

Infrared surveys to search for high proper motion stars

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Abstract

There are restrictions on the nature and characteristics of nearby brown dwarfs (including hypothetical component of the Sun), imposed by the current results of the work of the Gaia space observatory. In particular, even close brown dwarfs of spectral type Y3 and colder will go unnoticed by the Gaia observatory, although they may well be already included in infrared survey catalogues. Here we present information on modern infrared surveys, which can be used for a search for such objects.

Keywords: *brown dwarfs, infrared photometric surveys*

1. Introduction

Results of the work of the Gaia space observatory (Gaia Collaboration et al., 2016, 2022) impose certain restrictions on the nature and location of nearby brown dwarfs (including hypothetical component of the Sun). The fact that the companion is not registered by the observatory leaves the following marginal possibilities: a cool brown dwarf (Y3 and later) in an orbit inside the Oort cloud, or an L/T brown dwarf in a higher orbit (from 10^5 AU). At the same time, the companion is quite likely cataloged in the 2MASS, WISE or other infrared surveys. In particular, it was shown (Malkov, 2023) that such an object should demonstrate a noticeable proper motion – units or tens of arc seconds per year. In the next Section we present information on modern infrared surveys, which can be used for a search for such objects. The last Section contains conclusions.

2. Infrared Missions

2.1. Two Micron All Sky Survey

2MASS (Cutri & et al, 2003) was held between 1997 - 2001 using two telescopes in order to cover both Northern and Southern hemispheres, resulting in the All-Sky Data Release. It's products include a Point Source Catalog, containing positions and photometry for more than 4.7 billion objects. The sky was observed in bands J ($1.24 \mu\text{m}$), H ($1.66 \mu\text{m}$), and K_S ($2.16 \mu\text{m}$) with limits of 15.8^m , 15.1^m , 14.3^m respectively.

2.2. Wide-field Infrared Survey Explorer

WISE (Cutri & et al, 2014) is an imaging survey in the W1 ($3.4 \mu\text{m}$), W2 ($4.6 \mu\text{m}$), W3 ($12 \mu\text{m}$) and W4 ($22 \mu\text{m}$) mid-infrared bands. The WISE All-Sky Data Release includes data taken in 2010 and covers >99 percent of the sky with total of ~ 0.56 billion sources detected. Limiting magnitudes are W1: 17.30^m , W2: 15.84^m , W3: 11.59^m , W4: 8.0^m .

2.3. Deep Near-Infrared Survey

DENIS project (DENIS Consortium, 2005) surveyed all-southern sky in three wavelength bands: Gunn-i ($0.82 \mu\text{m}$), J ($1.25 \mu\text{m}$), and K_S ($2.15 \mu\text{m}$) with limiting magnitudes 18.5^m , 16.5^m and 14.0^m , respectively. Observations were carried out between 1995 and 2001 and the third release of DENIS data consists of 355,220,325 point sources.

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2.4. Infrared Astronomical Satellite mission

IRAS (Neugebauer et al., 1984) was launched in space in 1983 and was the pioneering mission produced the first maps of the entire sky (95 percent) at four infrared wavelengths: 12 μm , 25 μm , 60 μm and 100 μm . IRAS Catalog of Point Sources contains about 250000 well-confirmed objects.

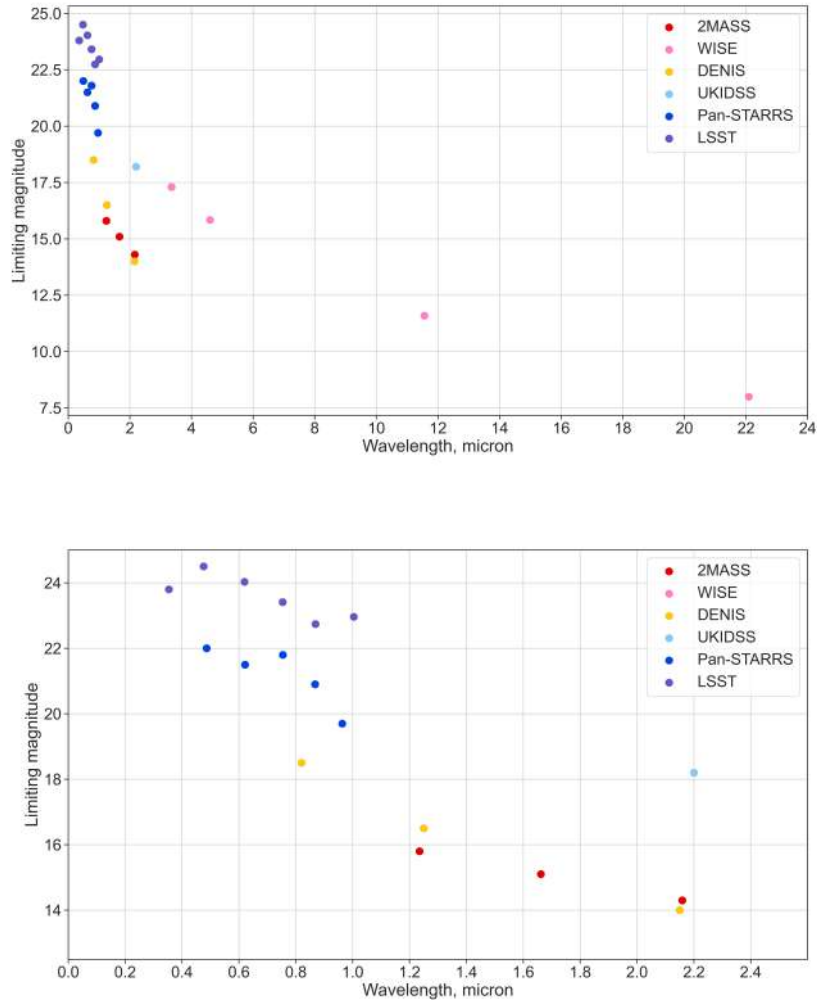


Figure 1. Limiting magnitudes for surveys' bandpasses. Every dot responds to a center of band in micrometers. The bottom picture highlights the left part of the top figure.

2.5. UKIRT Infrared Deep Sky Survey

UKIDSS (Lawrence & et al, 2007) is a set of surveys conducted on the United Kingdom Infra-red Telescope (UKIRT) which began in 2005. Covering 7500 square degrees of the Northern sky, UKIDSS Release 9 contains around 140 million sources. Survey utilizes four bands: Y (1.0 μm) J (1.2 μm) H (1.6 μm) and K (2.2 μm) with limit of K = 18.4^m.

2.6. The Panoramic Survey Telescope & Rapid Response System

Pan-STARRS (Chambers & et al, 2016) is a system for wide-field sky imaging in five bands: g (0.4866 μm), r (0.6215 μm), i (0.7545 μm), z (0.8679 μm), y (0.9633 μm) with depths of 23.3, 23.2, 23.1, 22.3 and 21.3 respectively. The Pan-STARRS release 1 (PS1) covers 30000 square degrees, containing more than 1.9 billion sources.

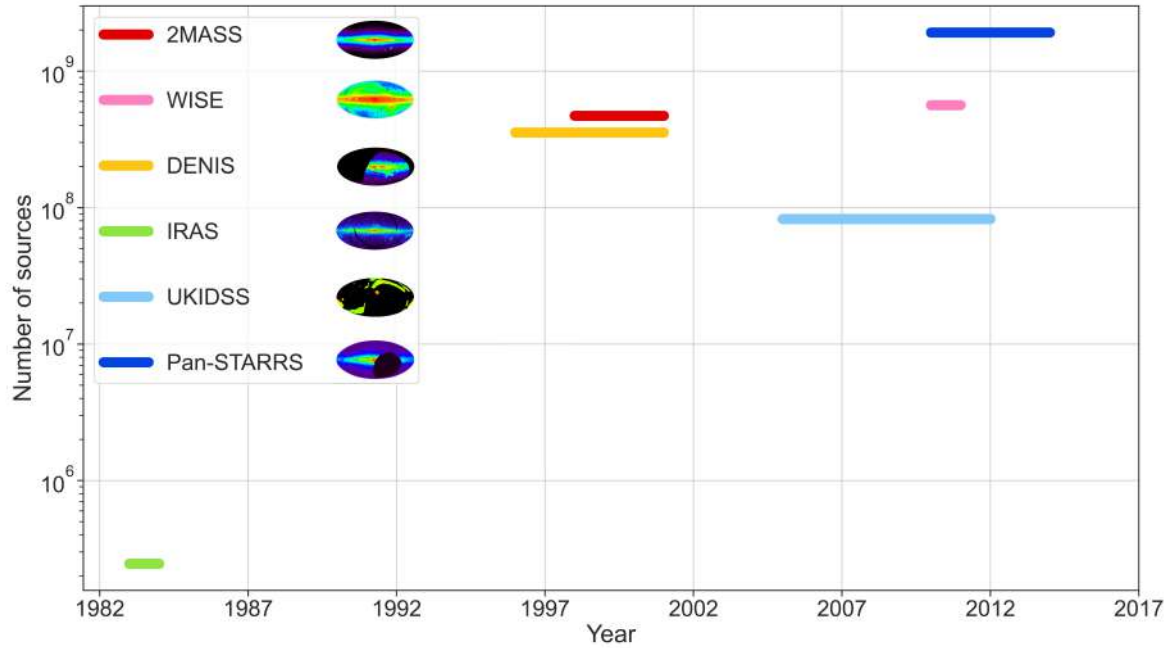


Figure 2. Number of detected sources for completed missions.

2.7. Large Synoptic Survey Telescope

LSST (Ivezić et al., 2019) is upcoming survey. It will observe 18000 square degrees area, resulting in about 32 trillion observations of 20 billion galaxies and stars. Observations will be carried out in six bands: u (0.3539 μm), g (0.47595 μm), r (0.6197 μm), i (0.75385 μm), z (0.86925 μm), y (1.00375 μm). Limiting magnitudes are u: 23.8^m, g: 24.5^m, r: 24.03^m, i: 23.41^m, z: 22.74^m, y: 22.96^m.

Table 1. Surveys description

Survey	Number of sources	Sky coverage	Epoch years
2MASS	470992970	95%	1998-2001
WISE	563921584	>99%	2010
DENIS	355220325	~16700 sq. degs	1996-2001
IRAS	245889	>96%	1983
UKIDSS	82655526	4000 sq. degs	2005-2012
Pan-STARRS	1919106885	30000 sq. degs	2010-2014
LSST	-	18000 sq. degs	2022-2032

Table 2. Surveys description: photometry

Survey	Passbands wavelengths μm	Limit magnitude mag
2MASS	J: 1.235, H: 1.662, K_s : 2.159	J: 15.8, H: 15.1, K_s : 14.3
WISE	W1: 3.35, W2: 4.60, W3: 11.56, W4: 22.09	W1: 17.30, W2: 15.84, W3: 11.59, W4: 8.0
DENIS	Gunn-i: 0.82, J: 1.25, K_s : 2.15	Gunn-i: 18.5, J: 16.5, K_s : 14.0
IRAS	12, 25, 60, 100	
UKIDSS	Y: 1.02, J: 1.25, H: 1.63, K: 2.20, H2: 2.12	K: 18.2
Pan-STARRS	g: 0.4866, r: 0.6215, i: 0.7545, z: 0.8679, y: 0.9633	g: 22.0, r: 21.8, i: 21.5, z: 20.9, y: 19.7
LSST	u: 0.3539, g: 0.47595, r: 0.6197, i: 0.75385, z: 0.86925, y: 1.00375	u: 23.8, g: 24.5, r: 24.03, i: 23.41, z: 22.74, y: 22.96

3. Conclusion

This paper presents information on modern photometric infrared surveys (2MASS, WISE, DENIS, IRAS, UKIDSS, Pan-STARRS, LSST) that can be used to find high proper motion stars. Here we give information about the number of objects in the surveys, sky coverage, epoch of observations and photometric bands.

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