The Thermal Anomaly Search for Non-communicating Intelligence (TASNI): Discovery of Four Fading Thermal Orphans in the AllWISE Catalog

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Abstract

We present the Thermal Anomaly Search for Non-communicating Intelligence (TASNI), a systematic pipeline to identify mid-infrared sources in the AllWISE catalog that lack counterparts at optical, near-infrared, and radio wavelengths. From 747 million AllWISE sources, our multi-wavelength veto strategy isolates 4,137 "thermal anomalies"—objects detectable only in the mid-infrared with thermal colors (W1−W2 > 0.5 mag). The 100 highest-scoring candidates ("golden sample") have mean effective temperature $T_{\rm eff} = 265 \pm 36$ K, mean W1−W2 color of 1.99 ± 0.36 mag, and mean proper motion $\mu = 216 \pm 149$ mas yr^{-1}. Parallax analysis of 58 sources with significant detections (SNR ≥ 3) yields a median distance of 33.8 pc, with the closest sources at 11.8, 13.3, and 15.4 pc. Population synthesis indicates 87.9% of the sample has $T_{\rm eff} < 300$ K, a space density $\sim$0.6$\times$ that of known Y dwarfs, and a sample size 3.3$\times$ larger than the current Y dwarf census ($\sim$30 objects). Cross-matching with eROSITA DR1 reveals that 95% of the golden sample is X-ray quiet, with none of the fading sources detected, ruling out AGN or coronally active stellar contamination. Analysis of 10-year NEOWISE light curves reveals that 45% of the golden sample is photometrically stable, 50% shows variability consistent with brown dwarf atmospheres, and 5% exhibits systematic fading. We identify four "fading thermal orphans"—sources with unprecedented combinations of extreme W1−W2 colors (1.53–3.37 mag), room-temperature emission ($T_{\rm eff} =$ 251–293 K), high proper motions (55–359 mas yr^{-1}), and monotonic fading at rates of 18–53 mmag yr^{-1} over the decade-long baseline. Parallax measurements place the fading source J143046.35−025927.8 at 17.4 ± 3.0 pc ($T_{\rm eff} = 293$ K, SNR = 5.8), establishing it as one of the nearest room-temperature objects known. None of these four sources appear in SIMBAD or any astronomical catalog. The most likely interpretation is that these objects are extremely cold Y-type brown dwarfs, possibly young objects undergoing rapid cooling. While our search was partly motivated by the technosignature hypothesis, all observed properties are consistent with natural astrophysical sources. Spectroscopic follow-up is urgently needed to confirm the nature of these unusual objects and determine whether they represent the coldest brown dwarfs yet identified or an entirely new class of astronomical sources.

Keywords: brown dwarfs — infrared: stars — stars: low-mass — surveys — techniques: photometric

1 Introduction

1.1 Motivation: Searching for Thermal Anomalies

The identification of unusual astrophysical sources has historically driven major discoveries, from quasars [Schmidt, 1963] to gamma-ray bursts [Klebesadel et al., 1973]. In the modern era of large-area sky surveys, systematic searches for anomalous objects—those that defy easy classification—offer a promising avenue for discovering new phenomena.

One class of potentially anomalous sources comprises objects that emit primarily in the thermal infrared while remaining undetected at other wavelengths. Such "thermal orphans" could arise from several physical mechanisms:

1. **Extremely cold brown dwarfs**: Objects with $T_{\rm eff} \lesssim 300$ K emit predominantly at wavelengths $\lambda > 10$ μm, with negligible optical flux. The coldest known brown dwarf, WISE J085510.83−071442.5, has $T_{\rm eff} \approx 250$ K [Luhman, 2014] and is detectable only in the mid-infrared.

2. **Dust-obscured sources**: Objects embedded in optically thick dust shells re-radiate absorbed en-

ergy as thermal emission at temperatures set by the dust sublimation radius.

3. **Technosignatures**: Theoretical considerations suggest that advanced technological civilizations might be detectable through their waste heat [Dyson, 1960, Kardashev, 1964]. A structure intercepting stellar luminosity would re-radiate at temperatures $T \sim 300$ K for Sun-like stars at 1 AU separation [Wright et al., 2014a,b].

While the first two explanations invoke known astrophysics, the third—though speculative—motivates careful characterization of any genuinely anomalous thermal sources.

1.2 The Y Dwarf Population

Brown dwarfs are substellar objects with masses below the hydrogen-burning limit ($\sim 0.075\ M_\odot$). They cool continuously throughout their lifetimes, passing through spectral types M, L, T, and Y as their effective temperatures decline [Kirkpatrick, 2005, Cushing et al., 2011].

The Y dwarf spectral class, defined by $T_{\rm eff} \lesssim 500$ K, represents the coldest end of the brown dwarf sequence [Cushing et al., 2011, Kirkpatrick et al., 2012]. Approximately 30 Y dwarfs are currently known, identified primarily through WISE color selection [Kirkpatrick et al., 2012, 2021]. Population synthesis models predict a substantial population of cold ($T < 300$ K) brown dwarfs in the solar neighborhood awaiting discovery [Burgasser, 2004, Ryan and Reid, 2017].

1.3 This Work

We present the Thermal Anomaly Search for Non-communicating Intelligence (TASNI), a systematic pipeline to identify mid-infrared sources lacking counterparts across the electromagnetic spectrum. Our goals are to quantify the population of genuinely "invisible" thermal emitters, characterize their properties, and identify candidates for spectroscopic follow-up.

The paper is organized as follows. Section 2 describes our methodology. Section 3 presents the pipeline results. Section 4 discusses physical interpretation. Section 5 summarizes our conclusions.

2 Methods

2.1 Data Sources

Our parent sample is drawn from the AllWISE Source Catalog [Wright et al., 2010, Cutri et al., 2013], containing 747,634,026 sources. For temporal analysis, we utilize the NEOWISE Reactivation Single-Exposure Source Table [Mainzer et al., 2014].

To identify sources lacking counterparts, we cross-match against Gaia DR3 [Gaia Collaboration, 2023], 2MASS [Skrutskie et al., 2006], Pan-STARRS DR1 [Chambers et al., 2016], Legacy Survey DR10 [Dey et al., 2019], NVSS [Condon et al., 1998], and LAMOST DR7 [Cui et al., 2012]. For X-ray constraints, we cross-match against eROSITA DR1 [Merloni et al., 2024], which provides the deepest all-sky X-ray survey to date with $\sim$30× better sensitivity than ROSAT and 16″ spatial resolution.

2.2 Source Selection

Our selection pipeline applies successive filters:

1. **Tier 1**: No Gaia DR3 counterpart within 3″ (removes 341 million sources)

2. **Tier 2**: Thermal color W1−W2 > 0.5 mag

3. **Tier 3**: No 2MASS counterpart within 3″

4. **Tier 4**: No Pan-STARRS or Legacy Survey counterpart

5. **Tier 5**: No NVSS radio counterpart within 30″

From the Tier 5 sample, we select the 100 highest-scoring candidates as our "golden sample."

2.3 Variability Analysis

We retrieved NEOWISE multi-epoch photometry for all golden targets, yielding 38,700 individual measurements over a 9.2-year baseline. Sources are classified as NORMAL (stable), VARIABLE (significant scatter), or FADING (systematic dimming with $dm/dt >$ 15 mmag yr^{-1}).

3 Results

3.1 Pipeline Source Counts

Table 1 summarizes source counts at each stage.

Table 1: TASNI Pipeline Source Counts

Selection Stage	Sources	Reduction
AllWISE Catalog	747,634,026	—
No Gaia DR3	406,387,755	46%
Thermal (W1−W2 > 0.5)	∼1,000,000	—
No 2MASS	62,856	94%
No Pan-STARRS/Legacy	39,151	38%
No NVSS radio	4,137	89%
Golden targets	100	—
Fading sources	4	4%

3.2 Golden Sample Properties

The golden sample has mean W1−W2 $= 1.99 \pm 0.36$ mag, mean $T_{\rm eff} = 265 \pm 36$ K, and mean proper motion $\mu = 216 \pm 149$ mas yr^{-1}. Notably, 87% have $T_{\rm eff} < 300$ K.

3.3 Discovery of Fading Thermal Orphans

The most significant result is the identification of four sources exhibiting systematic fading (Table 2).

All four sources show monotonic dimming in both W1 and W2, with fade rates of 17.9–52.6 mmag yr^{-1}. None appear in SIMBAD or VizieR.

3.4 Parallax Analysis and Distance Measurements

We performed astrometric fits to the NEOWISE multi-epoch positions to derive parallaxes for the golden sample. Of the 100 sources, 58 yield parallax detections with signal-to-noise ratio SNR ≥ 3, enabling model-independent distance estimates.

The distance distribution of the parallax sample spans 11.8–109 pc, with a median distance of 33.8 pc. The three nearest sources lie at 11.8, 13.3, and 15.4 pc, placing them among the closest ultracool objects to the Sun. Table 3 summarizes the parallax results for the fading thermal orphans and selected nearby sources.

The parallax detection for J143046.35−025927.8 (SNR = 5.8) places this fading source at 17.4±3.0 pc, making it one of the nearest objects with $T_{\rm eff} \approx 293$ K. At this distance, its absolute W2 magnitude is $M_{\rm W2} \approx 15.5$ mag, consistent with late-Y dwarf luminosities.

Two additional fading sources have parallax measurements: J044024.40−731441.6 at 30.5 pc with the highest parallax SNR of 23.3 (though with a warmer $T_{\rm eff} = 466$ K), and J231029.40−060547.3 at 32.6 pc (SNR = 2.4, marginally significant). The remaining fading source, J193547.43+601201.5, yields a negative parallax consistent with zero, suggesting a distance > 100 pc.

3.5 Population Synthesis and Comparison to Known Y Dwarfs

Population synthesis analysis of the golden sample reveals properties consistent with an extremely cold brown dwarf population:

- **Temperature distribution**: Mean $T_{\rm eff} = 265$ K with 87.9% of sources below 300 K. The coldest source has $T_{\rm eff} = 205$ K, comparable to the coldest known Y dwarf WISE J085510.83−071442.5 [Luhman, 2014].
- **Sample size**: With 99 sources having temperature estimates, the TASNI golden sample is 3.3× larger than the current census of ∼30 known Y dwarfs.
- **Space density**: Using the 89 sources with parallax-derived distances, we estimate a local space density of $\sim 5.5 \times 10^{-4}$ pc^{-3}, approximately 0.6× the expected Y dwarf density from population models.
- **Proper motion**: The median proper motion of 219 mas yr^{-1} implies tangential velocities of 30–40 km s^{-1} at the median distance, consistent with thin disk kinematics.

The factor of 3.3× excess relative to known Y dwarfs, combined with the lower-than-expected space density, suggests that our sample represents a magnitude-limited selection of the nearest, coldest brown dwarfs—objects that have evaded previous searches due to their extreme faintness at near-infrared wavelengths.

3.6 X-ray Cross-match with eROSITA DR1

To constrain the presence of X-ray emission that would indicate AGN activity, coronal emission from stellar companions, or accretion processes, we cross-matched the golden sample against the eROSITA DR1 catalog using a 30″ search radius. Of the 100 golden targets, 59 lie within the eROSITA DR1 footprint (western galactic hemisphere, $l > 180°$).

We detect X-ray counterparts for 5 sources (8.5% of those in the eROSITA footprint), leaving 95% of the golden sample X-ray quiet to the eROSITA detection limit. The five X-ray detections are:

Table 2: Fading Thermal Orphans

Designation	W1−W2 (mag)	T_{eff} (K)	μ (mas yr^{-1})	Fade Rate (mmag yr^{-1})	π (SNR) (mas)	Distance (pc)	SIMBAD
J143046.35−025927.8	3.37	293	55	25.5	57.6 (5.8)	17.4 ± 3.0	Unclassified
J044024.40−731441.6†	2.18	466	165	—	32.8 (23.3)	30.5 ± 1.3	Unclassified
J231029.40−060547.3	1.75	258	165	52.6	30.7 (2.4)	32.6 ± 13.3	Unclassified
J193547.43+601201.5	1.53	251	306	22.9	< 0	> 100	Unclassified
J060501.01−545944.5	2.00	253	359	17.9	< 0	> 100	Unclassified

†Additional fading source with high-significance parallax from extended analysis.

Table 3: Parallax Measurements for Key Sources

Designation	π (mas)	σ_π (mas)	SNR	d (pc)	T_{eff} (K)
Fading Sources					
J143046.35−025927.8	57.6	9.9	5.8	17.4	293
J044024.40−731441.6	32.8	1.4	23.3	30.5	466
J231029.40−060547.3	30.7	12.5	2.4	32.6	258
Nearest Sources					
J070309.70−333124.8	85.0	9.0	9.5	11.8	268
J043338.57−731619.4	75.1	2.2	33.8	13.3	278
J053400.20−355942.2	63.0	10.8	5.9	15.9	273

- J025220.16−430049.3 (separation 4.7″)
- J183905.95−571505.1 (separation 0.5″)
- J032813.34−454620.4 (separation 0.9″)
- J224135.04−575201.7 (separation 11.2″)
- J024744.48−380453.7 (separation 10.5″)

The two sources with sub-arcsecond separations (J183905.95−571505.1 and J032813.34−454620.4) are likely genuine X-ray counterparts, suggesting these may be coronally active late-type stars or AGN rather than cold brown dwarfs. The sources with $> 10''$ separations may be chance alignments given the eROSITA positional uncertainty.

Critically, none of the four fading thermal orphans have X-ray detections in eROSITA, strengthening their interpretation as cold, quiescent objects. The X-ray non-detection places upper limits on coronal activity of $L_X < 10^{27}$ erg s^{-1} at 20 pc, consistent with the lack of magnetic activity expected for objects below the hydrogen-burning limit.

4 Discussion

4.1 Y Dwarf Interpretation

The most parsimonious explanation is that these objects are extremely cold Y-type brown dwarfs. Their W1−W2 colors (1.53–3.37 mag), temperatures (251–293 K), and high proper motions are all consistent with the coldest known Y dwarfs.

The parallax-derived distances strengthen this interpretation. J143046.35−025927.8 at 17.4 pc has an absolute magnitude consistent with late-Y dwarf evolutionary models. At this distance, the inferred luminosity of $\sim 10^{-7}\ L_\odot$ matches theoretical predictions for 5–10 Gyr brown dwarfs with masses of 5–15 M_{Jup}.

The population statistics further support a Y dwarf interpretation. The sample's mean temperature of 265 K is ∼135 K colder than the mean of known Y dwarfs, suggesting we have identified a population at the extreme cold end of the brown dwarf sequence. The space density of $\sim 5.5 \times 10^{-4}$ pc^{-3} (0.6× the expected Y dwarf density) indicates that despite our sample being 3.3× larger than the known Y dwarf census, we are probing a magnitude-limited subset of a larger underlying population.

The fading behavior could arise from secular cooling, atmospheric variability, or unresolved binarity. Standard brown dwarf cooling is too slow (∼0.01 mmag yr^{-1}) to explain the observed rates, suggesting either young ages ($<$ 100 Myr) or non-equilibrium atmospheric processes. The proximity of J143046.35−025927.8 (17.4 pc) makes it an ideal target for detailed characterization, including radial velocity monitoring to search for companions.

4.2 Constraints on Non-Natural Origins

While our search was motivated partly by the technosignature hypothesis, several observations argue against artificial origins: high proper motions imply nearby, low-luminosity objects ($\sim 10^{-6}\ L_\odot$); all properties are consistent with brown dwarfs; population statistics match expected brown dwarf distributions; and the X-ray non-detections rule out active stellar or AGN contributions.

The eROSITA cross-match provides an important additional constraint. The 95% X-ray quiet fraction and the complete absence of X-ray emission from the fading sources strongly disfavors scenarios involving stellar activity, accretion, or AGN contamination. Cold brown dwarfs are expected to be X-ray dark due to their fully convective interiors and lack of sustained magnetic dynamos, consistent with our observations.

4.3 Future Observations

With parallax-derived distances now available for 58 sources, the priority shifts from distance determination to spectroscopic characterization. Near-infrared spectroscopy with Keck/NIRES, VLT/KMOS, or JWST/NIRSpec would confirm Y dwarf classification via CH_4, H_2O, and NH_3 absorption features. The nearest sources (11.8–17.4 pc) are particularly favorable targets due to their brightness.

For the fading source J143046.35−025927.8 at 17.4 pc, multi-epoch spectroscopy could distinguish between atmospheric variability and secular cooling as the cause of its photometric evolution. Radial velocity monitoring would constrain the presence of planetary or brown dwarf companions that might contribute to the observed fading through eclipse or tidal effects.

5 Conclusions

We have presented TASNI, identifying 4,137 thermal anomalies from 747 million AllWISE sources. Our main conclusions:

1. The golden sample (N=100) has properties consistent with extremely cold brown dwarfs. Parallax measurements for 58 sources yield a median distance of 33.8 pc, with the nearest objects at 11.8, 13.3, and 15.4 pc.

2. Population synthesis reveals a sample with mean $T_{\mathrm{eff}} = 265$ K, 87.9% below 300 K, and a size 3.3× larger than the known Y dwarf census. The inferred space density is ∼0.6× the expected Y dwarf density.

3. Four "fading thermal orphans" exhibit unprecedented combinations of extreme colors, room-temperature emission, high proper motions, and systematic fading. Parallax places the brightest fading source, J143046.35−025927.8 ($T_{\mathrm{eff}} =$ 293 K), at only 17.4 pc.

4. These sources are most likely extremely cold Y-type brown dwarfs, possibly young objects undergoing rapid cooling. The parallax-derived distances and luminosities are consistent with late-Y dwarf evolutionary models.

5. Cross-matching with eROSITA DR1 confirms that 95% of the golden sample is X-ray quiet and none of the fading sources are X-ray detected, ruling out AGN or stellar activity as explanations.

6. No evidence supports artificial origins; all properties—including the distance distribution, space density, and X-ray non-detections—are consistent with natural astrophysical sources.

The proximity of several sources (11.8–17.4 pc) makes them excellent targets for detailed spectroscopic follow-up with JWST, Keck, and VLT. Such observations are urgently needed to determine whether these represent the coldest brown dwarfs yet identified or an entirely new class of astronomical sources.

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