Detection of substellar companions to eclipsing binary stars

PI: Theodor Pribulla

Short description: This project is aimed at finding timing variations in close eclipsing binaries indicating presence of substellar circum-binary components

The observations will be performed with two 60/750cm Zeiss telesopes. The Moravian Instruments G4-9000 CCD camera is used in the G2 pavilion (FoV is 16.9 × 16.9', 3kx3k chip) while FLI ML3041 (FoV is 14.1 × 14.1', 2kx2k chip) is used in the G1 pavillion.

Because the goal of the project is going to be accomplished by the accurate (at the seconds level) timing of the light-curve extrema (in our case minima), it is crucial to regularly synchronize the computer clock with the ntp servers to provide the system time within 1 second off the UTC.

The observing project includes three groups of objects : (i) systems with K or/and M dwarf components (ii) systems with hot subdwarf (sd) and M dwarf components (iii) systems with white dwarf (WD) component(s). To get the best S/N it is advisable to use the R or I filter for the first group, and the B or V filter for the second and V or B filter in the third group. Several faint or short-period objects should be observed without a filter to provide more light. Using two or more filters would decrease the cadency of the photometry and decrease duty-cycle because of filter change overheads. It is always better to observe the deeper (primary) minimum (in the case WD systems the secondary eclipse is very shallow and can hardly be detected).

The filter and exposure time (can be adjusted if needed) are given in the last two columns of the second table (page 3). The precision of the timing for the systems with triangular shape of the minima (groups 1-2, i.e., binaries with non-degenerate components) can be estimated as:

$$\delta T = \frac{D\sigma}{2d\sqrt{N}}, \tag{1}$$

where d is the depth and D duration of the minimum, N number of observational points (during the eclipse), and σ the uncertainty of a single observational point. In the case of eclipses of degenerate components, where egress and ingress last typically from couple of seconds to a minute, the time resolution of the photometry defines the timing precision. Because there could be night-to-night systematic shifts of the LC, it is always better to cover both branches of the minimum.

To avoid systematic shifts of the LCs it is advisable to always keep the targets at the same place on the CCD chip (often dictated by the guide star necessary to autoguide the telescope). The red noise can be minimized by using autoguiding and comparison star(s) of similar spectral type.

For each field 2x2 binning should be used. Every night do Darks (10 frames for each exposure time is enough) and Flat-fields (exposed to 40000-60000 counts, at least 5 frames for each passband), if possible. Try not to change exposure times and keep CCD chip temperature at 5 K multiples (e.g., −25 C, −30 C, −35 C etc.) so the reduction frames from previous nights can be utilized. Always try to avoid 20% margin to prevent vignetting (this would have profound effect on the LC obtained without an autoguider).

DSS2 (red) 0.5 degree fields for all targets taken from `http://skyview.gsfc.nasa.gov/`) are given below.

Targets with strong wavelength dependence of minimum depth: PTFEB11.441 ($\Delta B = 1.3$, $\Delta V = 0.50$, $\Delta I < 0.05$), V471 Tau ($\Delta B = 0.08$), DE CVn ($\Delta B = 0.13$), RX213 ($\Delta B = 1.1$, $\Delta I = 0.05$).

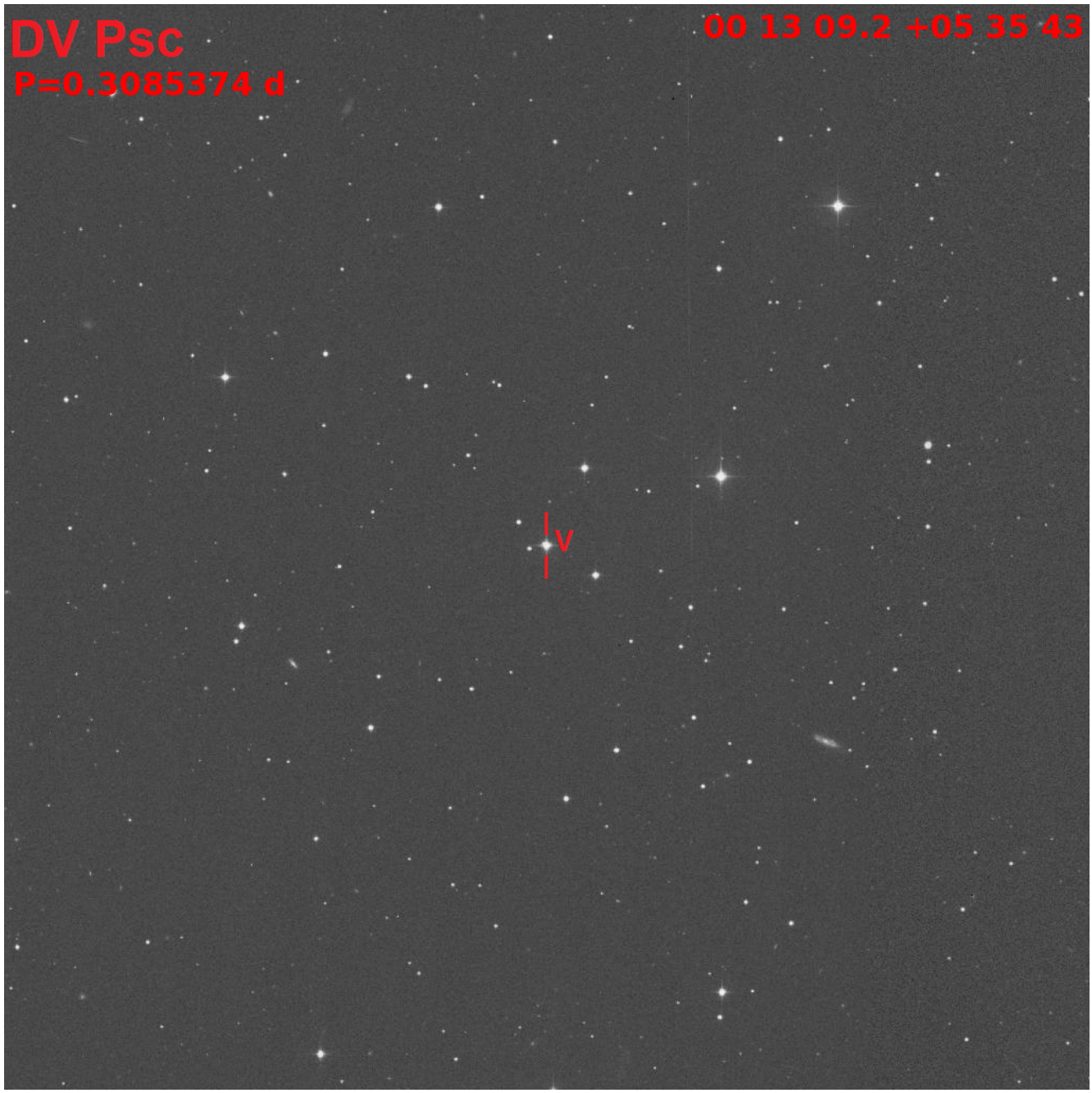
List of targets in this project:

Target	α_{2000}	δ_{2000}	M_1 [$M_\odot$]	M_2 [$M_\odot$]	sp. type	spots	LITE [sec]	Reference
DV Psc	00 13 09.2	+05 35 43	0.490	0.510	K5V+M1V	YES	4.5	NewA 15, 362 (2010)
PTFEB11.441	00 45 46.0	+41 50 30	0.510	0.350	M3.5+WD	NO	5.0	ApJ 757, 133 (2012)
WD 0107+131	01 10 09.1	+13 26 17			WD+dMe	NO		MNRAS 394, 978 (2009)
NSVS 06507557	01 58 23.9	+25 21 20	0.660	0.280	K9+M3		4.7	MNRAS 401, 1141 (2010)
BX Tri	02 20 50.8	+33 20 48	0.510	0.260	M1V+M4V	YES	5.4	MNRAS 406, 2559 (2010)
V449 Per	02 57 33.5	+35 14 01						A&A 446, 785 (2006)
GJ 3236	03 37 14.1	+69 10 50	0.380	0.280	M3.8+M4.4	NO	5.9	ApJ 701, 146 (2010)
V912 Per	03 44 32.2	+39 59 35			K4V	NO		AJ 141, 166 (2011)
NLTT11748	03 45 16.8	+17 48 09			WD+WD	NO		ApJ 716, 14 (2011)
V471 Tau	03 50 25.0	+17 14 47			K2V+DA	YES		Ap&SS 331, 121 (2011)
HAT-216-0003316	04 40 23.0	+31 26 46	0.200	0.140	M4.2V+M5.0V			ApJ 716, 1522 (2010)
AP Tau	04 54 45.0	+26 55 24						A&A 446, 785 (2006)
HAT-131-0026711	05 16 36.9	+48 35 44						AJ 141, 166 (2011)
V608 Aur	05 27 37.9	+39 55 33			K2IV?	YES		
V641 Aur	06 03 47.6	+42 19 07						M. Wolf
HAT-133-0002525	06 36 25.2	+43 49 47						AJ 141, 166 (2011)
V470 Cam	07 10 42.1	+66 55 44	0.480	0.130	sdB+M	NO	6.3	NA 17, 325 (2012)
YY Gem	07 34 37.4	+31 52 10	0.600	0.600	dM1e	YES	4.0	ApJ 567, 1140 (2002)
VSX J075328.9+722424	07 53 28.9	+72 24 24			sdB+M			AAVSO
HAT-136-0003262	08 11 34.8	+43 02 33						AJ 141, 166 (2011)
CSS 42362	08 13 51.39	+11 01 36.2			WD+M?	NO		http://arxiv.org/abs/1009.3048
SDSS J08025+0008	08 20 53.5	+00 08 43			sdB+BD	NO		ApJ 731, L22 (2011)
GSC 1941 1746	08 25 51.9	+24 27 04	0.560	0.650	M2V+M2V	YES	4.0	JSARA 1,7 (2007)
CU Cnc	08 31 37.6	+19 23 39	0.430	0.400	M5Ve	NO	5.1	A&A 398, 239 (2003)
NSVS 02502726	08 44 11.0	+54 23 47	0.714	0.347	K5V+M1V	YES	4.3	NewA 14, 496 (2009)
GSC 2499 246	09 16 12.3	+36 15 34	0.680	0.730	M3V+M3V	NO	3.6	AJ 136, 1067 (2008)
HAT-225-0003429	09 21 28.4	+33 25 59						AJ 141, 166 (2011)
CSS 40809	09 35 33.55	+22 51 54.8			WD+M?	NO		http://arxiv.org/abs/1009.3048
ASAS 0938	09 38 13.51	-01 04 24	0.771	0.768	K5V+K5V	YES	3.4	A&A 527, A14 (2011)
CSS 41177	10 05 59.1	+22 49 32.3	0.283	0.274	WD+WD	NO		ApJL 735, 30 (2011)
SW Sex	10 15 09.39	-03 08 32.8			WD+M?			NA 17,533 (2012)
BS UMa	11 25 41.0	+42 34 50			K9-M1V	YES		IBVS 5940
HW Vir	12 44 20.2	-08 40 17	0.480	0.140	sdB+M6-7	NO	6.2	AJ 137, 3181 (2009)
DE CVn	13 26 53.3	+45 32 47	0.510	0.410	M3V+DA	NO	4.8	A&A 466, 1031 (2007)
NY Vir	13 38 48.1	-02 01 49	0.500	0.150	sdB+M5	NO	6.0	NA 17, 325 (2012)
NSVS 00967819	13 44 34.2	+69 18 06			K-M?			suggested by Christopoulou
HAT-145-0001586	13 45 13.2	+46 18 40				YES		AJ 141, 166 (2011)
NSVS 01031772	13 45 34.9	+79 23 48	0.540	0.500	M2V	NO	4.4	2006astro.ph.10225L
SDSS-1435	14 35 48.0	+37 33 38.7			WD+M?			MNRAS 394, 978 (2009)
GK Boo	14 38 20.7	+36 32 25			K2V	YES		A&A 537, 109 (2012)
GU Boo	15 21 54.8	+33 56 09	0.600	0.590	M0/M1.5	YES	4.0	ApJ 712, 1003 (2010)
NSVS 07826147	15 33 49.4	+37 59 28	0.376	0.113	sdB+M5	YES	7.2	ApJ 708, 253 (2010)
G179-55	15 47 27.4	+45 07 51	0.258	0.258	M4	NO	7.0	AJ 141, 166 (2011)
NN Ser	15 52 56.1	+12 54 45	0.535	0.111	DAO1+M4		6.0	MNRAS 402, 2591 (2010)
V1024 Her	16 10 05.1	+25 36 55						AJ 136, 1067 (2008)
HAT-192-0001841	16 12 16.7	+41 13 51						AJ 141, 166 (2011)
CM Dra	16 34 20.4	+57 09 44	0.231	0.214	M4.5V	NO	7.7	ApJ 691, 1400 (2009)
T-Lyr1-17236	19 07 16.6	+46 39 53	0.680	0.523	K7V+M1V	NO	4.0	ApJ 687, 1253 (2008)
KIC 6464285	19 50 41.0	+41 52 36						M. Wolf
KIC 5300878	19 52 20.0	+40 28 42						M. Wolf
NSVS 14256825	20 20 00.4	+04 37 56	0.460	0.210	sdO+M2	NO	5.9	IBVS 5800
MR Del	20 31 13.5	+05 13 08	0.690	0.630	K0V	YES	3.7	A&A 525, A66 (2011)
RX J2130.6+4710	21 30 18.5	+47 10 07	0.550	0.550	M4V+WD	NO	4.2	MNRAS 355, 1143 (2004)
HS 2231+2441	22 34 21.5	+24 56 57	0.300	0.300	sdB+dM	NO	6.3	ASP 392, 221 (2008)

Explanation of the columns: $M_{1,2}$ - masses of the components in $M_\odot$, LITE - expected full amplitude of the light-time effect caused by a Jupiter-mass companion revolving the eclipsing pair in a 10-years orbit

Target	T_0	P	ΔI_1	ΔI_2	ΔT	$V_{\max}$	$R_{\max}$	Fil.	σ	Exp.
	2 400 000+	[days]			[phase]	[mag]	[mag]			[sec]
DV Psc	52500.1540	0.30853476	0.40	0.15	0.200	10.6	10.0	I	0.9	30
PTFEB11.441	55438.3179	0.35870750	0.20	0.00	0.060		16.3	Clear		30
WD 0107+131	53994.4479	0.33268730	3.20	0.00	0.040	16.5	16.5	Clear		60
NSVS 06507557	54746.3801	0.51508836	0.70	0.20	0.120	13.4	12.6	I	1.8	60
BX Tri	51352.0616	0.19263590	0.33	0.27	0.400	13.4	12.5	I	4.2	60
V449 Per	51495.0873	0.47310382	0.50	0.15	0.100	12.0	12.5	I	1.2	120
GJ 3236	54734.9955	0.77125700	0.21	0.19	0.050	14.5	13.5	I	7.9	60
V912 Per	53287.8520	0.57759375	0.30	0.28	0.120	13.1	12.0	I	3.9	60
NLTT11748	55196.8783	0.23506060	0.06	0.04	0.010	16.7	16.3	Clear		30-60
V471 Tau	52500.3434	0.52118357	0.03	0.00	0.065	9.5	9.5	B		20
HAT-216-0003316	54471.3745	2.04813610	0.20	0.20	0.080	15.2	13.3	I	23.7	120
AP Tau	52500.1267	0.97197470	0.75	0.65	0.150	13.5	13.0	I	2.7	120
HAT-131-0026711	54497.4058	0.66395310	0.25	0.09	0.090	14.3		I	7.5	60
V608 Aur	51900.1194	0.76323870	0.40							60
V641 Aur	51274.6910	0.50487790	0.95		0.200	12.9	12.8	I	1.4	60
HAT-133-0002525	53632.4787	1.59457150	0.43	0.20	0.160	13.8		I	7.2	120
V470 Cam	51822.7608	0.09564665	0.95	0.20	0.160	14.7	14.6	V, Clear	1.2	30
YY Gem	52500.4573	0.81428301	0.55	0.50	0.100	10.6	9.1	I	0.7	120
VSX J075328.9+722424	56376.4685	0.20825210	4.00	0.30	0.080	16.5	16.5	Clear	0.7	60
HAT-136-0003262	53770.8471	0.64948470	0.60	0.65	0.110	14.3		I	3.4	60
CSS 42362								V,Clear		60
SDSS J08205+0008	55147.8564	0.096	0.30	0.10		15.2	15.5	Clear		60
GSC 1941 1746	53730.7303	2.26560000	0.90	0.40		12.9		I		120
CU Cnc	50208.5079	2.77146800	0.13	0.11	0.030	12.1	11.4	I	6.1	120
NSVS 02502726	54497.5507	0.55977847	0.95	0.45	0.150	14.0	13.4	I	2.1	60
GSC 2499 246	53456.8775	0.36696520	0.70	0.50	0.190	12.5		I	1.3	60
HAT-225-0003429	54534.1455	0.42647345	0.20	0.20	0.110	14.5		I	9.3	60
CSS 40809							15.5			60
ASAS 0938	55205.2949	0.89742040	0.65	0.55	0.100	12.5	12.1	I	1.6	90
CSS 41177	55619.4264	0.11601549	0.40	0.10	0.017			Clear		60
SW Sex	52500.0531	0.13493844	1.70	0.00			14.2	V		60
BS UMa	52500.3506	0.34950990	0.45	0.35	0.180	12.5	11.5	I	1.9	60
HW Vir	45730.5546	0.11671955	0.80	0.15	0.120	10.5		V	0.2	30
DE CVn	52784.5533	0.36413940	0.10	0.00	0.058	12.8	12.2	V		30
NY Vir	50223.3622	0.10101597	0.90	0.15	0.120	13.3	13.5	V	0.6	60
NSVS 00967819	56138.3741	0.38630644	0.55		0.170	12.6	12.6	V	1.7	60
HAT-145-0001586	53843.9136	1.58750840	0.75	0.60	0.050	14.3		I	3.0	120
NSVS 01031772	53456.6849	0.36813985	0.60	0.60	0.150	13.0	11.0	V	1.7	30
SDSS-1435	54148.7029	0.12563110	0.40	0.00	0.040	15.0		Clear	1.9	30
GK Boo	52500.4364	0.47777170	0.92	0.77	0.190	10.6	10.5	I	0.5	60
GU Boo	52723.9811	0.48872965	0.65	0.65	0.130	13.1	12.9	I	1.7	60
NSVS 07826147	54524.0203	0.16177045	1.35	0.18	0.100	13.0	13.4	V	0.4	30
G179-55	51232.8848	3.55001840	0.05	0.06	0.006	13.0	12.5	I	12.3	120
NN Ser	52500.1201	0.13008015	deep	0.00	0.055	16.7		V		60
V1024 Her	52500.4880	0.53082672	0.70	0.60	0.150	12.5	12.1	I	1.4	60
HAT-192-0001841	53853.9101	0.30873897	0.62	0.55	0.120	14.0		I	2.1	60
CM Dra	52500.7172	1.26838990	0.75	0.75	0.030	12.9	10.9	I	1.1	120
T-Lyr1-17236	53700.8773	8.42944100	0.60	0.27	0.015	14.4	14.4	I	4.7	120
KIC 6464285	55003.7554	0.84363240	0.50			13.8		I		90
KIC 5300878	55002.6150	1.27942400	0.70	0.70		14.8		I		120
NSVS 14256825	51288.9209	0.11037410	0.75	0.20	0.130	13.2	13.3	V	0.7	30
MR Del	52500.3087	0.52169040	0.30	0.19	0.140	11.0	8.9	I	1.5	60
RX J2130.6+4710	52785.6819	0.52103563	0.70	0.00	0.041	13.0		Clear,V		60
HS 2231+2441	53522.6687	0.11058788	0.25	0.08	0.100	14.3	13.7	V	3.3	30

Explanation of the columns: filename - generic name of FITS files produced with Maxim DL, T_0, P - preliminary ephemeris for the primary minimum, $\Delta I_{1,2}$ - approximate depth of the primary and secondary minima in the I passband, ΔT - duration of the (primary) minimum, $V_{\max}$, $R_{\max}$ - maximum brightness in the V and I passbands, Fil. - recommended filter for the observations, σ - theoretical minimum uncertainty for 60cm telescope an continuous read-out, Exp. - recommended exposure time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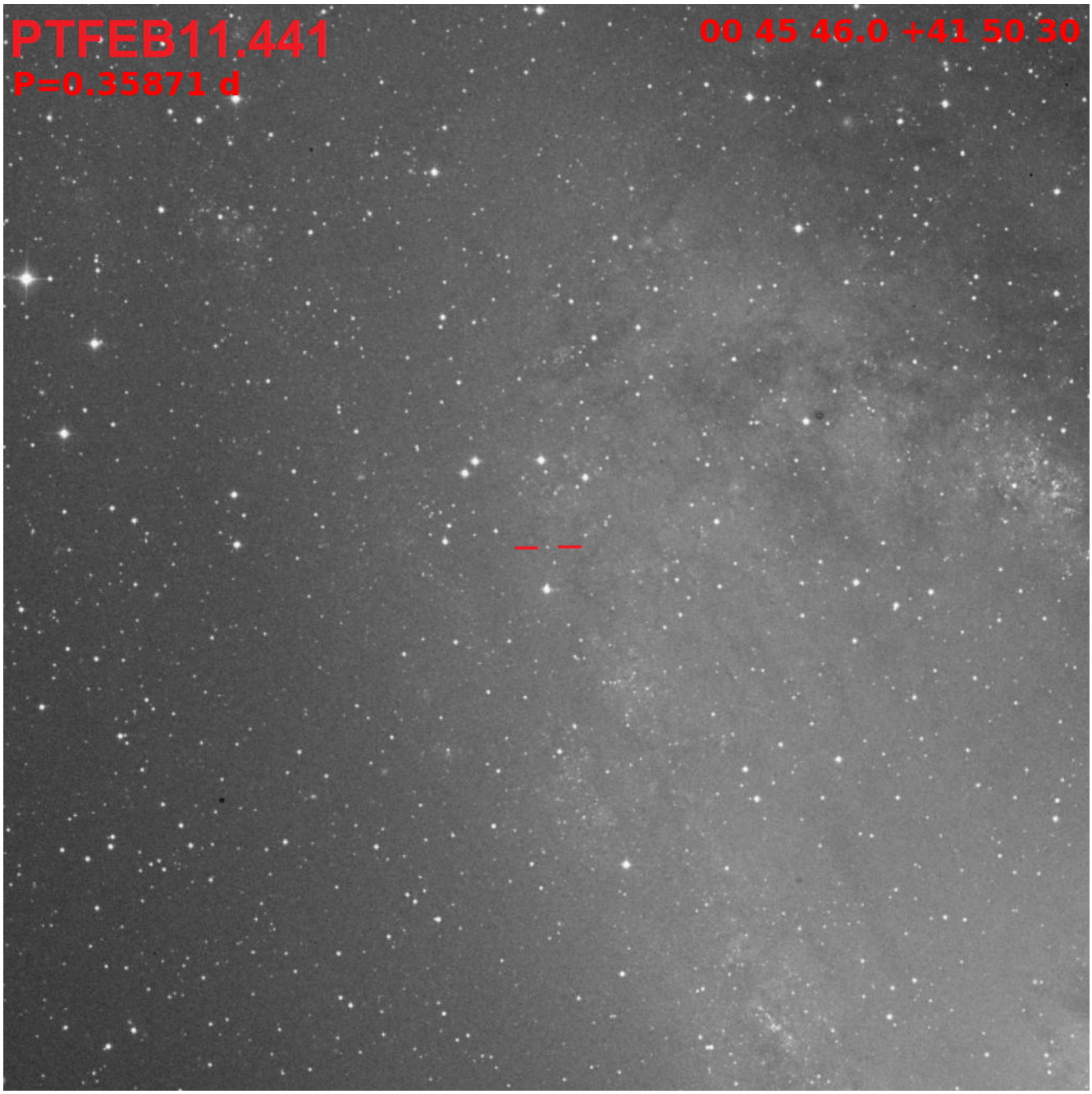
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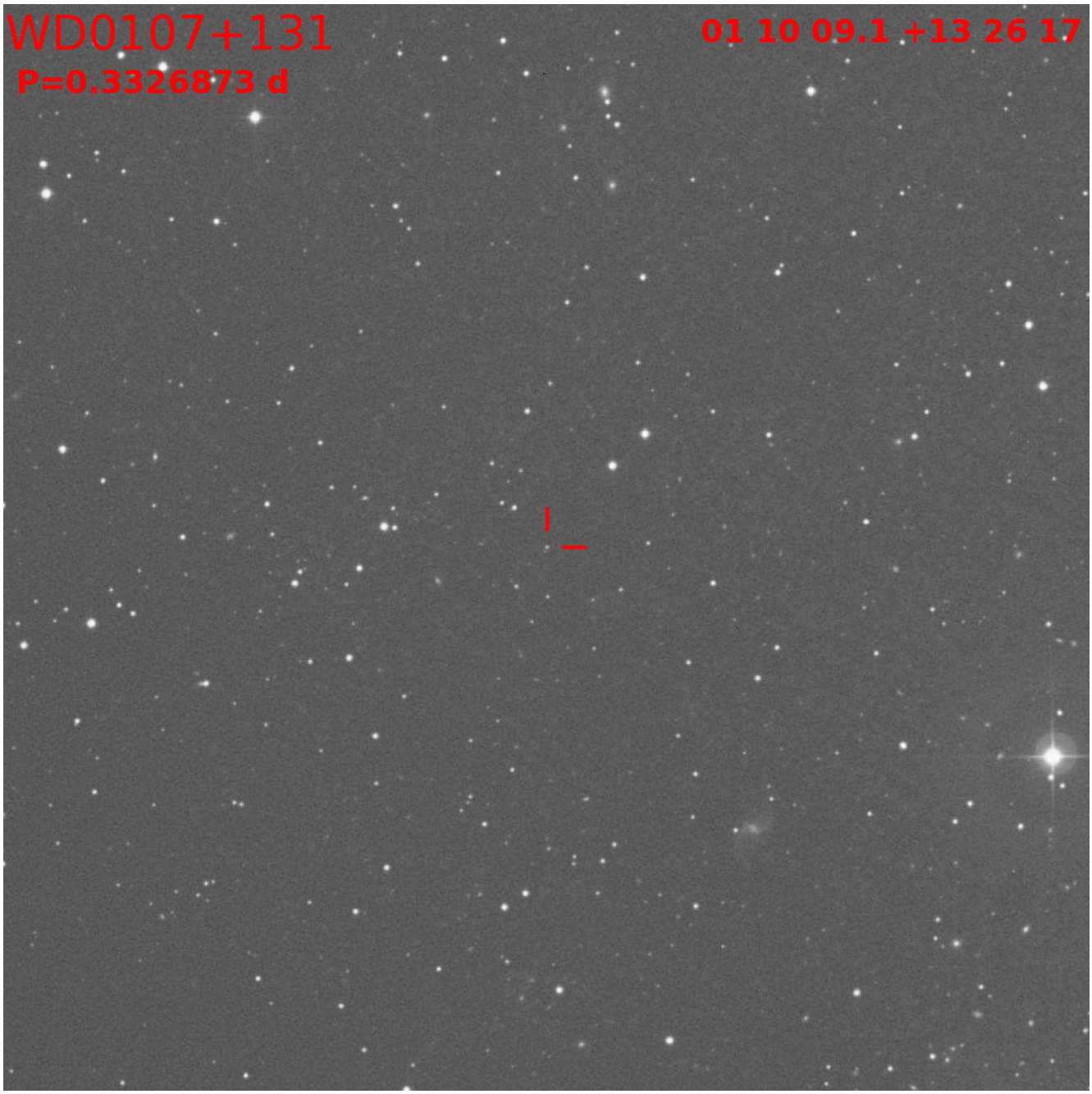
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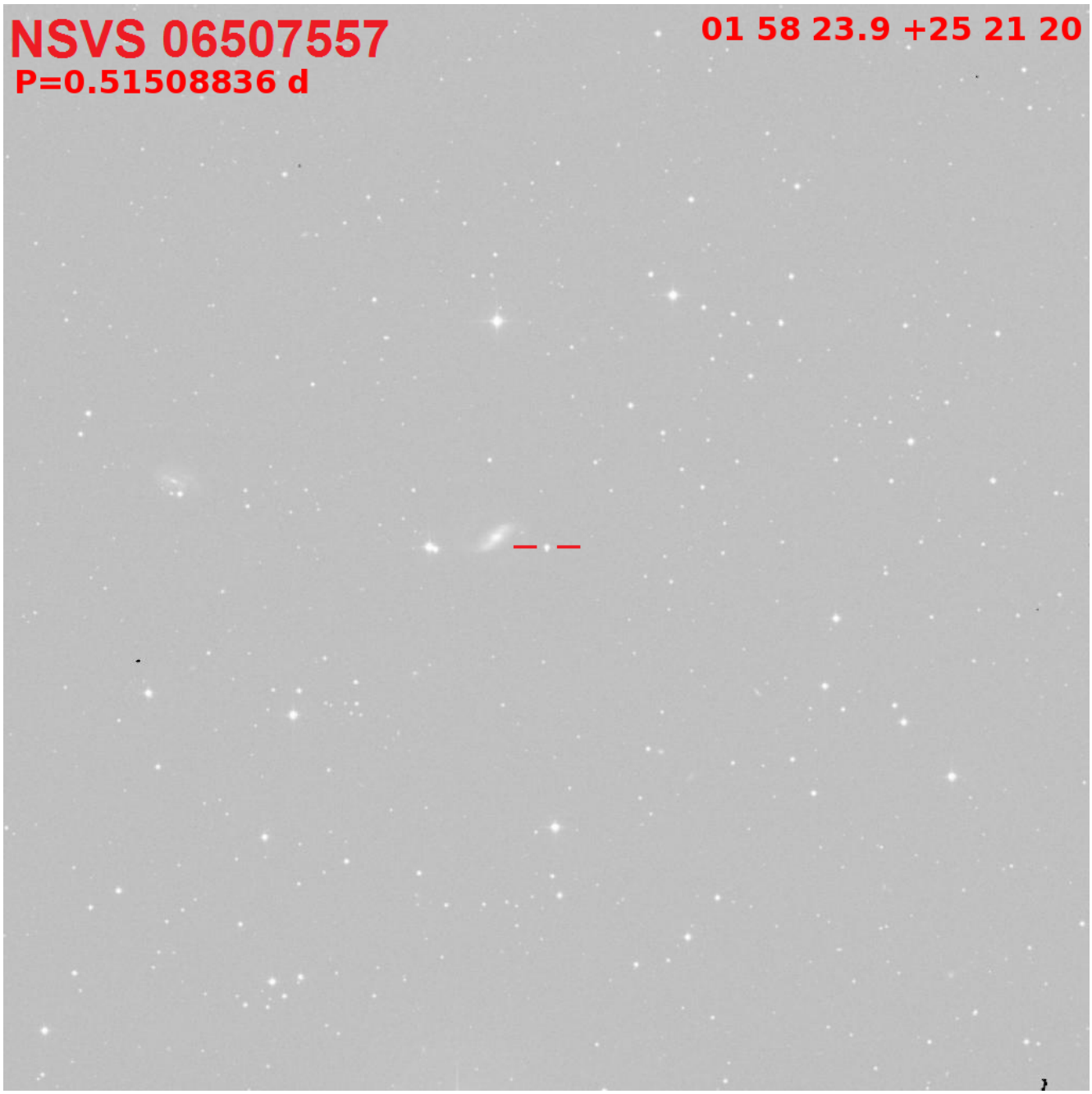
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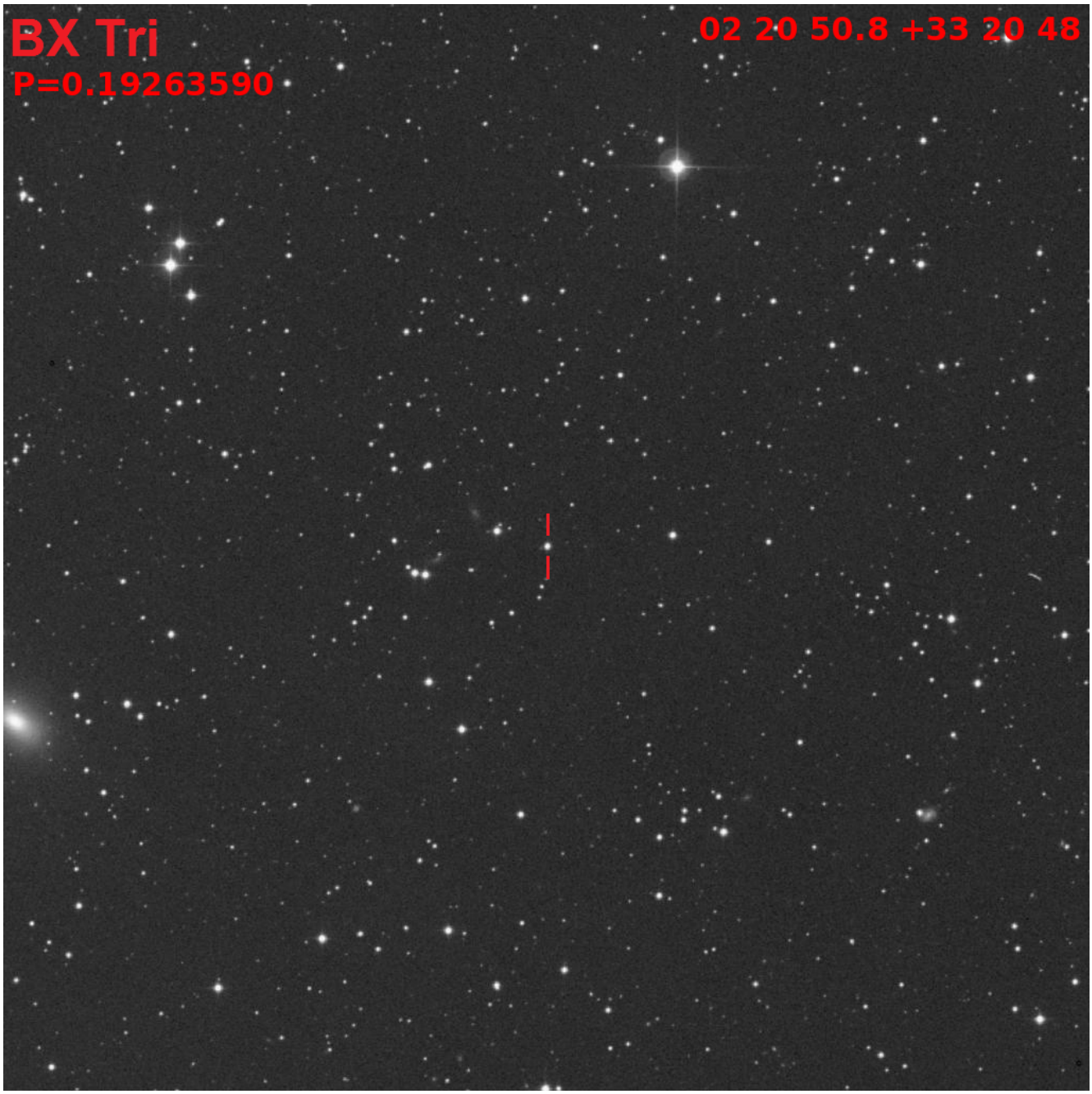
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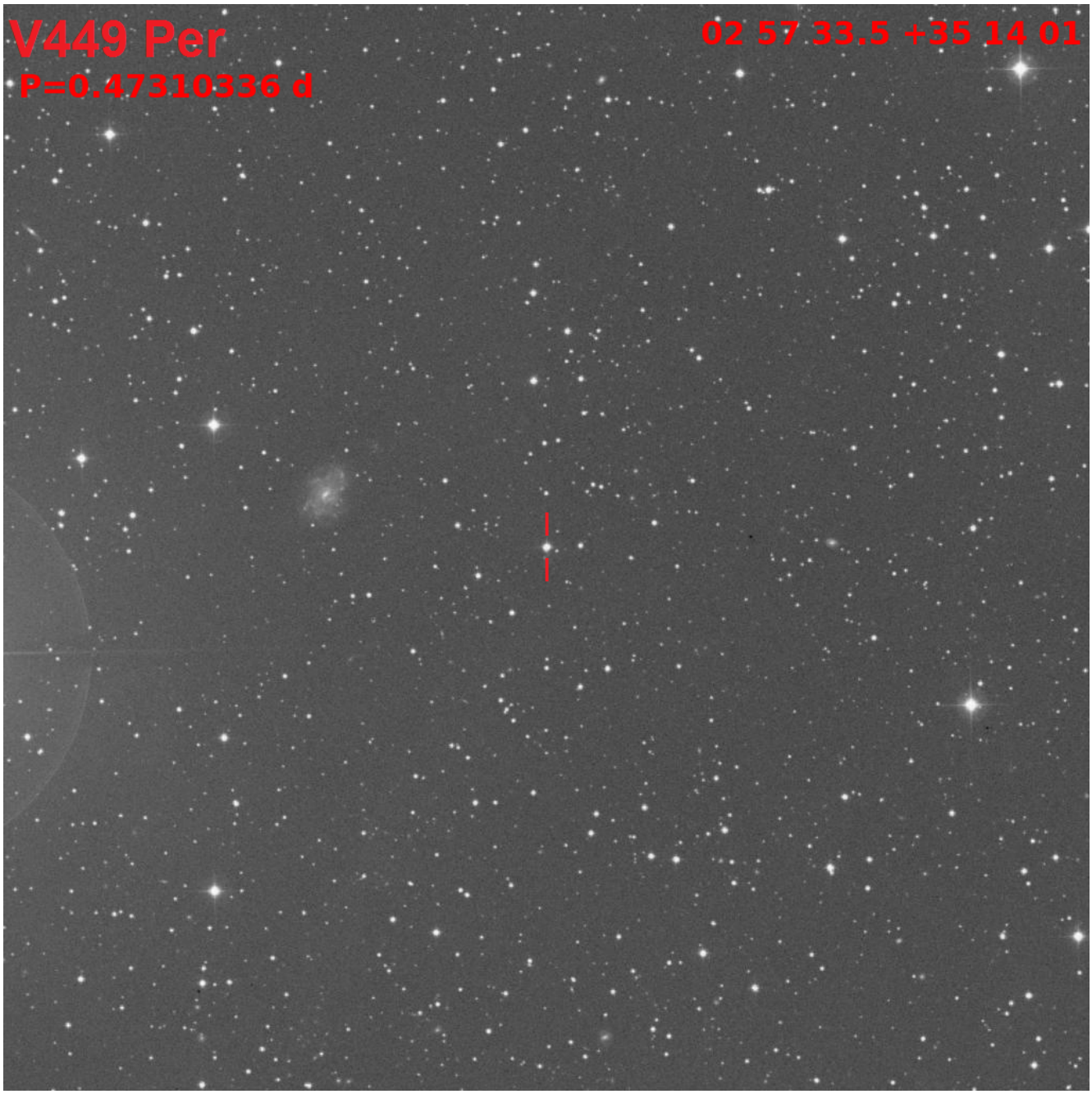
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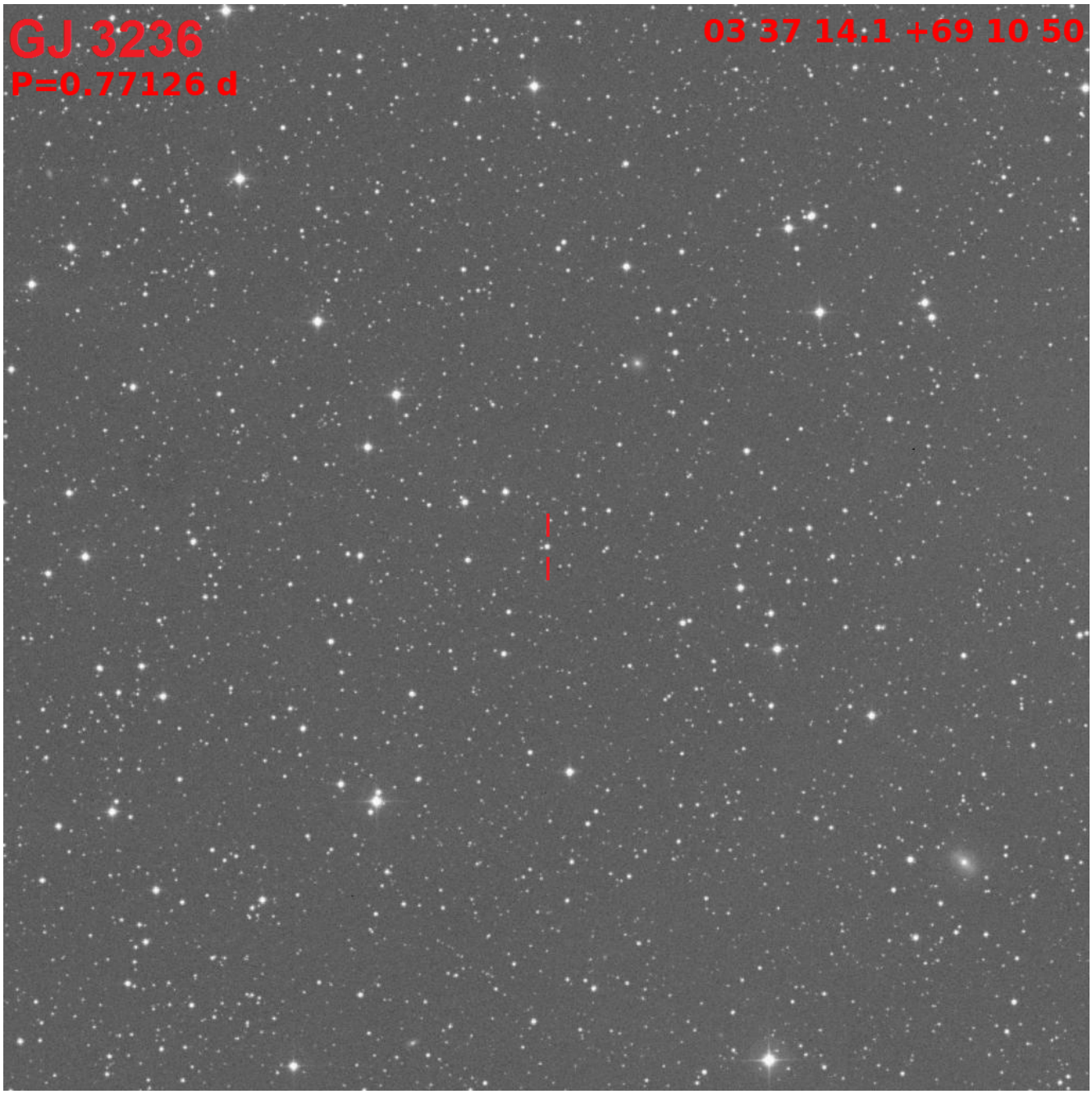
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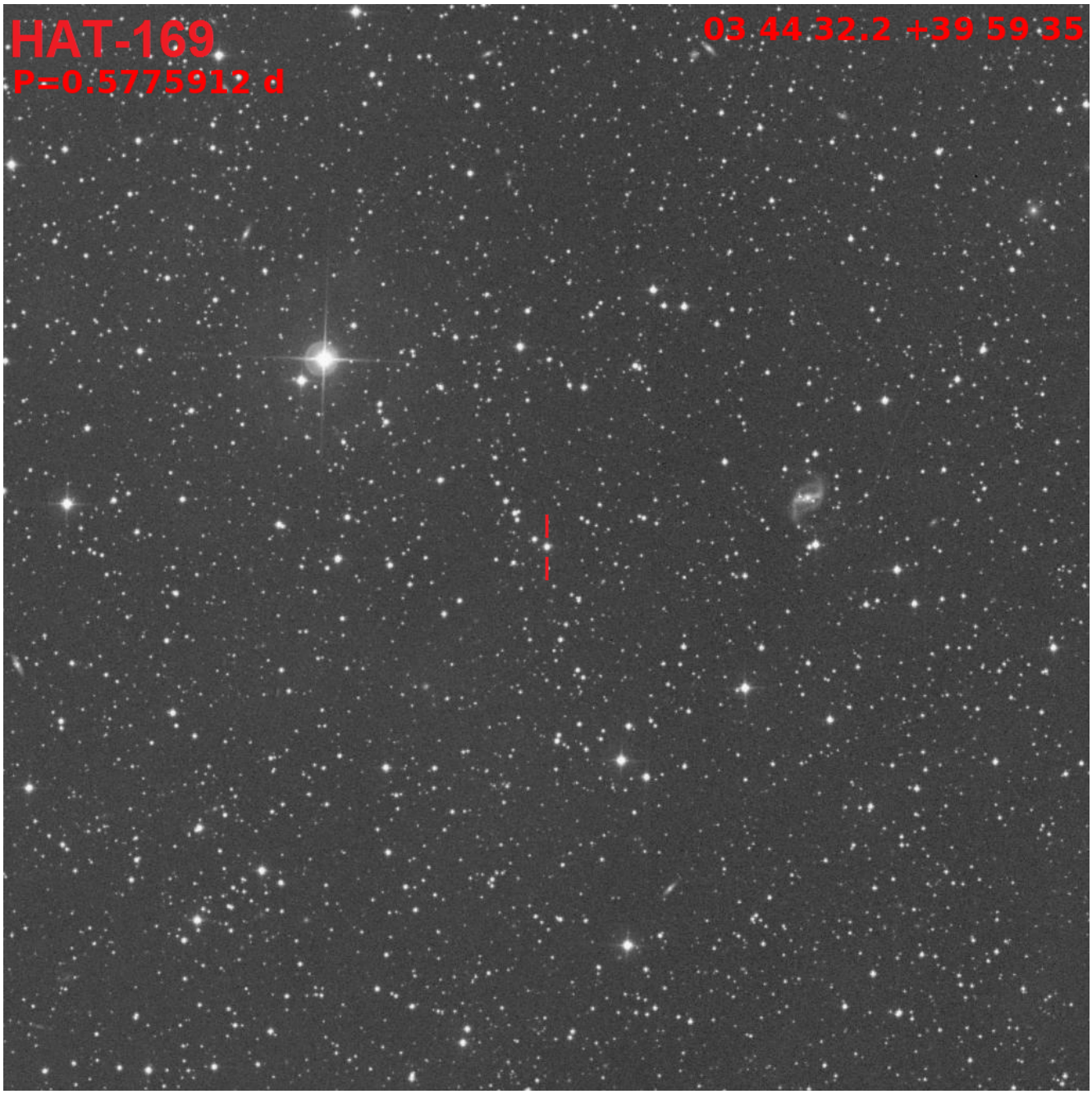
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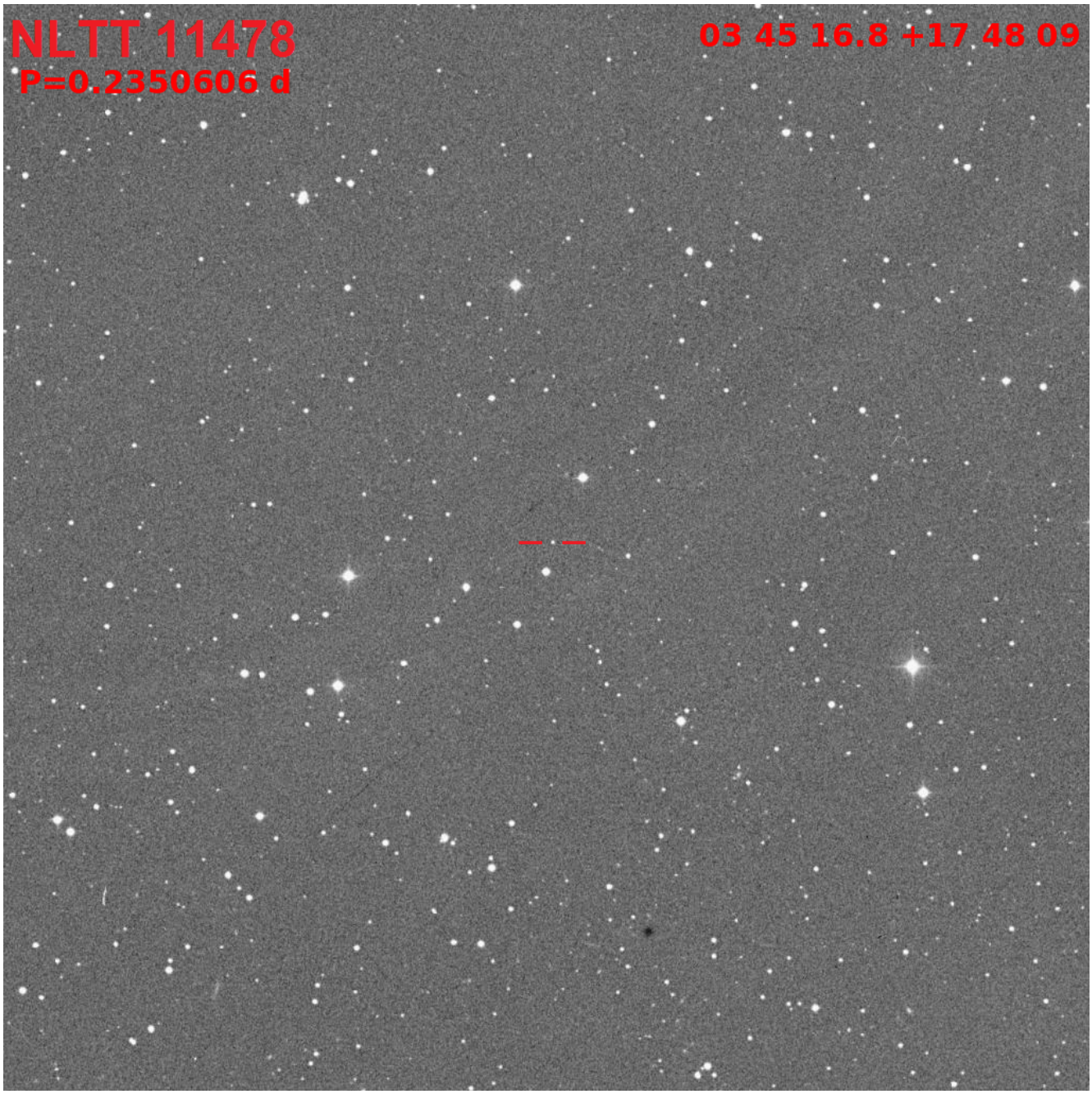
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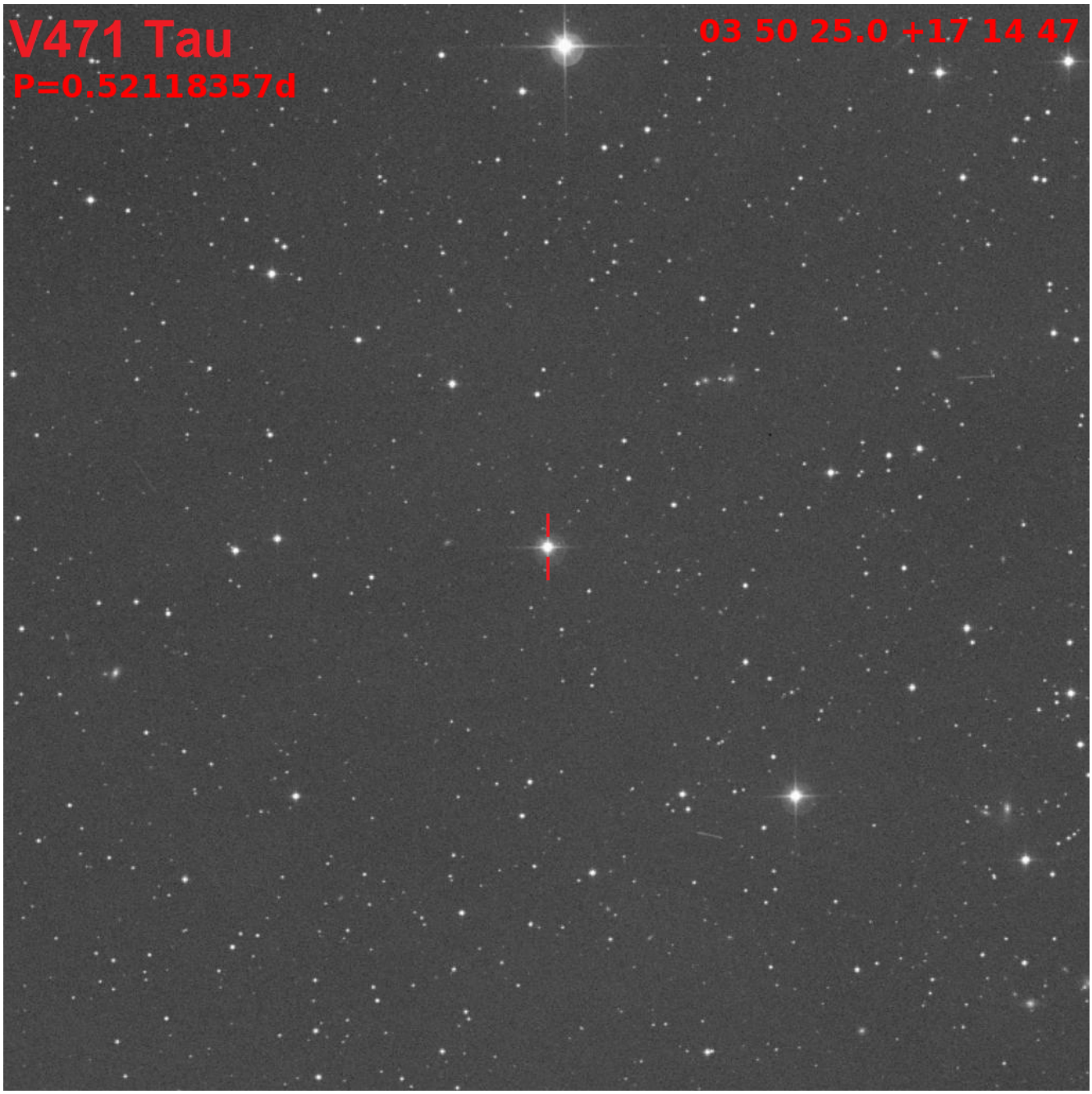
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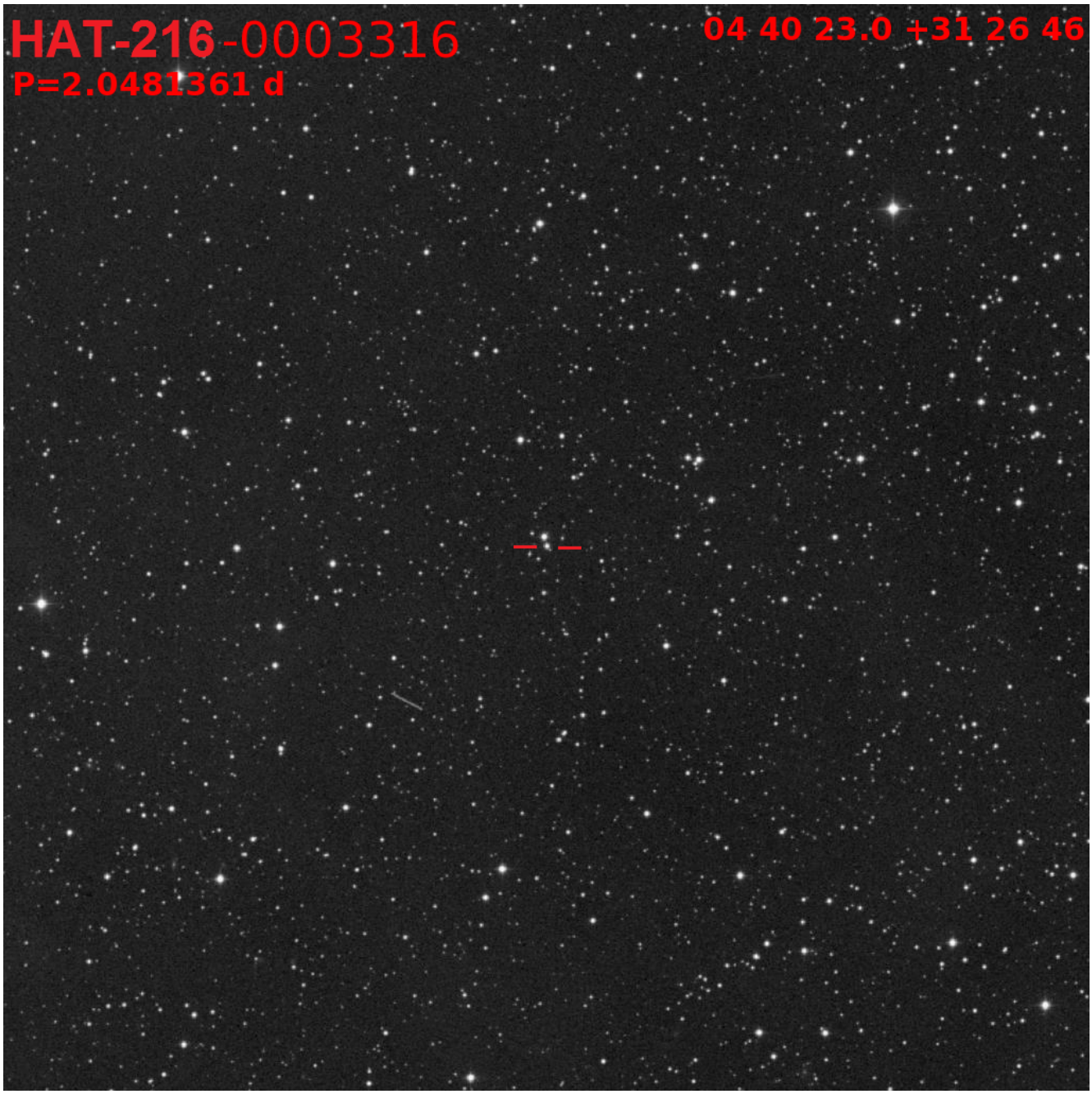
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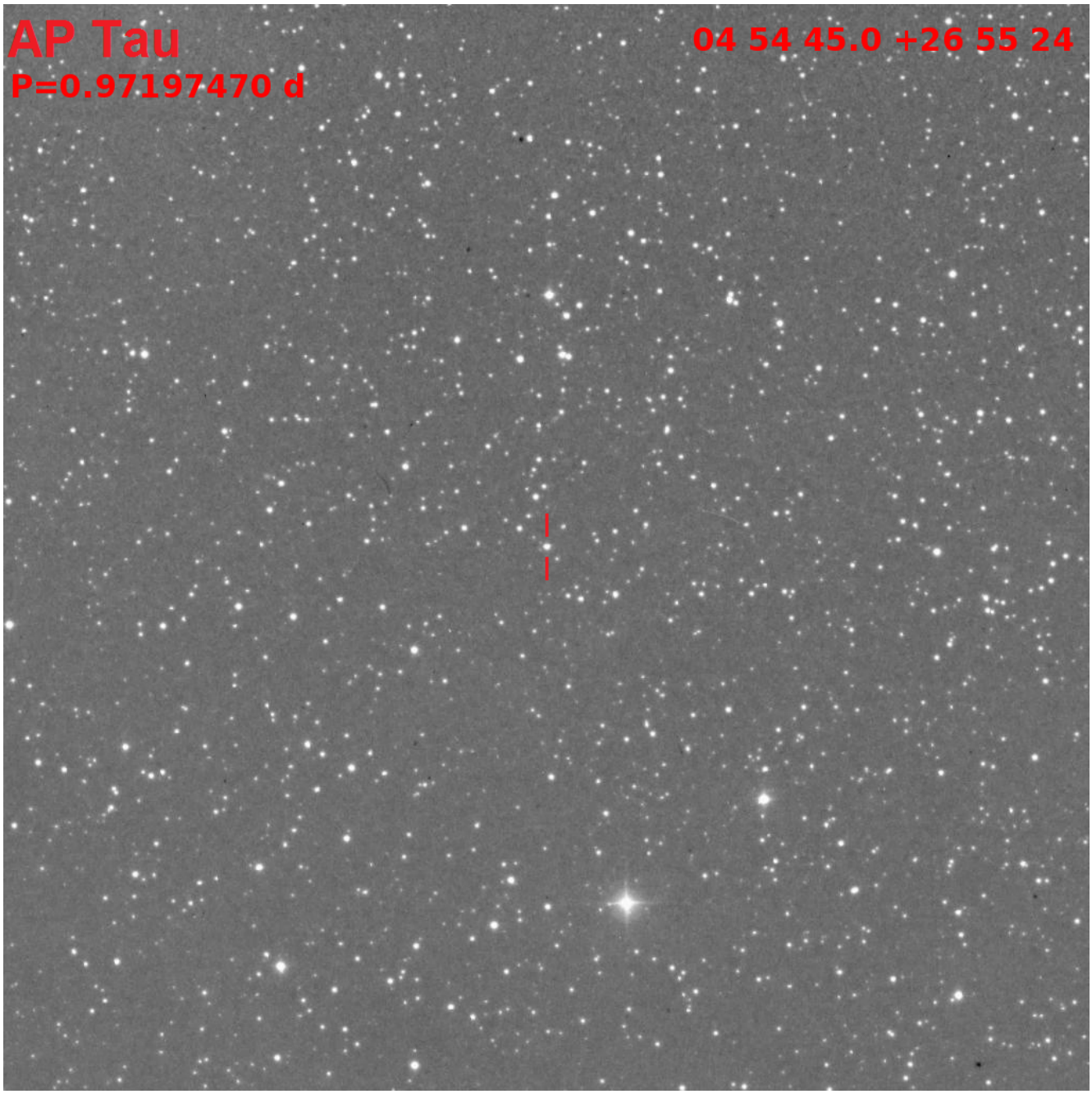
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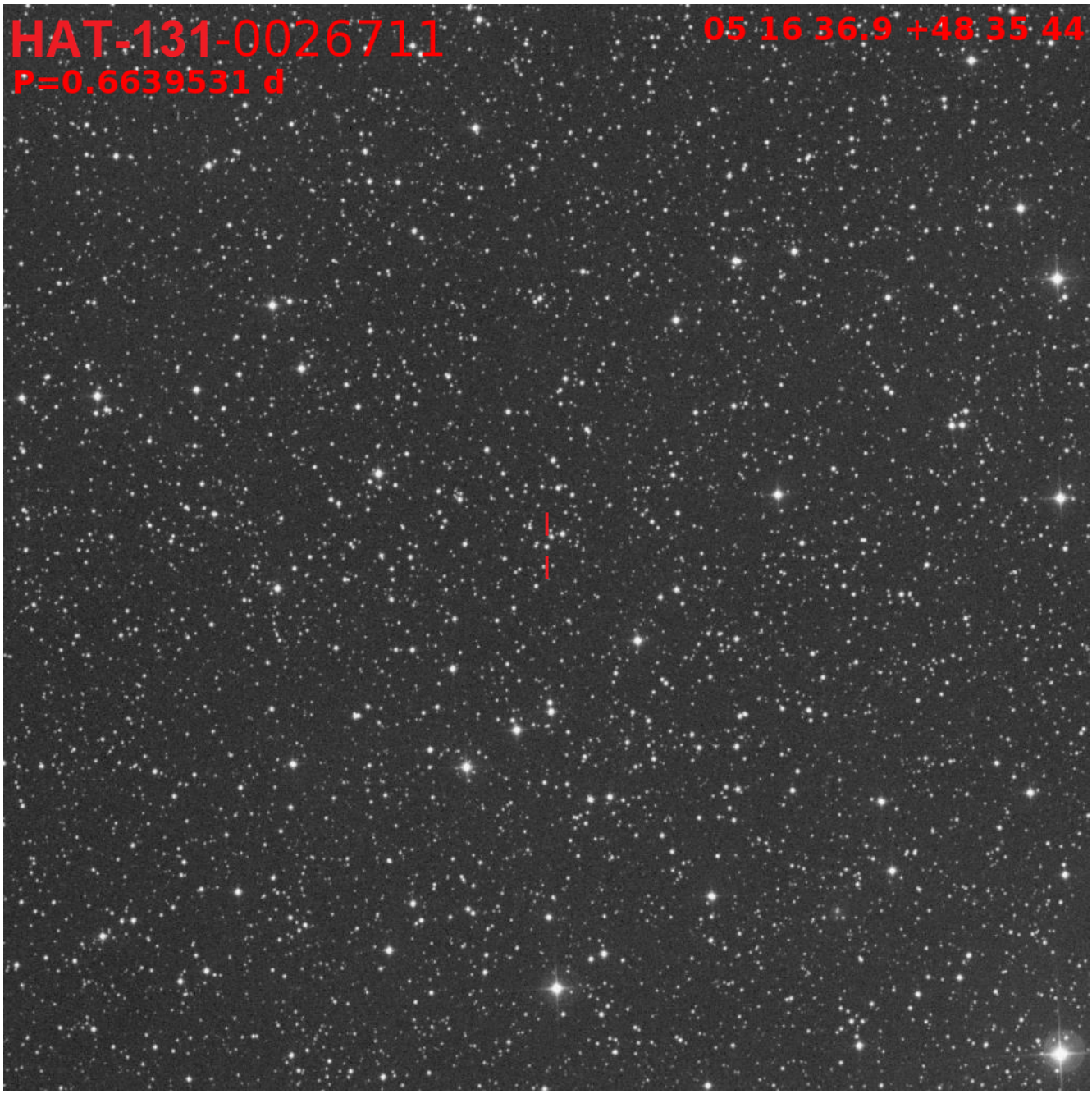
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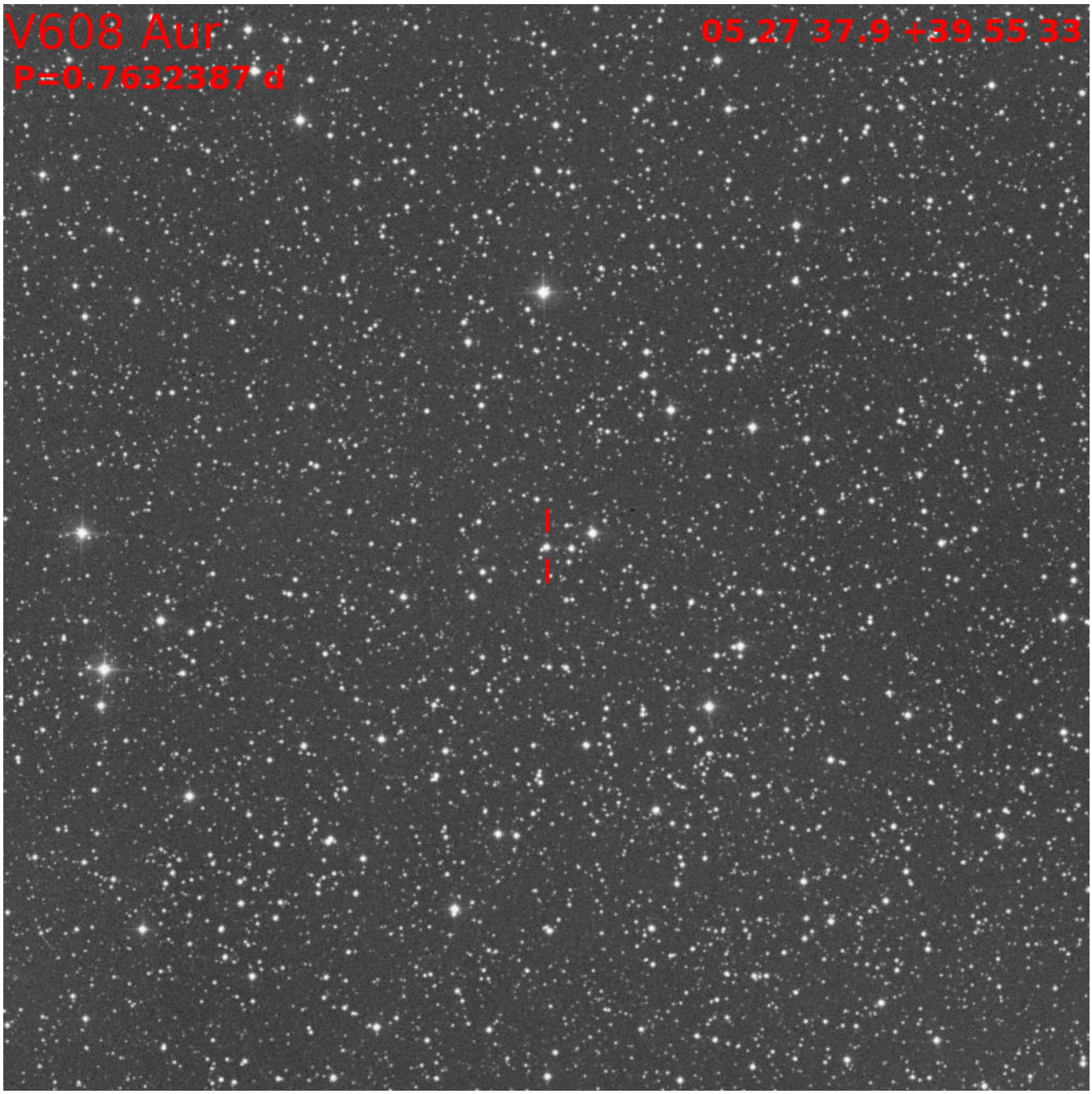
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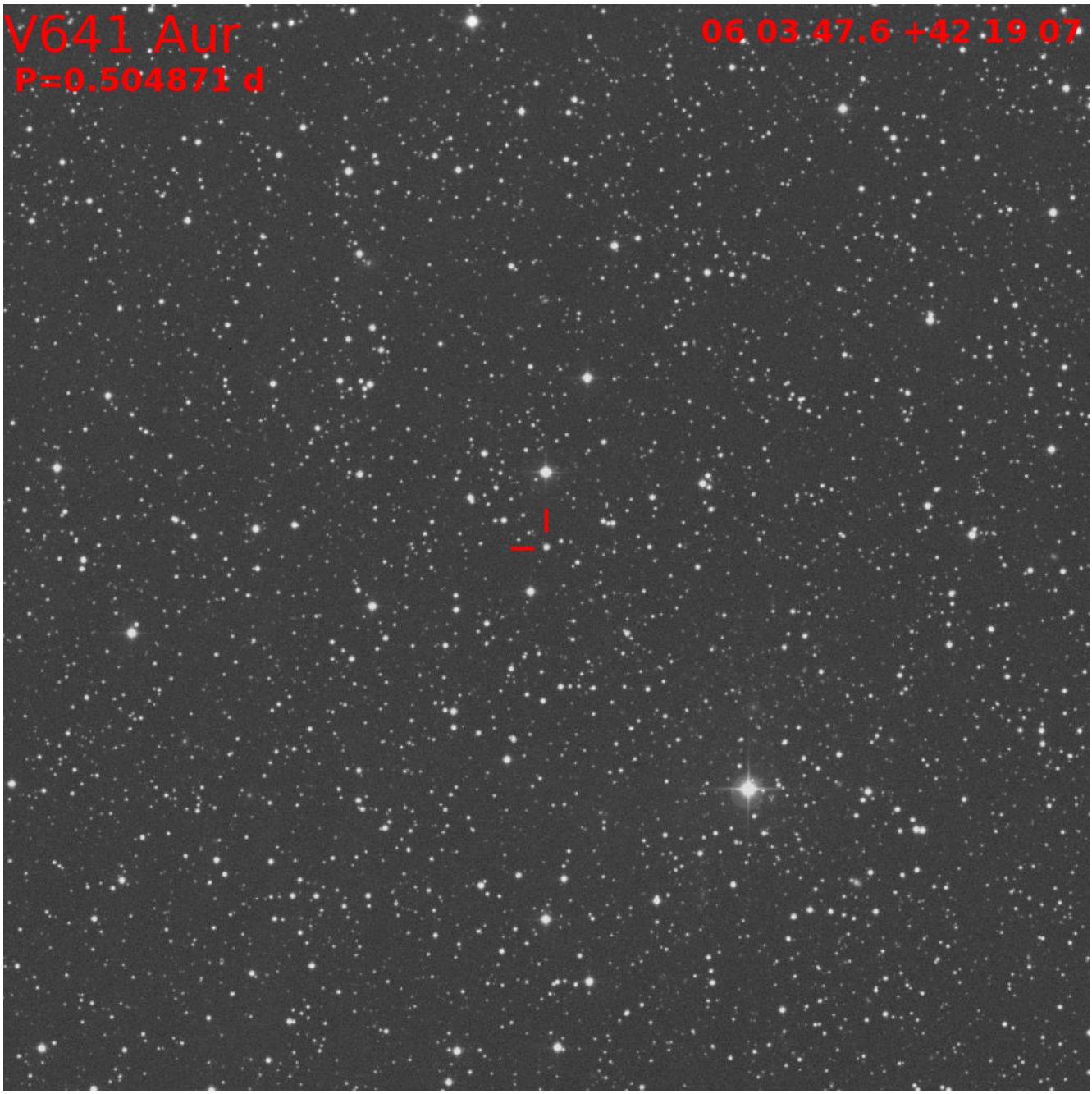
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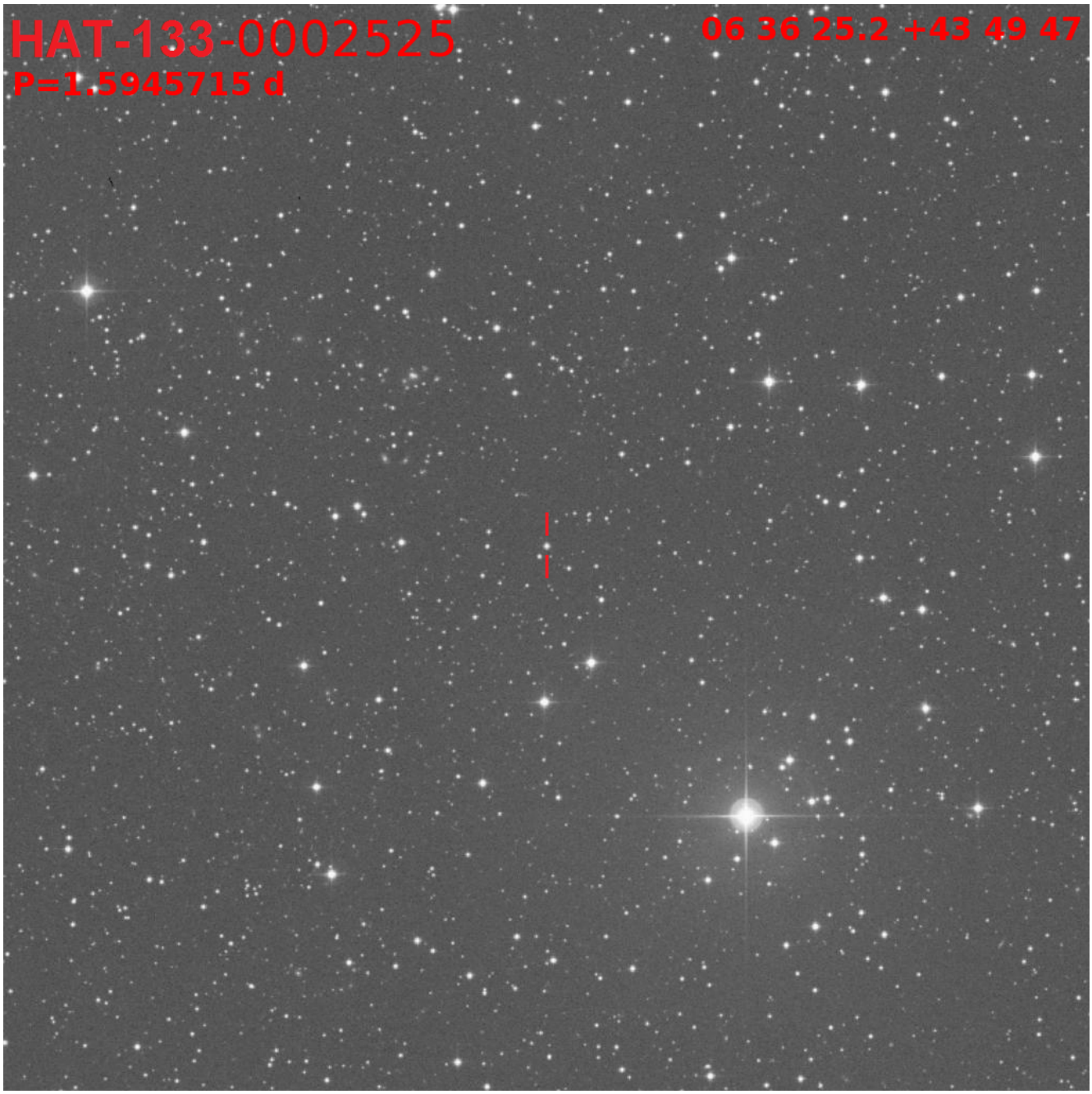
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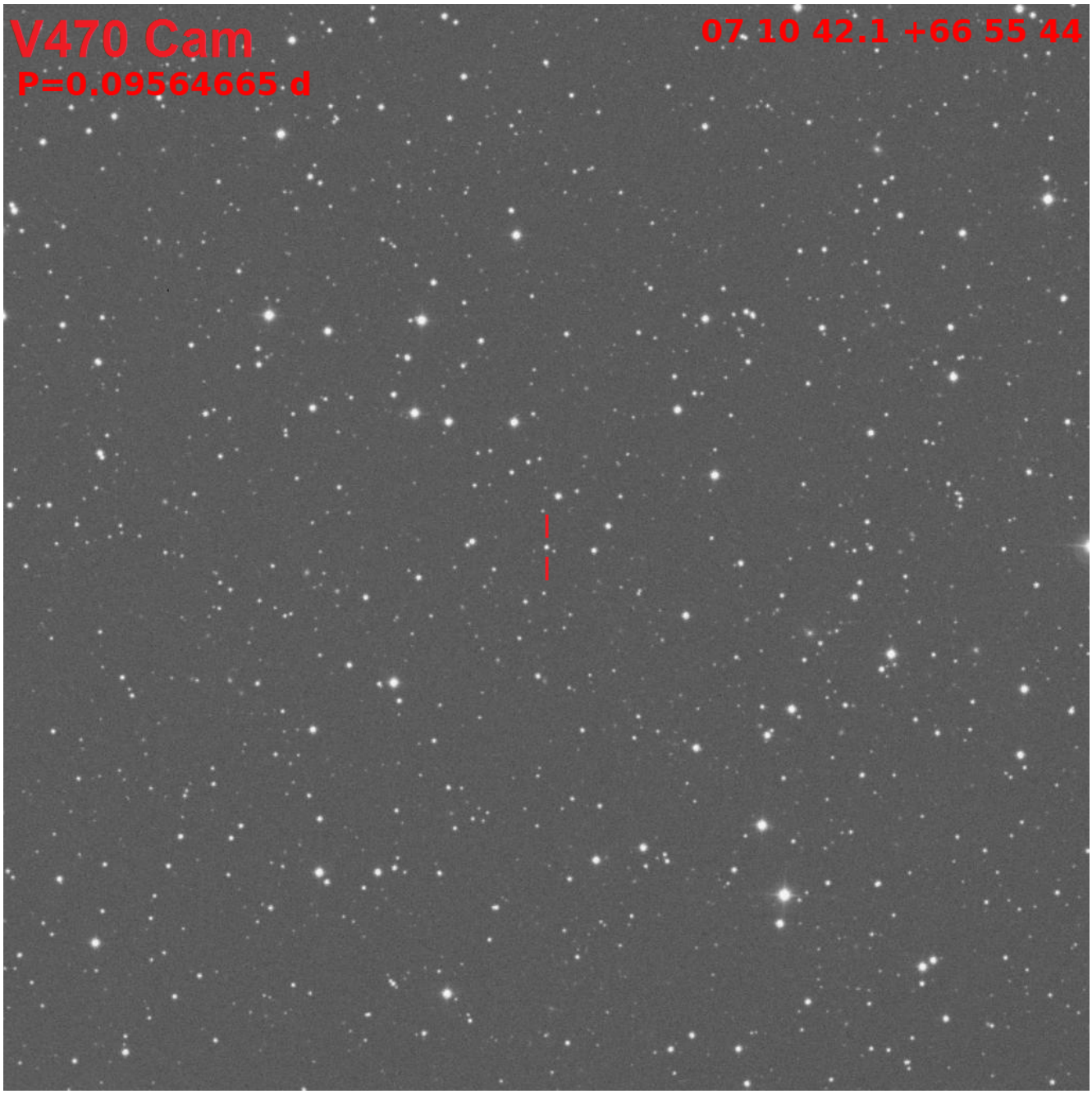
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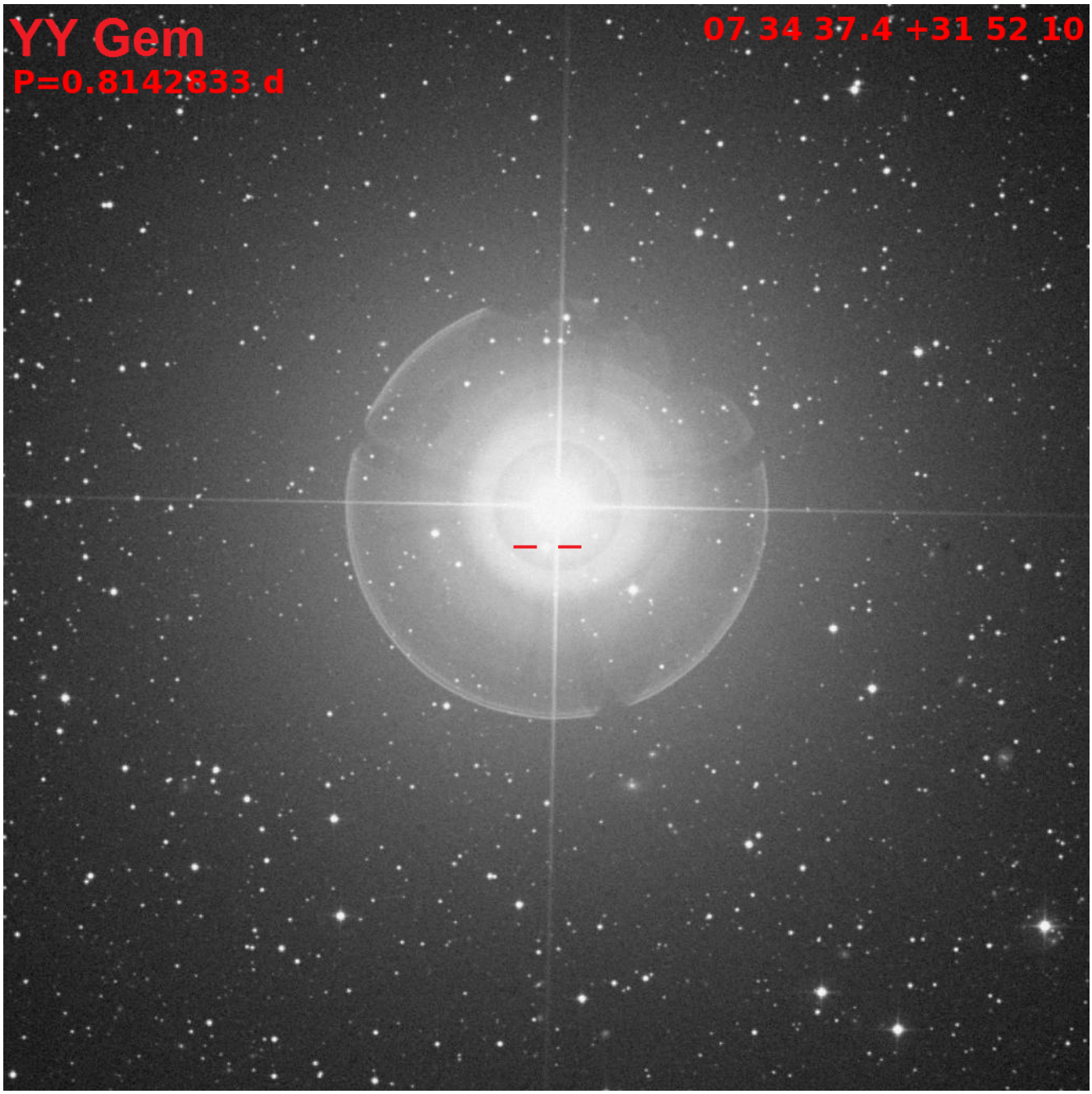
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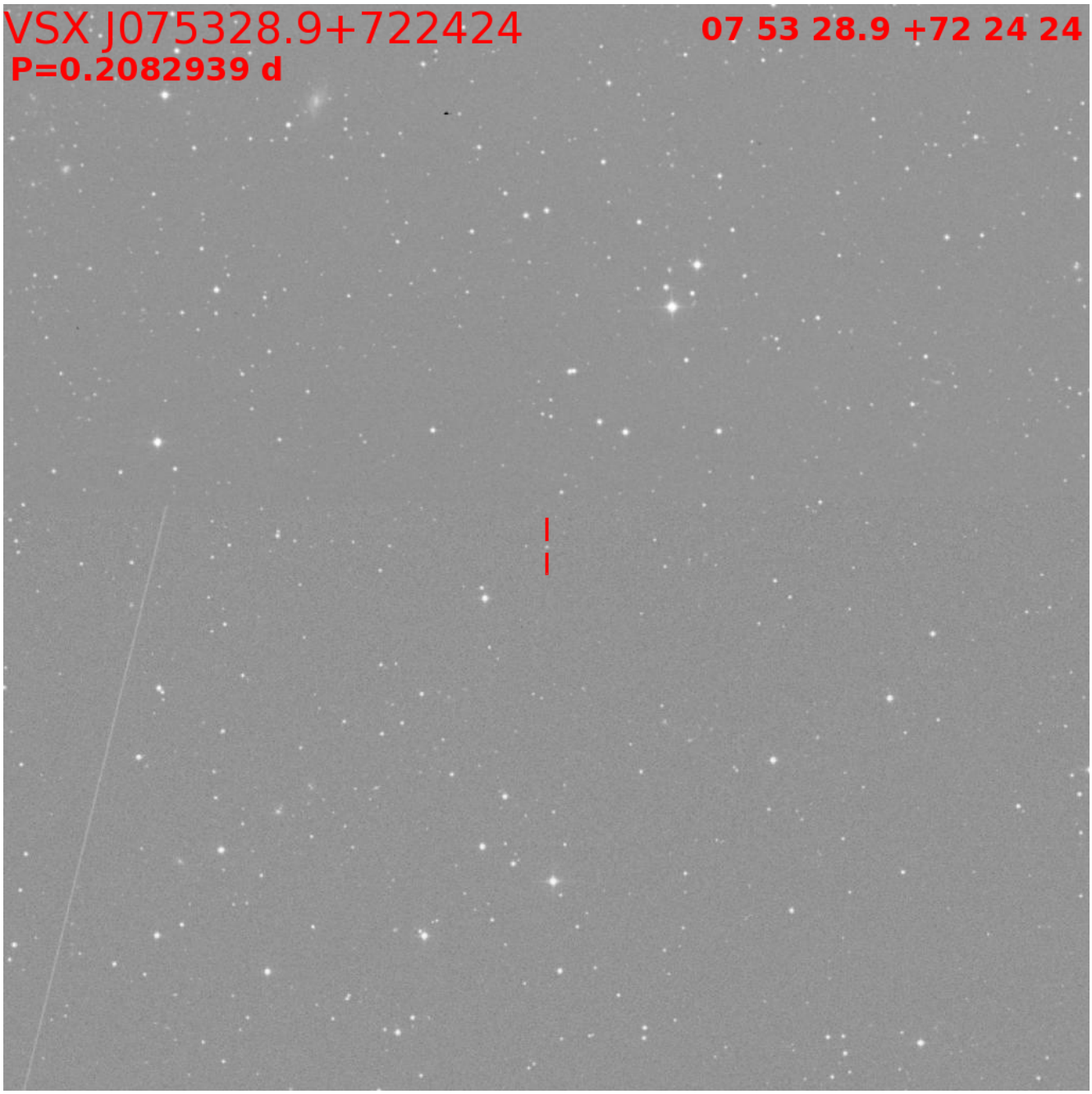
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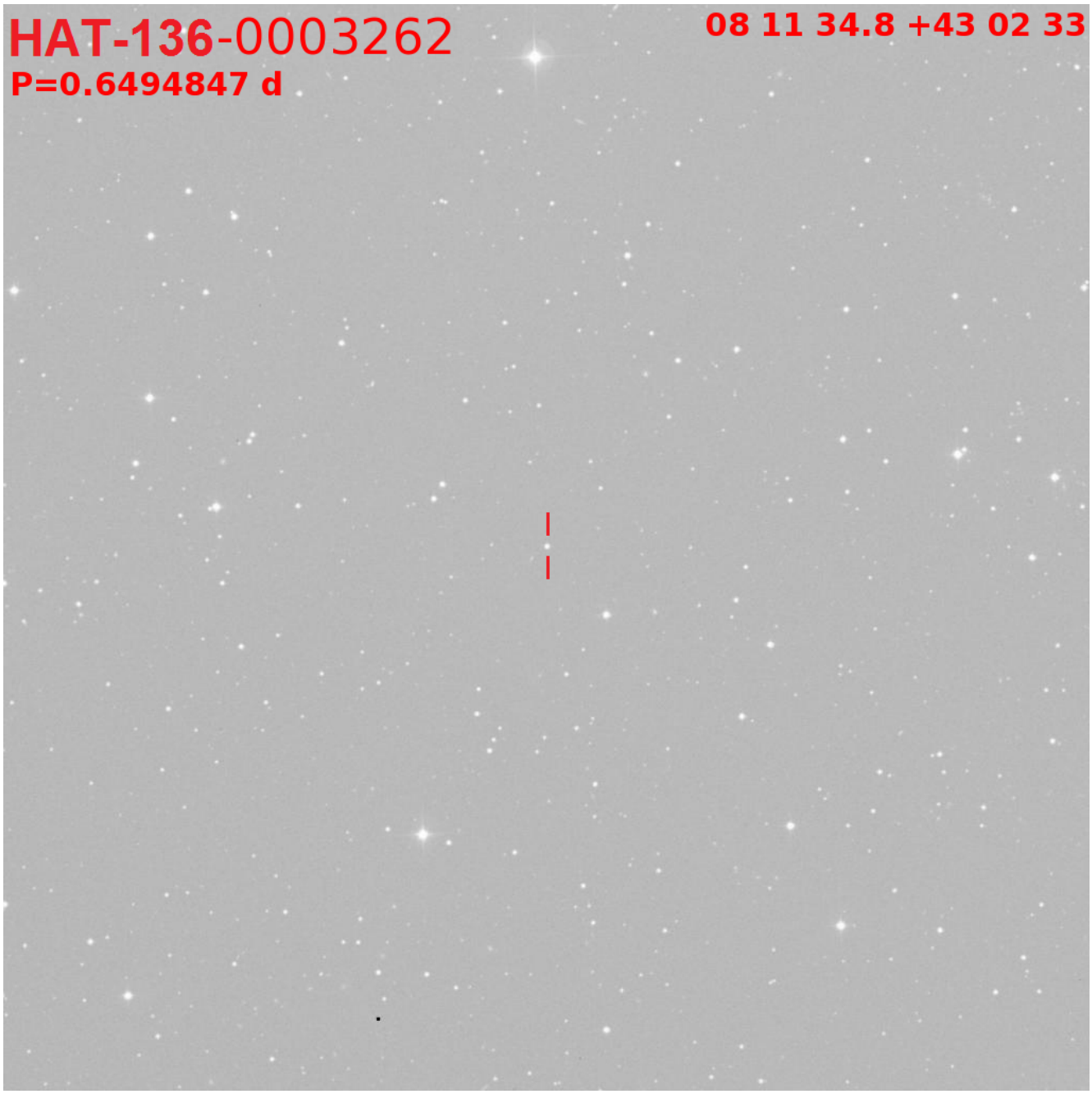
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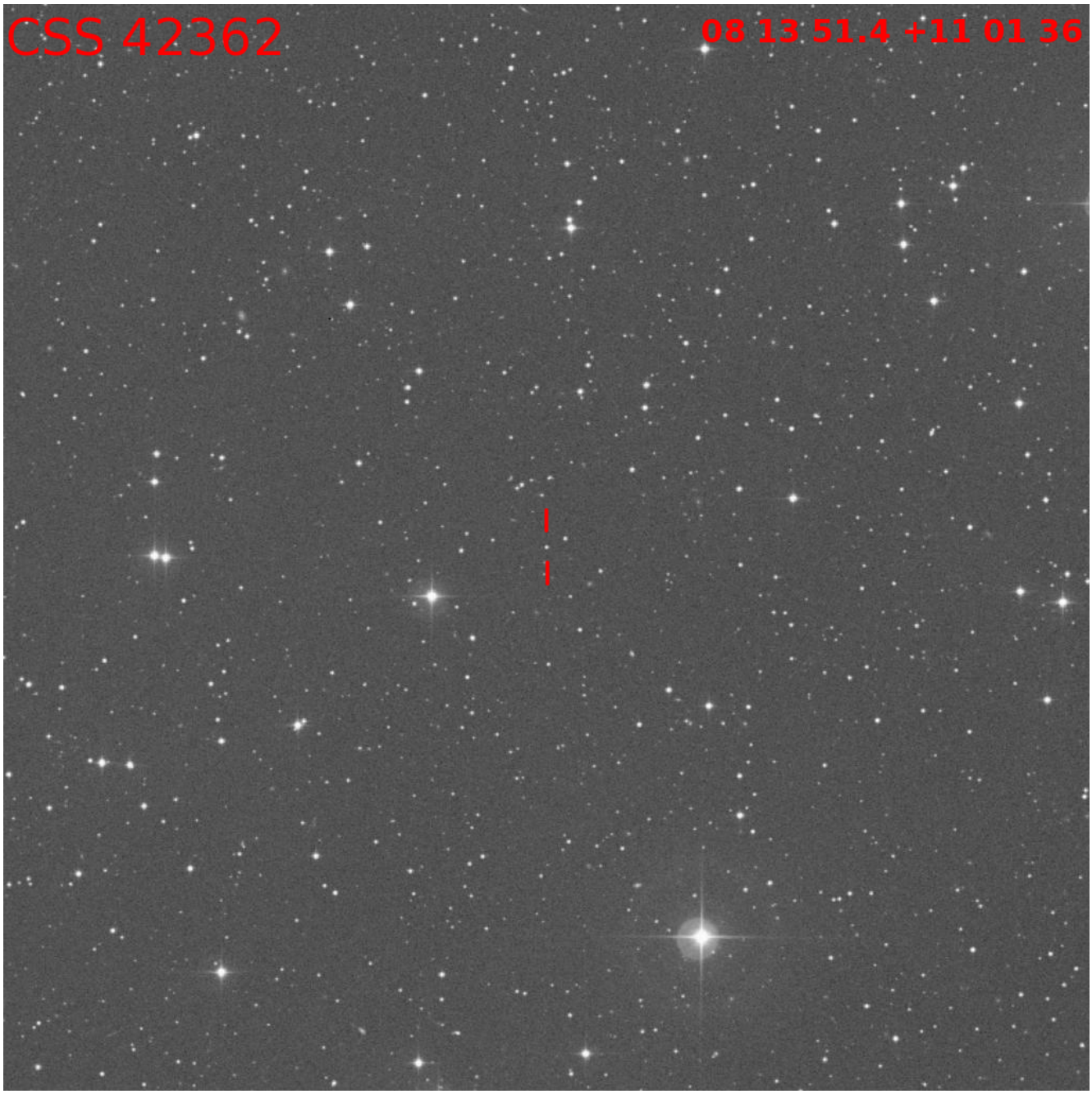
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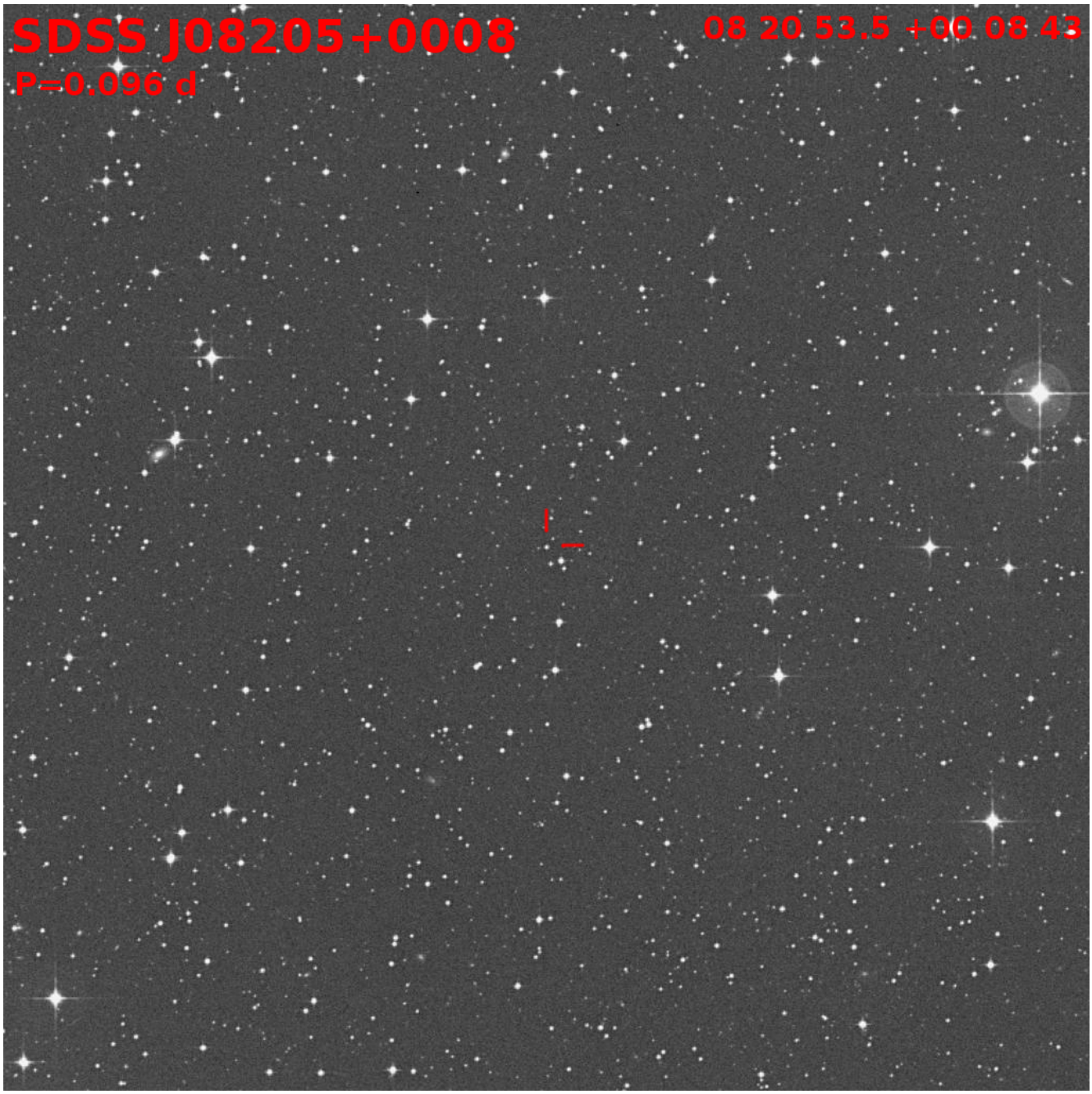
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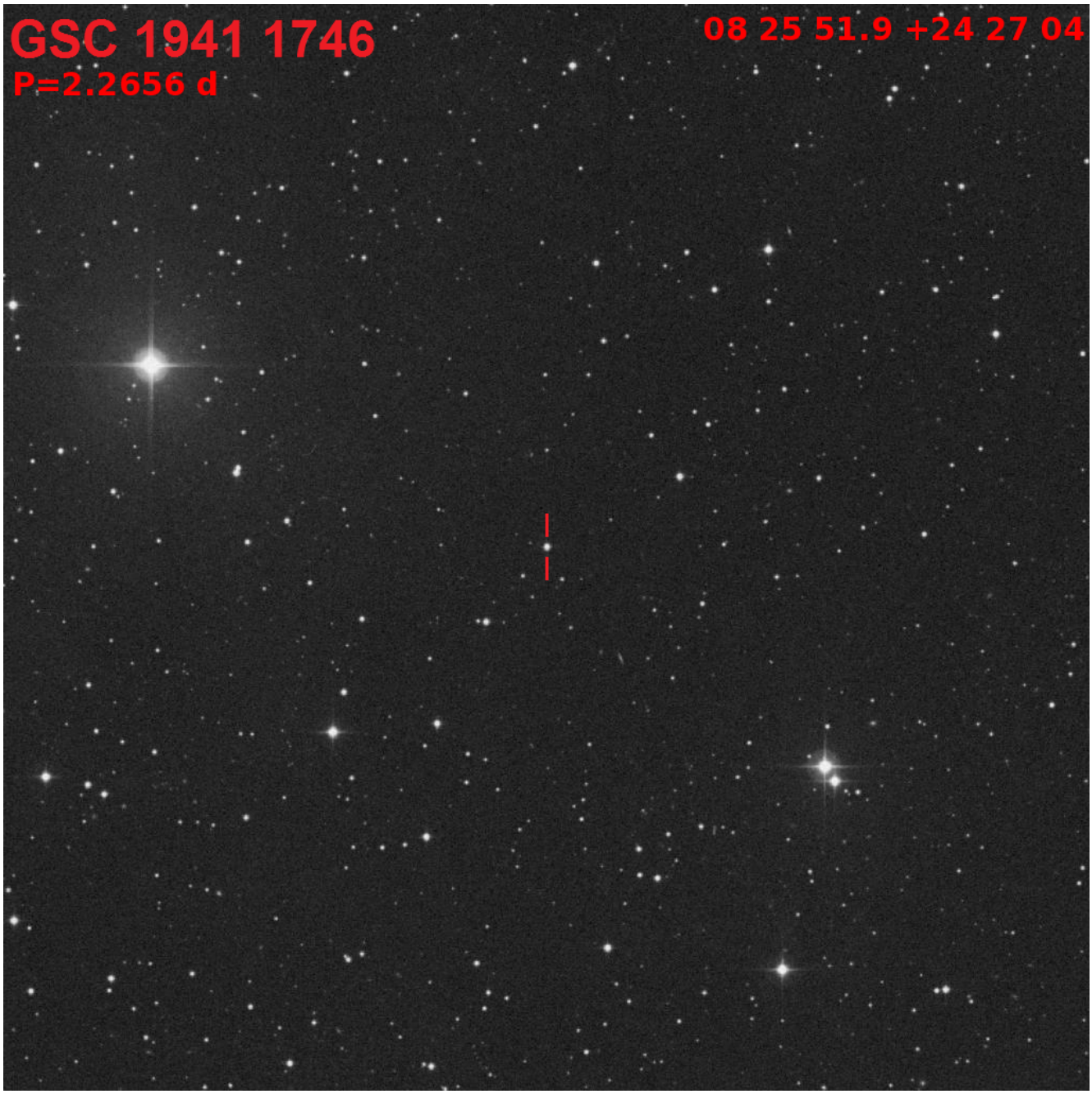
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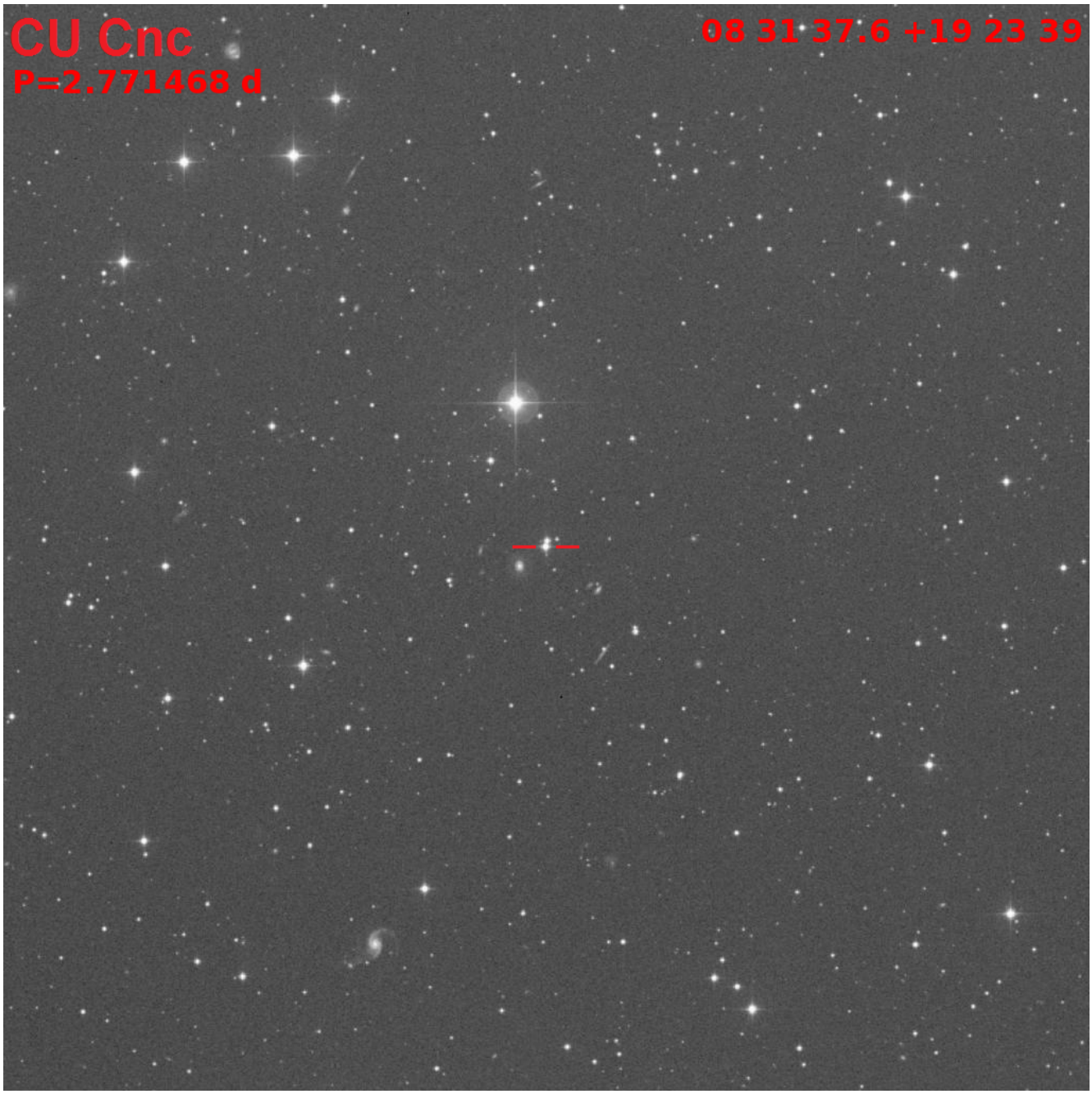
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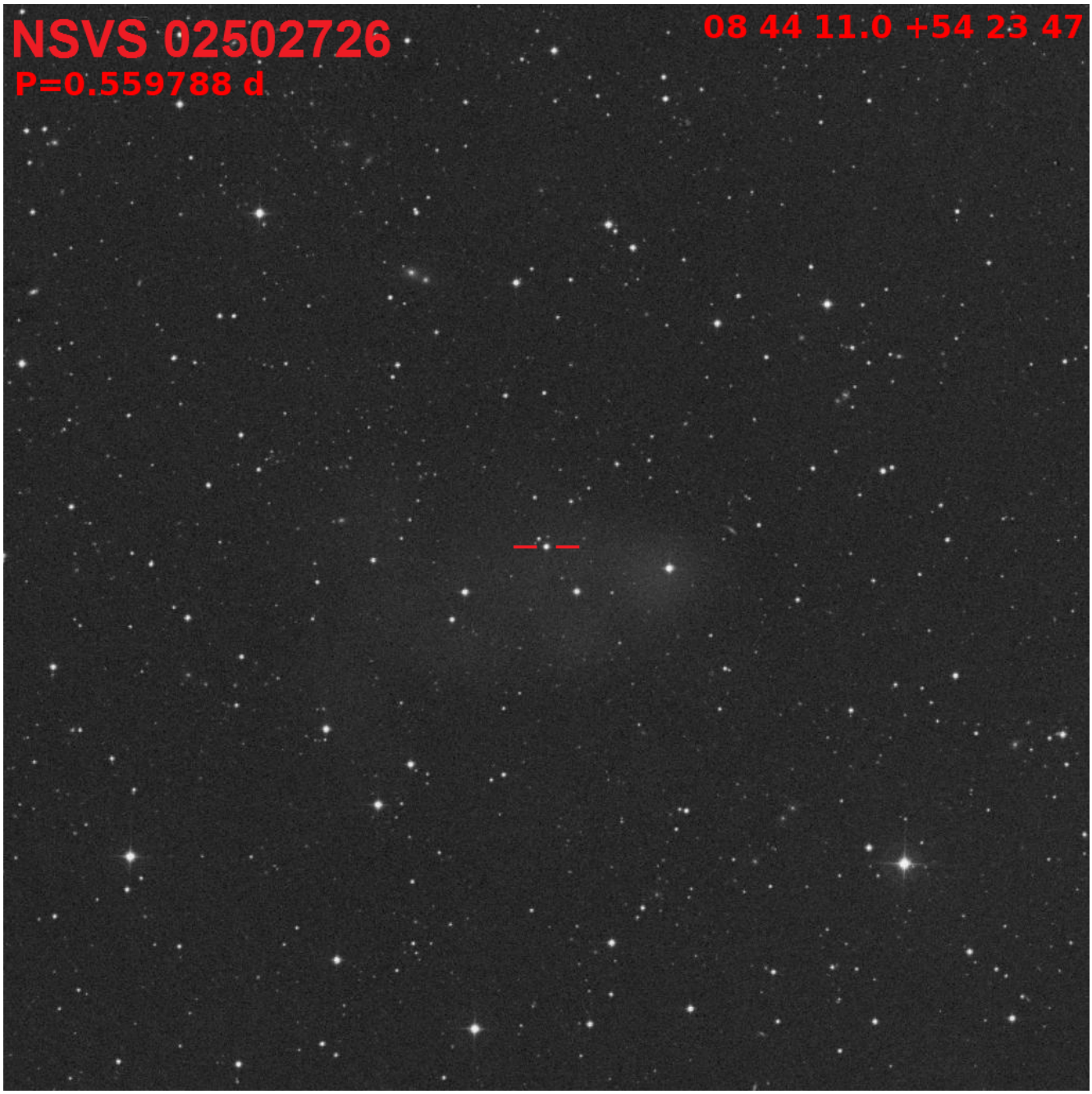
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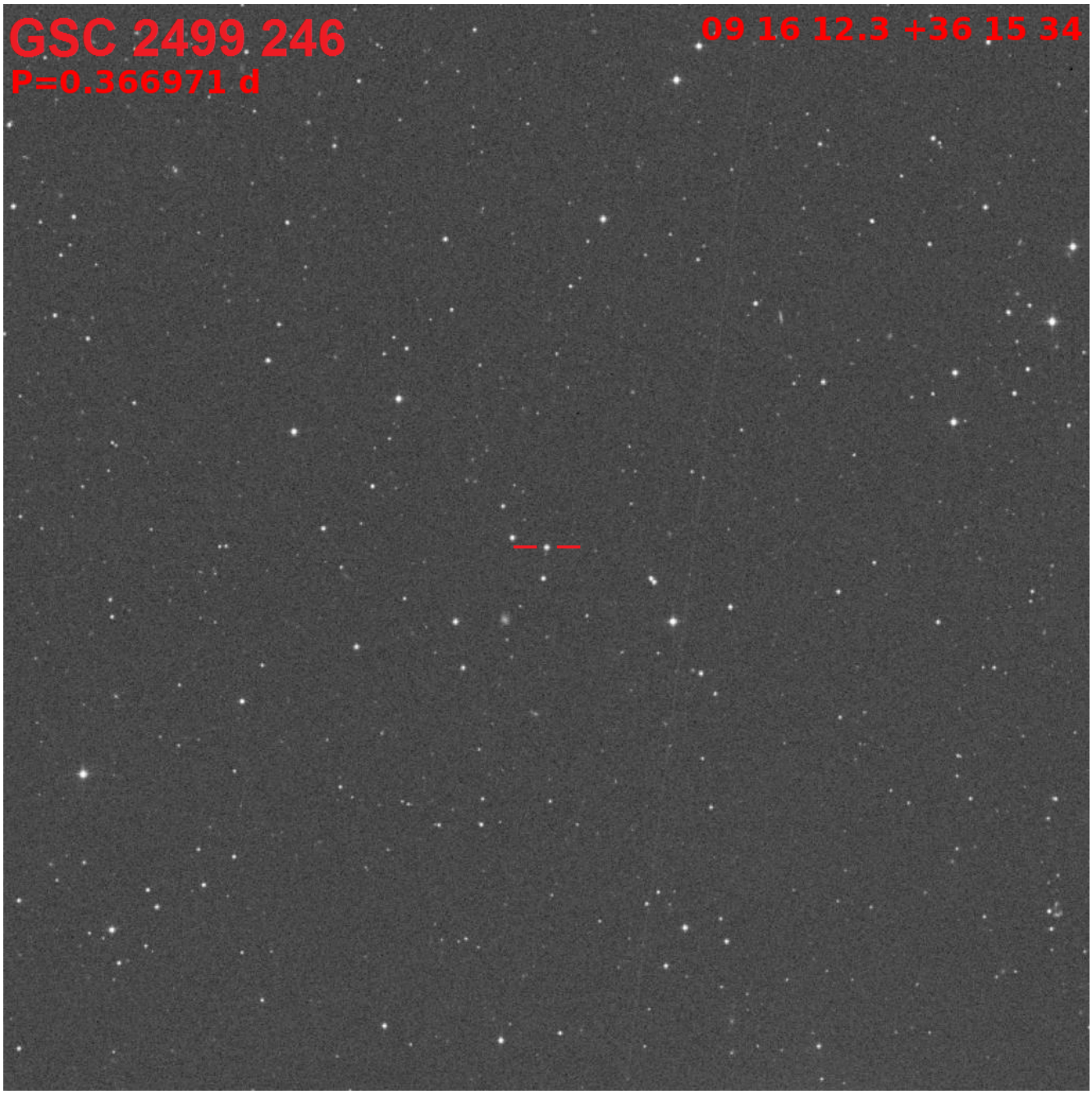
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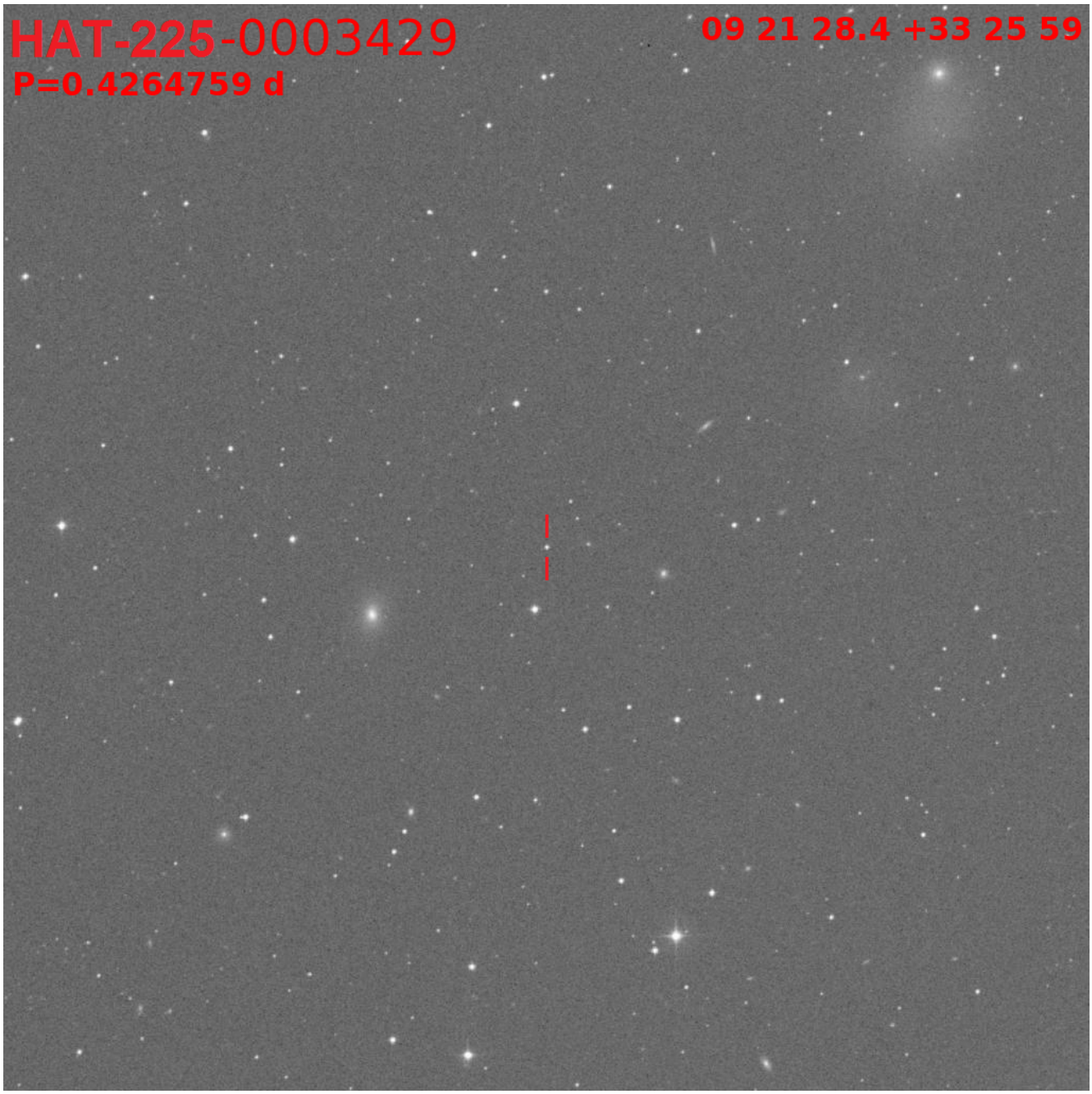
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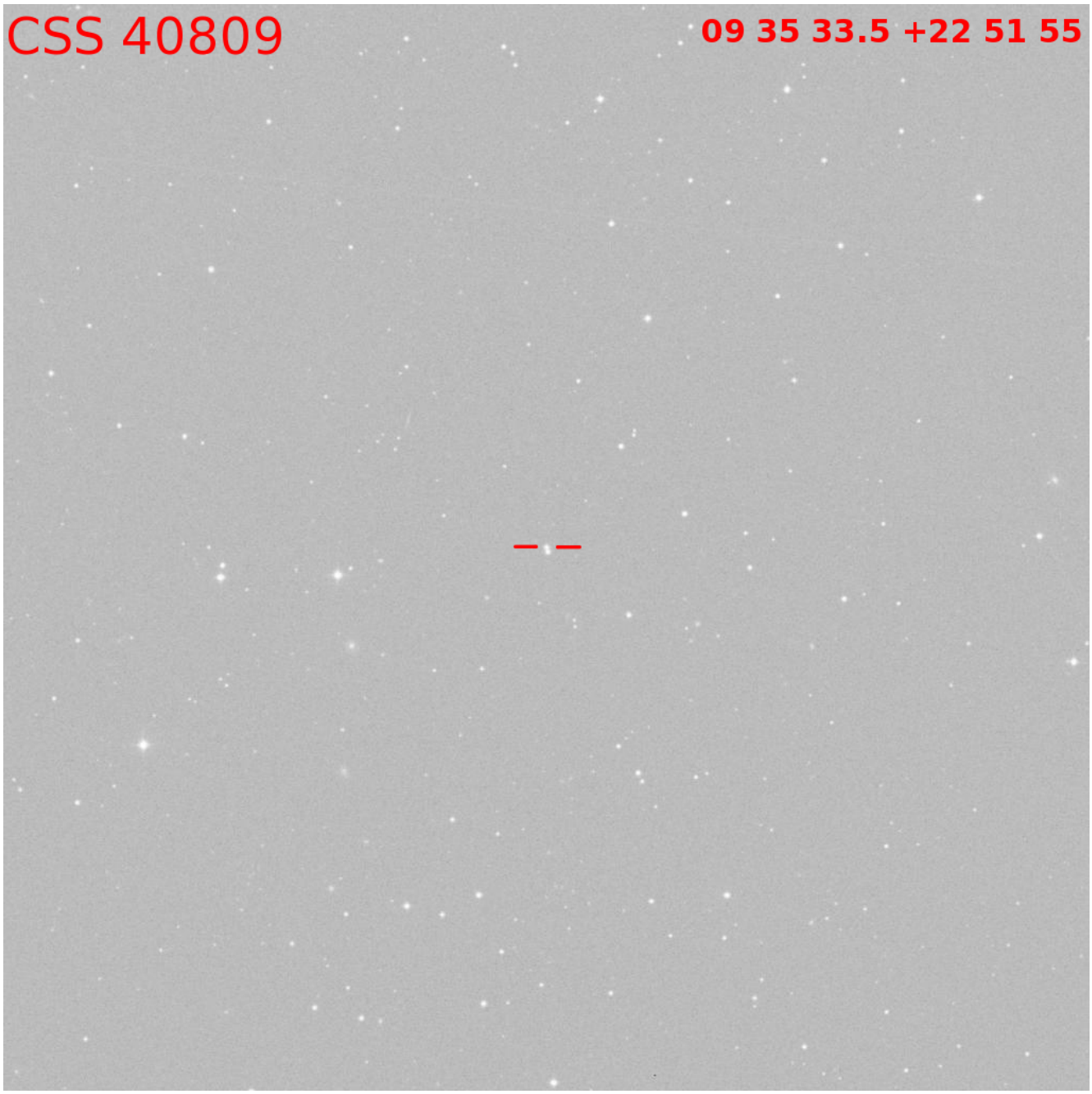
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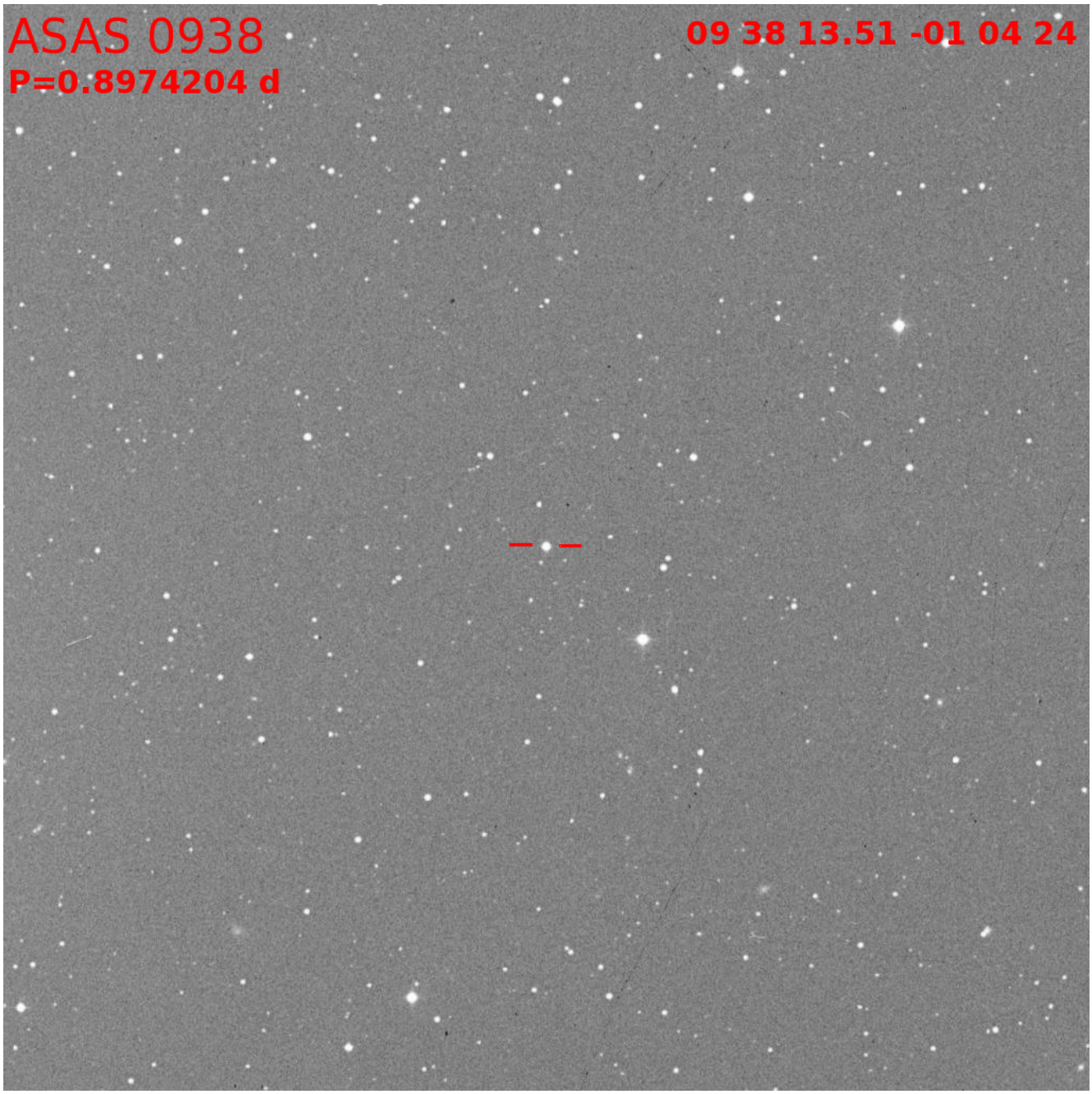
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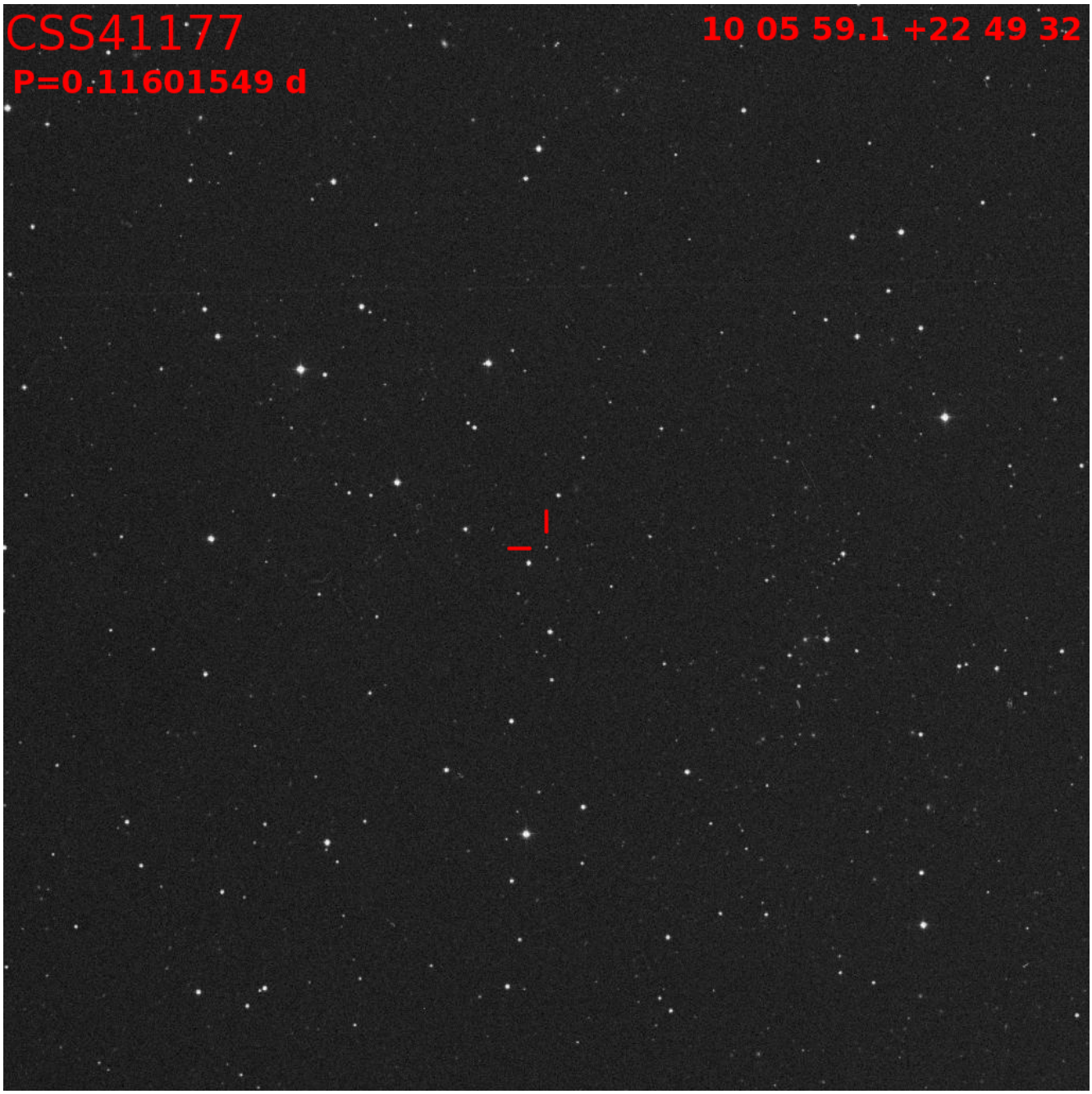
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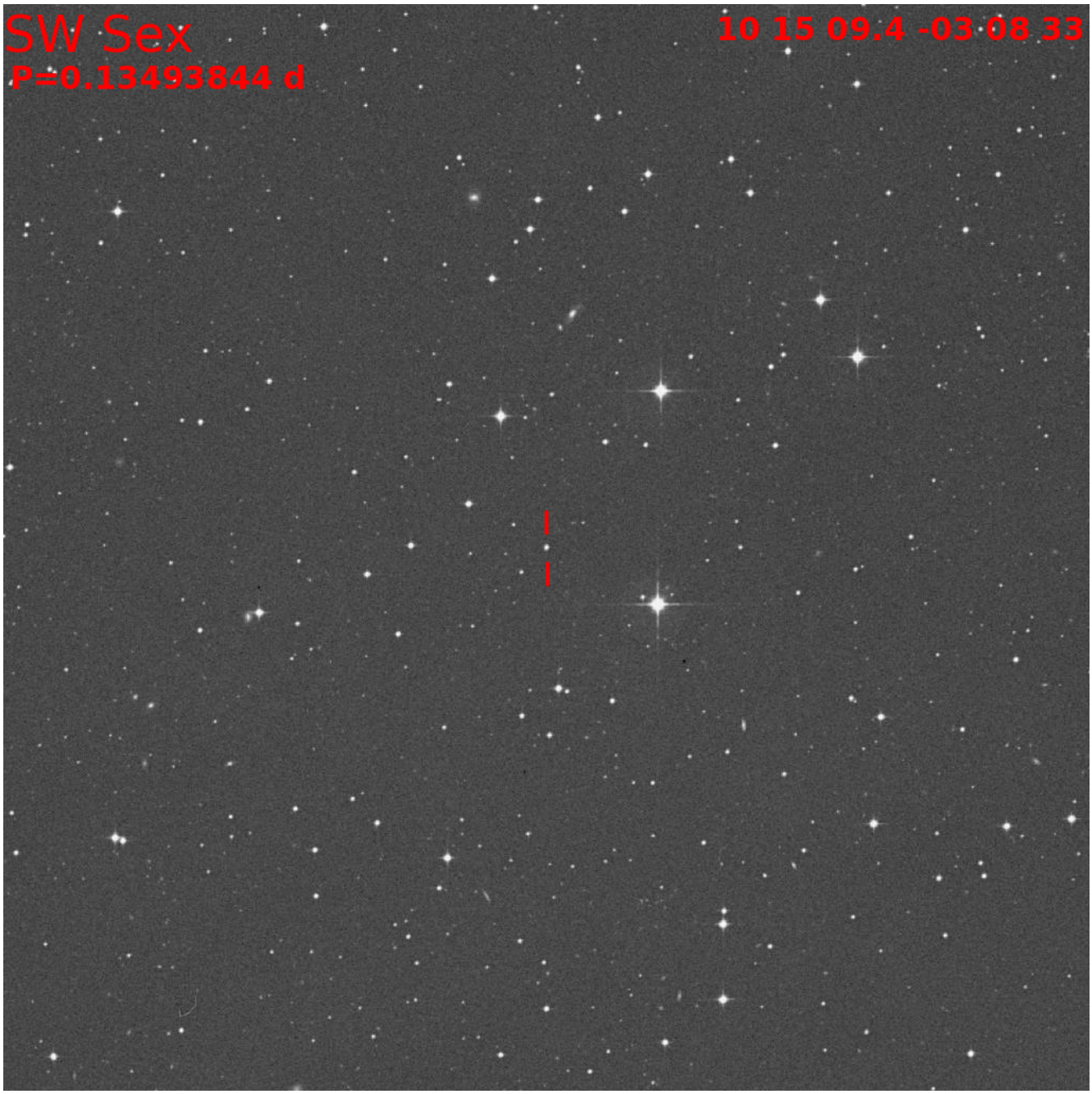
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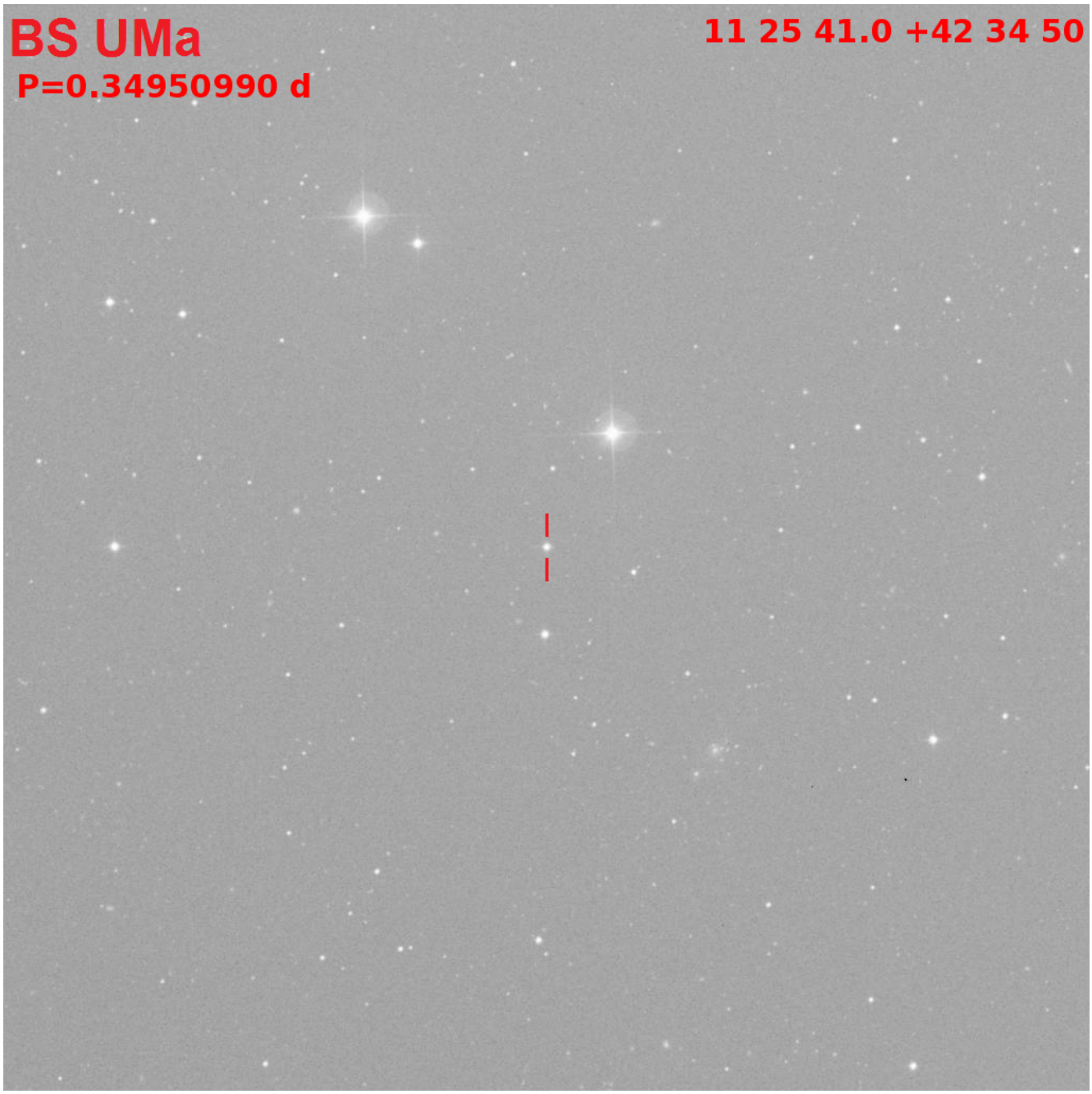
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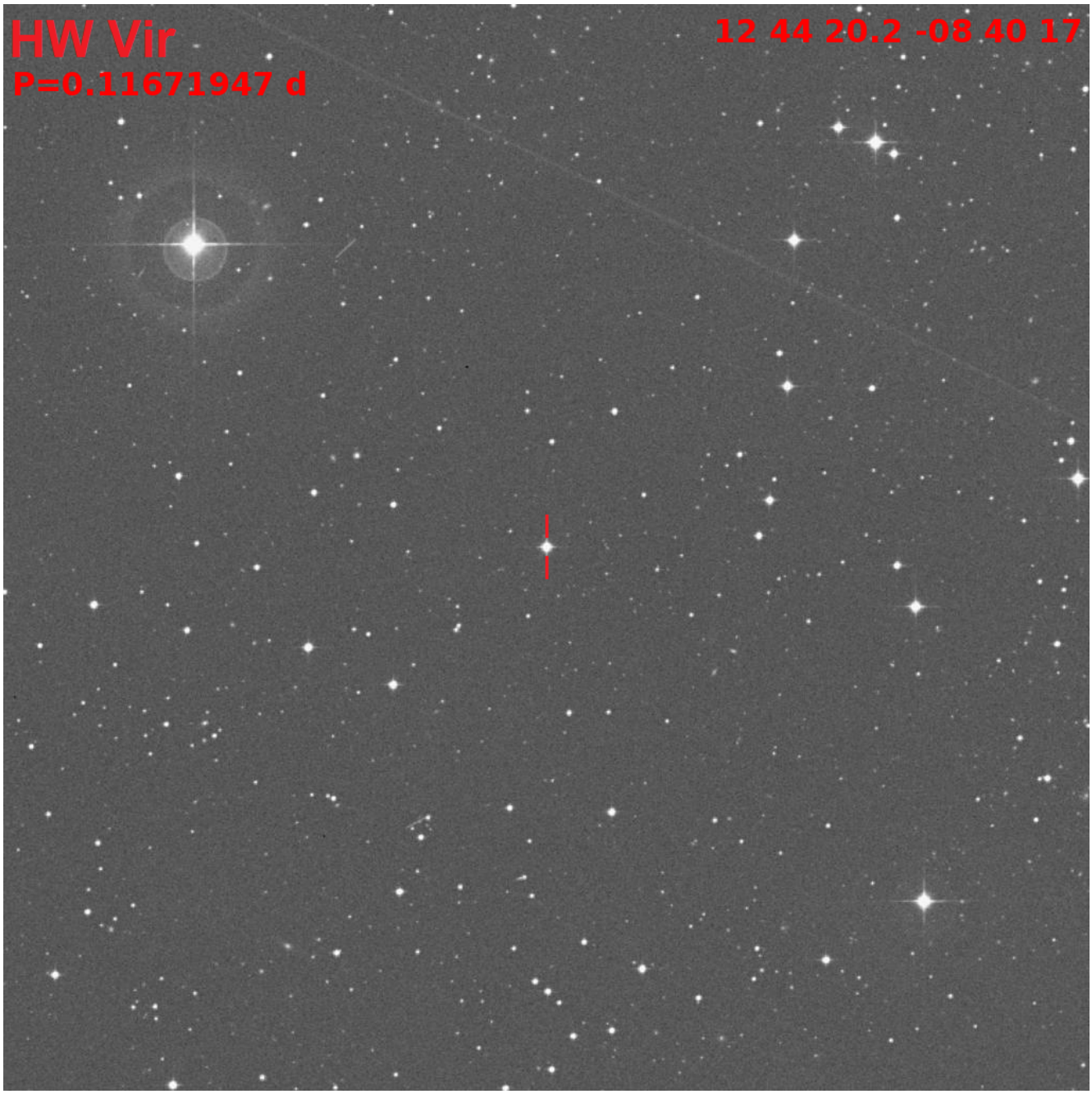
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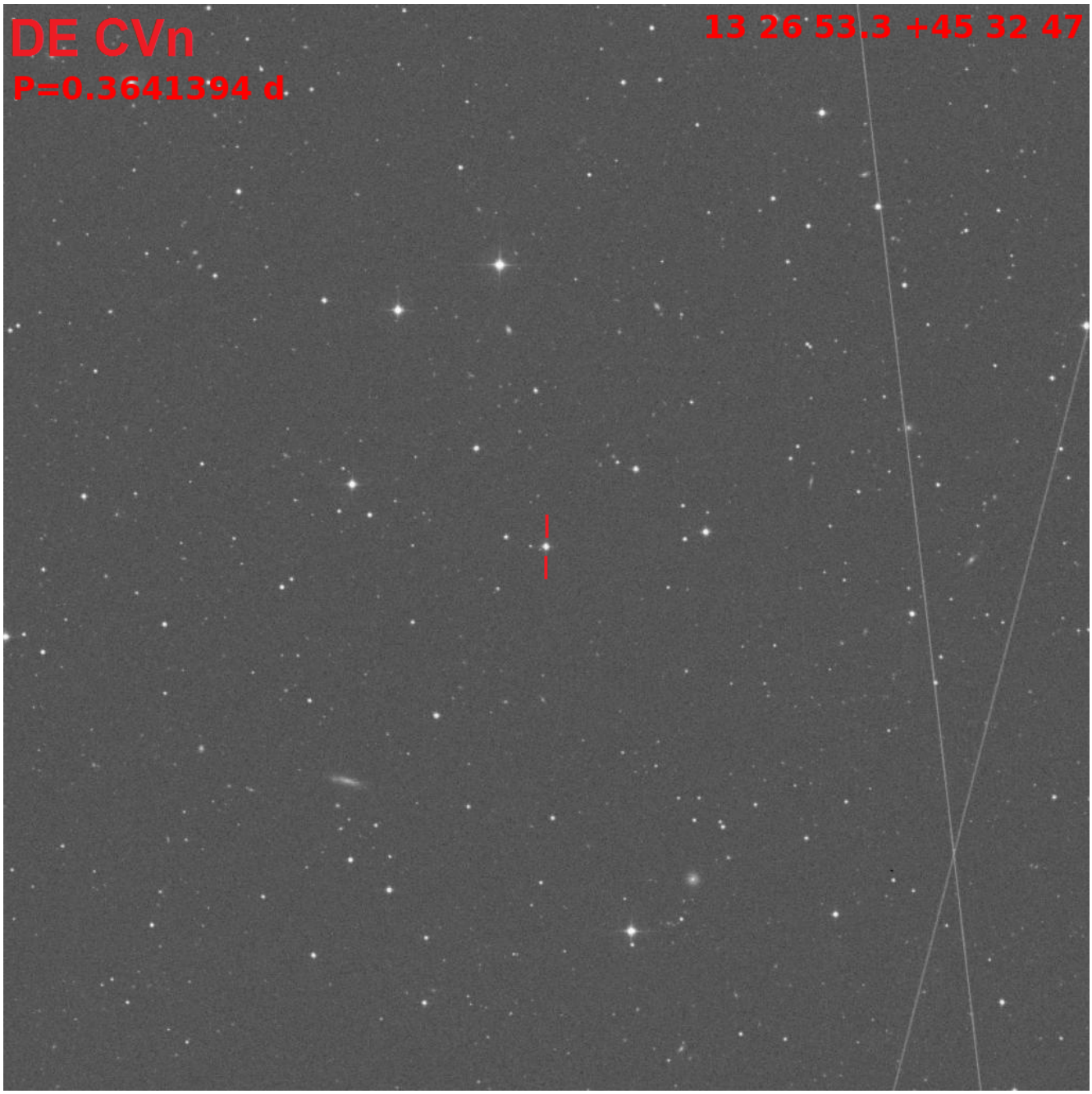
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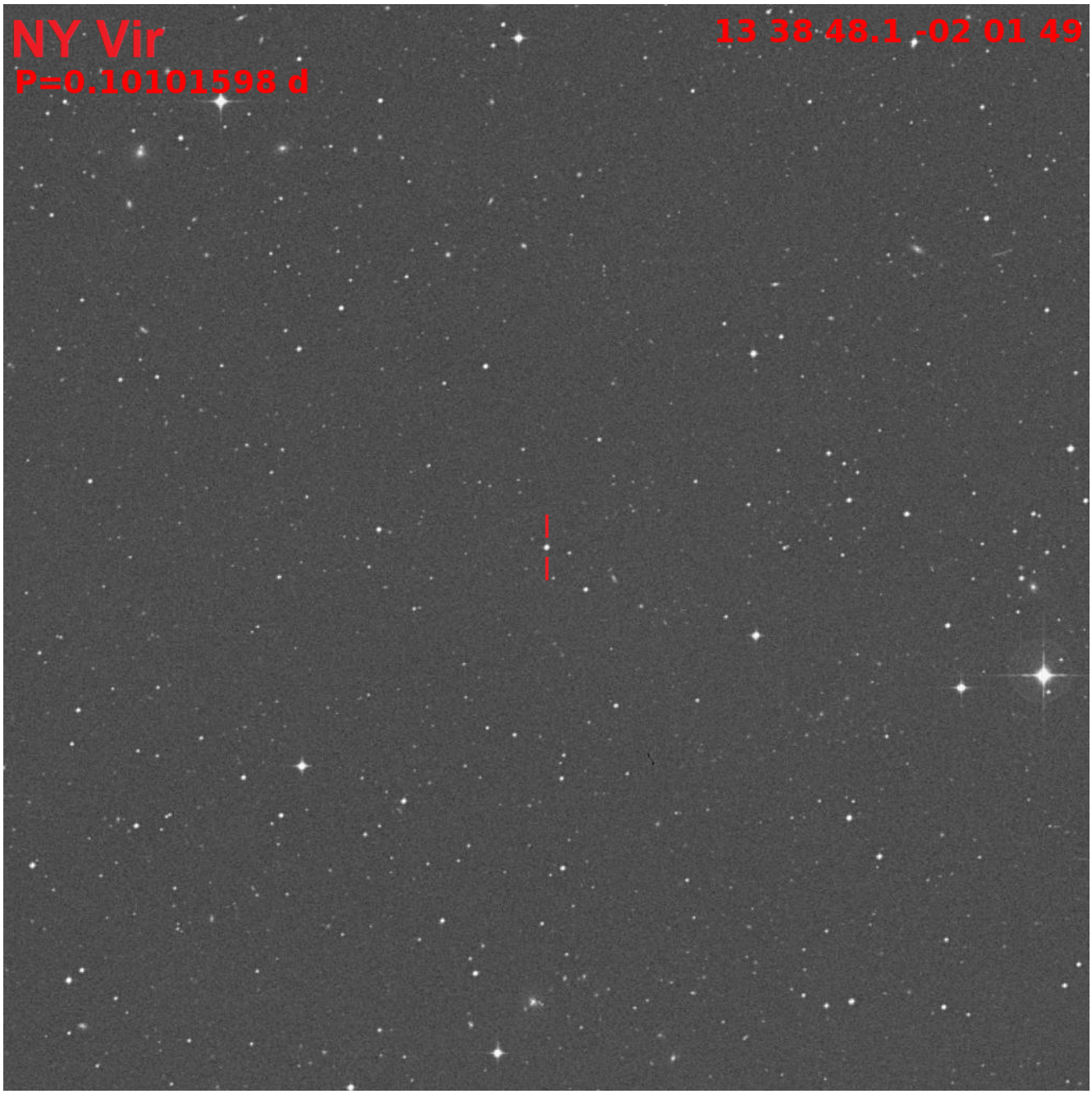
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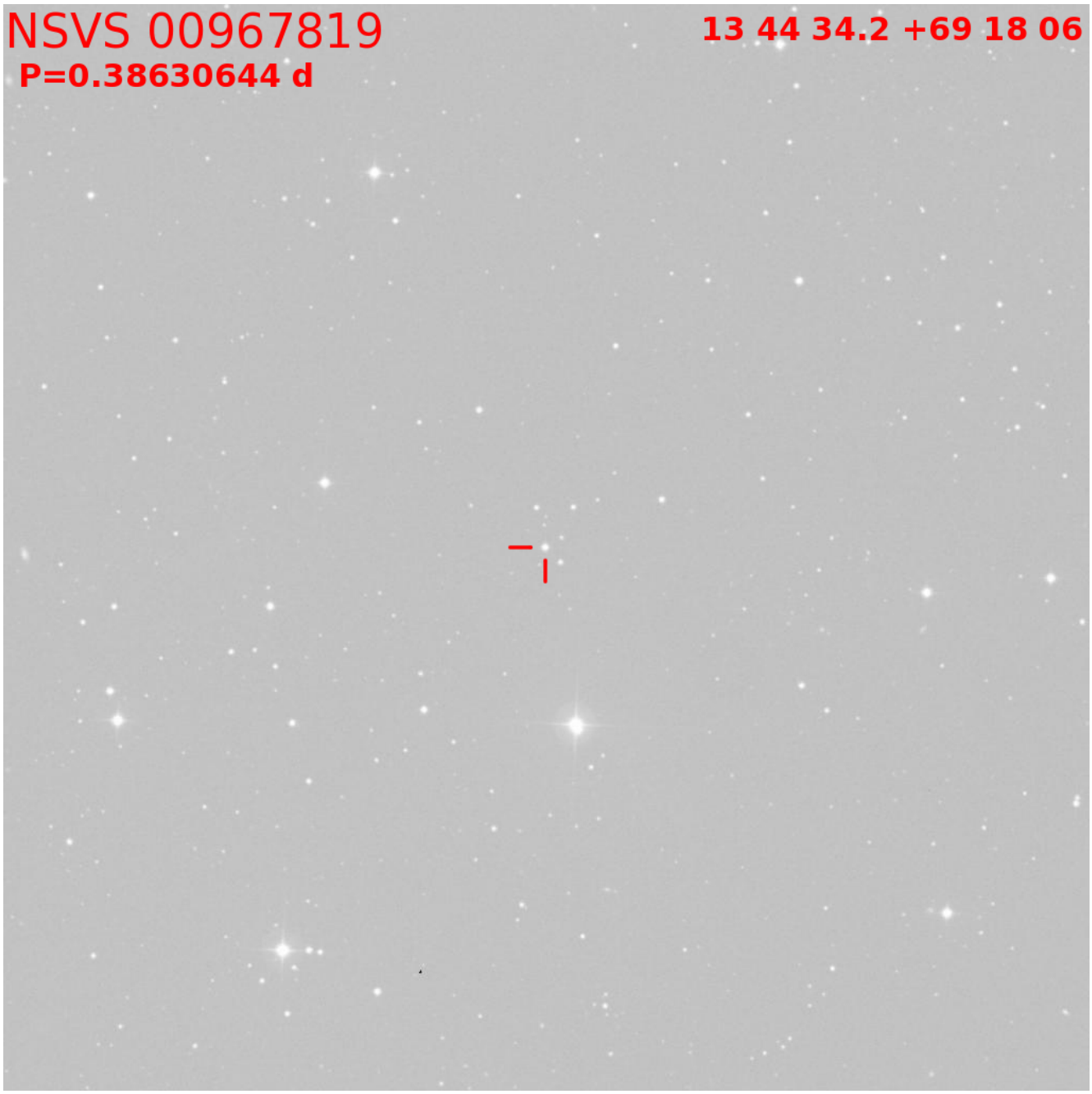
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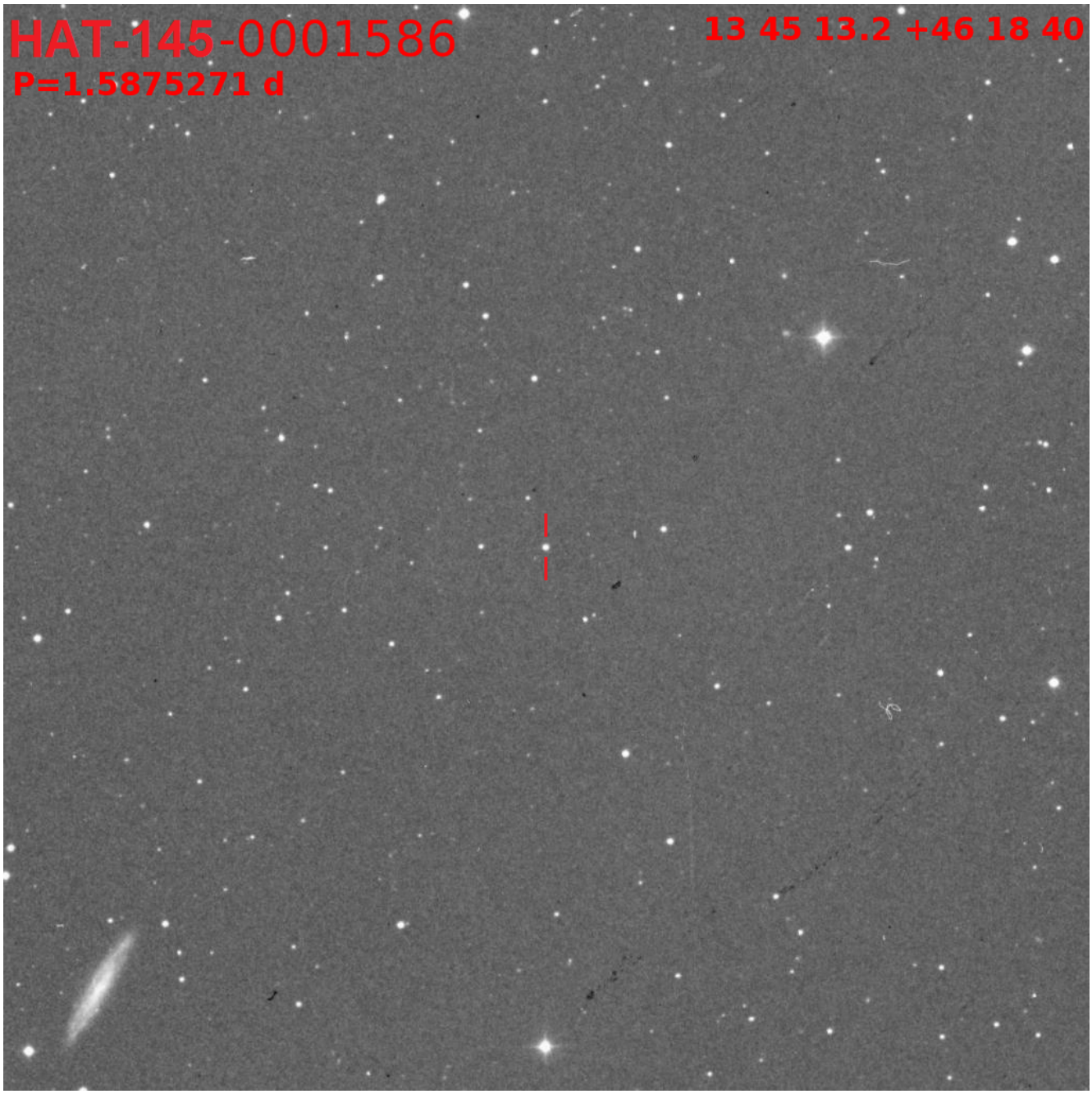
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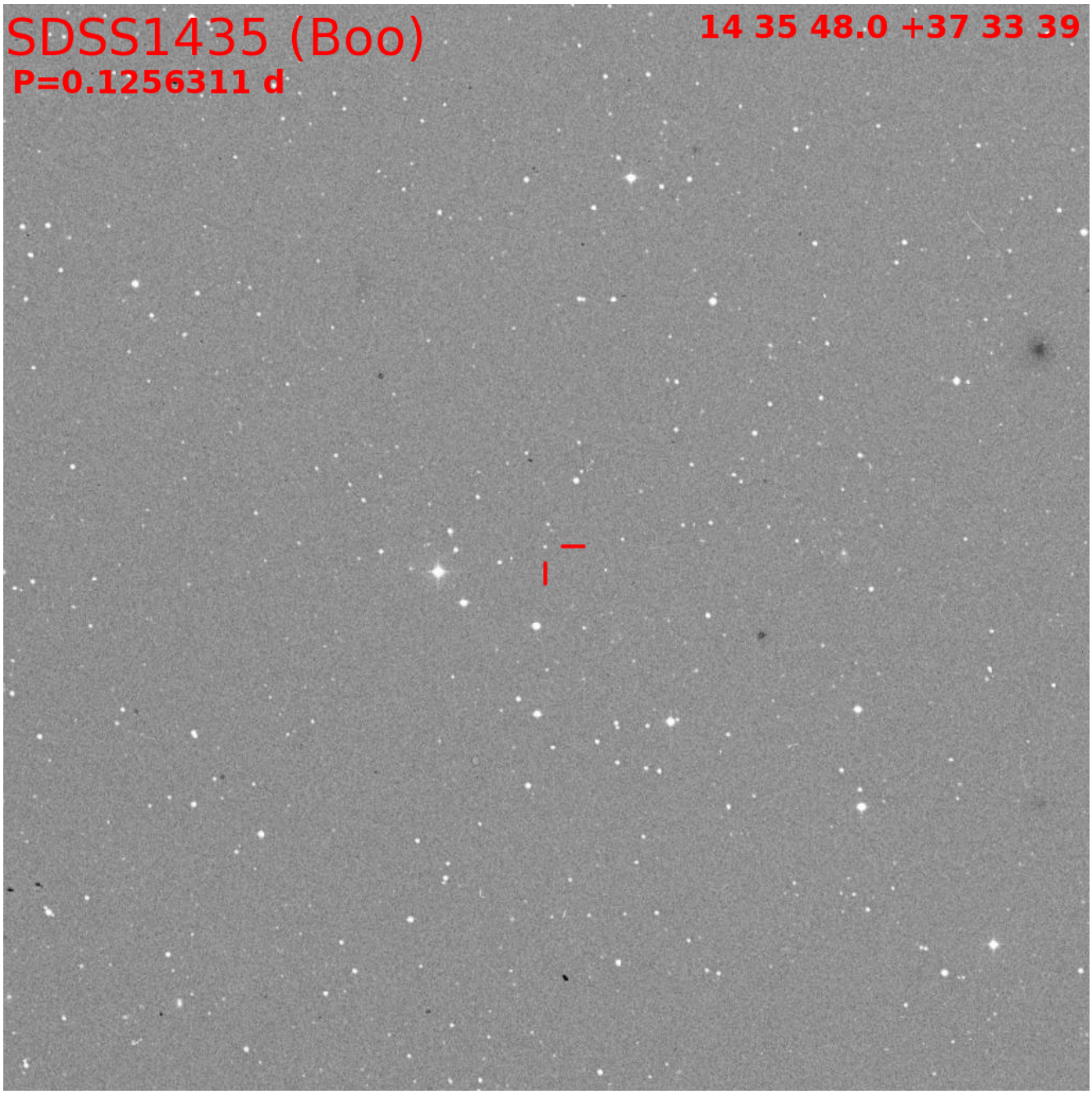
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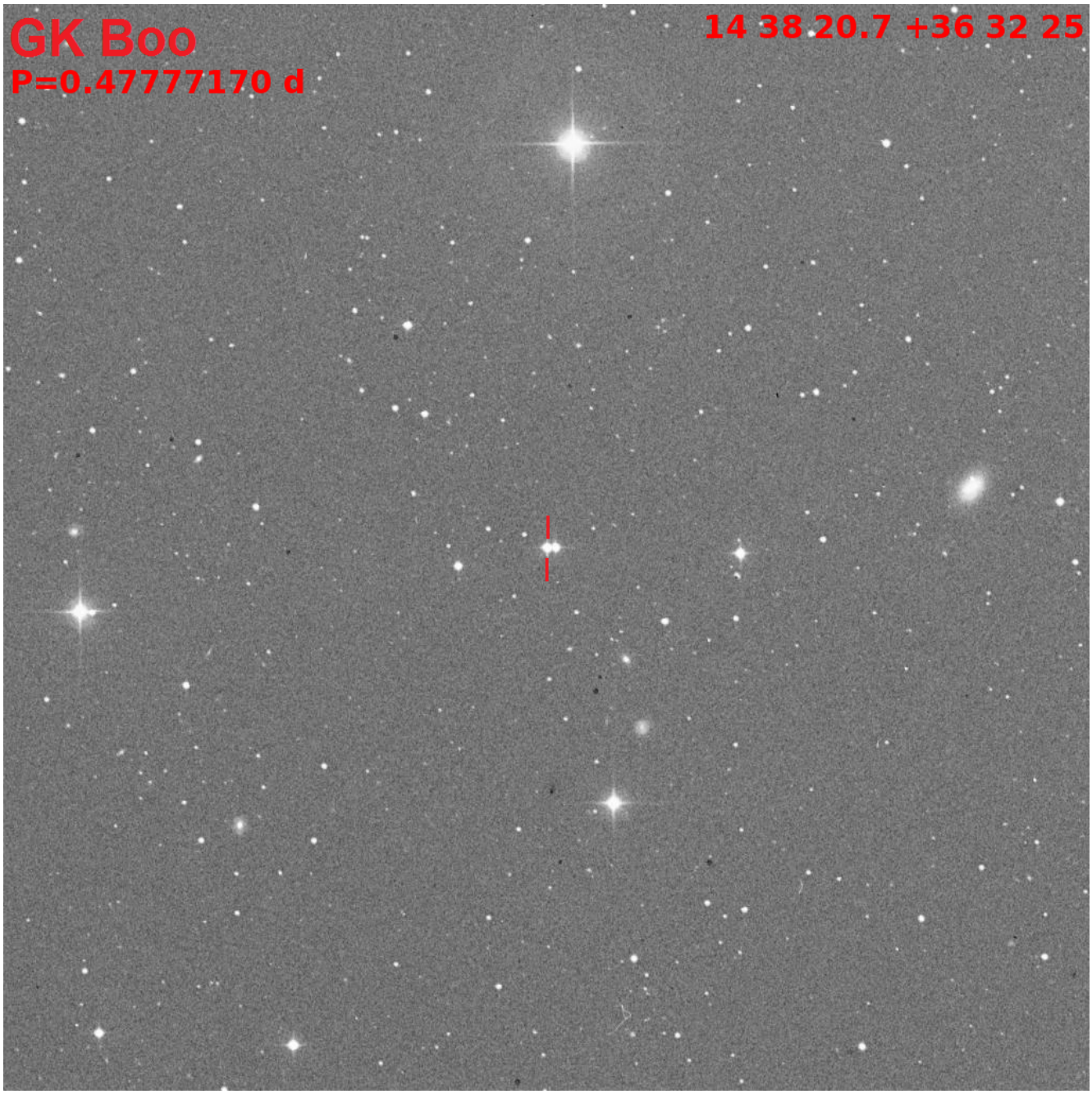
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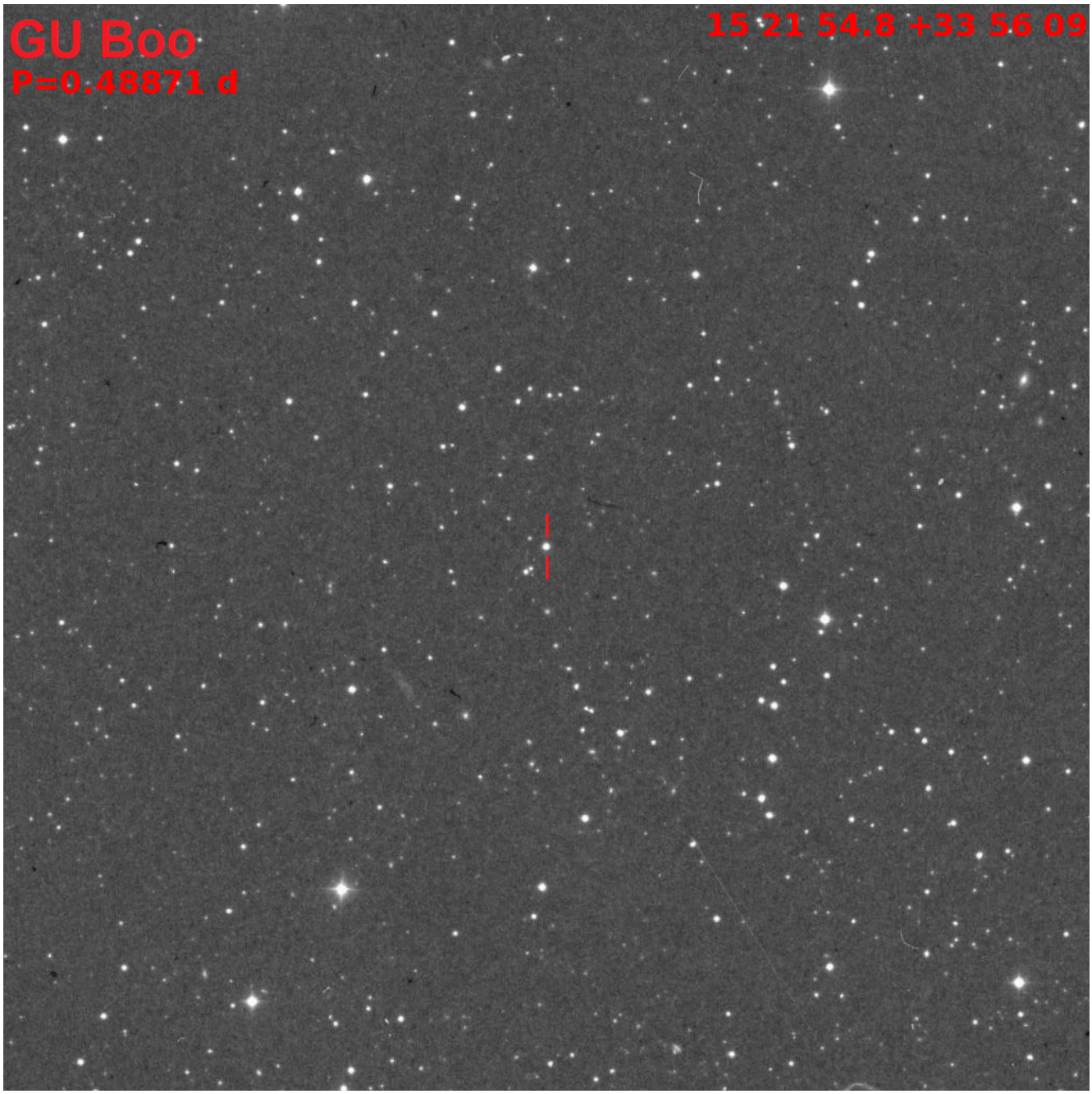
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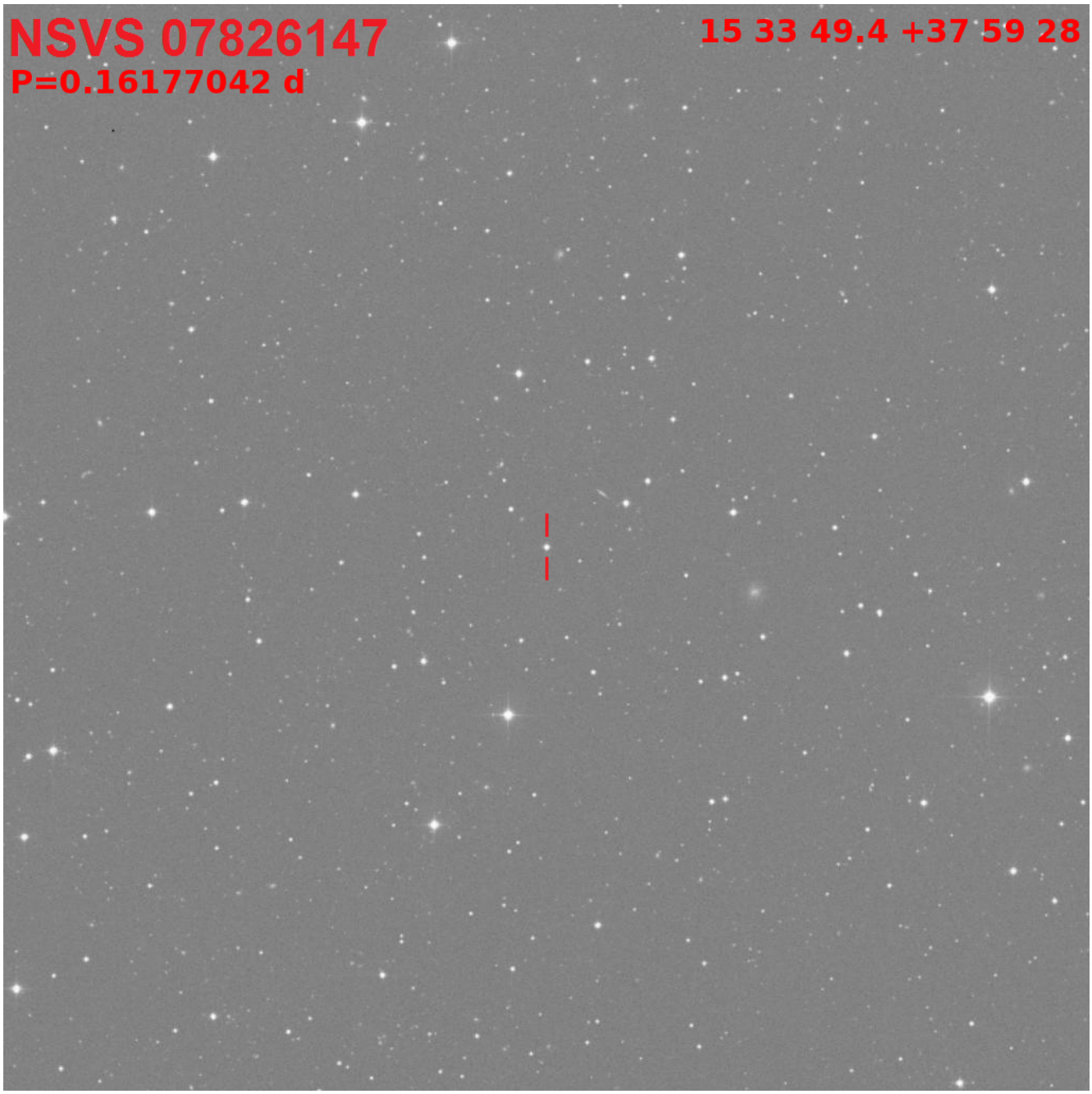
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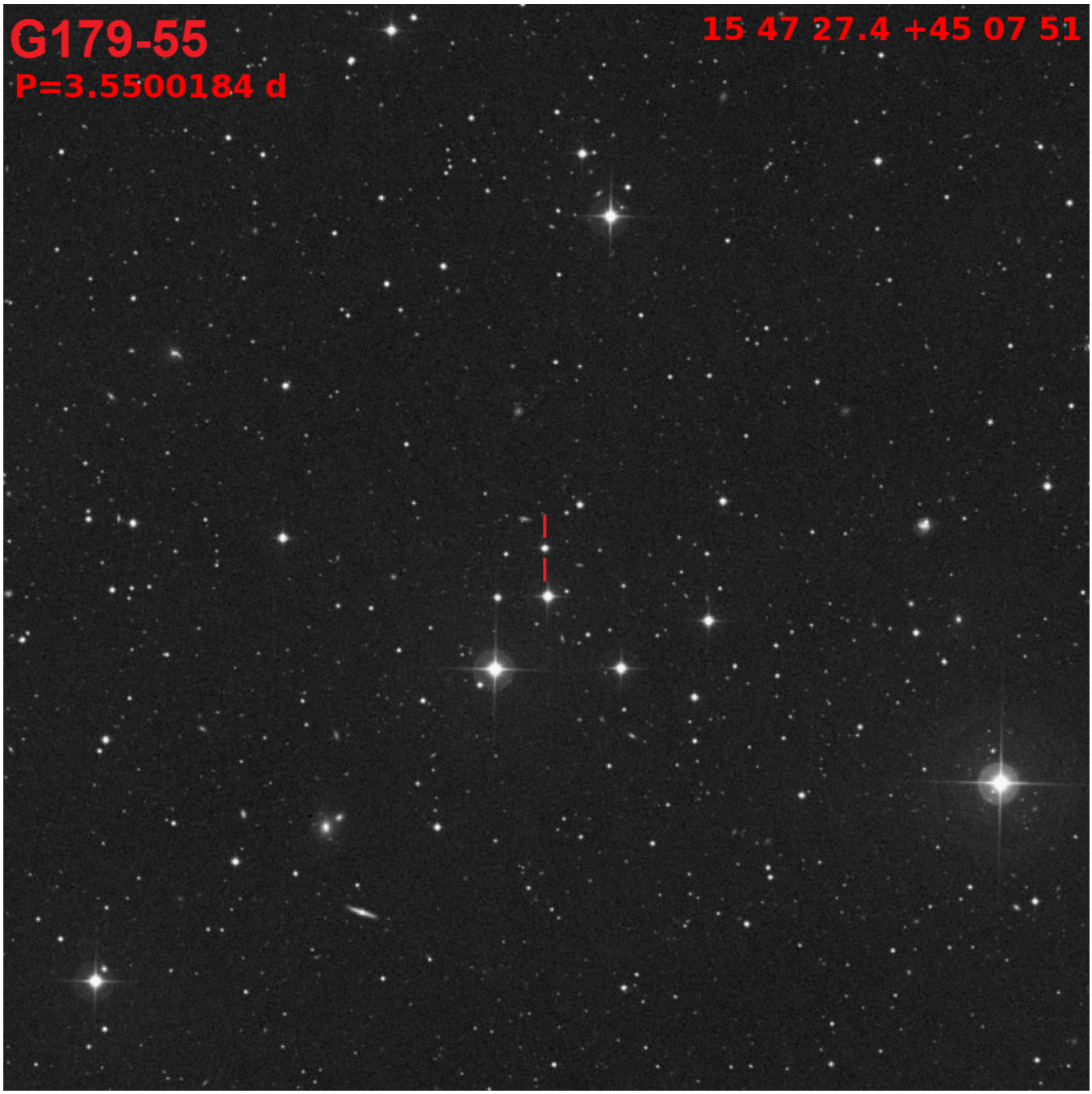
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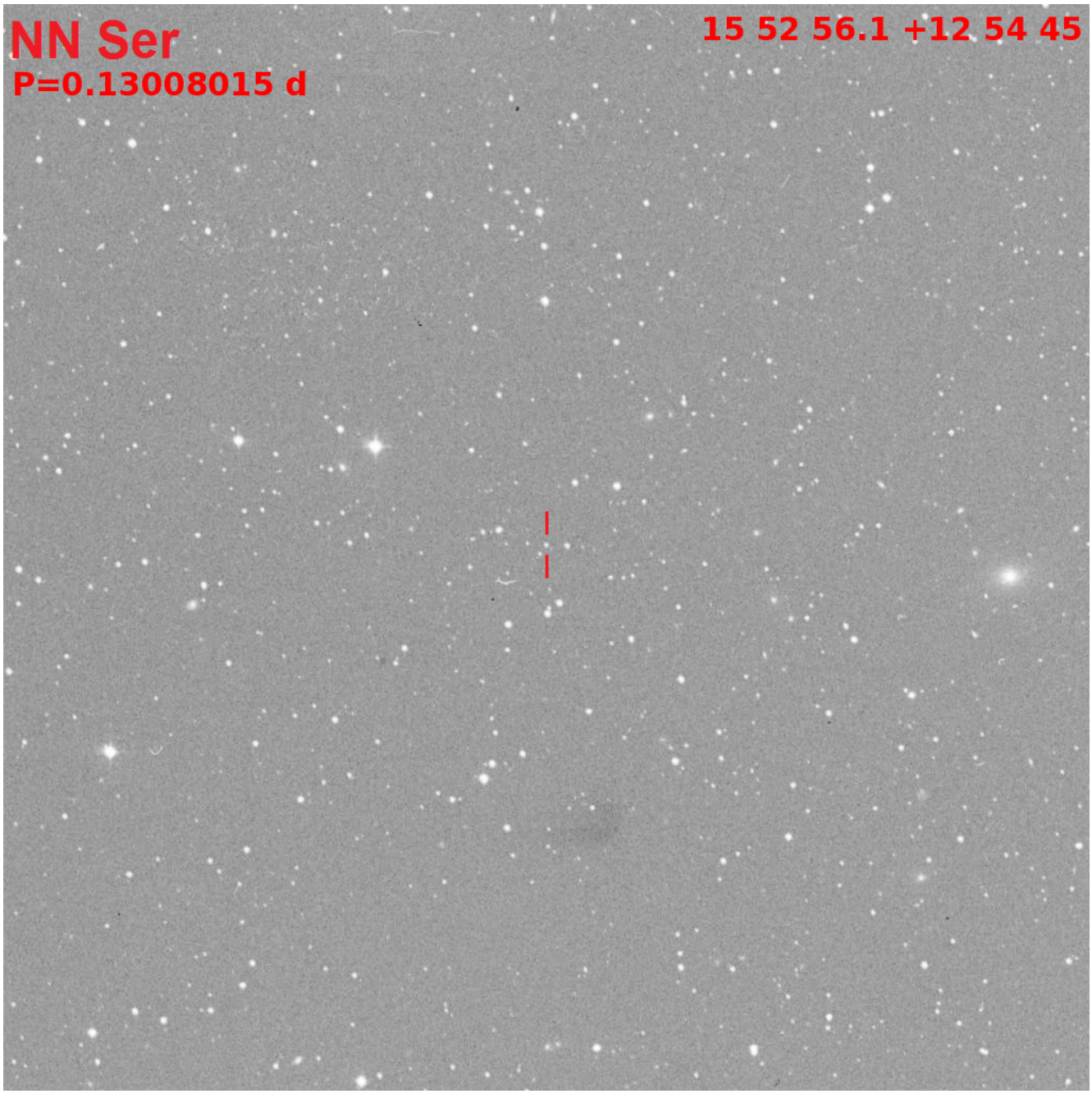
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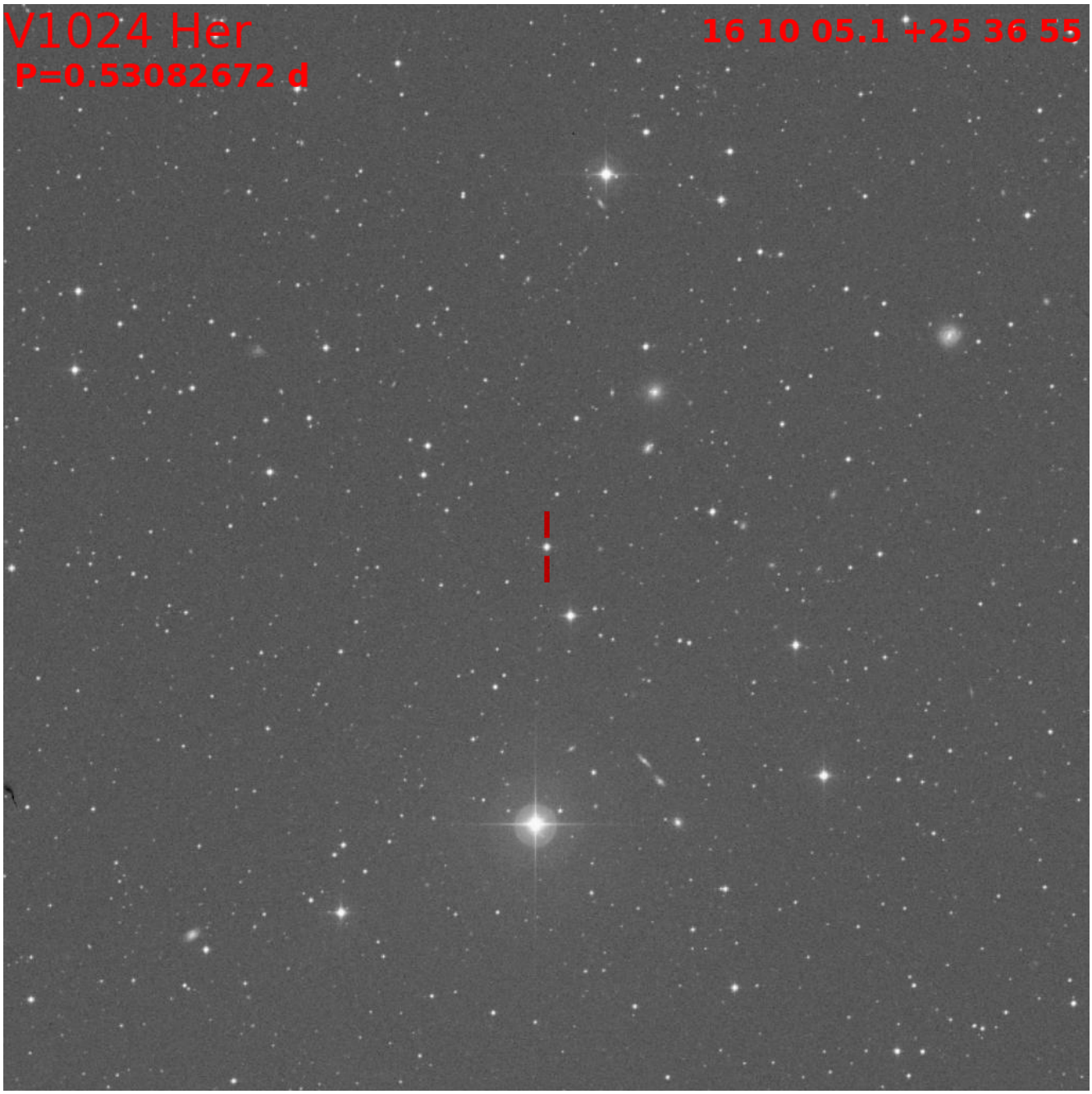
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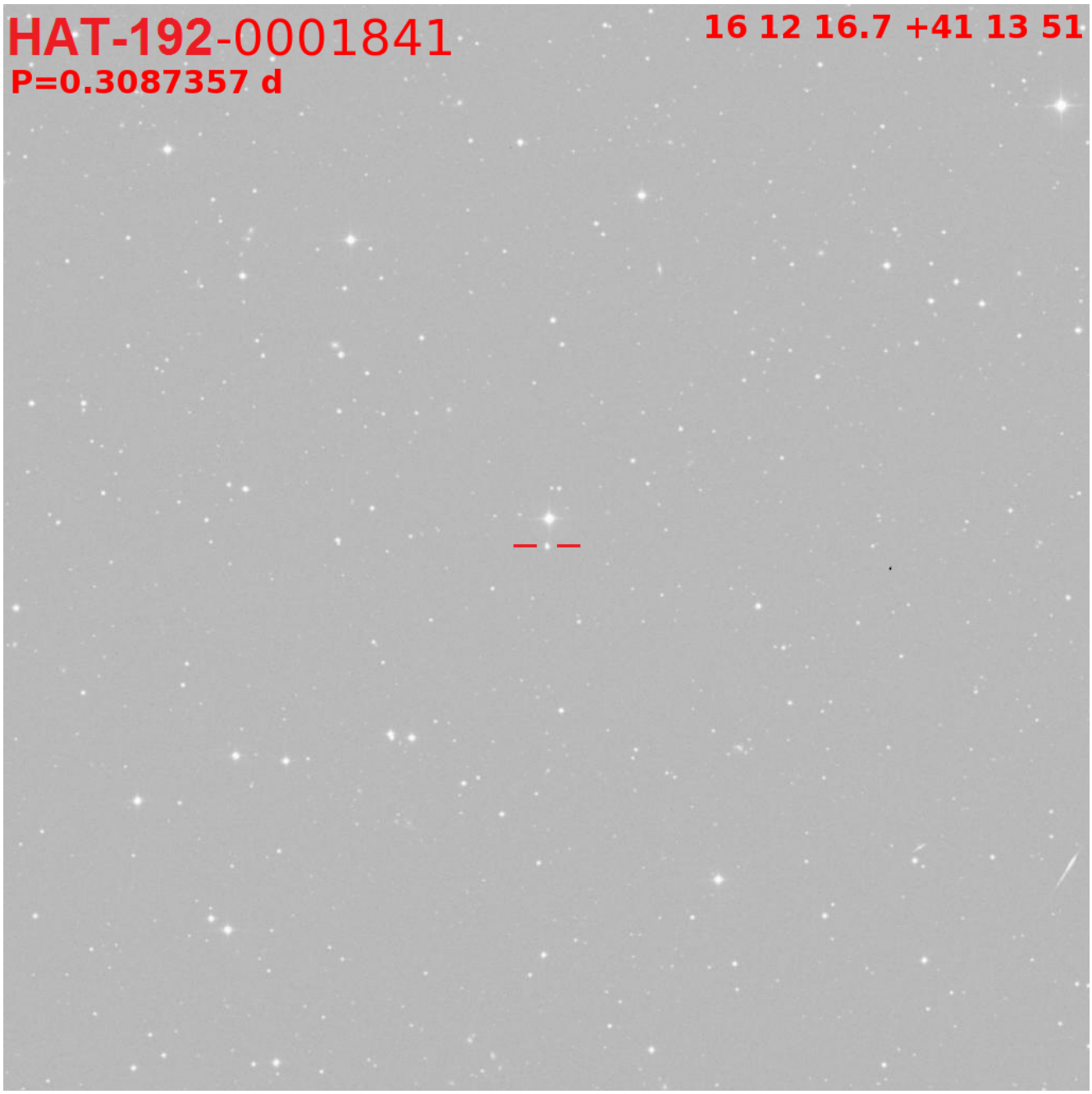
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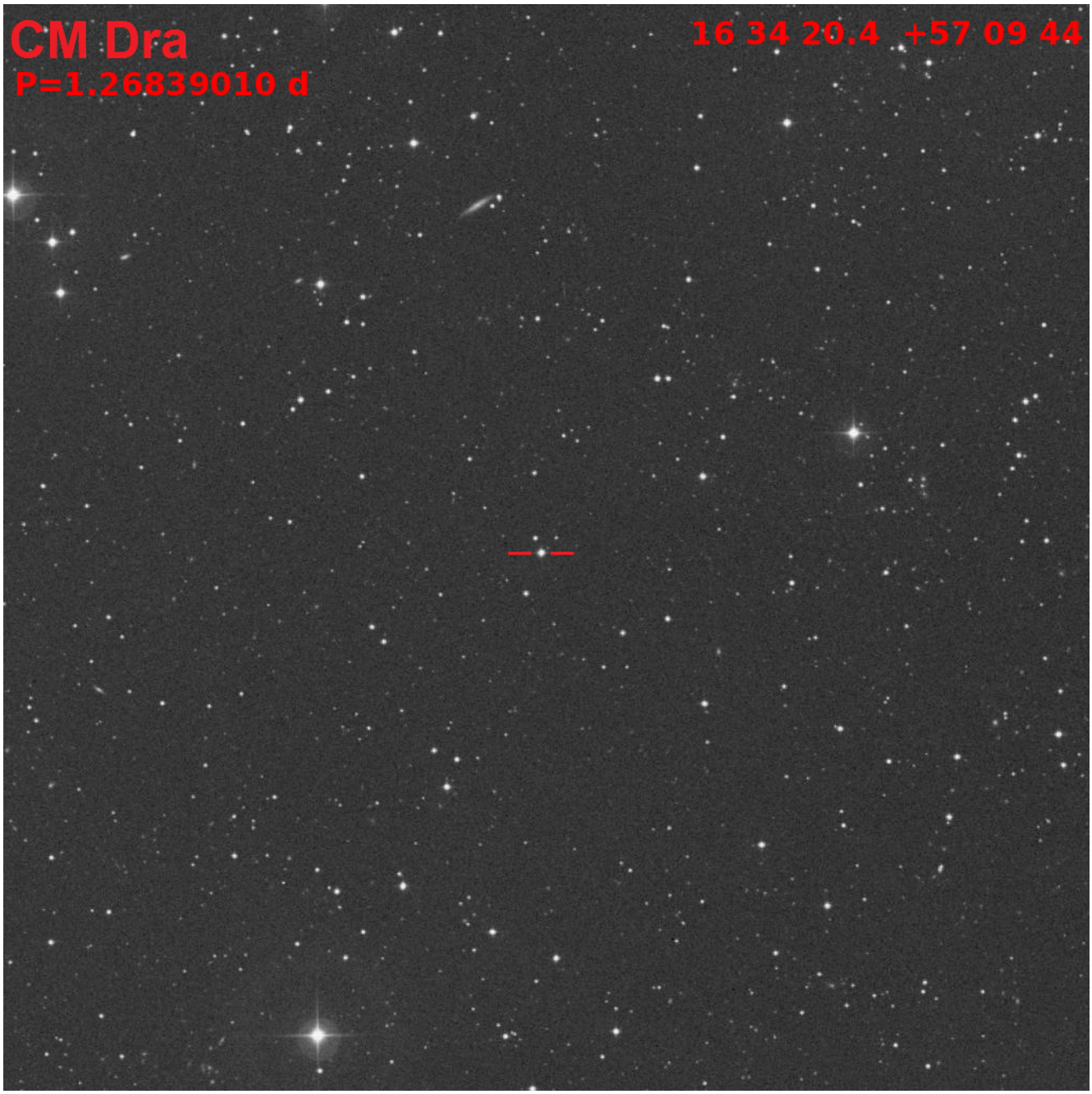
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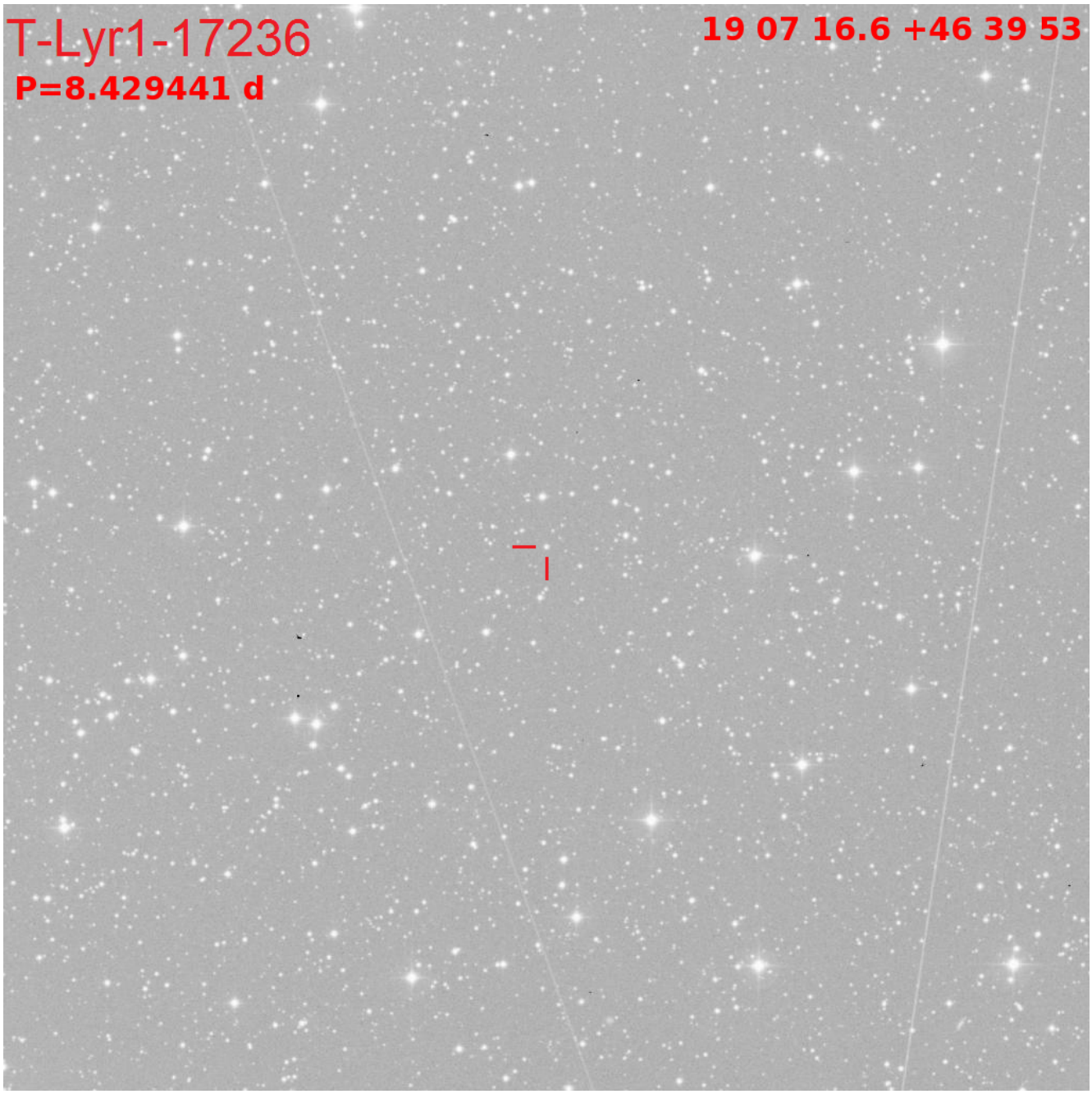
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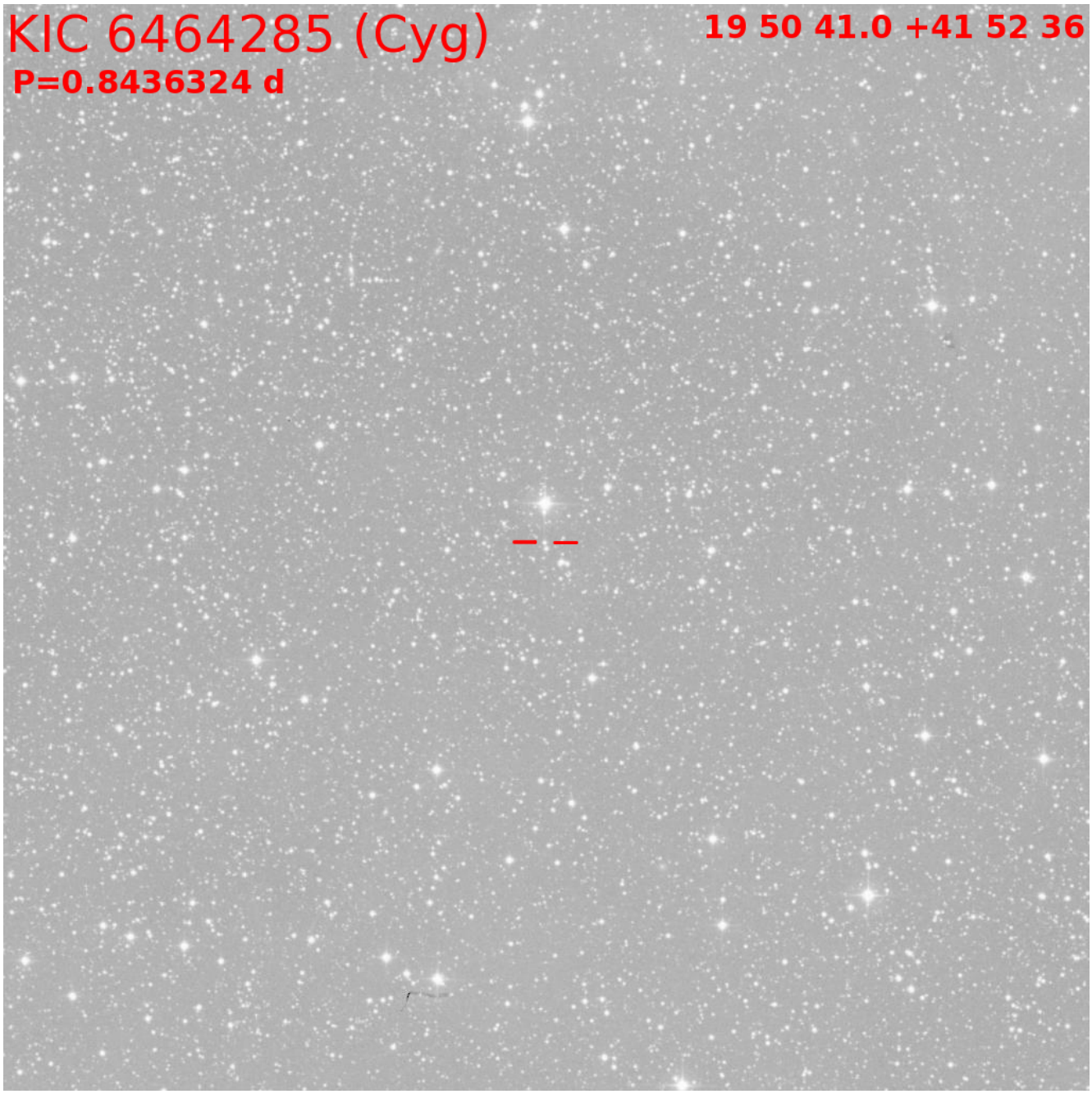
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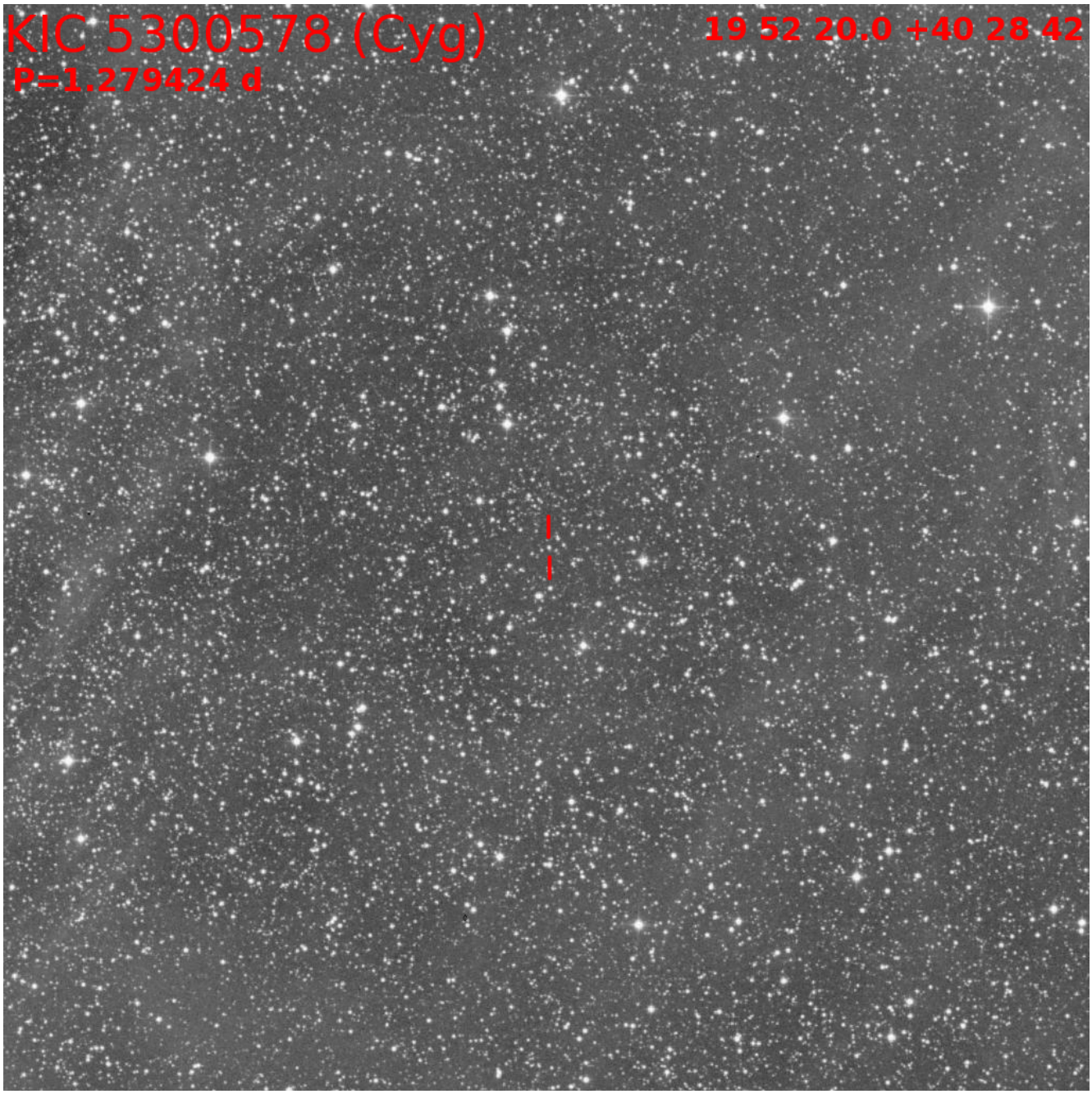
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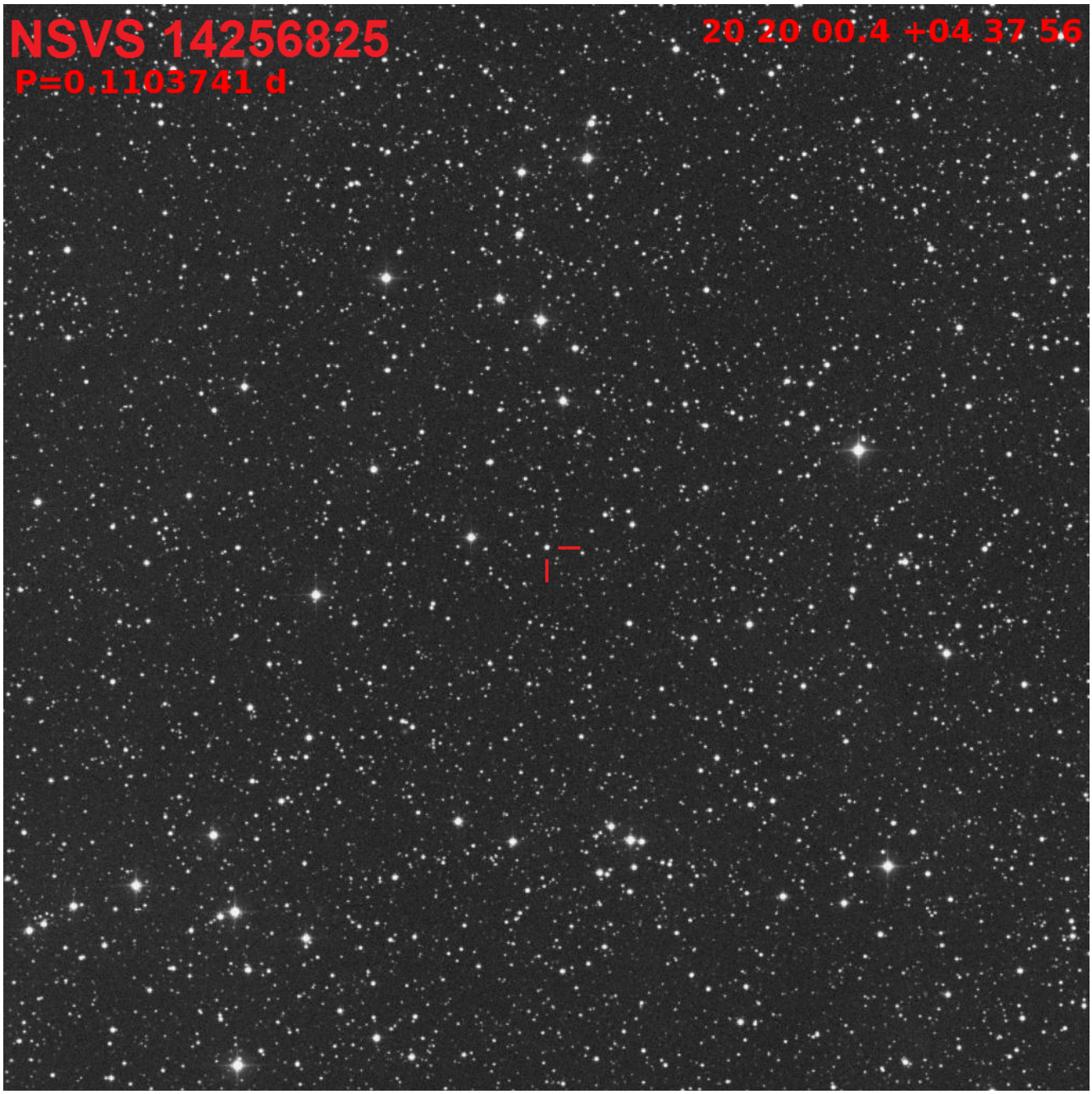
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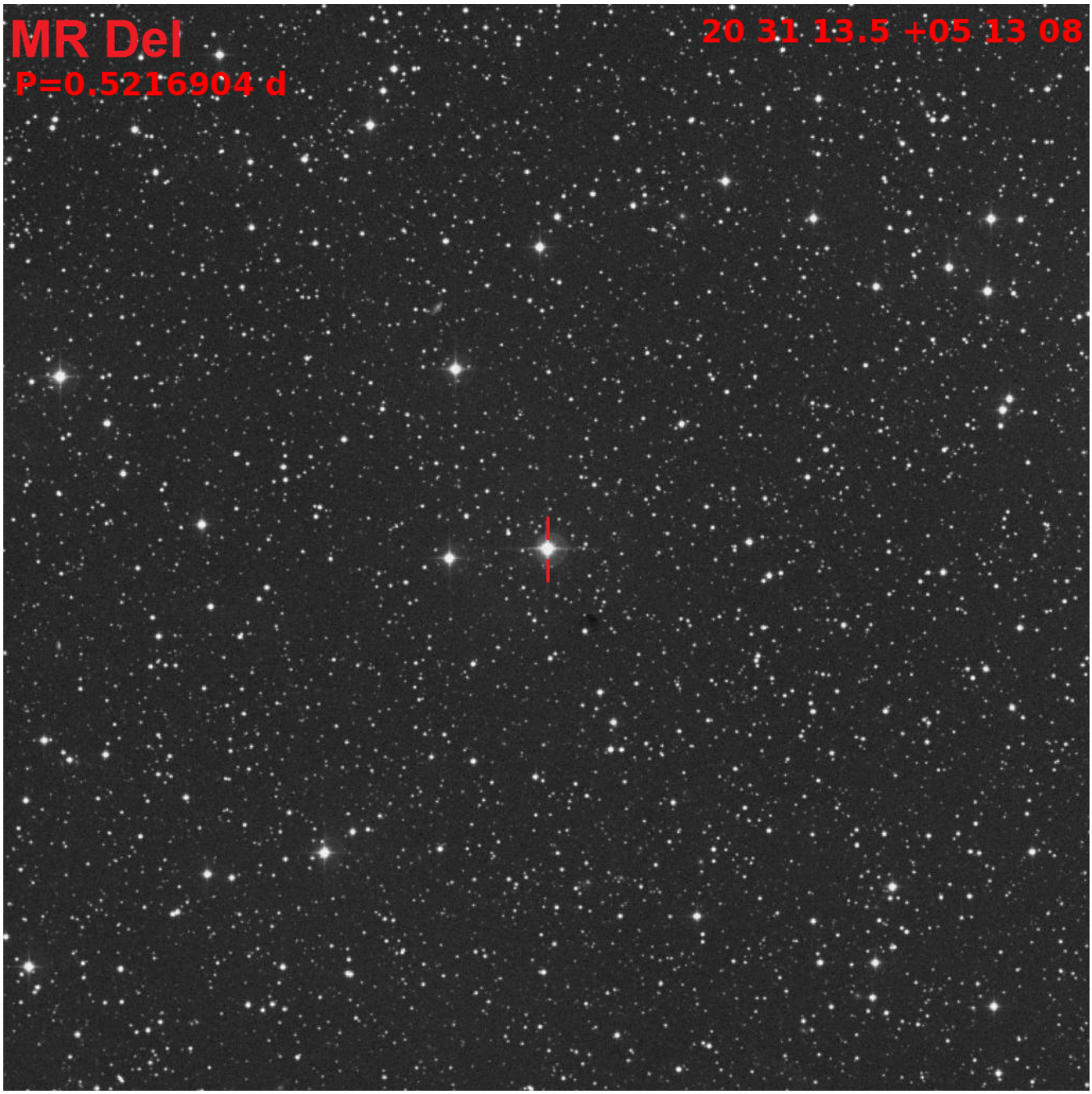
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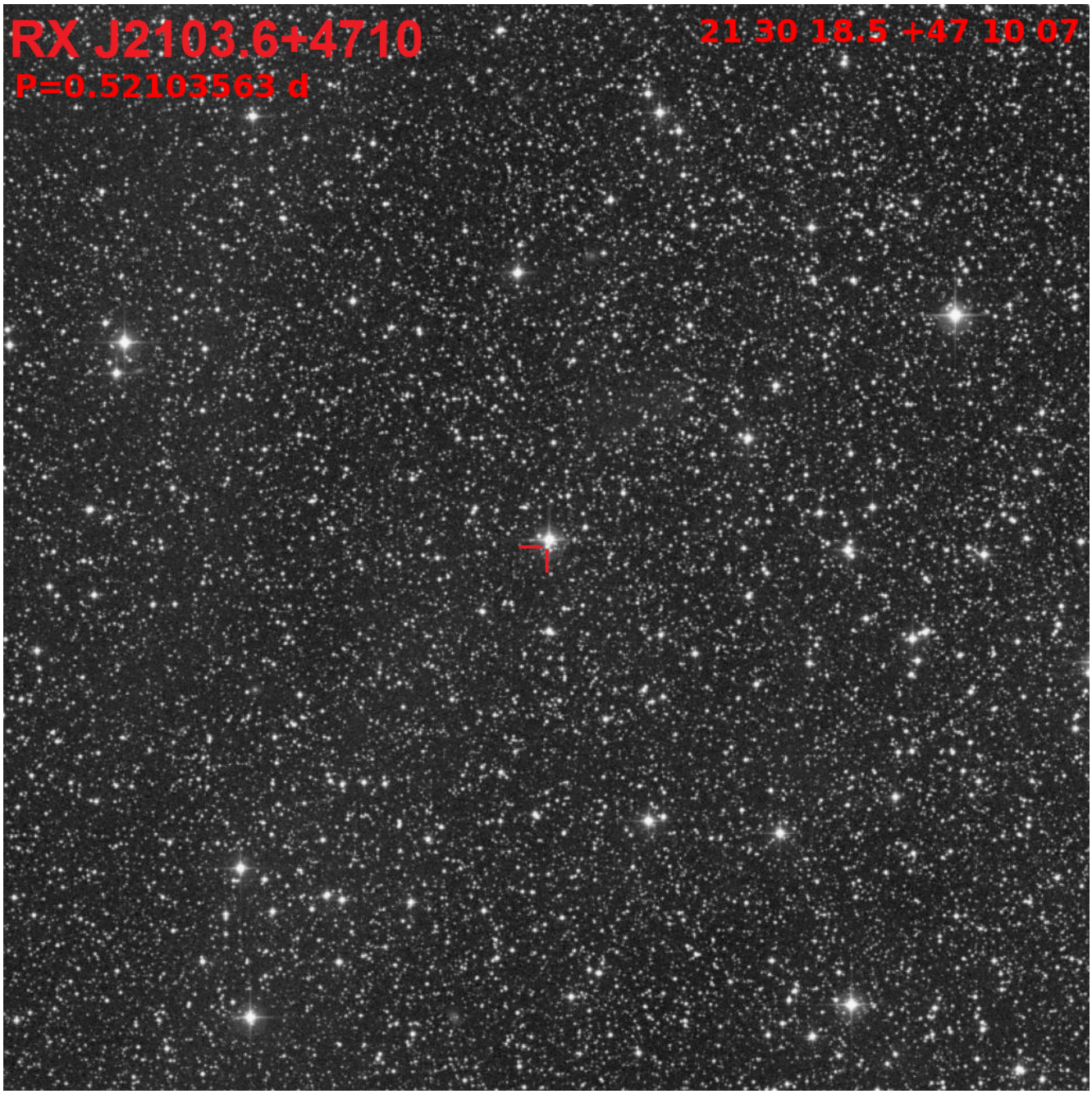
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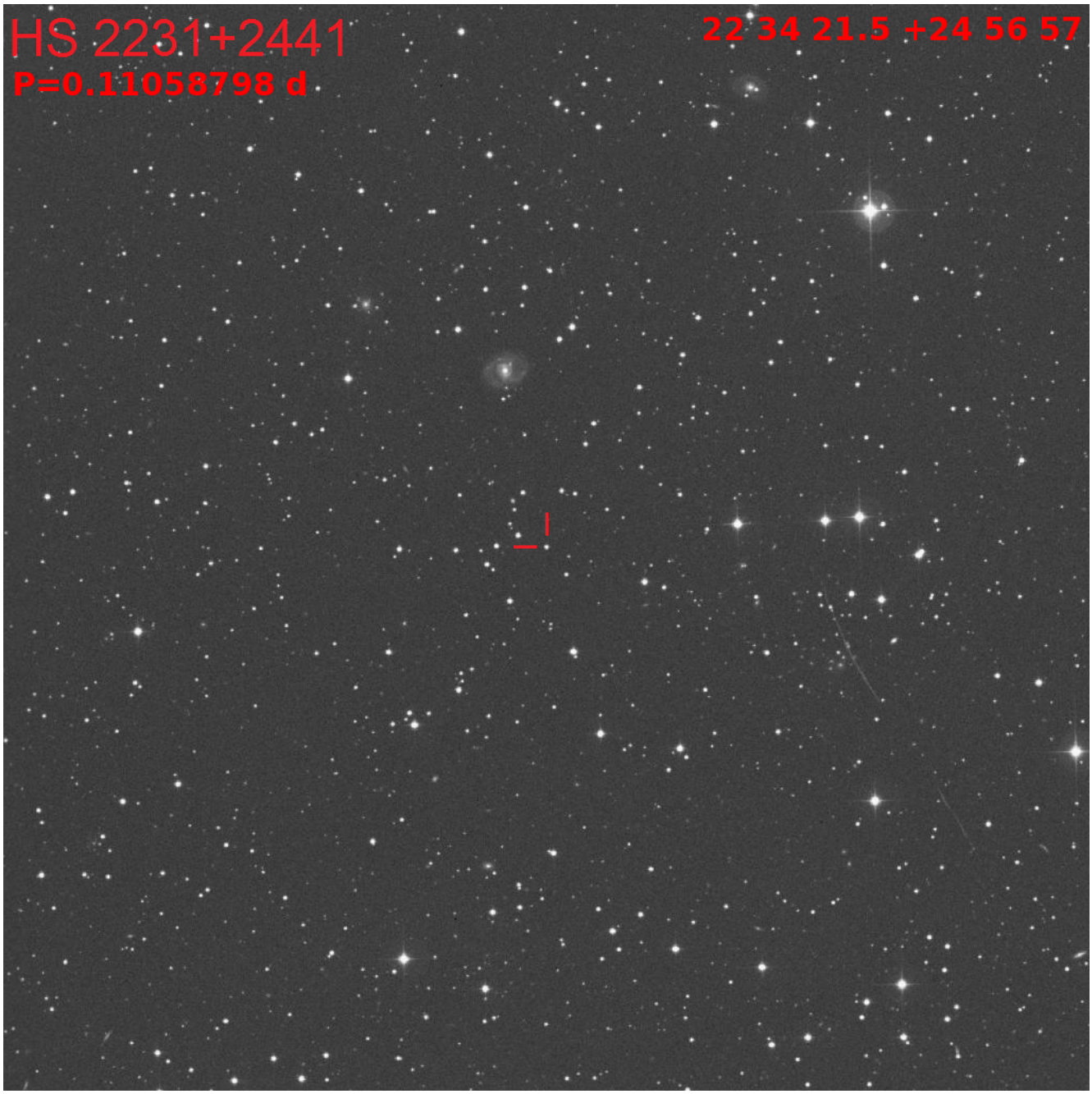
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