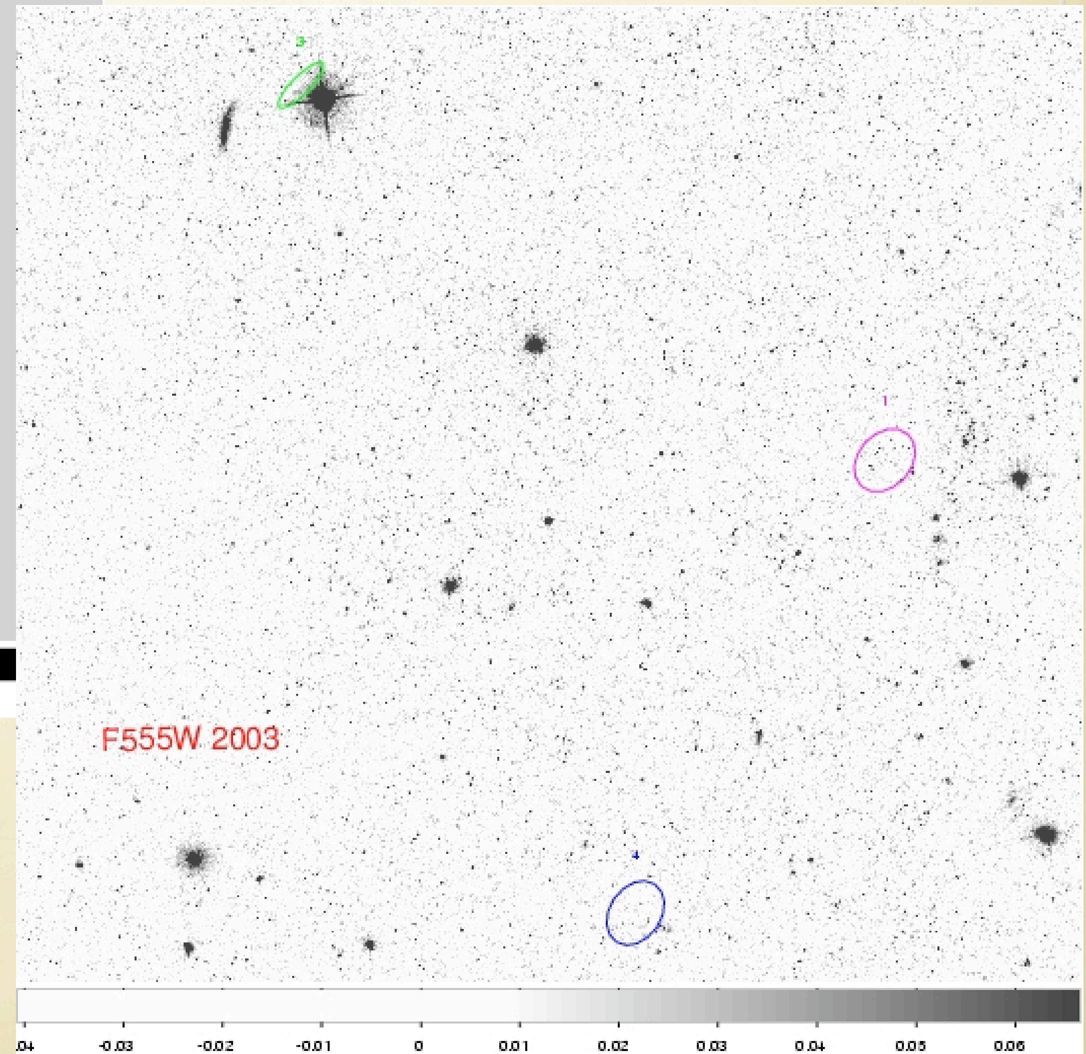

x3: foreground star
x4: background AGN

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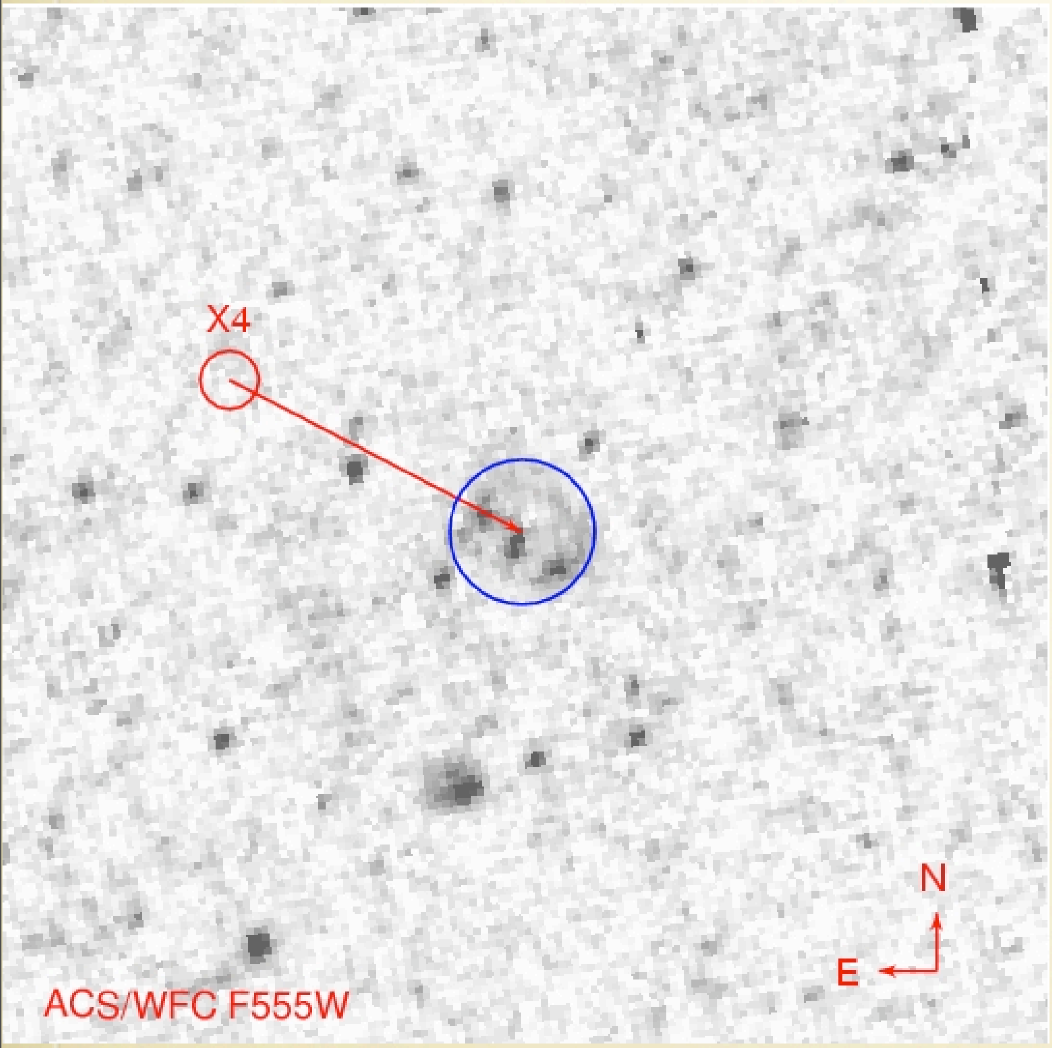

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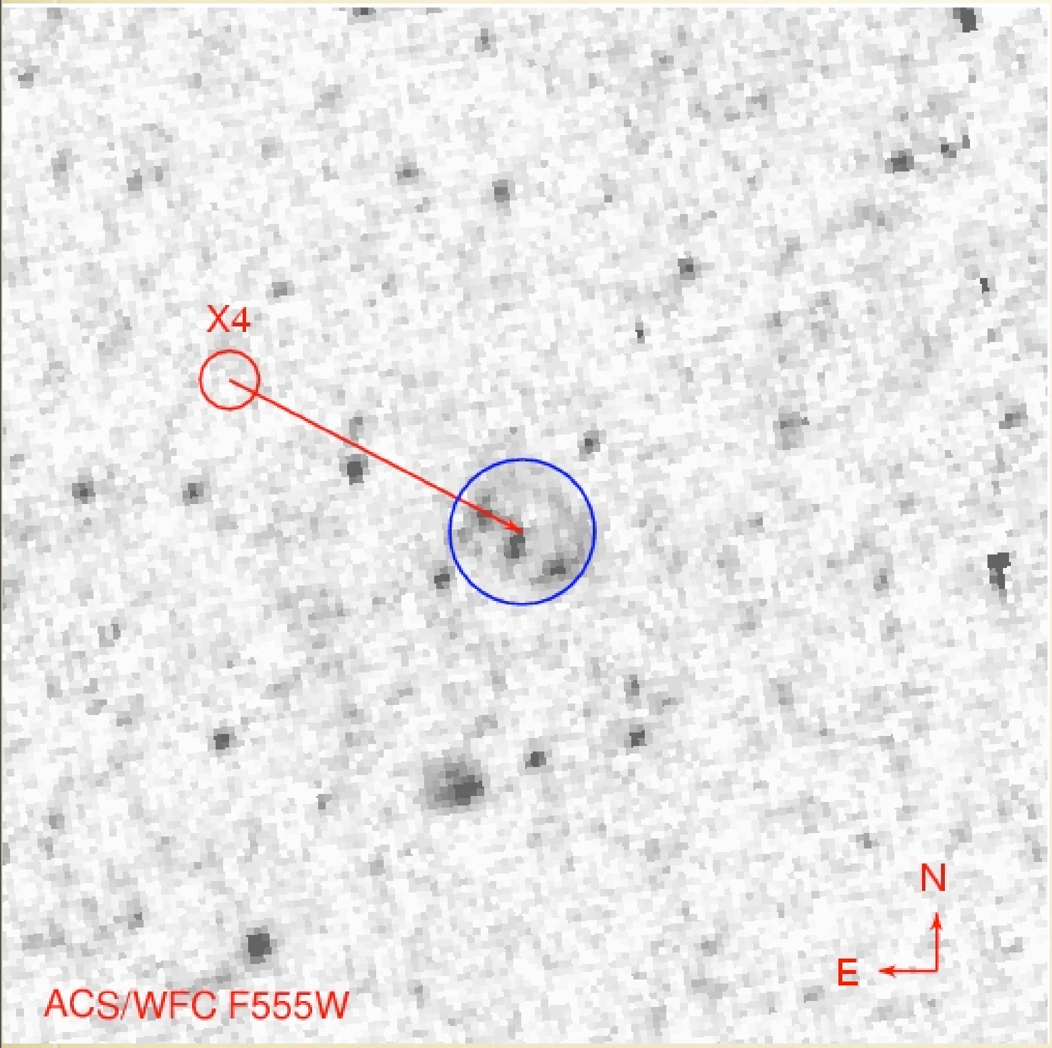

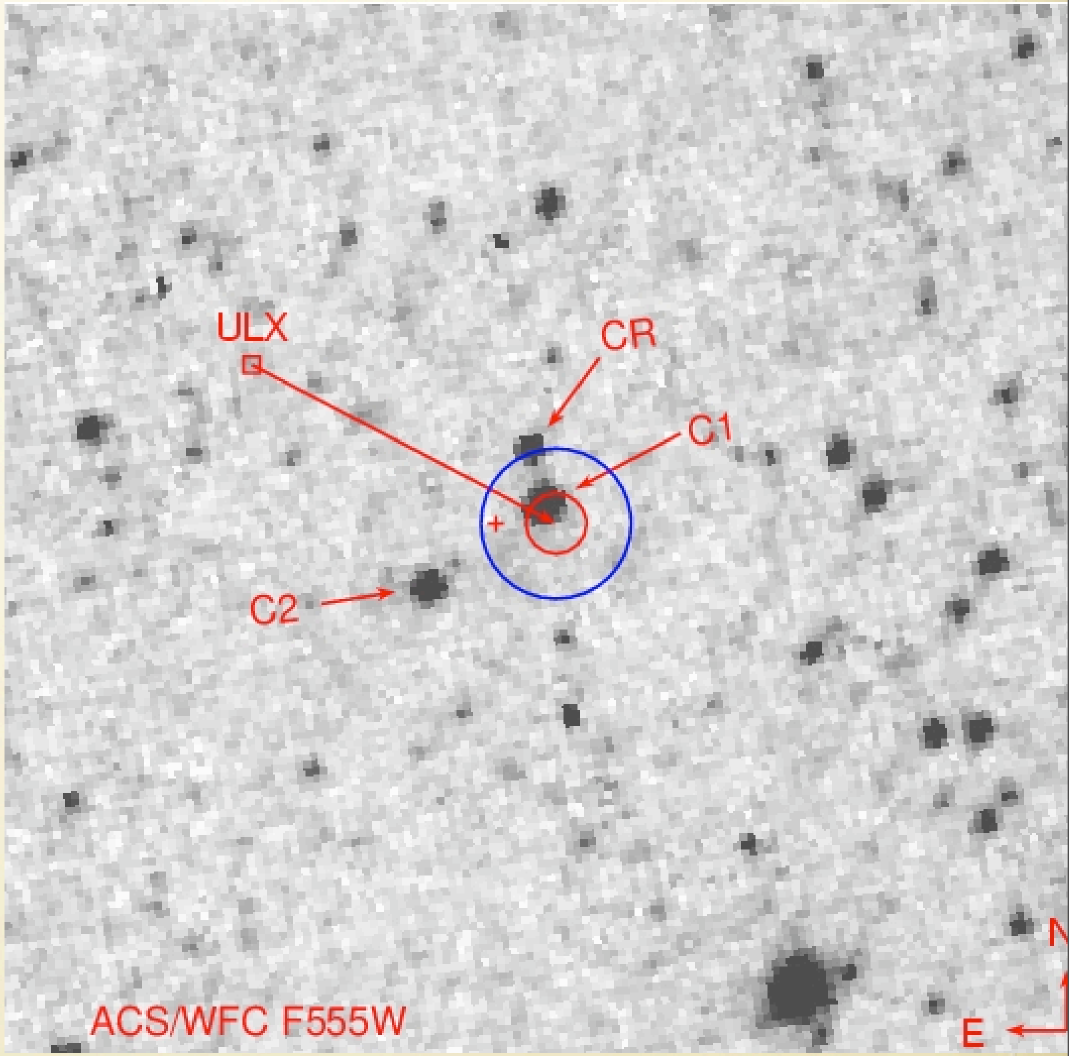

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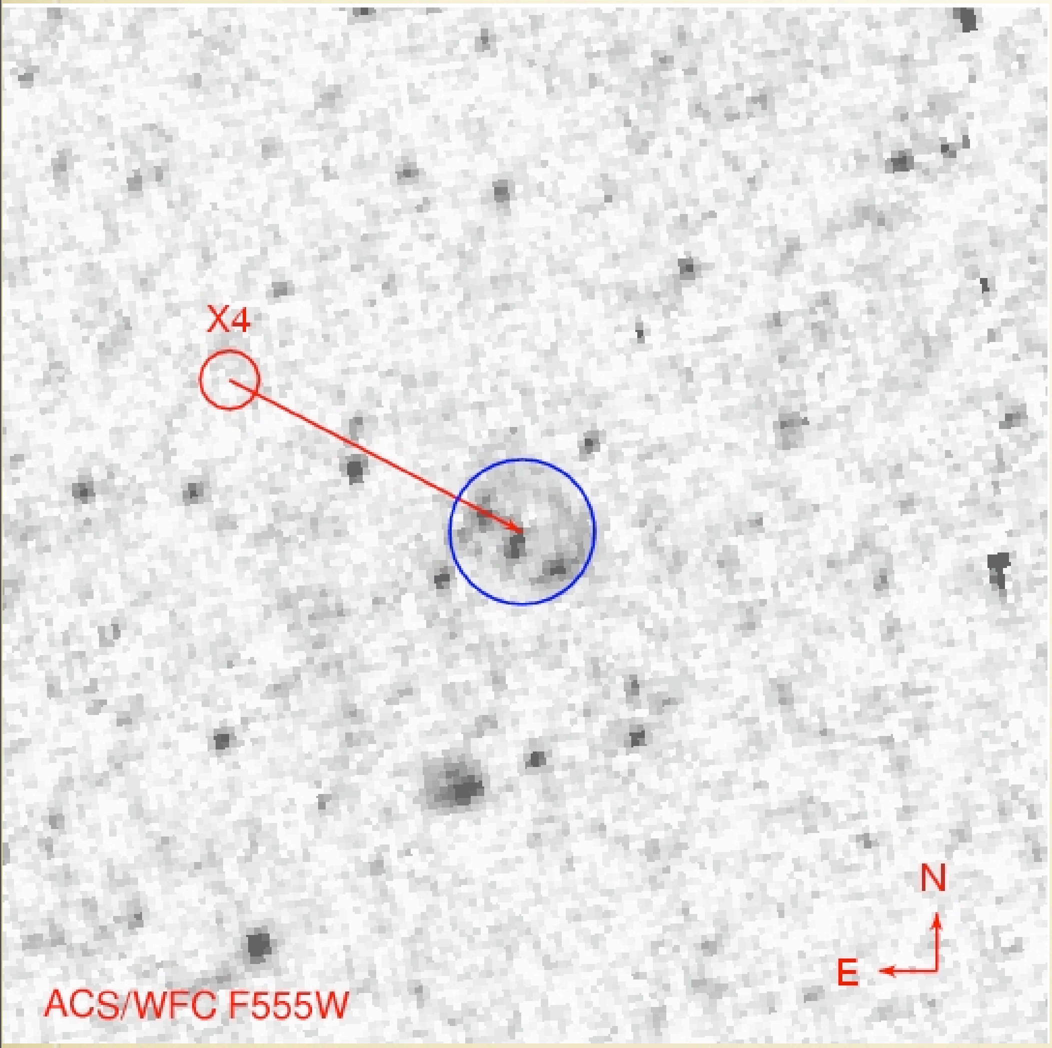
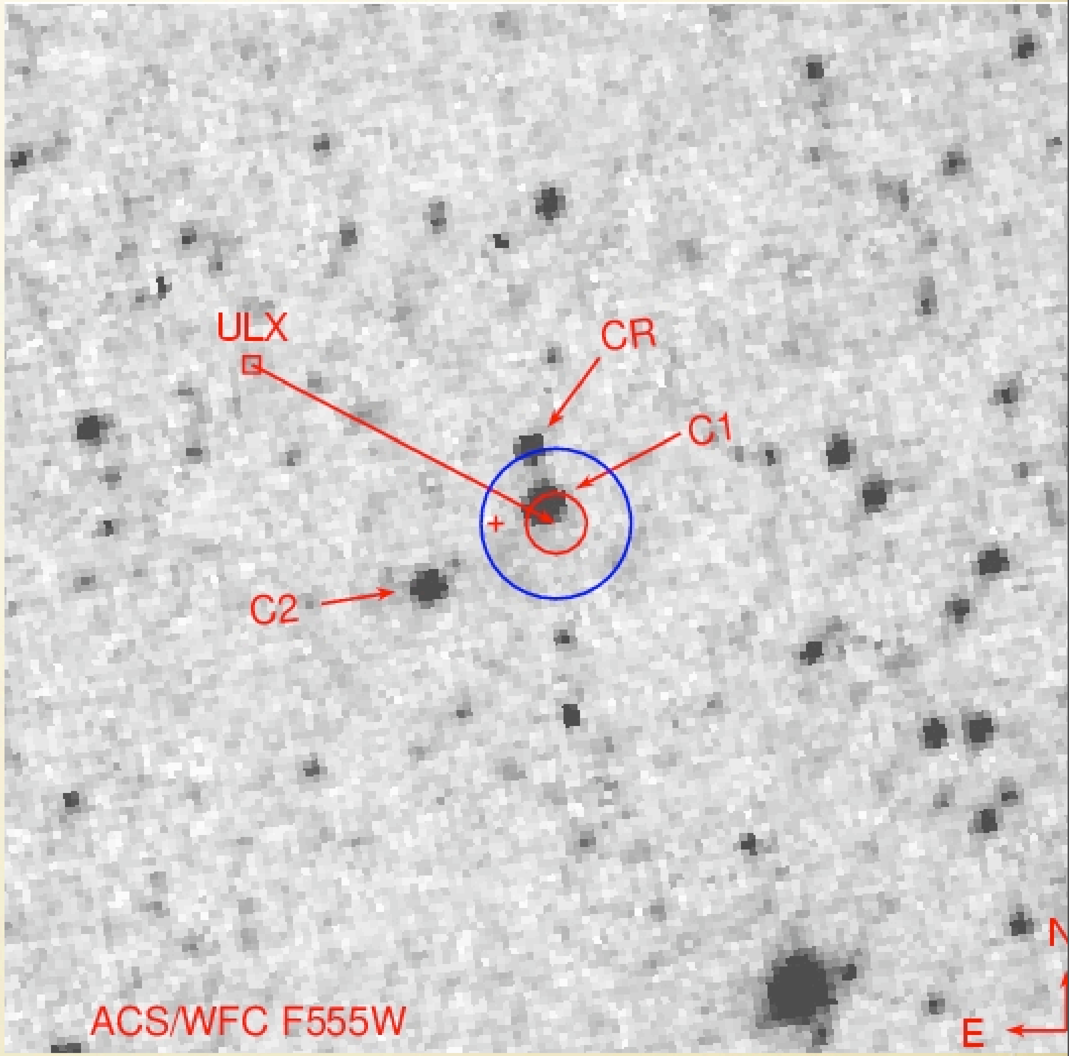
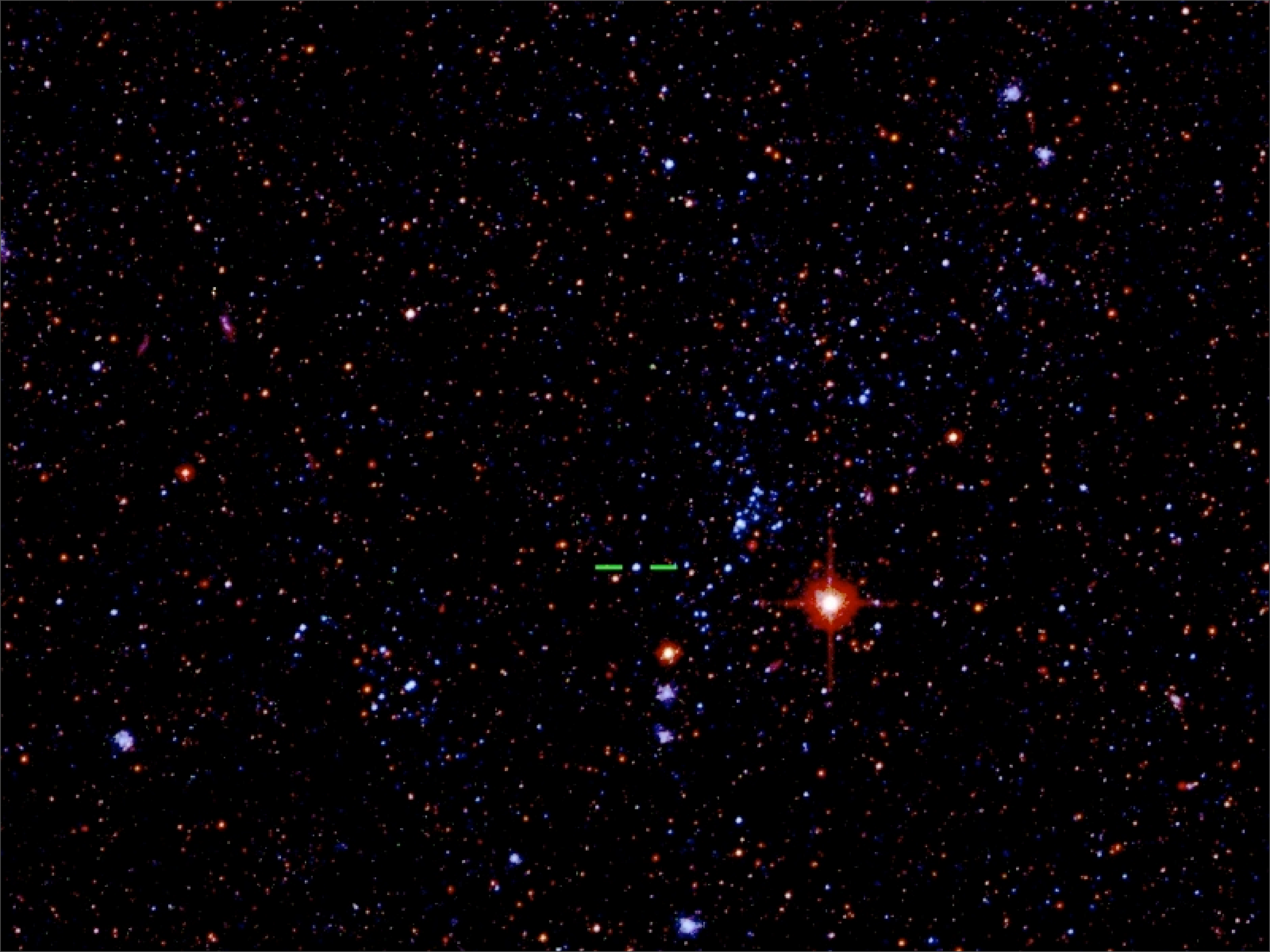




Counterpart: C1

OPTICAL OBSERVATIONS: ENVIRONMENTS



OPTICAL OBSERVATIONS: PHOTOMETRY

- IRAF/DAOPHOT was used
- VEGAmag and STMAG were computed

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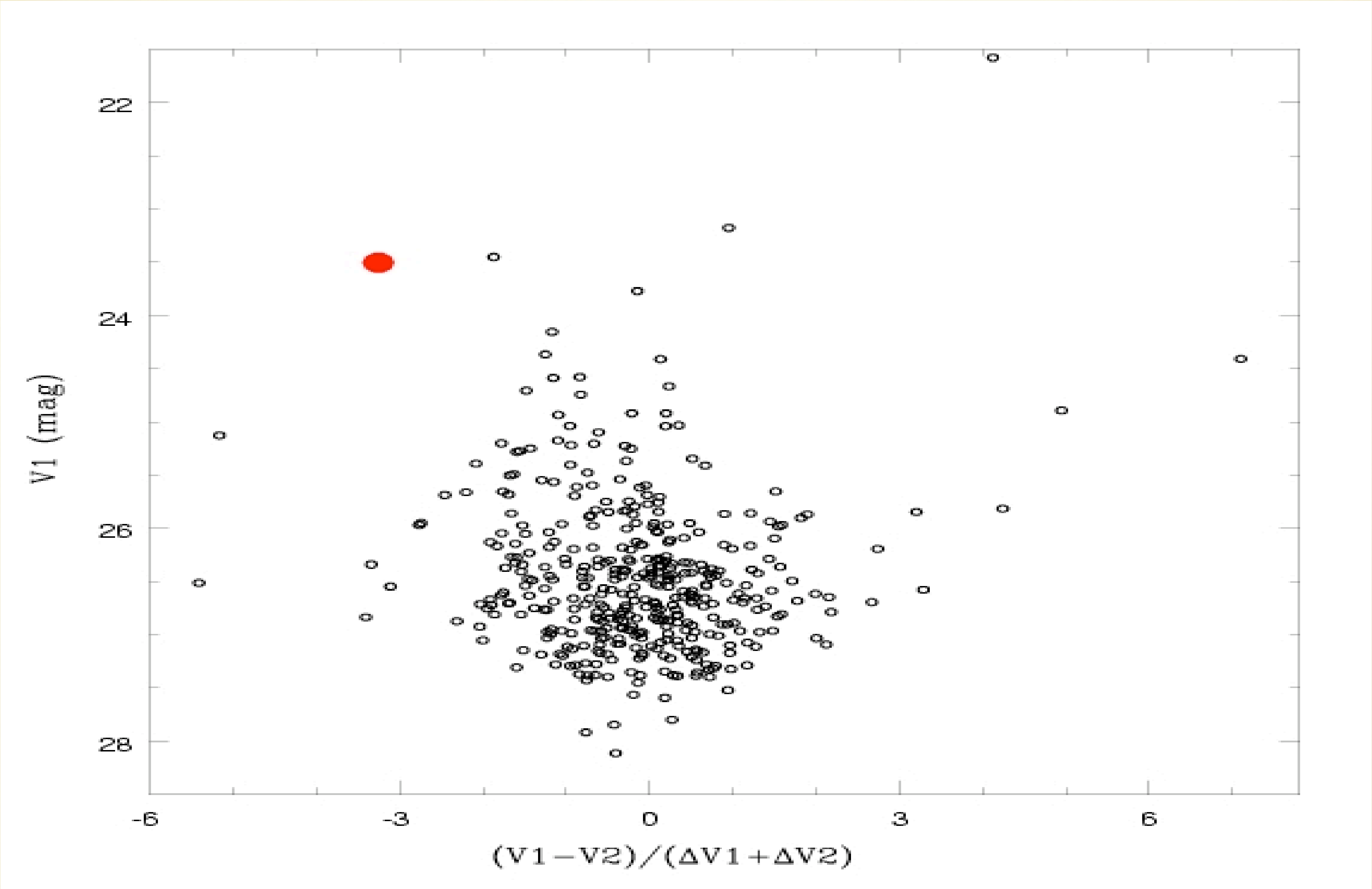

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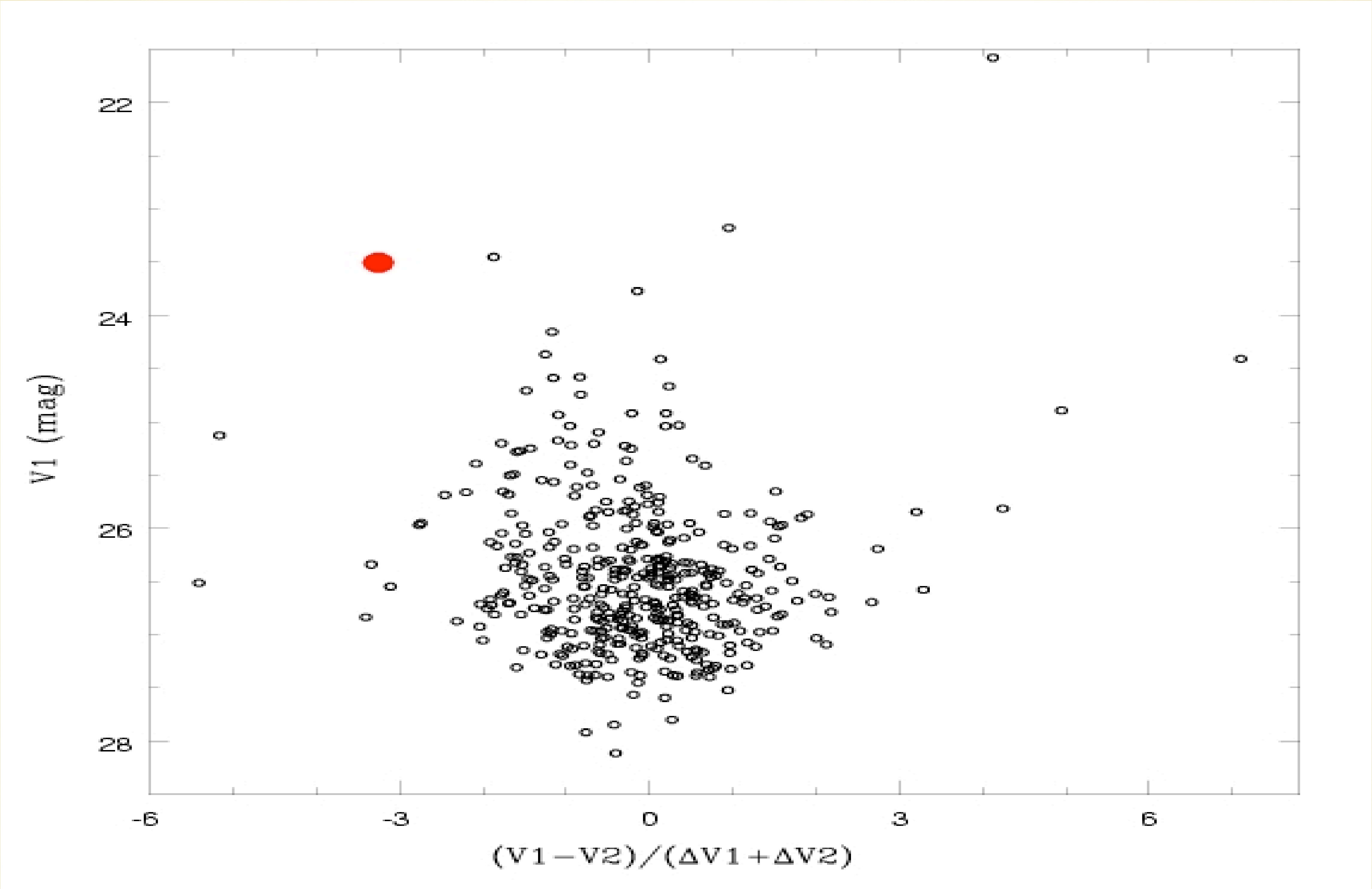
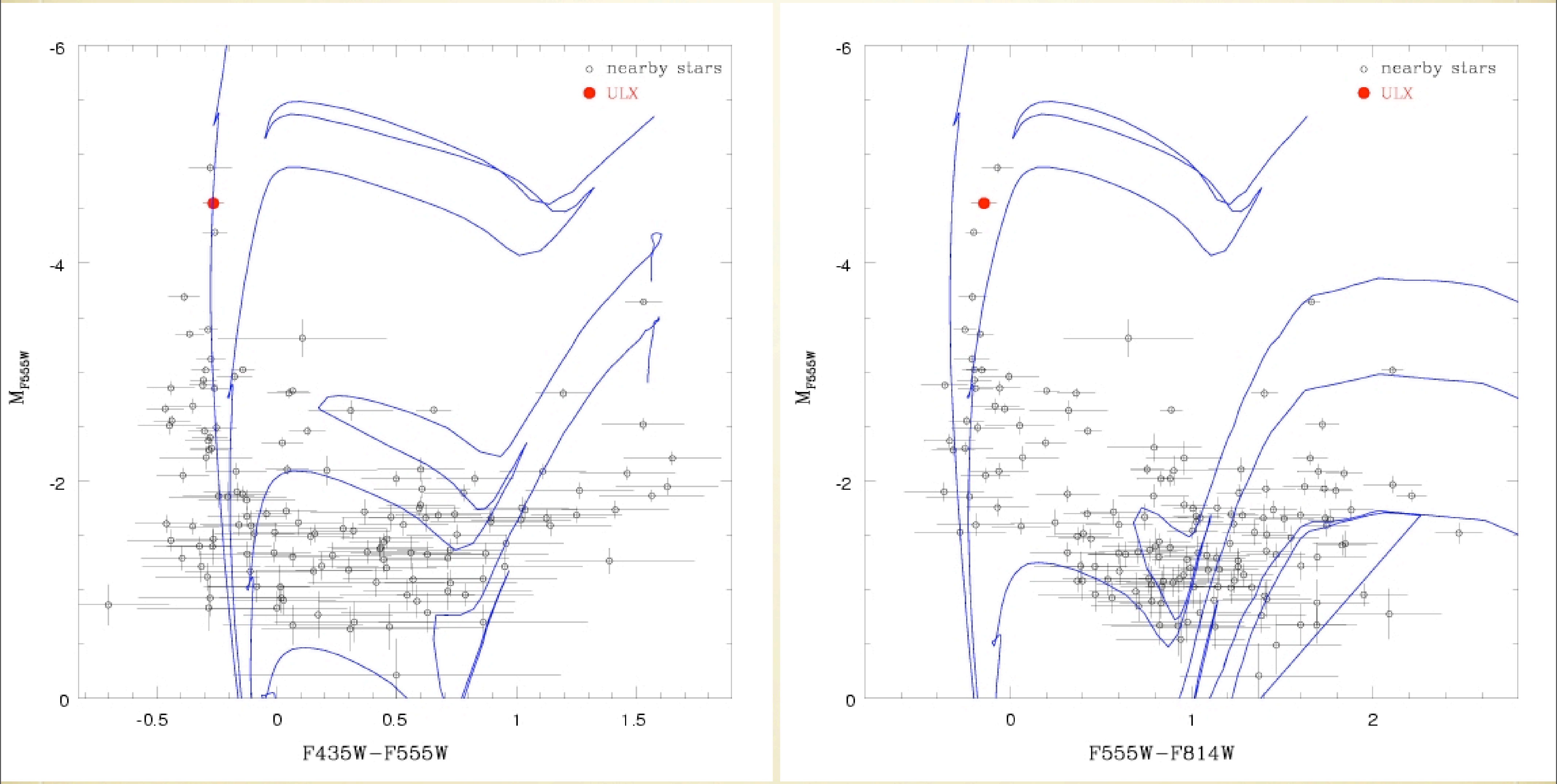


- only 12 out of 400 stars are variable above 3 sigma
- counterpart: ΔF555W = 0.153±0.047 mag

COLOR-MAGNITUDE DIAGRAMS

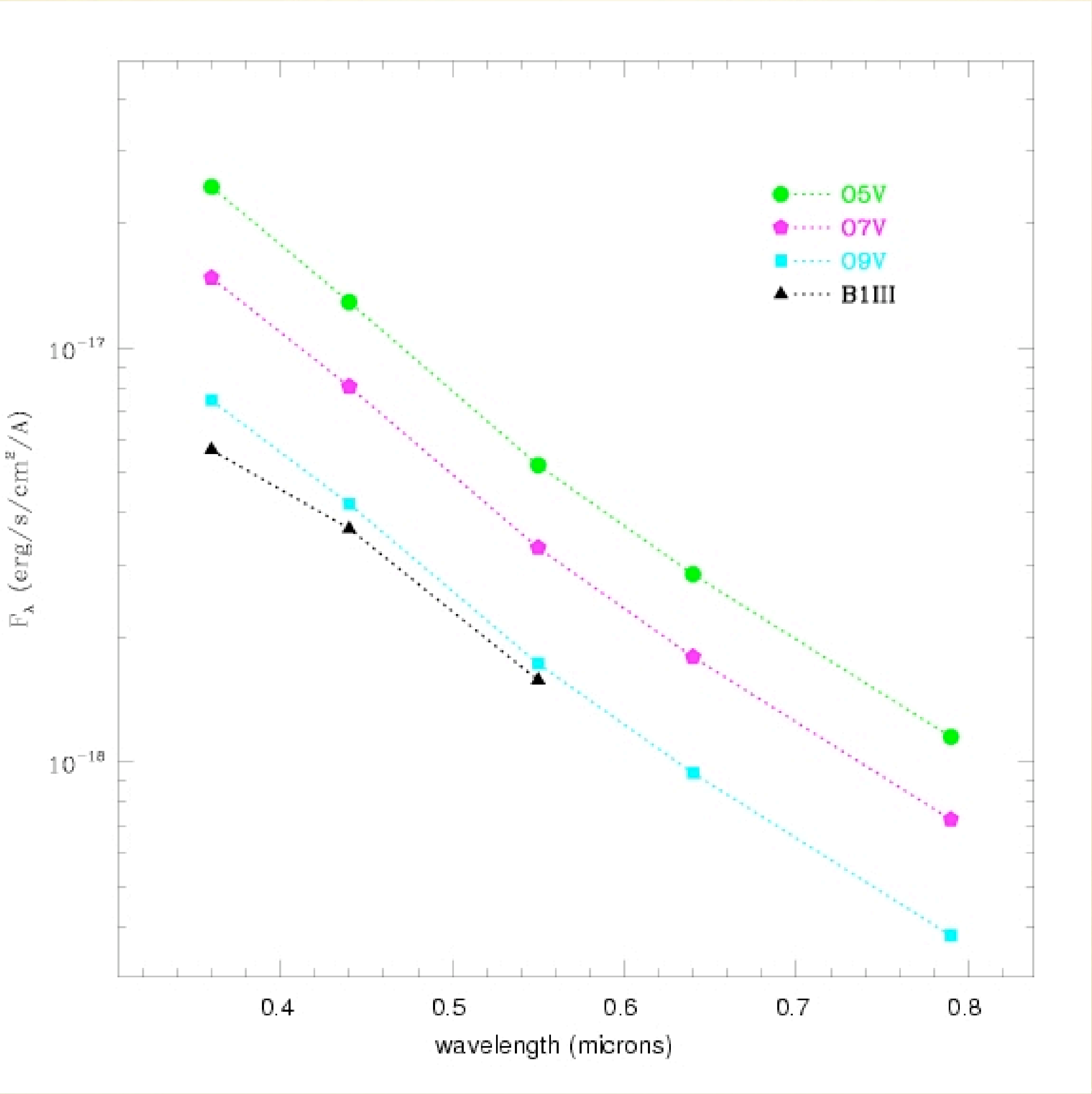


- use HST ACS/WFC VEGAmag photometric system for data and isochrones
- Z=0.2Zs isochrones (Leo Girardi) , E(B-V)=0.11
- (a) t=1e7,5e7,2e8,5e8 years (b) t=1e7,5e7,3e8,1e9,3e9

COLOR-MAGNITUDE DIAGRAMS

- two populations
  - young: < a few 10^7 years
  - old: 3-30x10^8 years
- ULX age for E(B-V)=0.11 mag
  - 10^7 years from F435W-F555W
  - 3x10^7 years from F555W-F814W
- two ages converge at 5 X10^6 years for E(B-V)= 0.33 mag [E(B-V)=0.44 mag from X-ray absorption]
  - initial/current mass of 52/8.5 Ms, radius of 7 Rs

SPECTRAL ENERGY DISTRIBUTION



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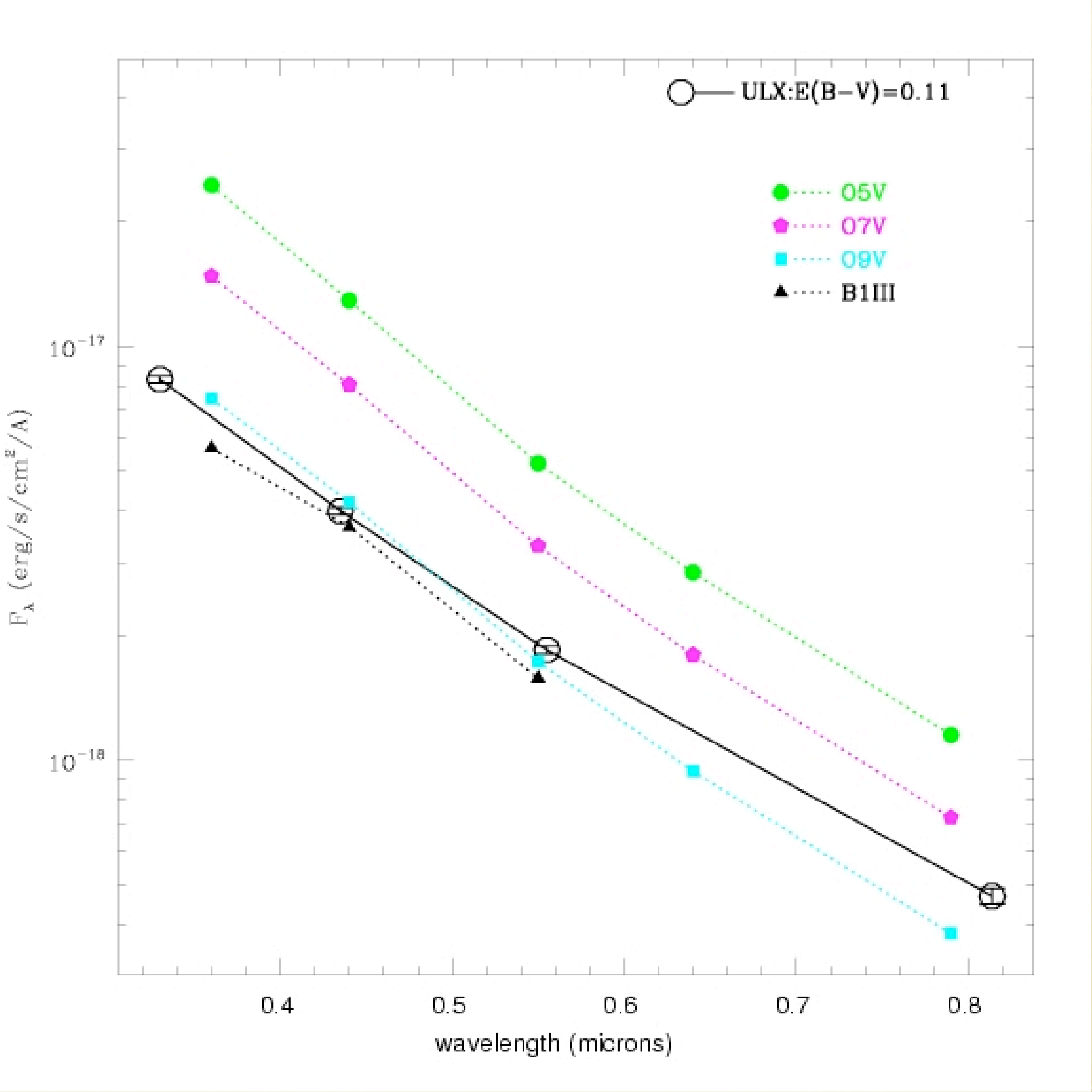

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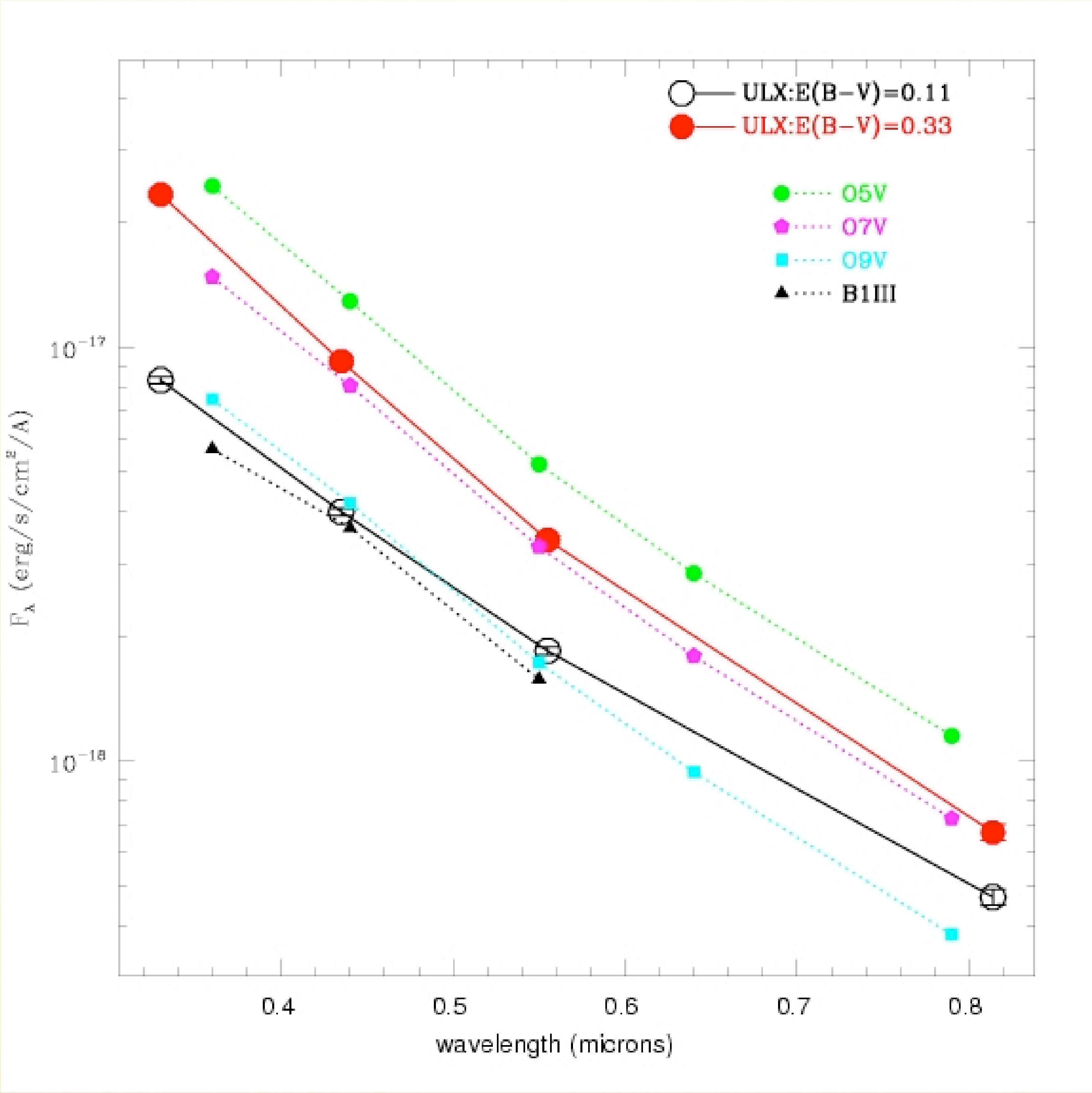

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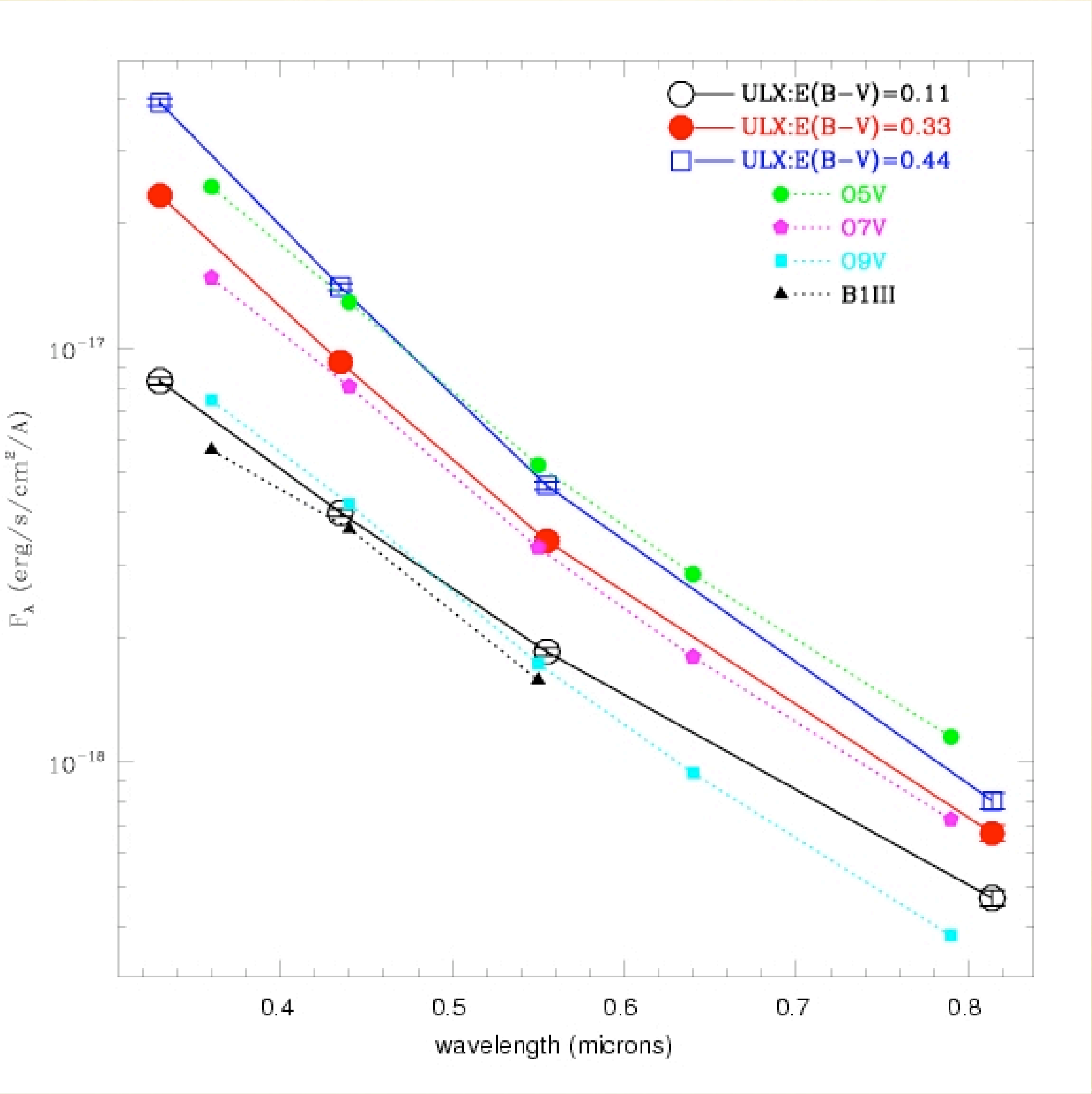

SUMMARY

- counterpart identified with C1
- showed 15% variability
- SED consistent with O7V (Zs, 30Ms, 9Rs) for E(B-V) =0.33 mag
- E(B-V)=0.33 mag, Z=0.2Zs: an age of 5 million years, mass 8.5 Ms, and radius 7 Rs
- on the edge of a young open cluster, amid dominant old stars

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merging of	black holes	massive stars	proto stars
birthplace	globular cluster	super star cluster	proto cluster
timescale	>>10^7 years	<3Myr	<0.5Myr
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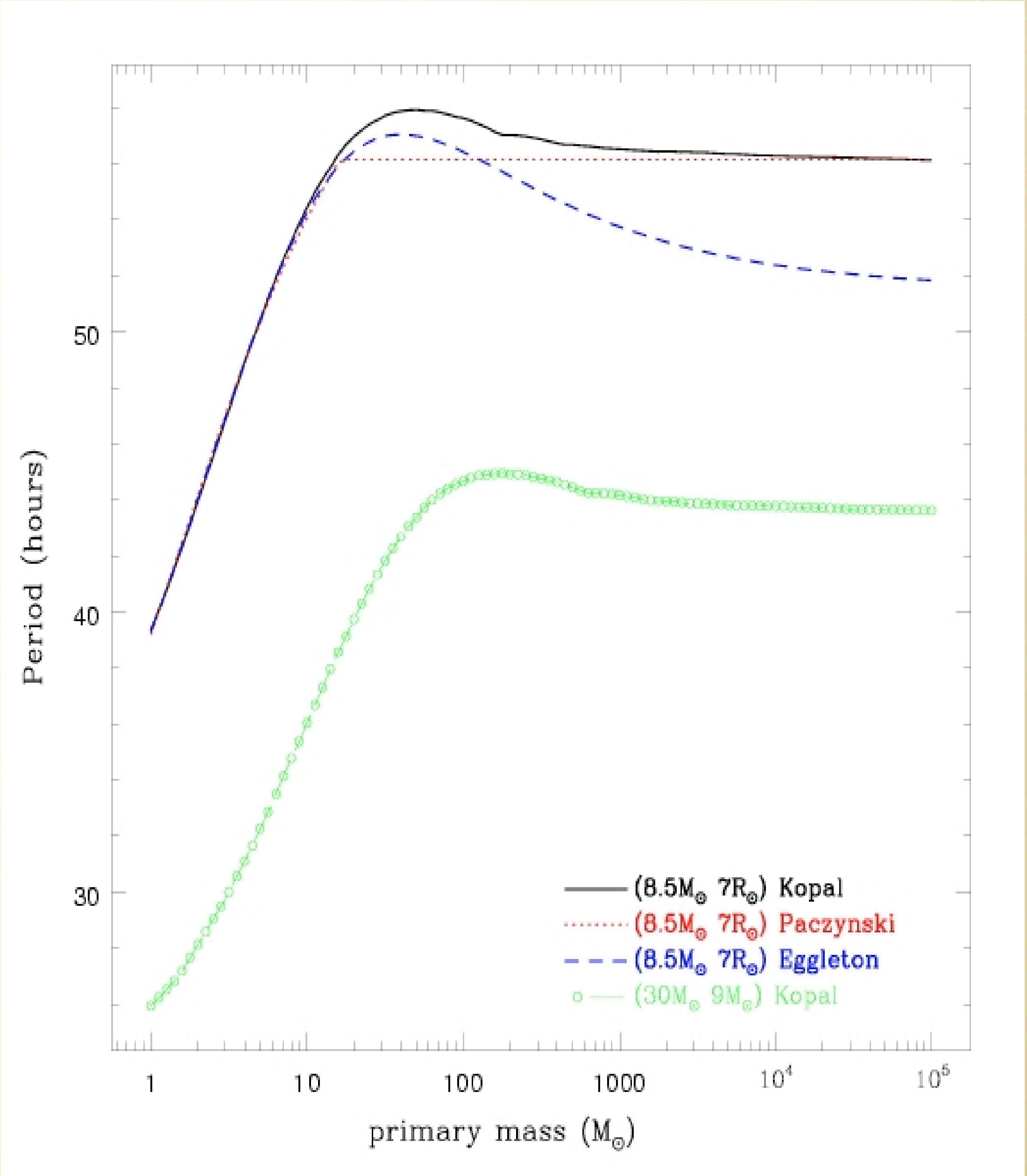
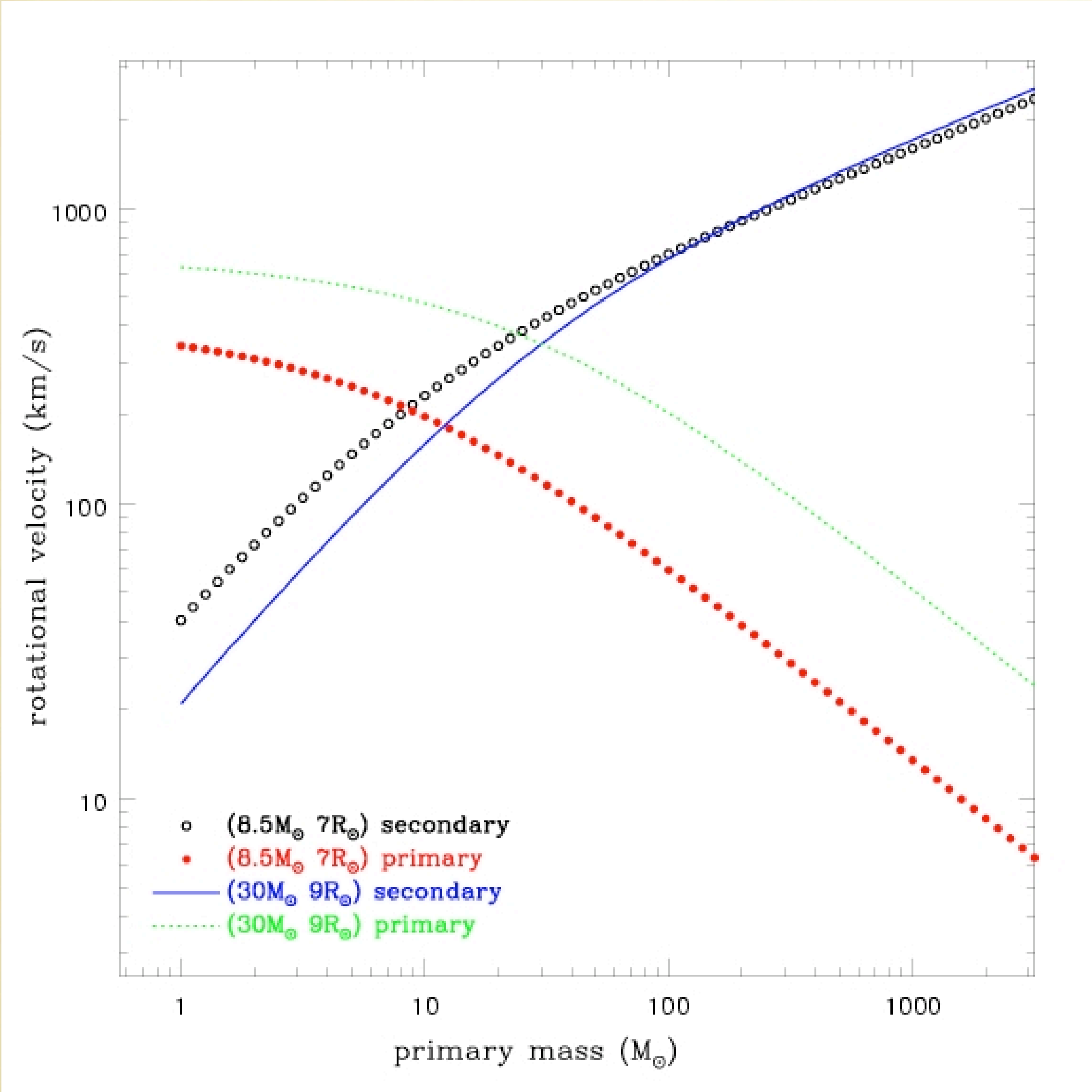
X2's location close to a young open cluster, the low Z, and possible collision/disruption may point to the merging of proto stars in proto clusters

ORBITAL PERIOD?

- estimate the period assuming C1 overflows its Roche lobe
- Roche lobe size Rcr = a * f(q)
    - q = Msec/Mprimary
    - Kopal tabulation (1959)
    - Paczynski approximation (1971)
    - Eggleton approximation (1983)
- equating Rsec = Rcr ...
    - shorter P for larger q
    - $\rho = 110/P^2$ for $q < 0.3$
- constraints
    - P=56 hr?
    - P<56 hr => M<15 Ms
- propose observations to detect such a period



RADIAL VELOCITY



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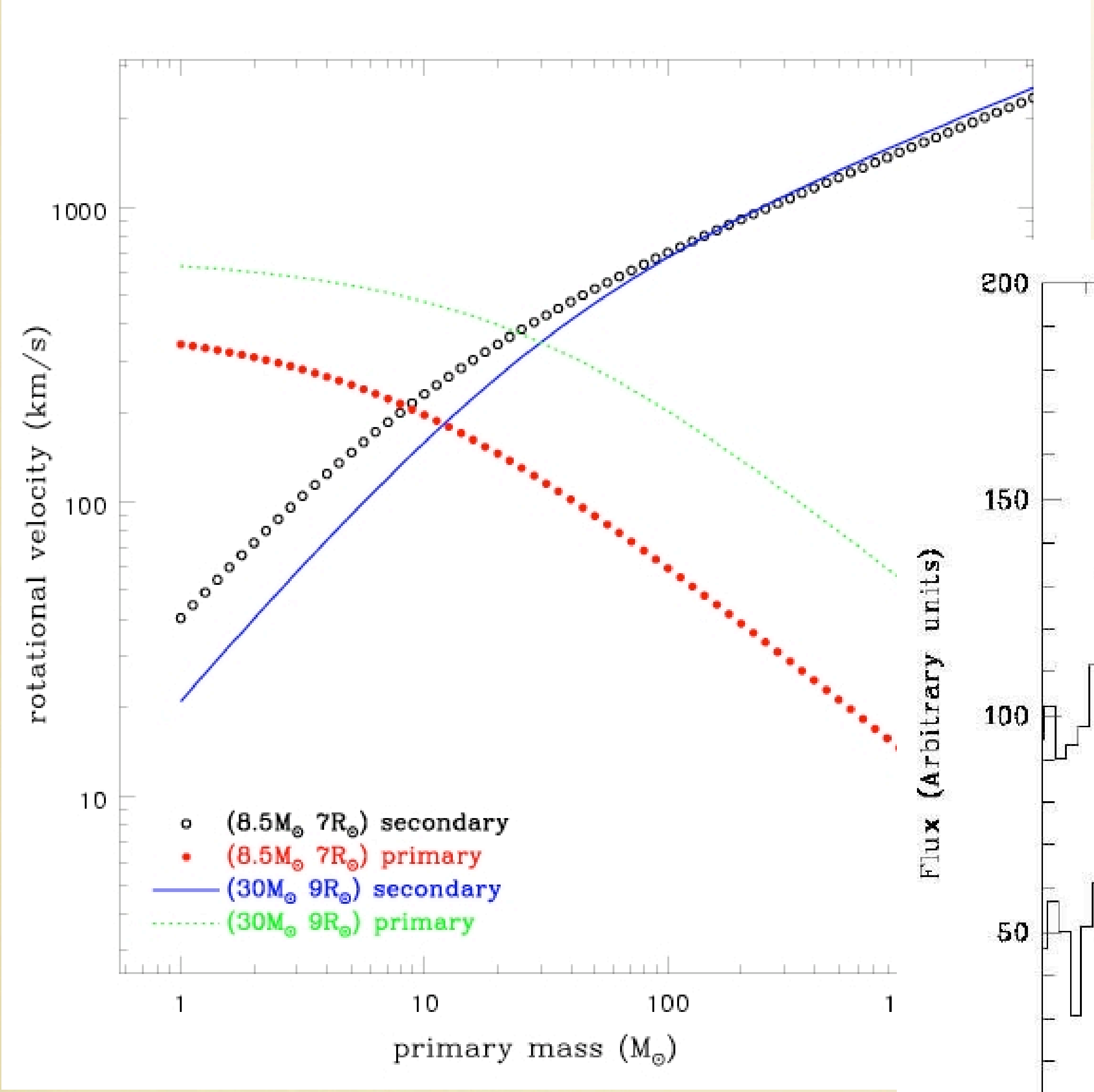

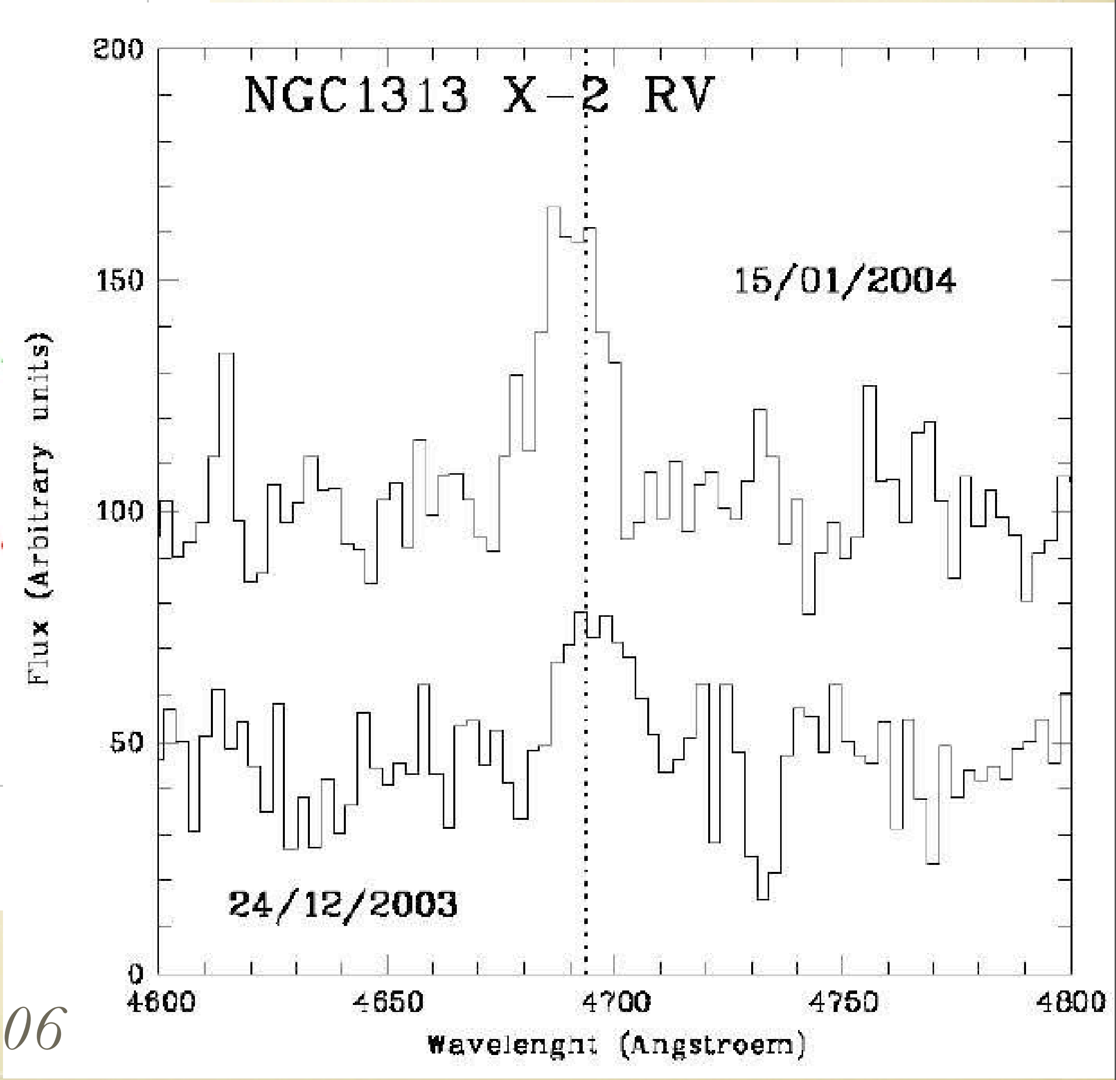

Pakull et al. 2006

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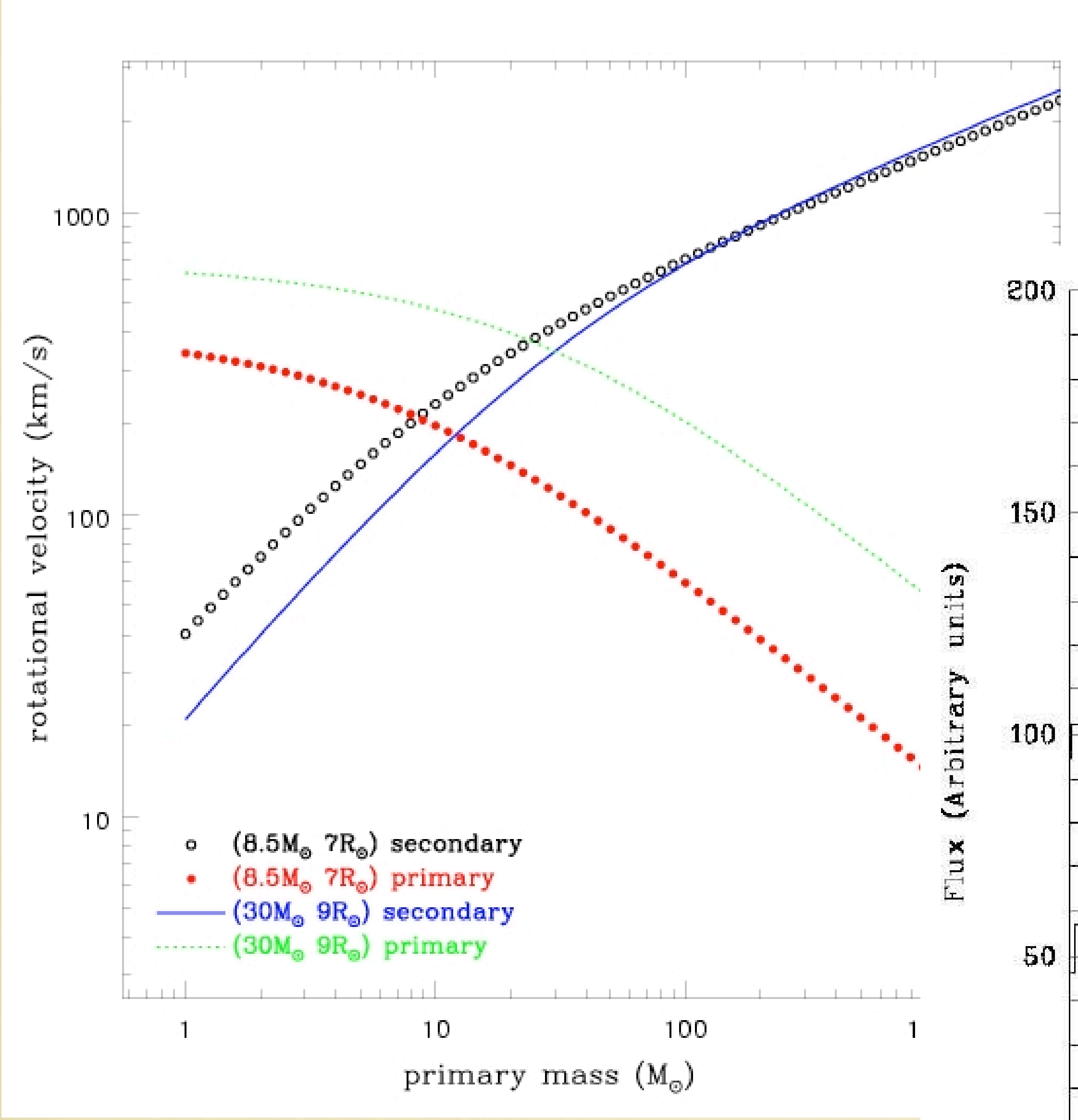
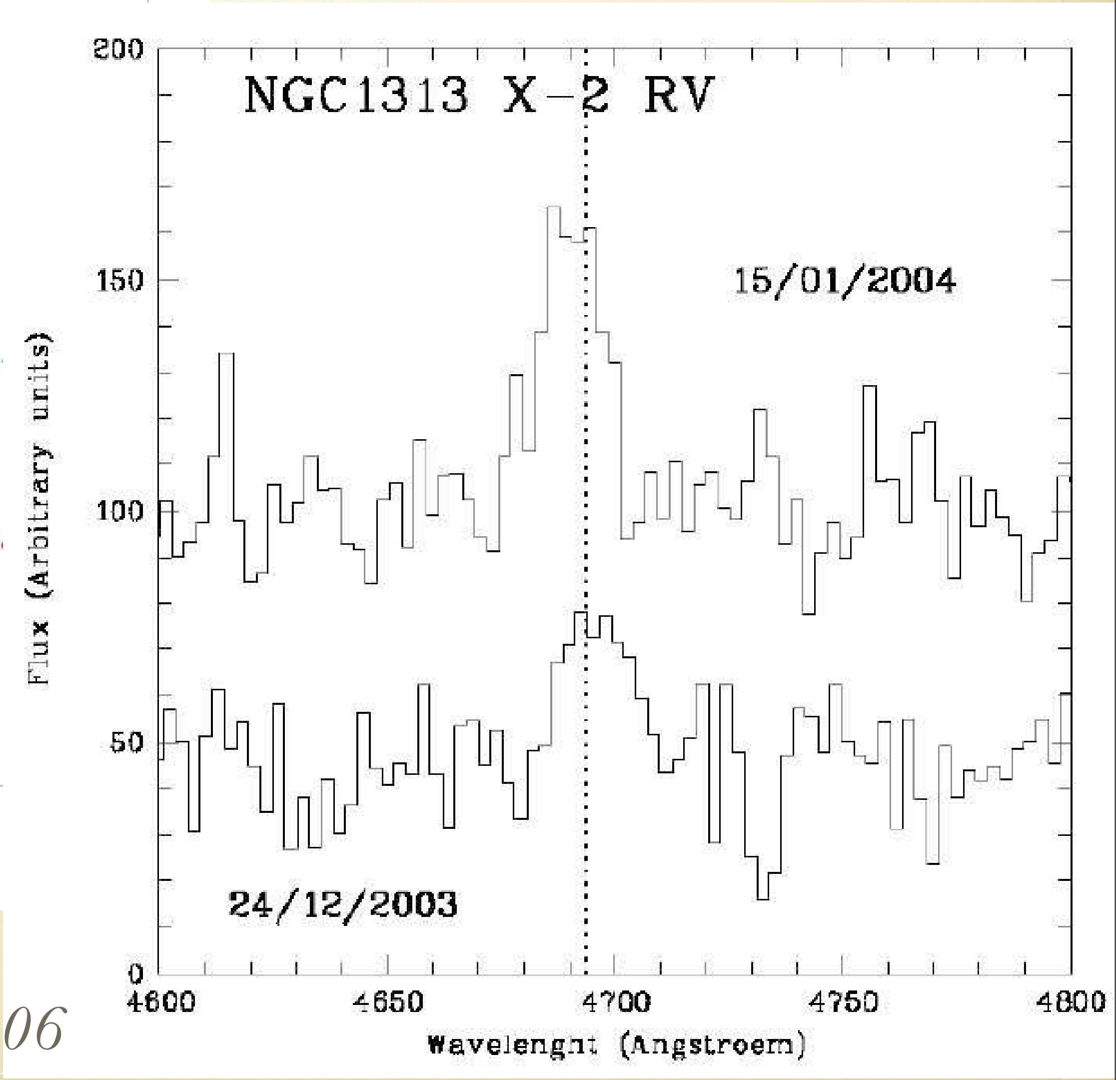


HeII line FWHM: 600 km/s

line shift: 300 km/s



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