OPTICAL/INFRARED COUNTERPARTS OF ULXS

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Caltech

ULX NAMES

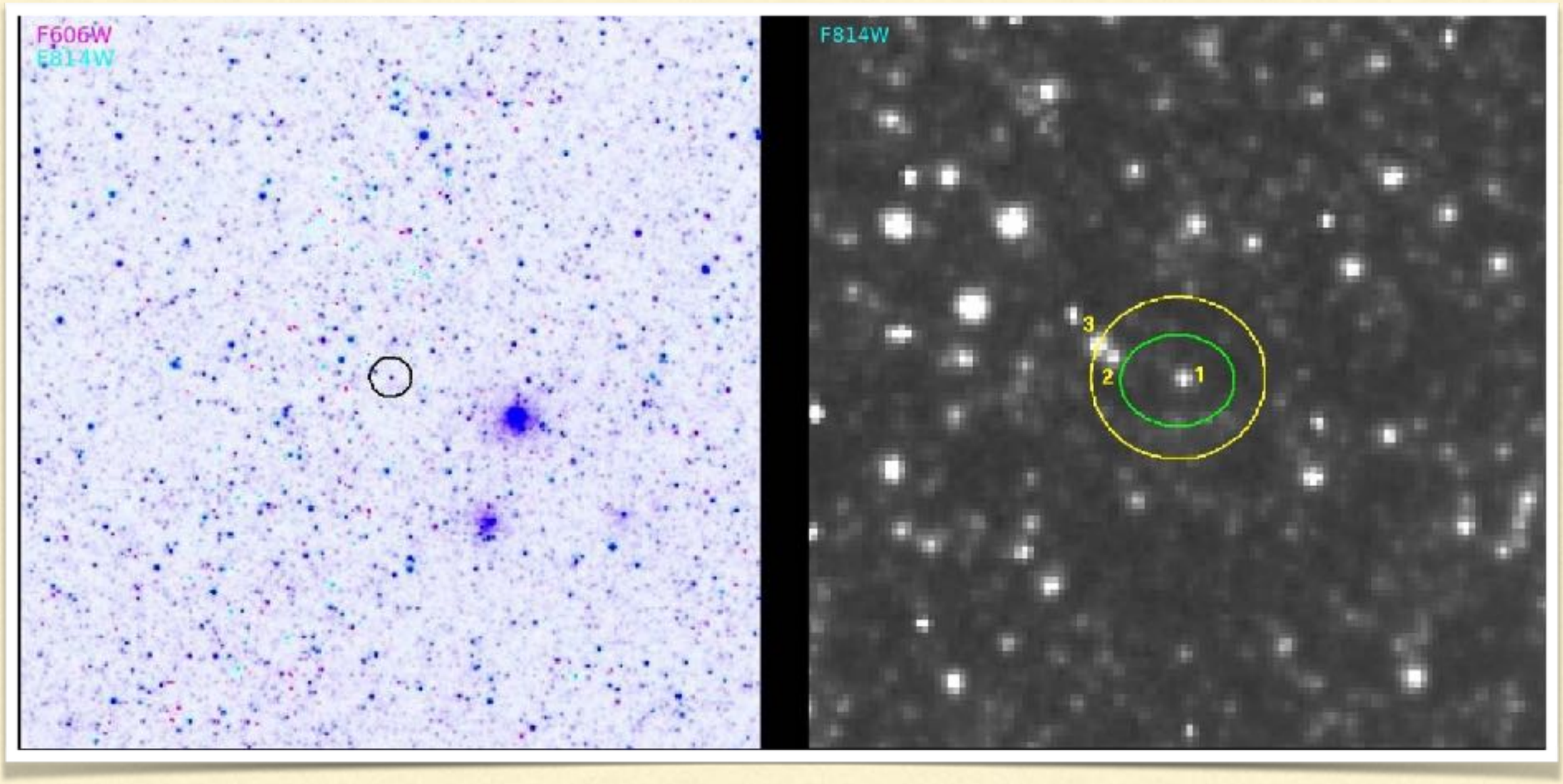
- Please please please do **not** make up your own naming scheme for your ULX(s) if one (or more likely several) already exists

- Please please please **do** mention coordinates somewhere in your paper if there is *any* possibility of ambiguity

OUTLINE

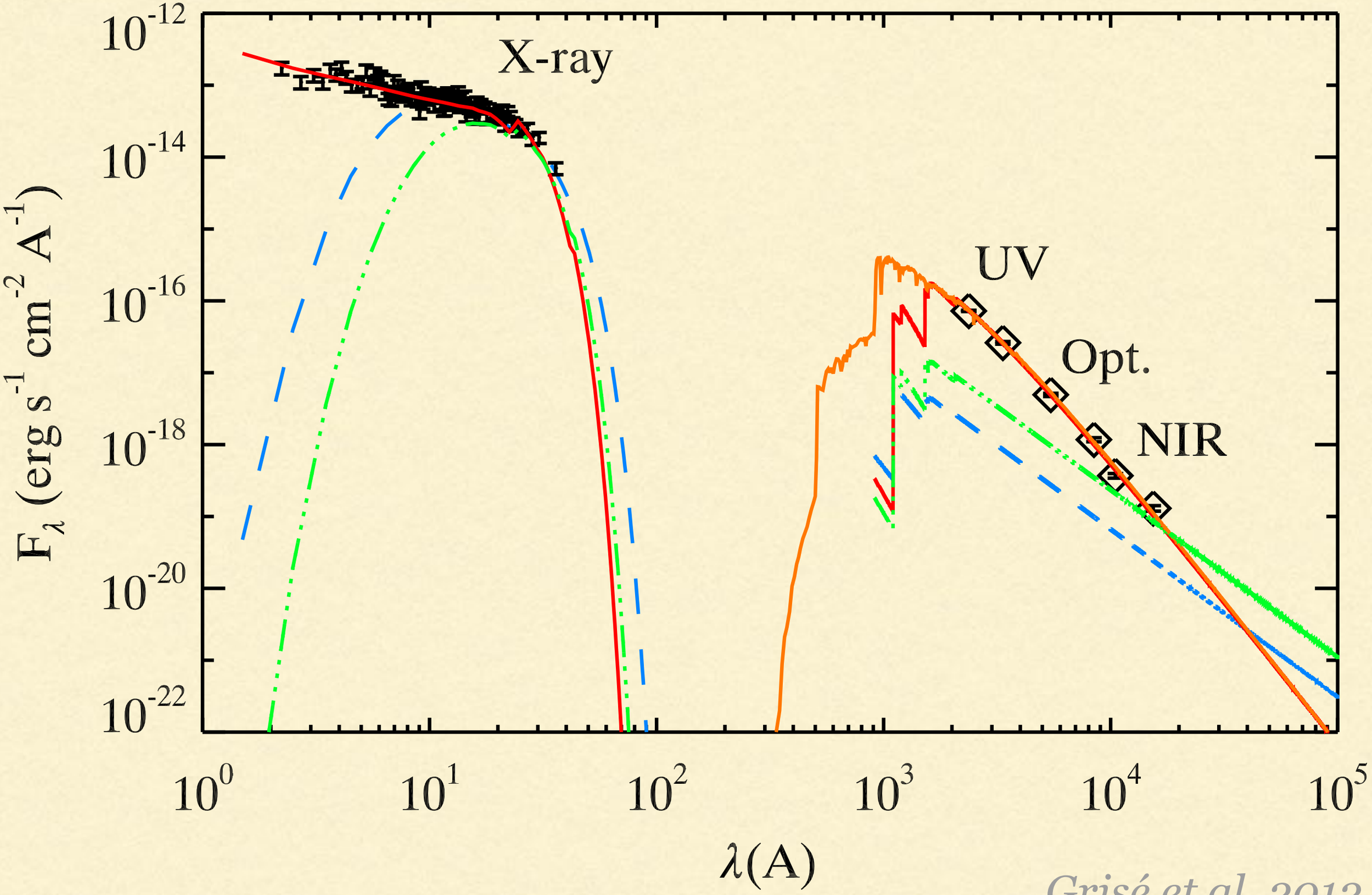
Subaru/HST

- Donor stars - optical
- Donor stars - infrared
- Other counterparts

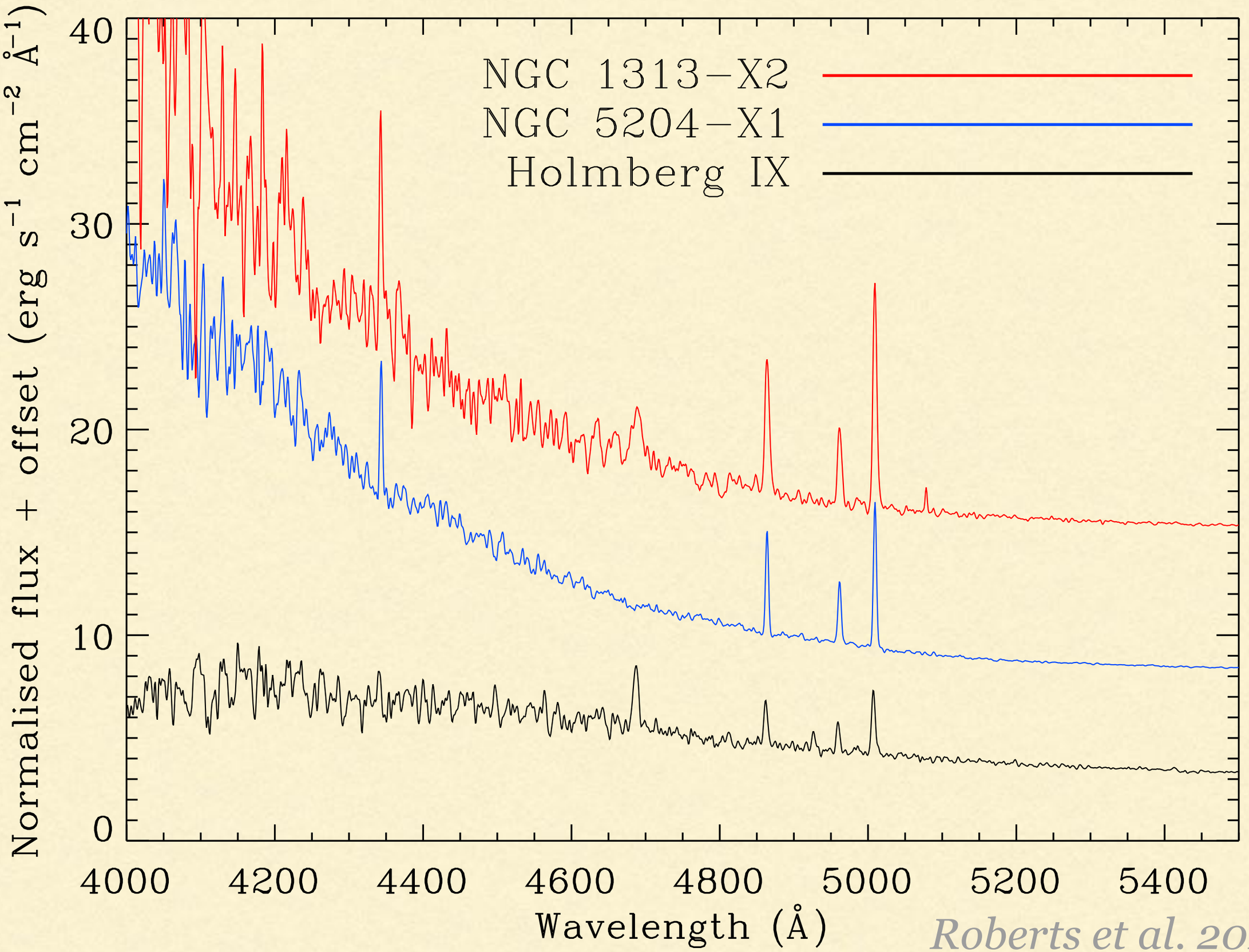


Gladstone et al. 2009

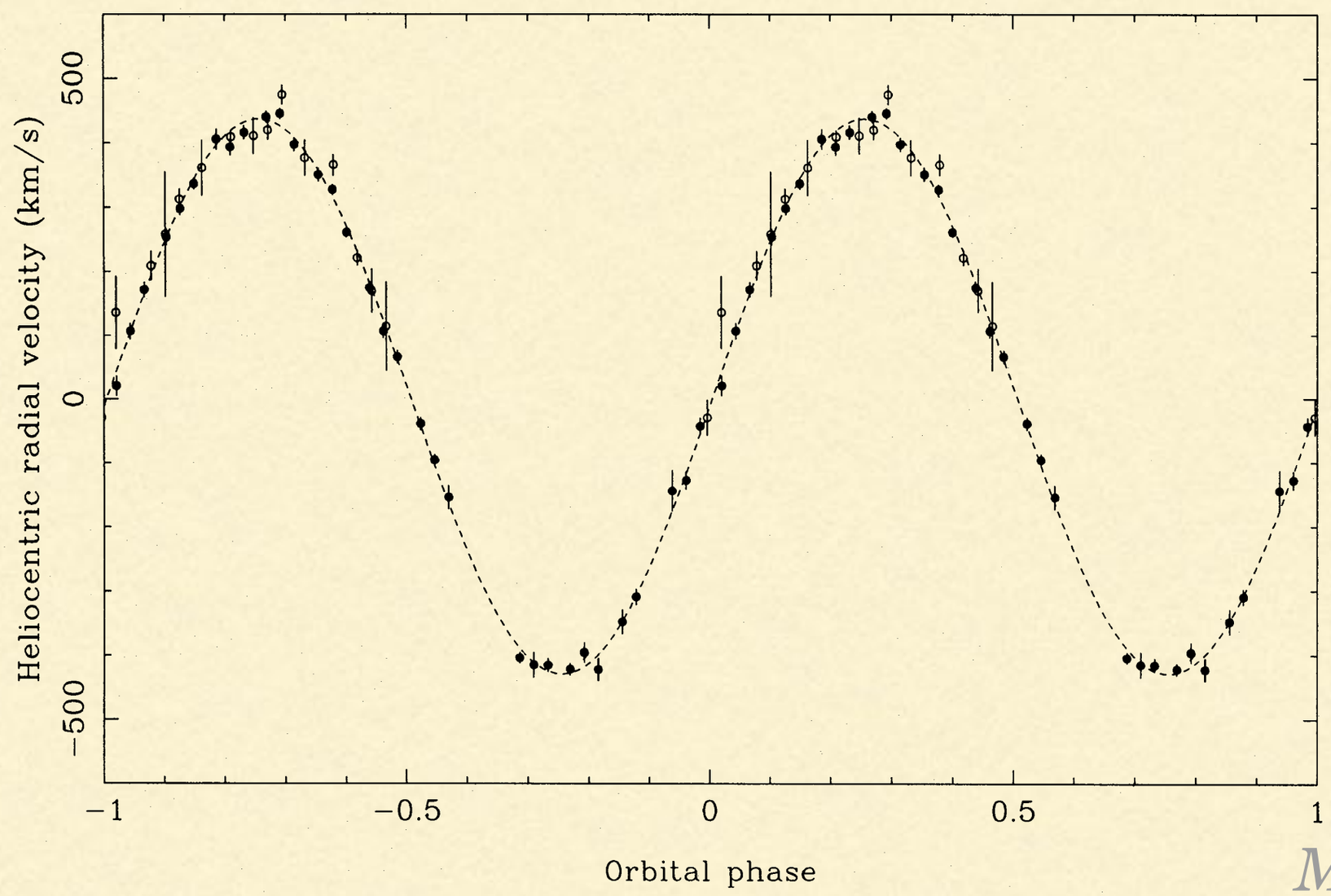
DONOR STARS - OPTICAL



Grisé et al. 2012

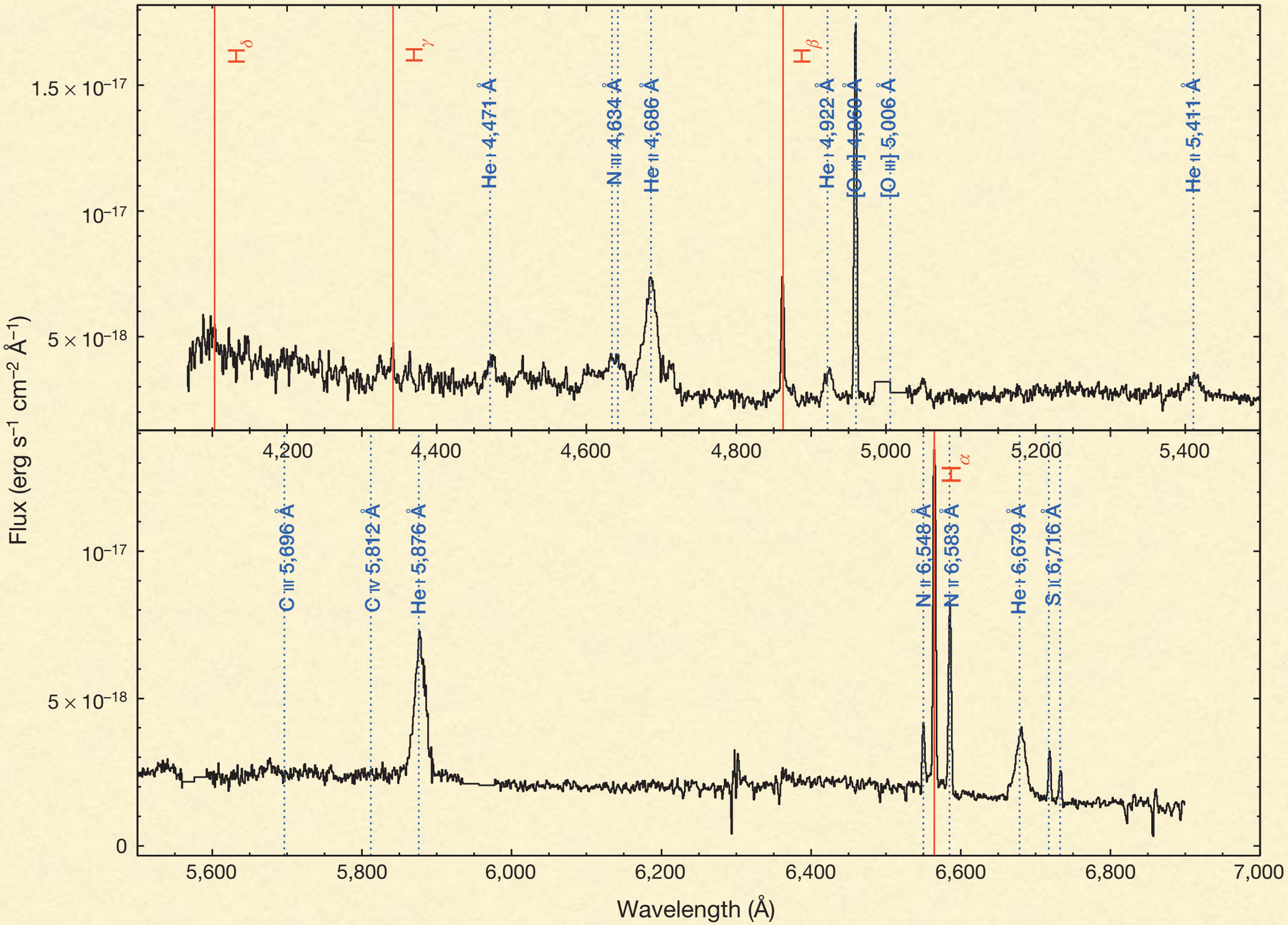


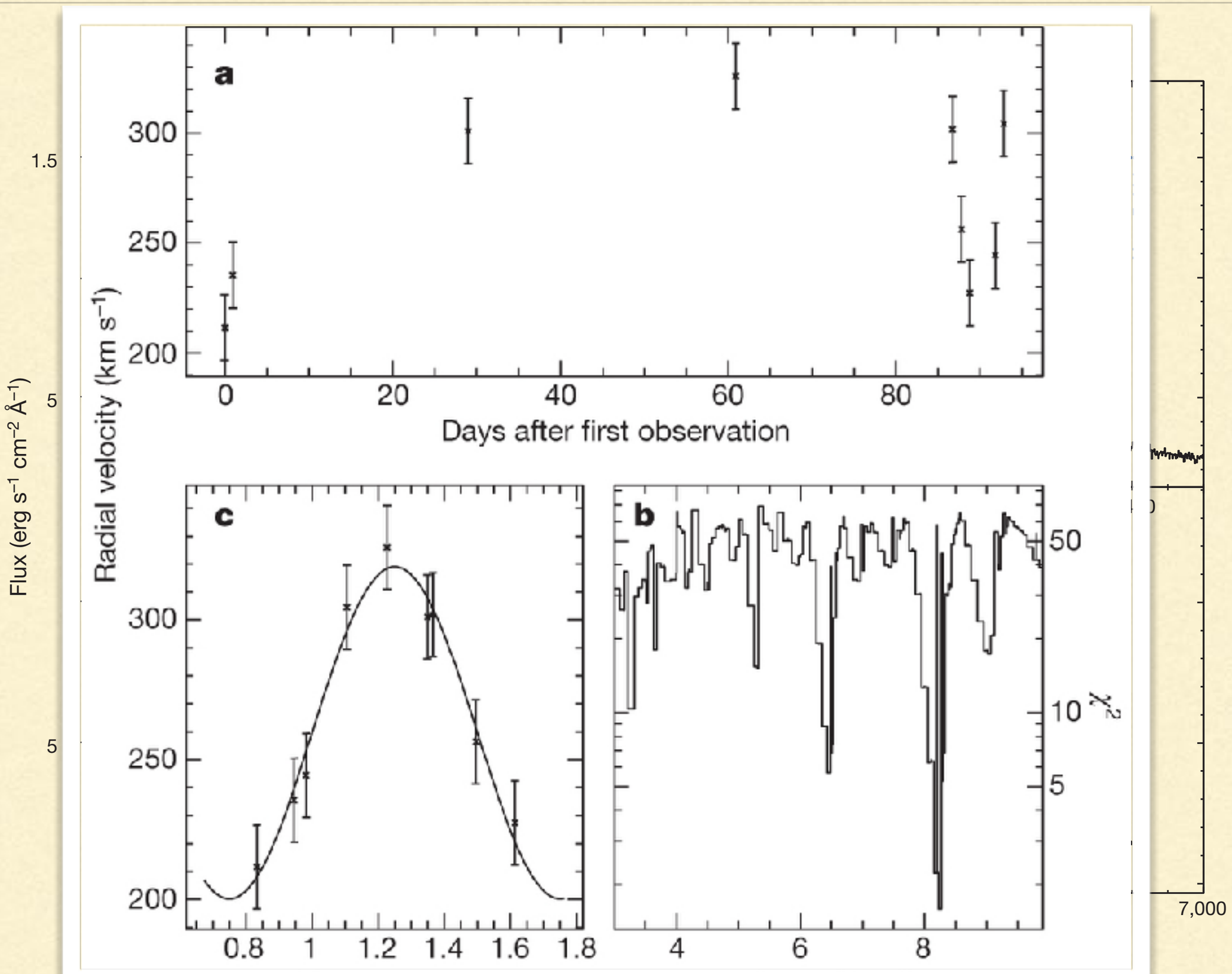
Roberts et al. 2011

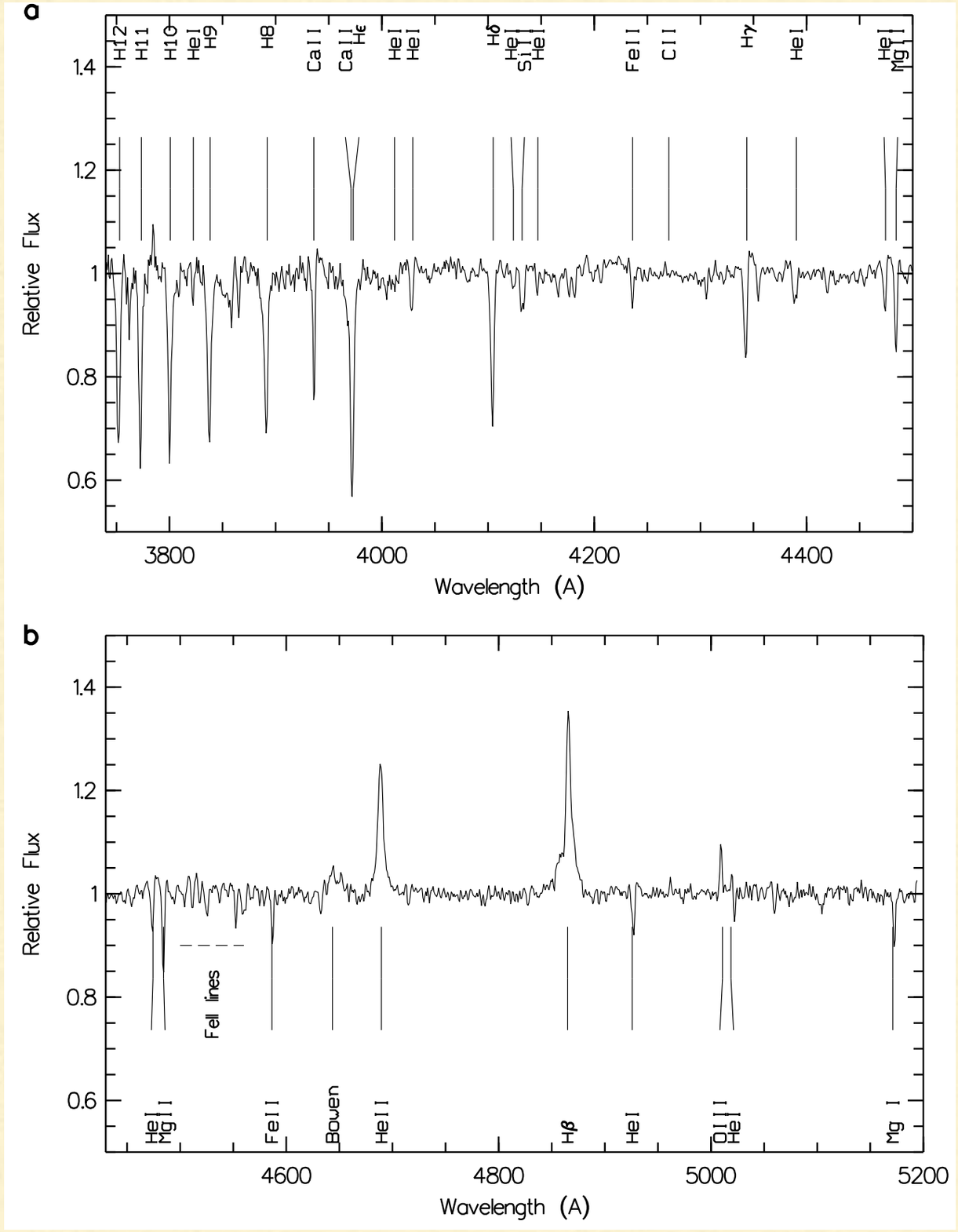


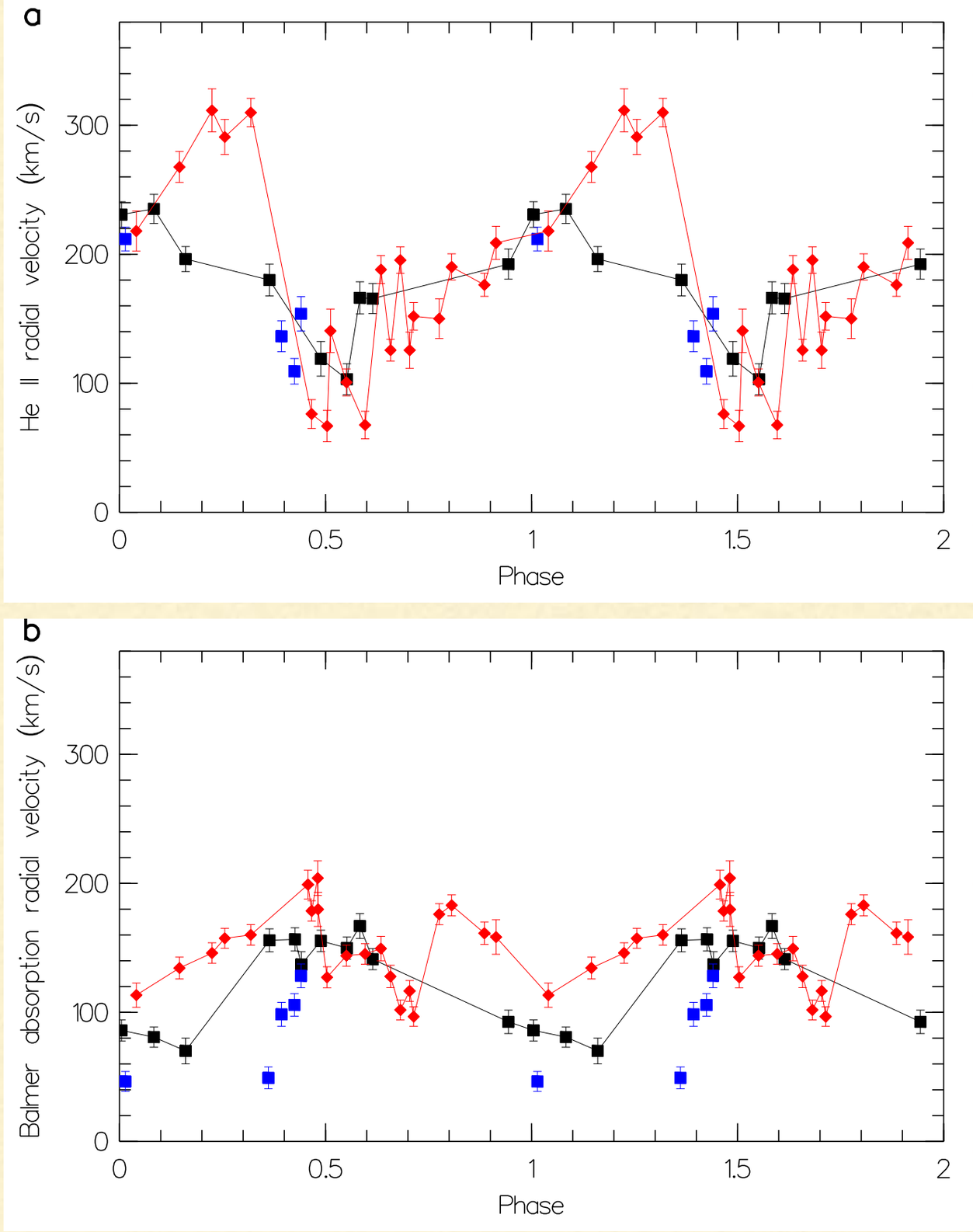
Marsh 1994

$$\frac{P_{\rm orb} K_C^3}{2\pi G} = \frac{M_{\rm BH} \sin^3 i}{(1+q)^2}$$

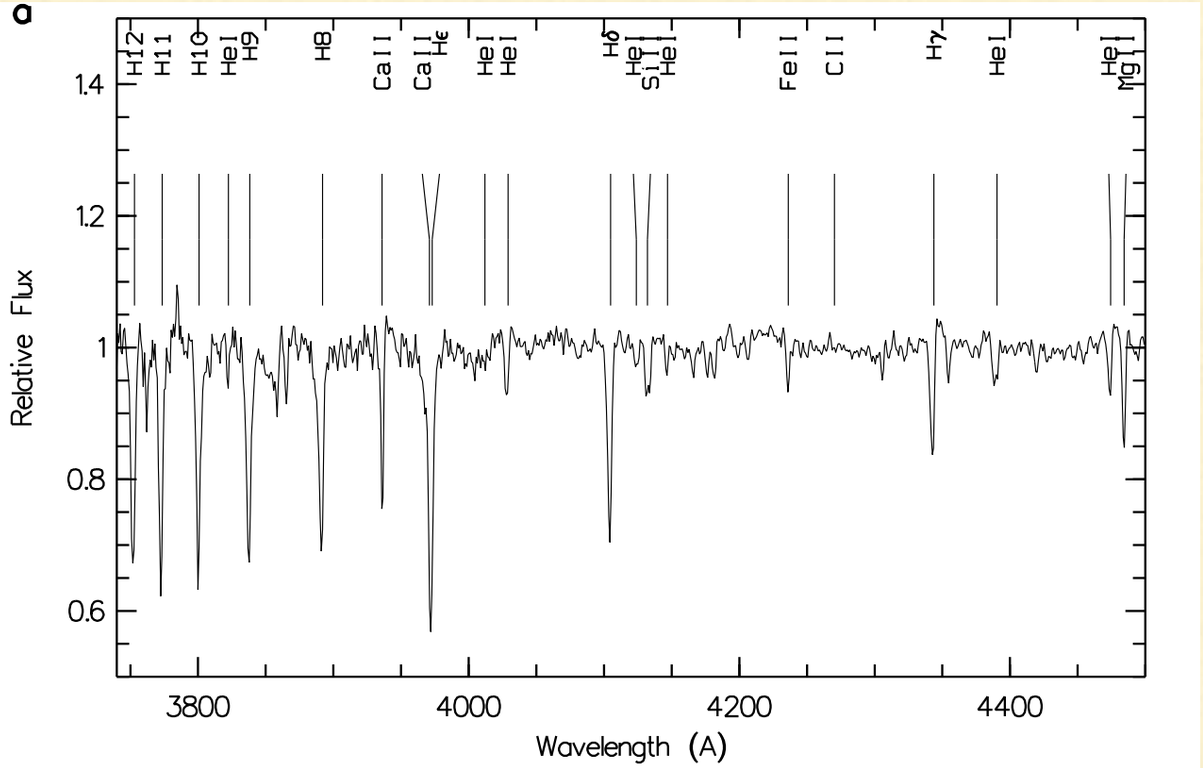

Hδ
Hγ
He I 4,471 Å
N III 4,634 Å
He II 4,686 Å
Hβ
He I 4,922 Å
[O III] 4,960 Å
[O III] 5,006 Å
He II 5,411 Å
Hα
C III 5,696 Å
C IV 5,812 Å
He I 5,876 Å
N II 6,548 Å
N II 6,583 Å
He I 6,679 Å
S II 6,716 Å
1.5 × 10−17
10−17
5 × 10−18
0
Flux (erg s−1 cm−2 Å−1)
4,200
4,400
4,600
4,800
5,000
5,200
5,400
5,600
5,800
6,000
6,200
6,400
6,600
6,800
7,000
Wavelength (Å)

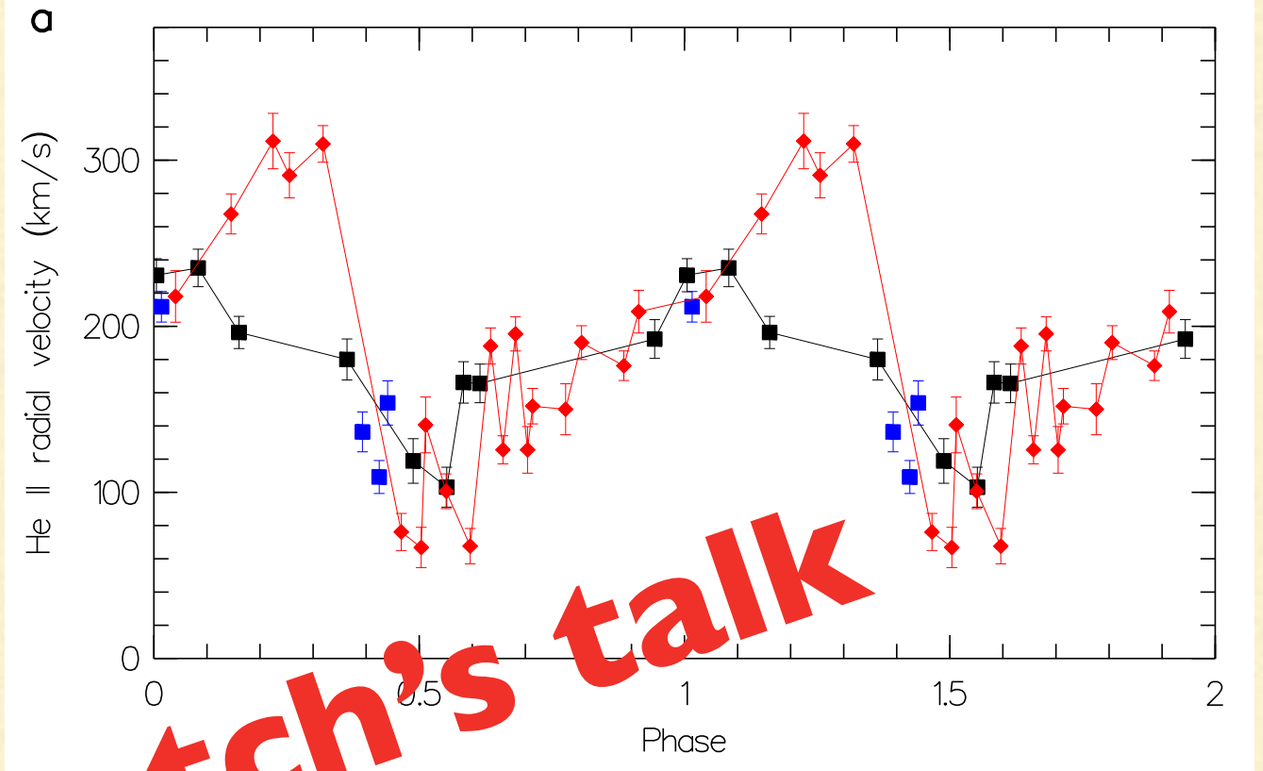

a
300
250
200
0
20
40
60
80
Days after first observation
Radial velocity (km s^{-1})
c
300
250
200
0.8
1
1.2
1.4
1.6
1.8
b
50
10
5
χ^2
4
6
8
1.5
5
5
Flux (erg s^{-1} cm^{-2} Å^{-1})
7,000

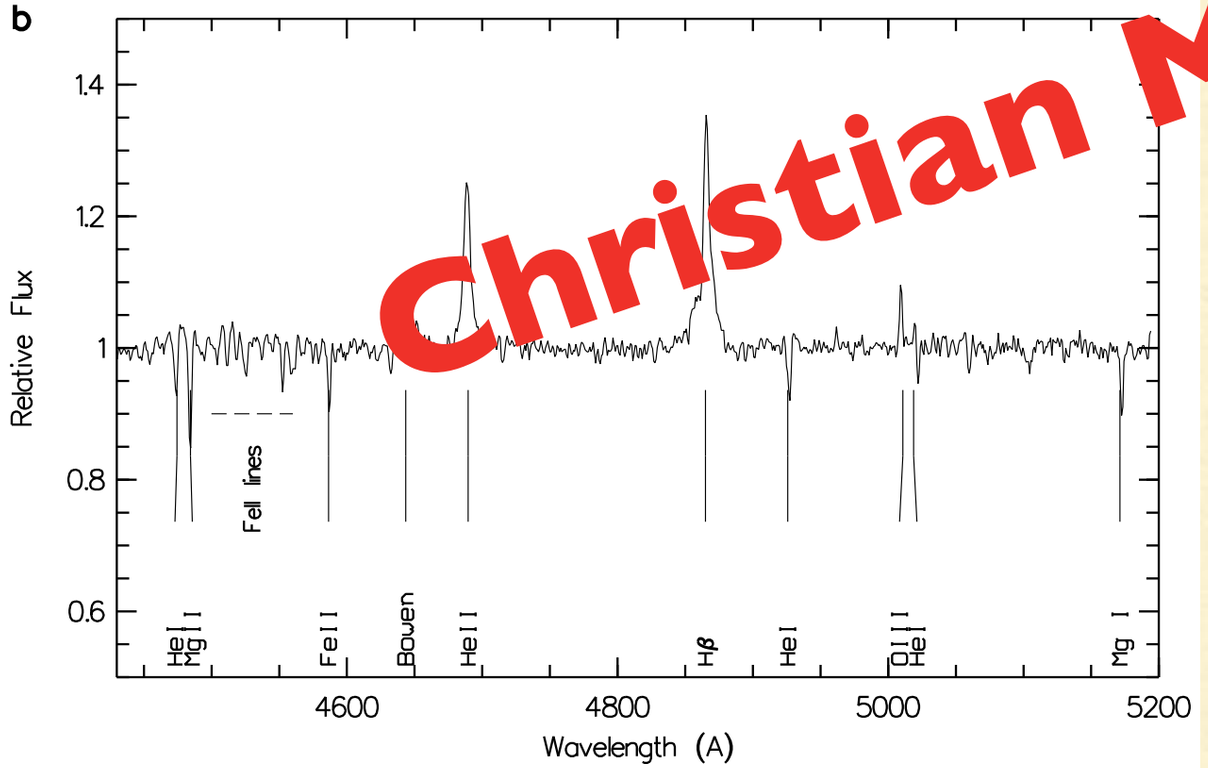


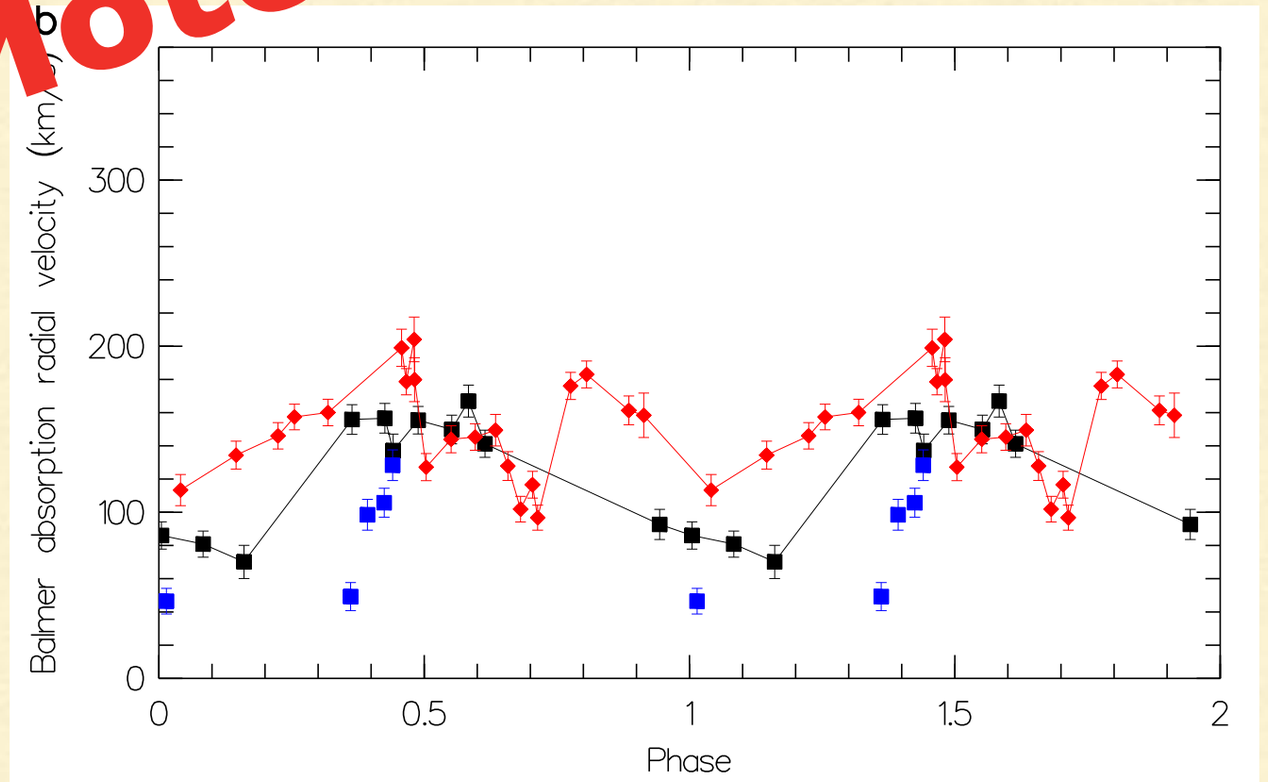


Motch et al. 2014

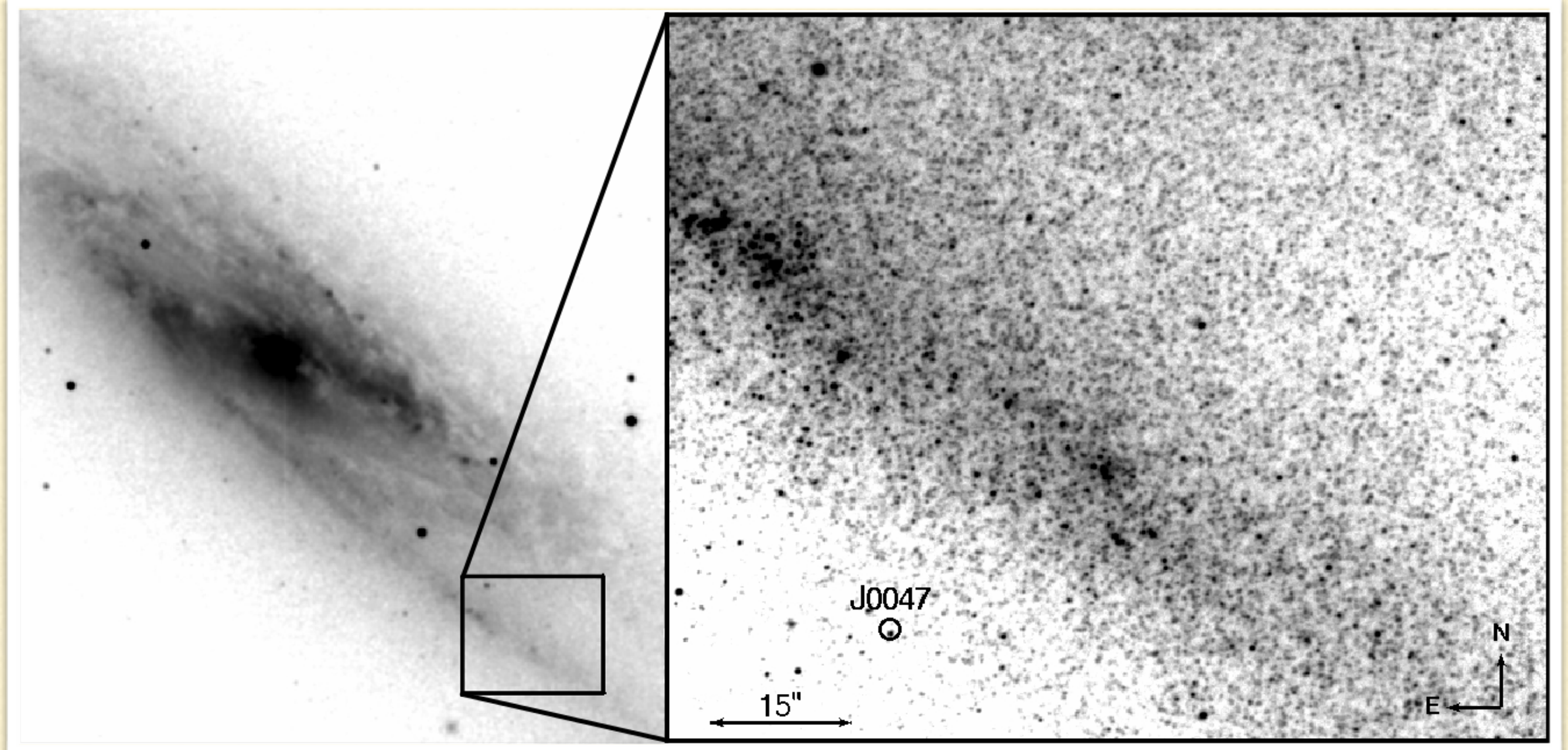






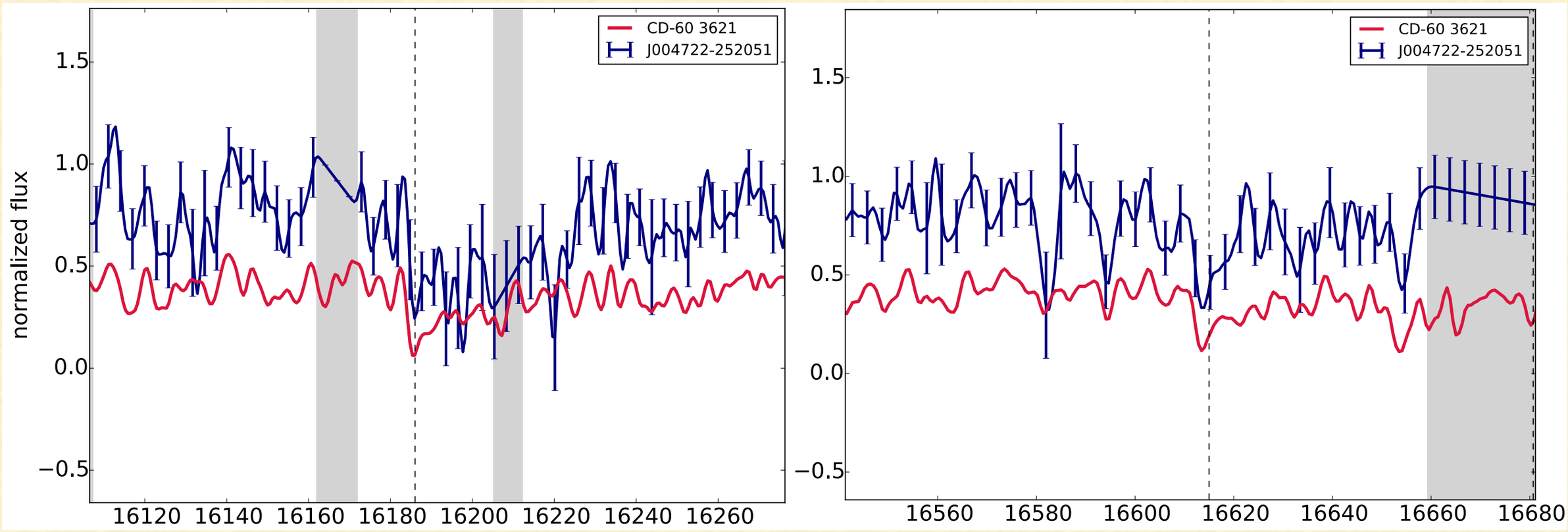


Motch et al. 2014

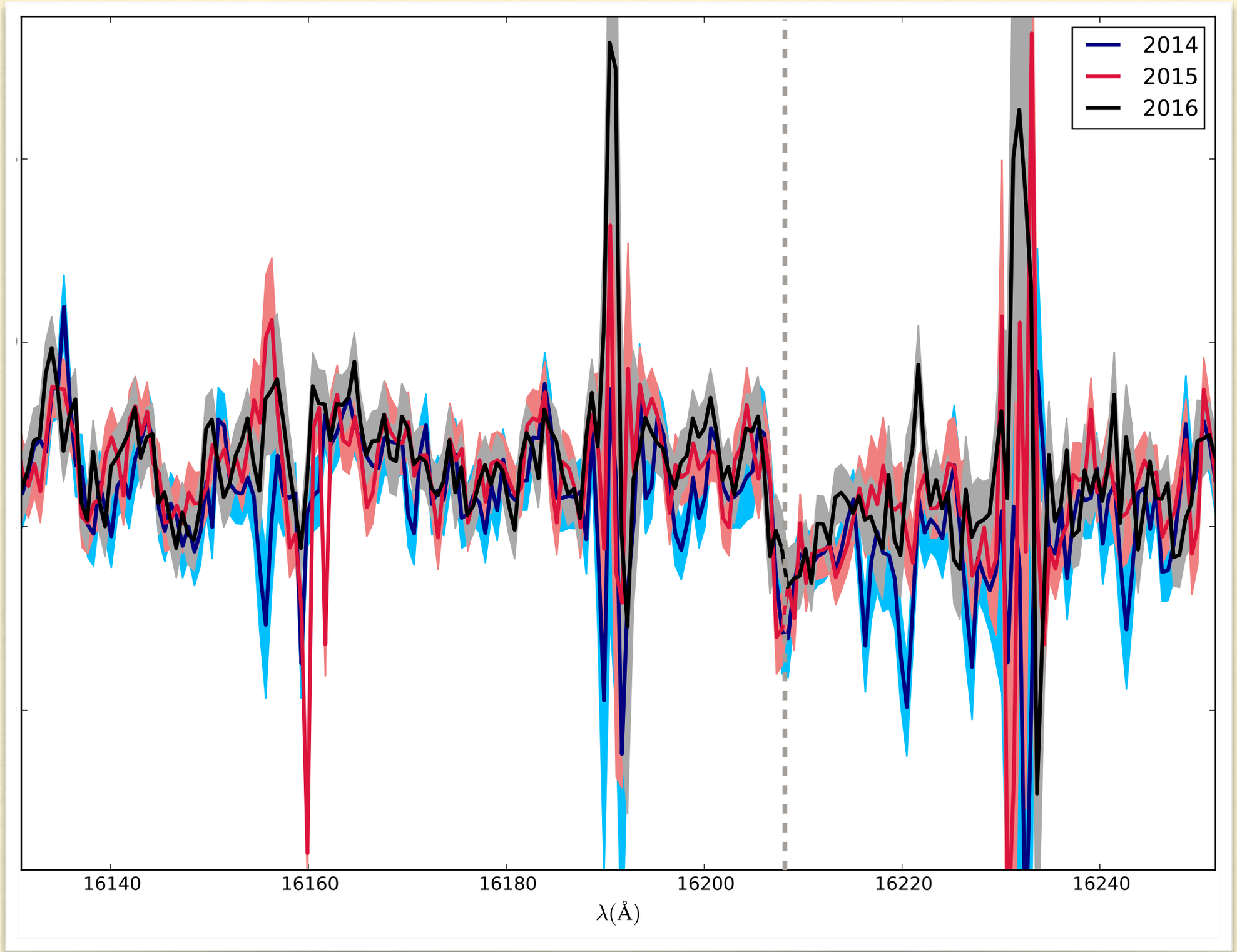


BETTER LUCK IN INFRARED?

VLT/X-shooter, NIR arm

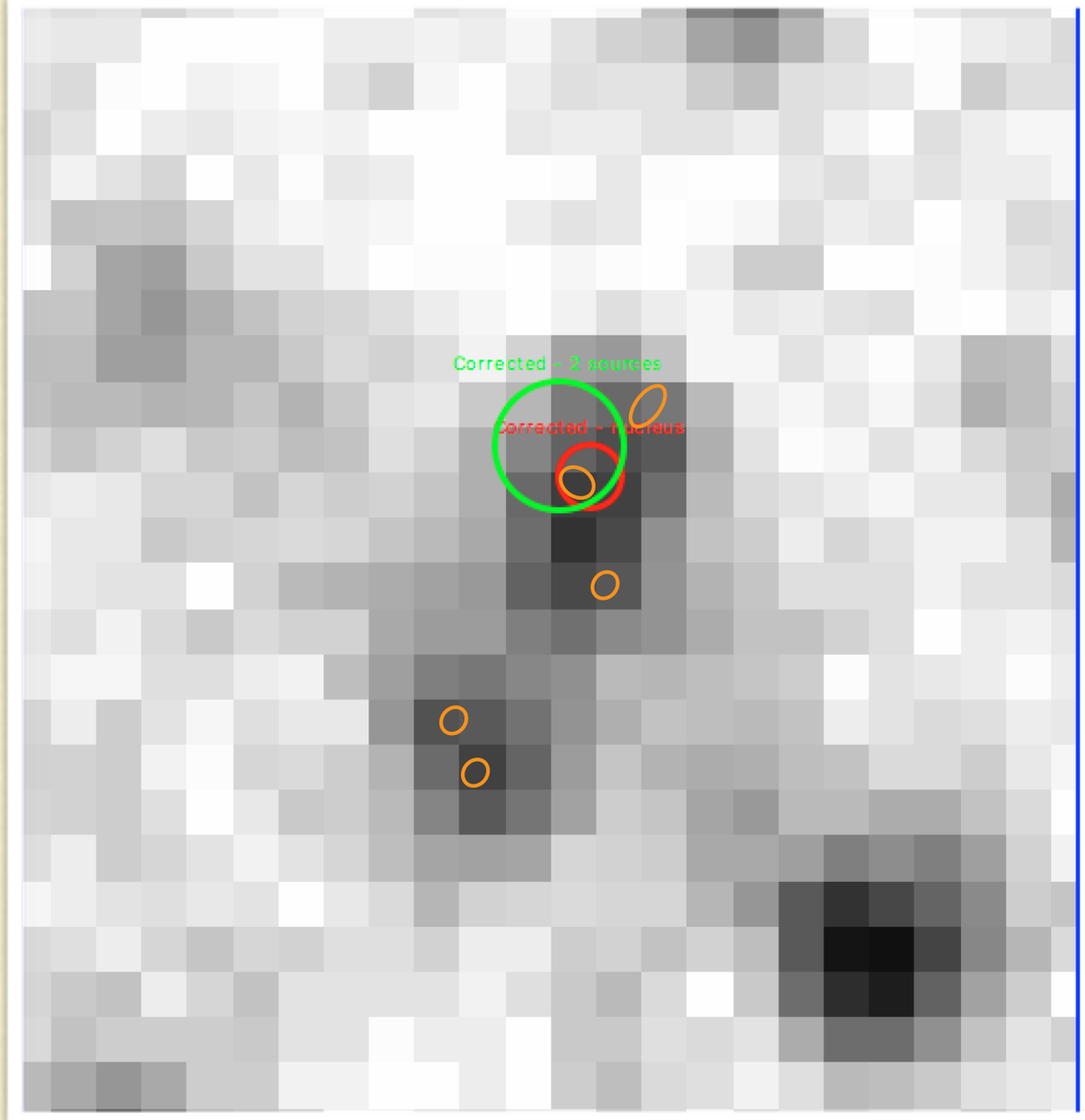


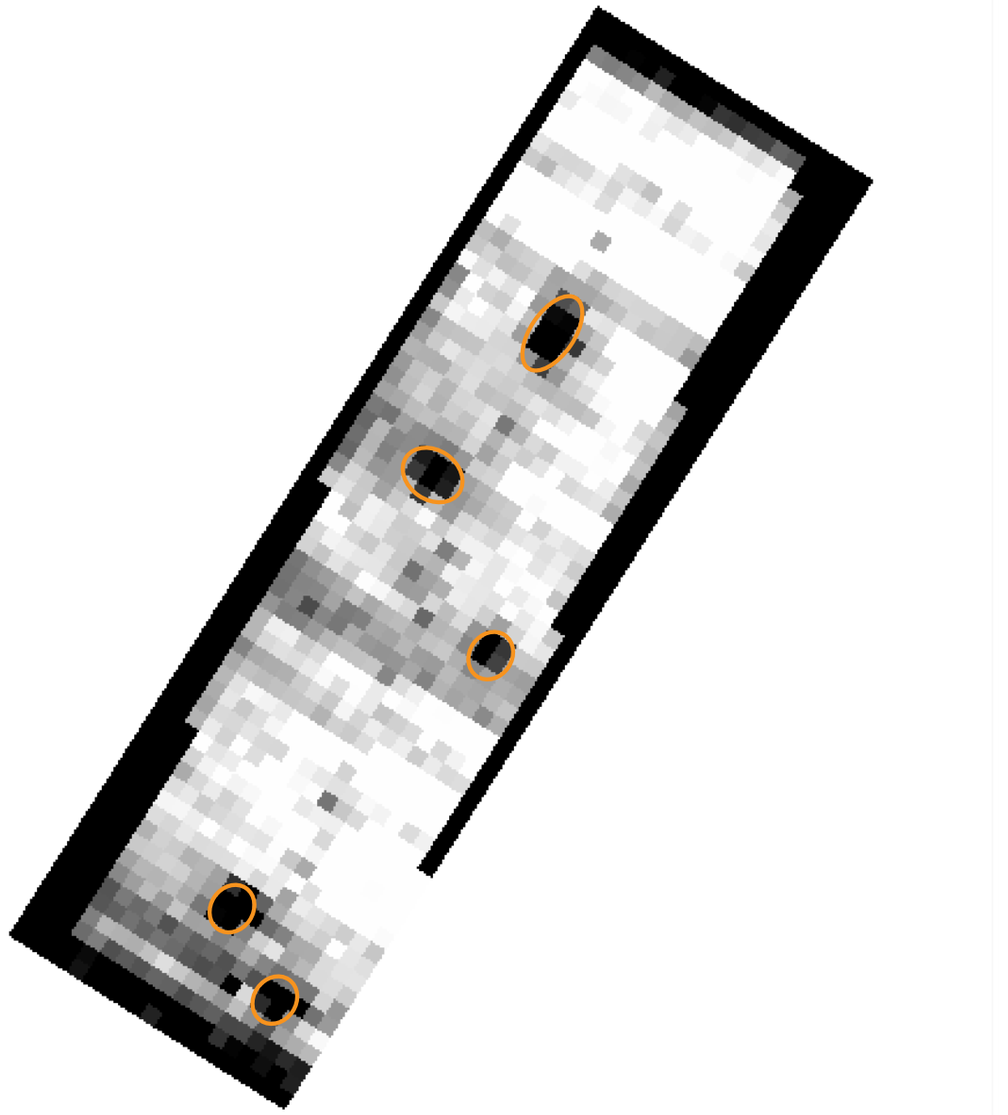
Heida et al. 2015



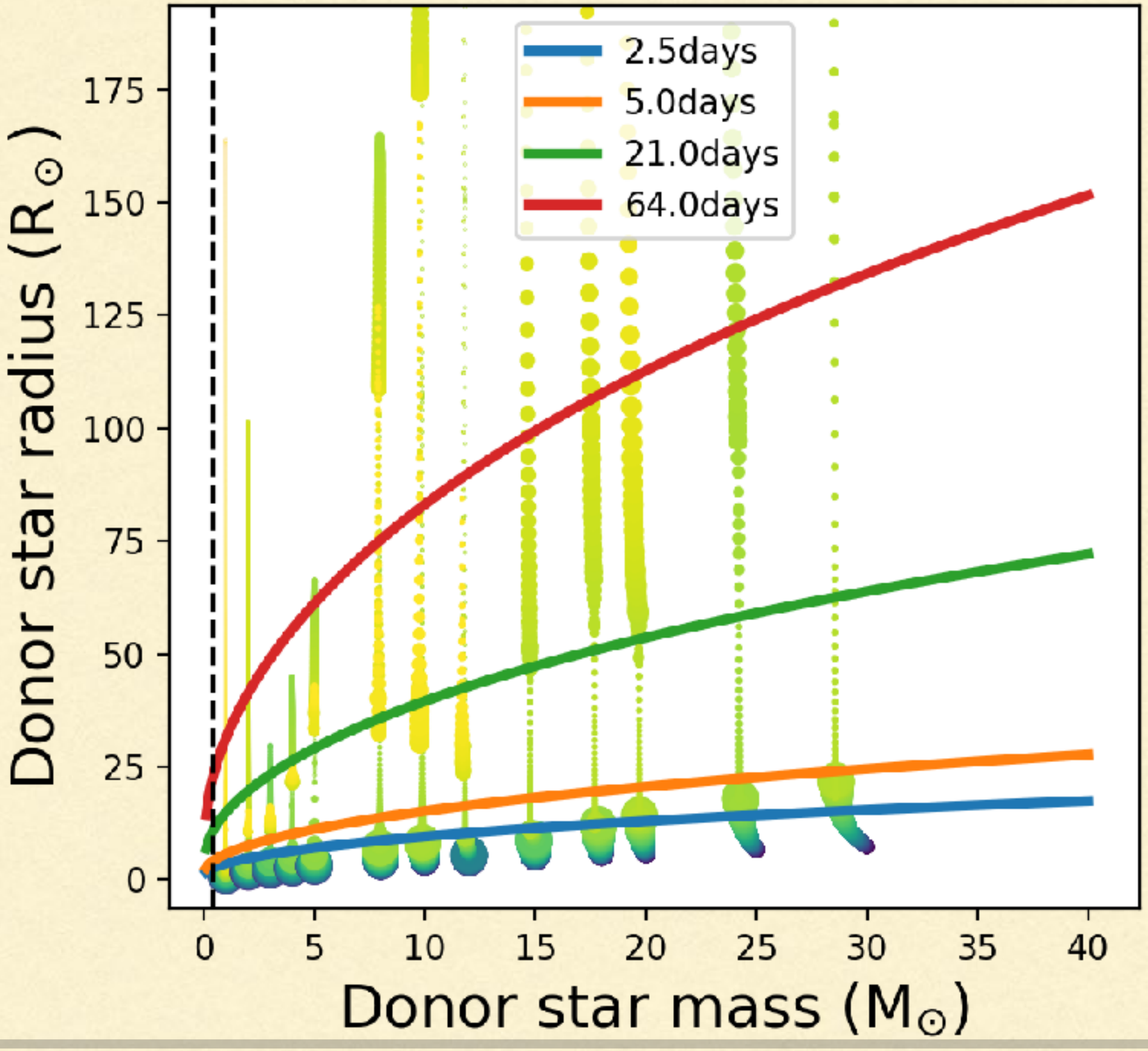
Heida et al. in prep.

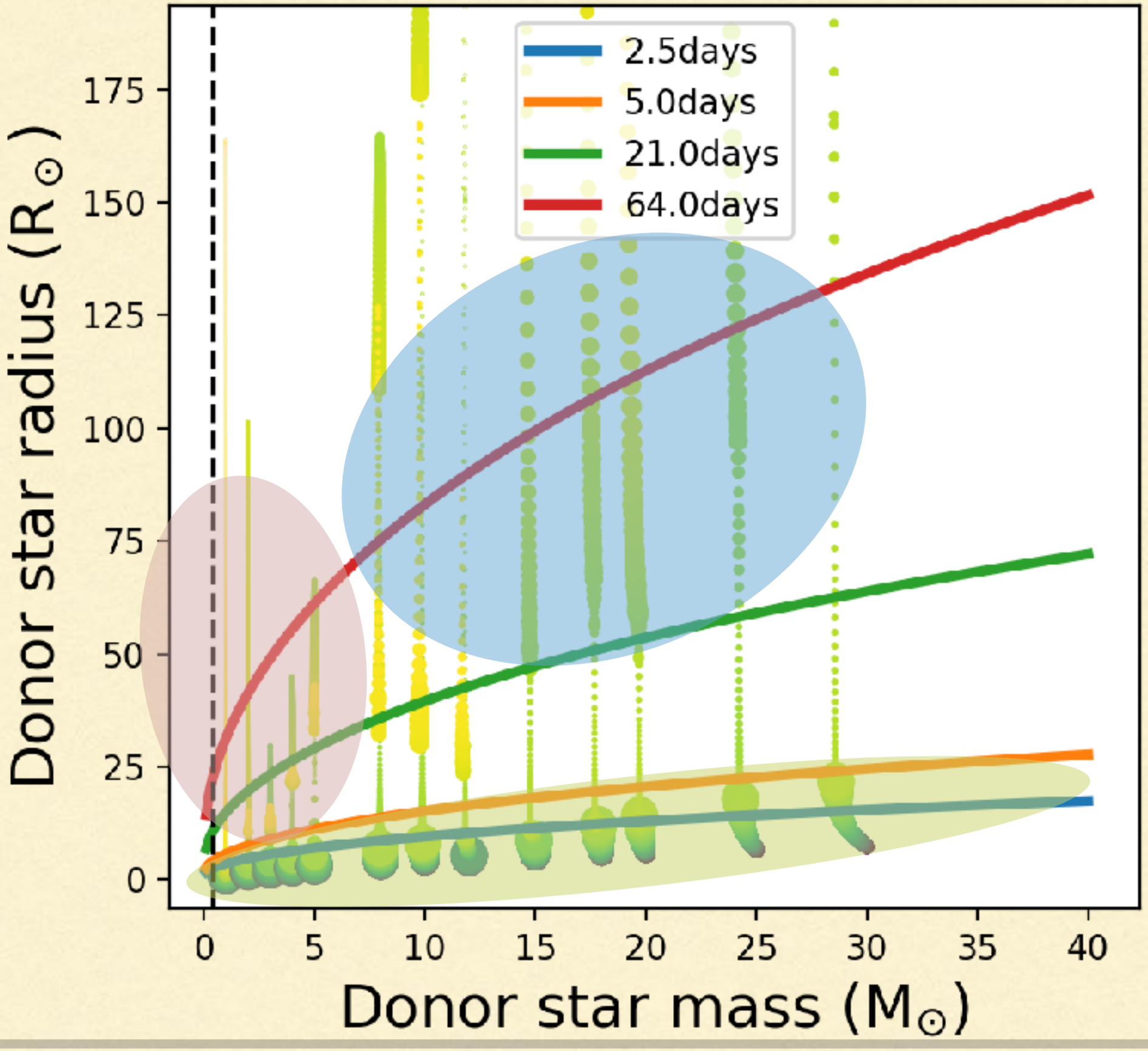
NGC 925 J022721+333500 (‘ULX2’)

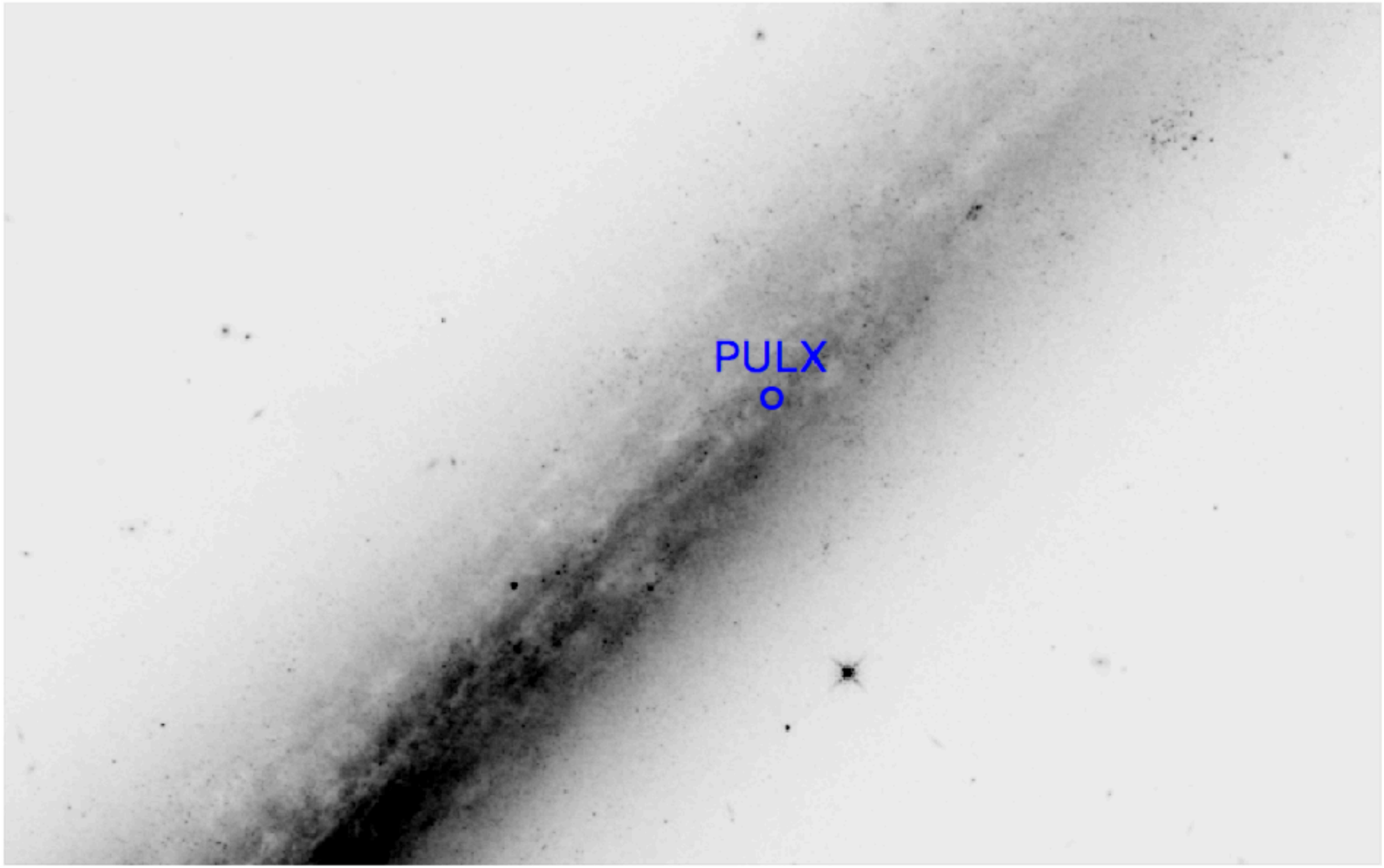




Heida et al. in prep.


2.5days
5.0days
21.0days
64.0days
Donor star radius ($R_\odot$)
0
25
50
75
100
125
150
175
0
5
10
15
20
25
30
35
40
Donor star mass ($M_\odot$)


2.5days
5.0days
21.0days
64.0days
Donor star radius ($R_\odot$)
Donor star mass ($M_\odot$)
0
25
50
75
100
125
150
175
0
5
10
15
20
25
30
35
40



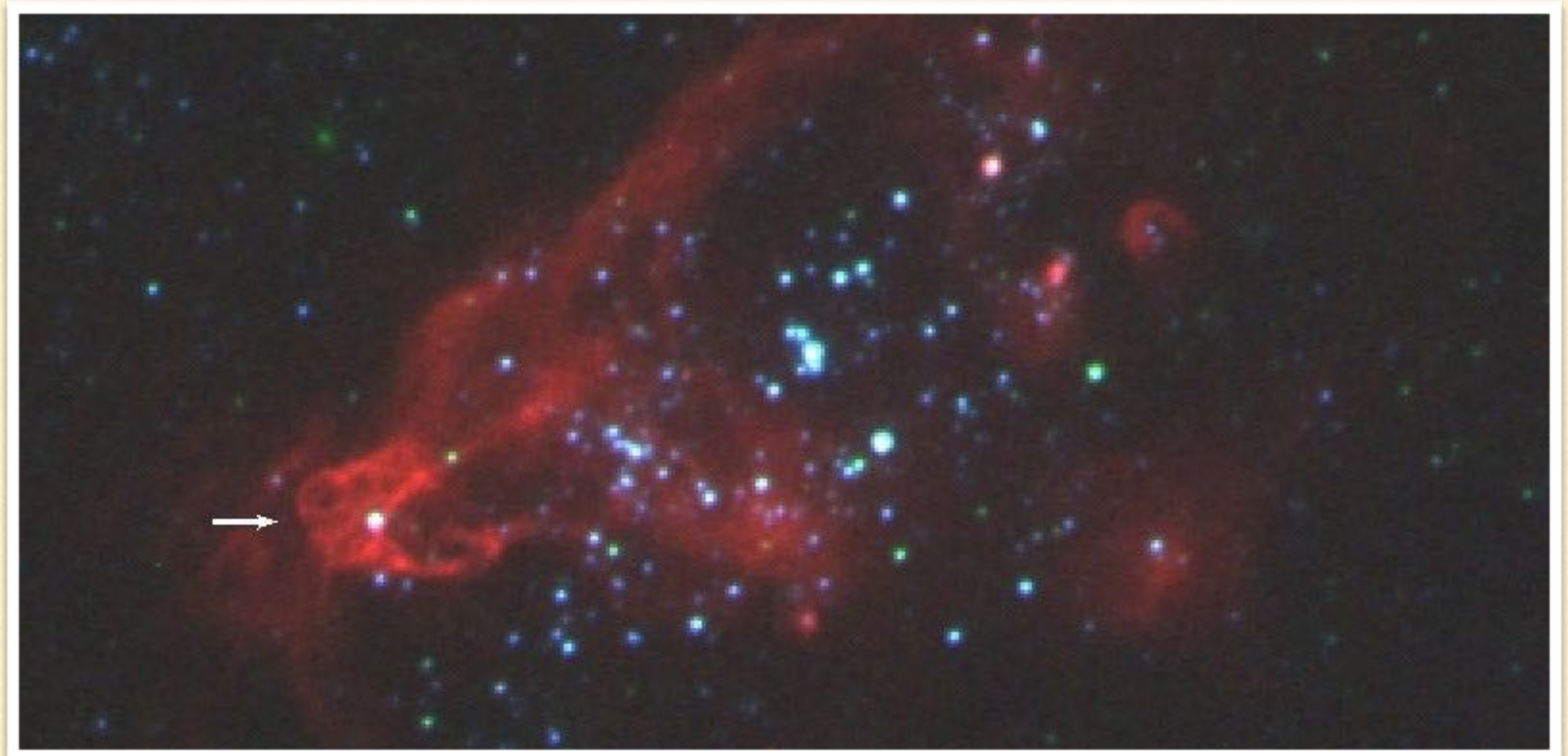
Heida et al. in prep.

DONOR STARS

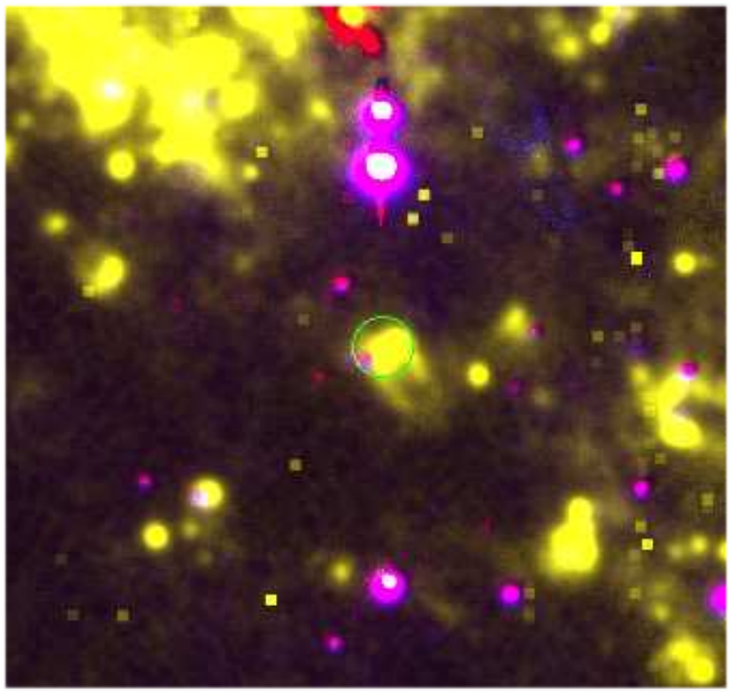
- Many (~50) nearby ULXs have optical/near-IR counterparts but most are too faint for spectroscopy (wait for ELT/TMT/GMT…)
- Photometry alone can not distinguish between donor stars and irradiated accretion discs
- 5 ULXs with donor star features (2 optical, 3 near-IR): 1 WR, 1 BSG, 3 RSG

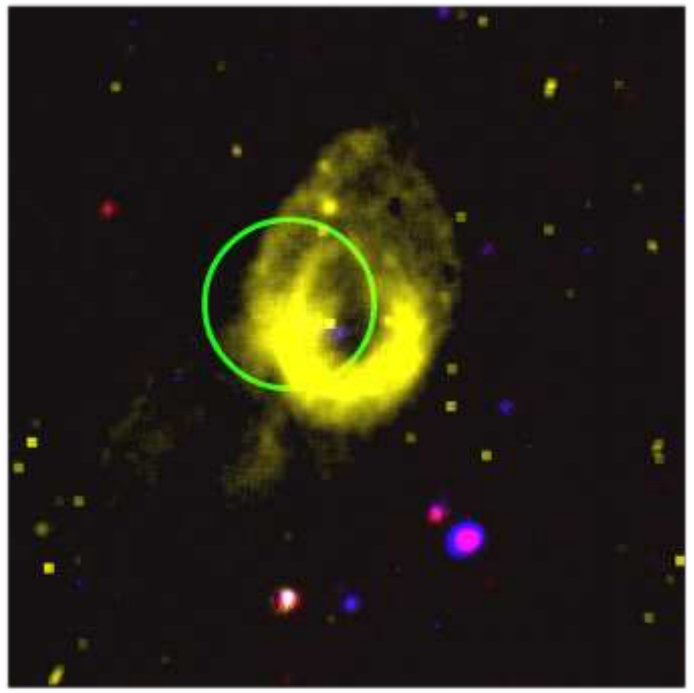
DONOR STARS

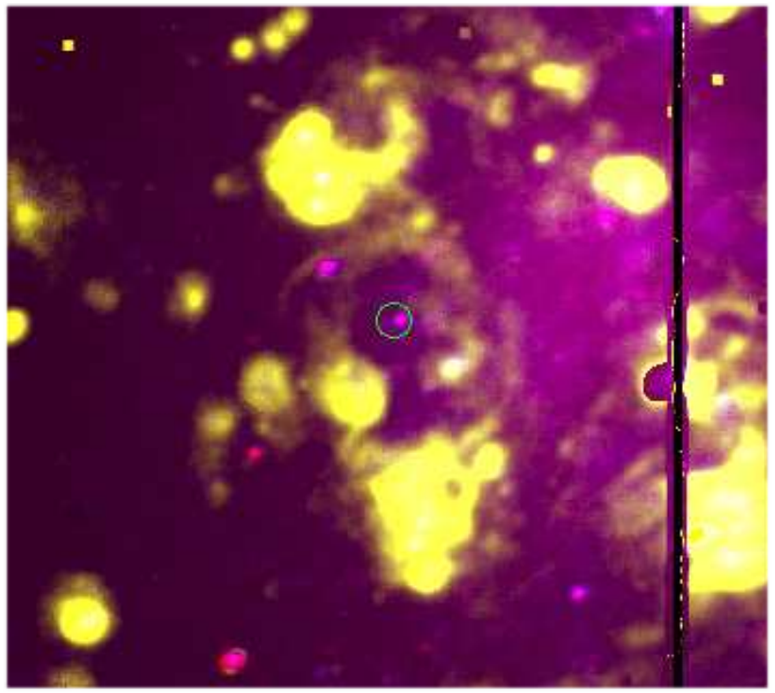
- Donor stars are the only way to get masses of BH ULXs!
- If we want to test evolution scenarios we need to know donor star types of a population of ULXs!

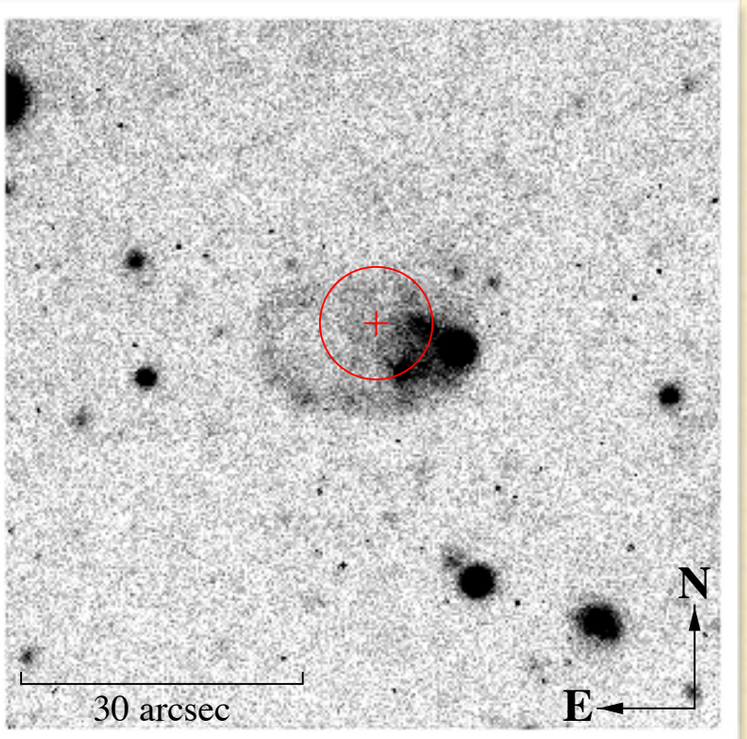


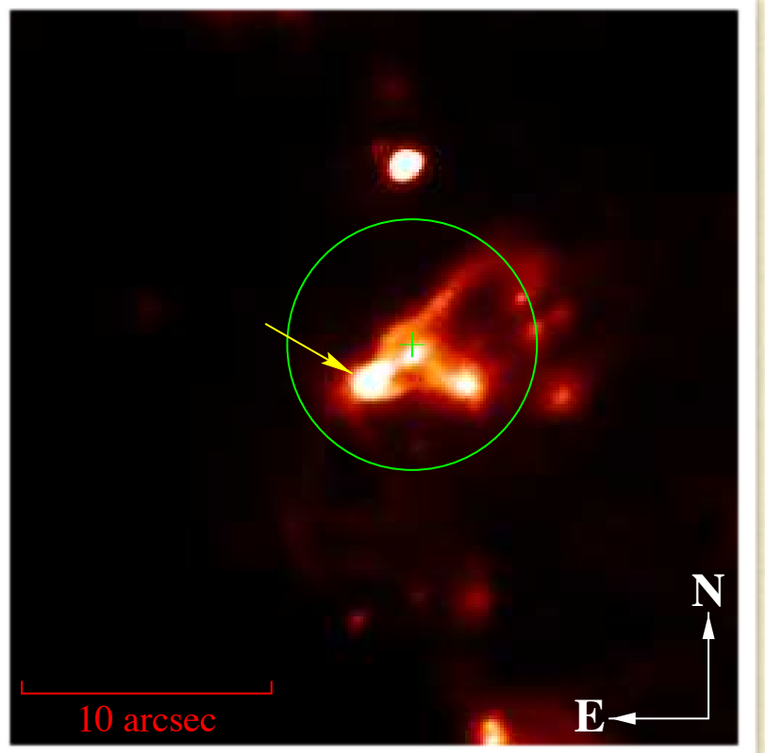
OTHER OPTICAL/IR COUNTERPARTS



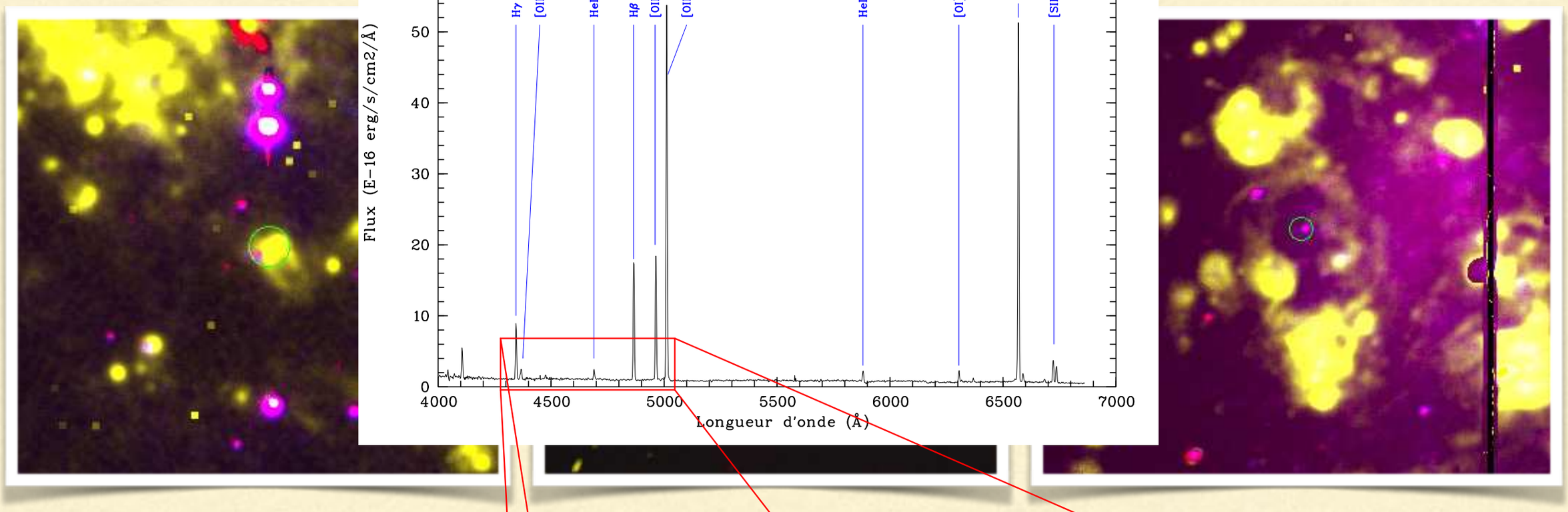






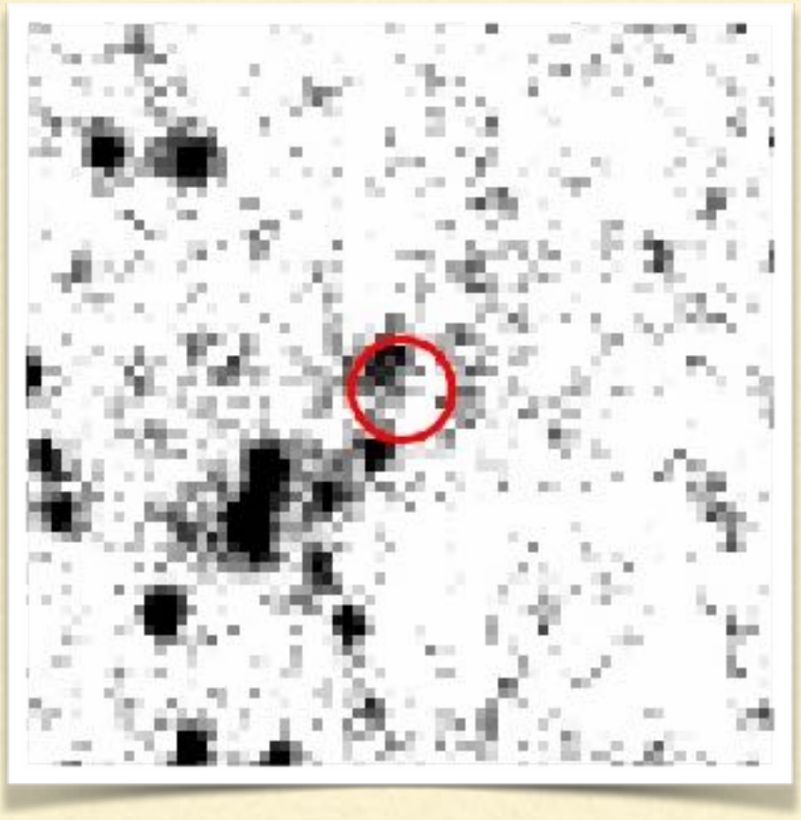


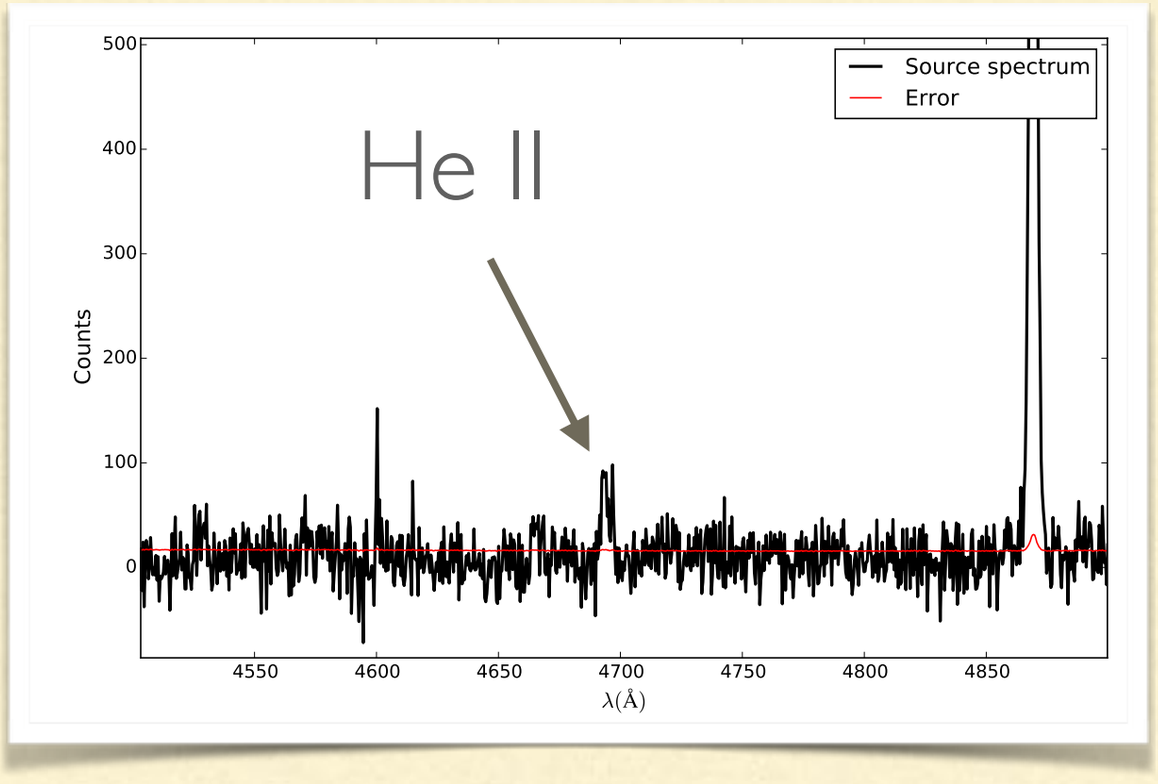
Pakull & Mirioni 2002

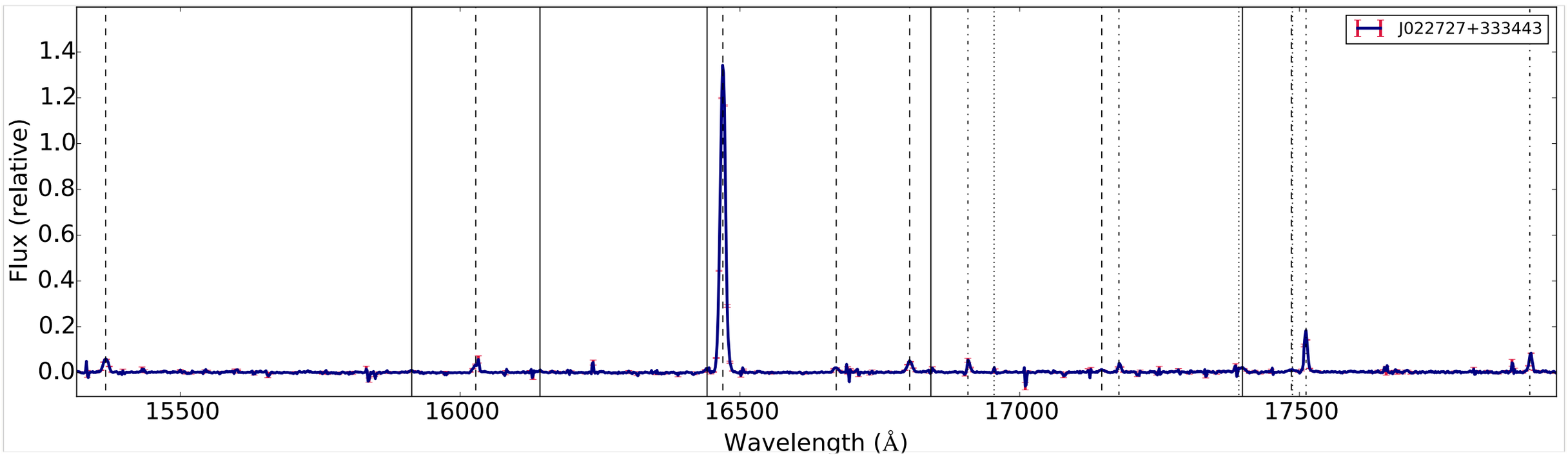


& Mirioni 2002

NGC 925 J022727+333443 ('ULX1')

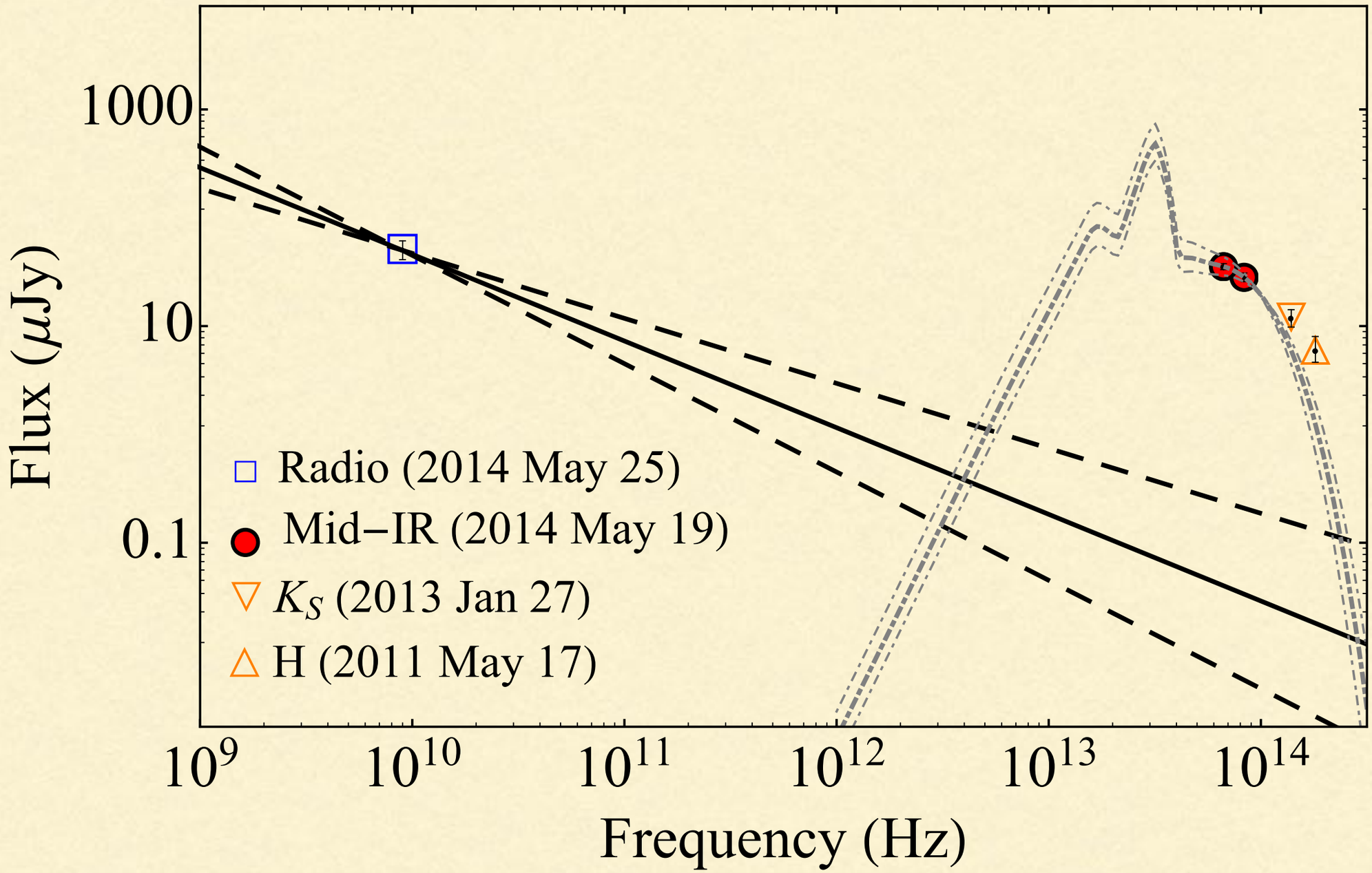






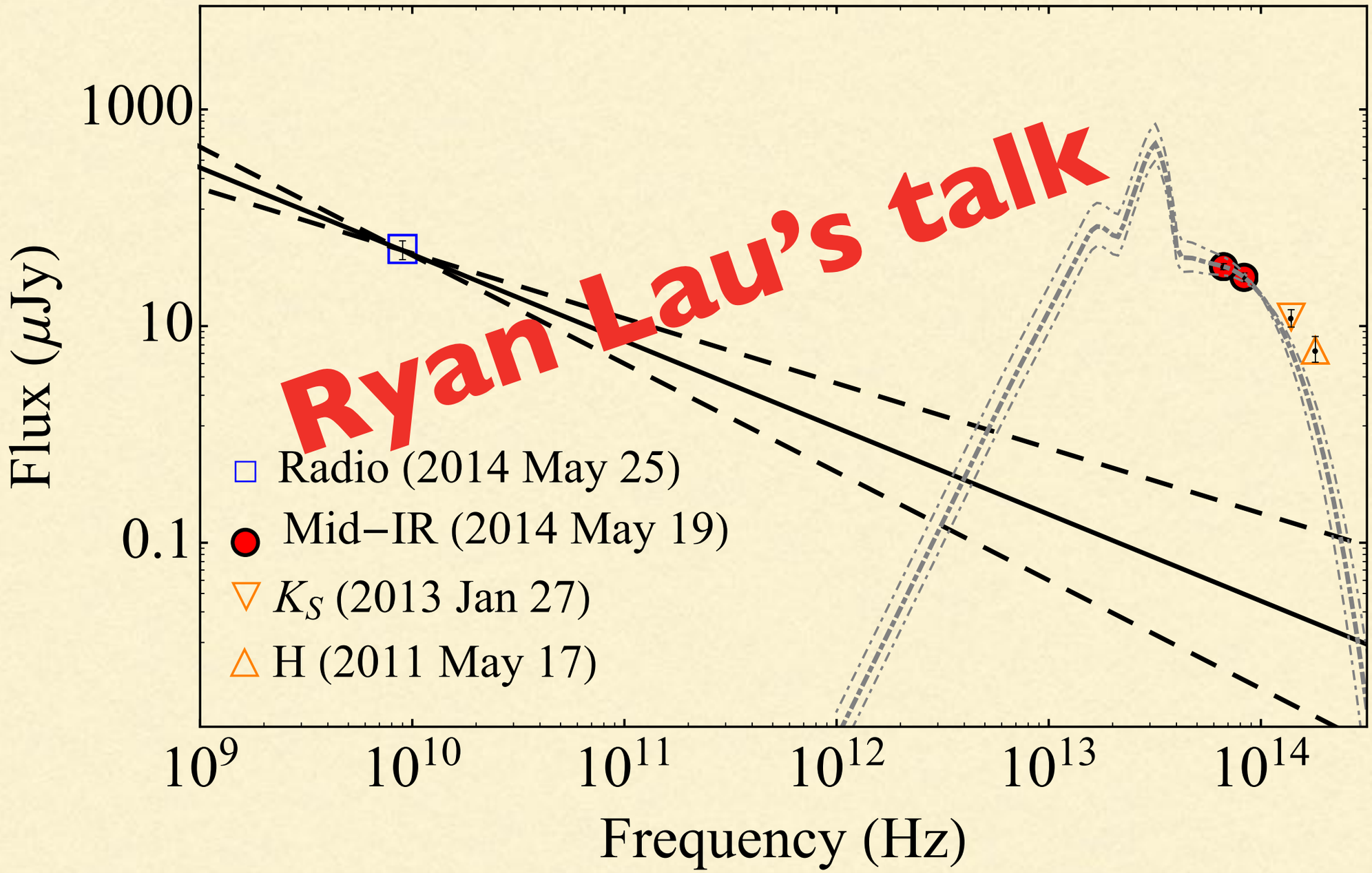
Heida et al. 2016

MID-IR: JETS OR DUST?



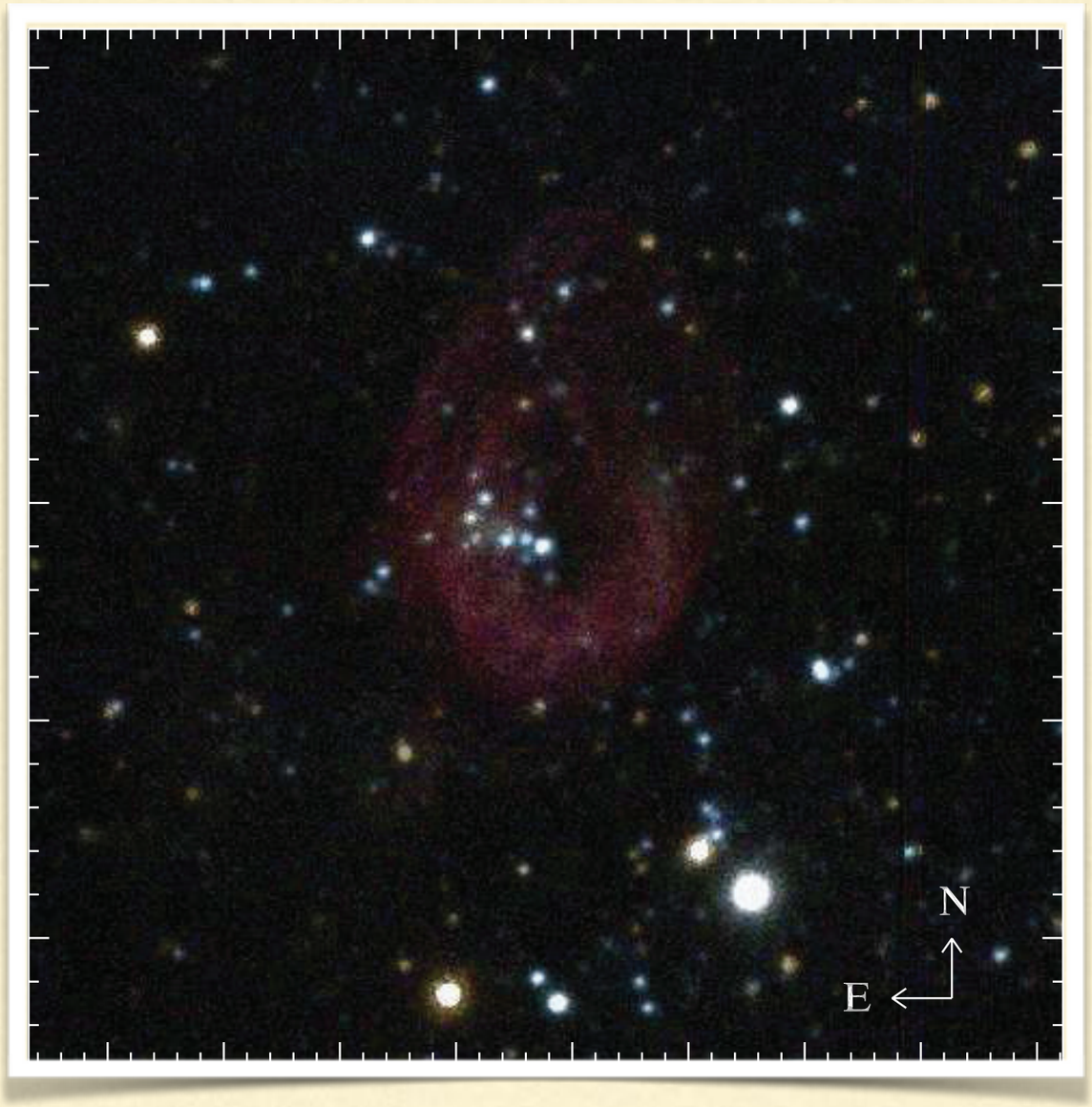
Lau et al. 2017

MID-IR: JETS OR DUST?



Lau et al. 2017

ENVIRONMENT



Grisé et al. 2011

- Nearby stars give clues about age/mass of ULX donors
- Example: Ho IX X-1, age of nearby cluster ≲ 20 Myr, mass upper limit ~ 20 $M_\odot$

SOME OPEN QUESTIONS

- Do some ULXs have low-mass donor stars? Can we tell without 40m telescopes?
- Are all ULXs Roche-lobe overflowing or can they be wind-fed?
- Can we reconcile donor star statistics with population synthesis models to find the evolutionary pathways that produce ULXs?