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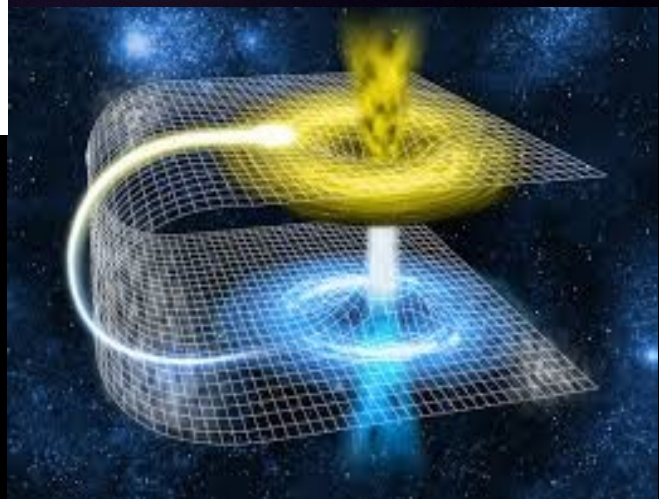
The VASCO mission: Searches for Vanishing Stars with Gaia

Beatriz Villarroel

Department of Physics & Astronomy /
Center of Interdisciplinary Mathematics, Uppsala University

Searching for Extraterrestrial Intelligence



Traditional and direct SETI

- Searching for clear signals of communication
- Necessary for confirmation
- + Accurate
- - Costly

SEARCHING FOR INTERSTELLAR COMMUNICATIONS

By GIUSEPPE COCCONI* and PHILIP MORRISON†
Cornell University, Ithaca, New York

NO theories yet exist which enable a reliable estimate of the probabilities of (1) planet formation ; (2) origin of life ; (3) evolution of societies possessing advanced scientific capabilities. In the absence of such theories, our environment suggests that stars of the main sequence with a lifetime of many billions of years can possess planets, that of a small set of such planets two (Earth and very probably Mars) support life, that life on one such planet includes a society recently capable of considerable scientific investigation. The lifetime of such societies is not known ; but it seems unwarranted to deny that among such societies some might maintain themselves for times very long compared to the time of human history, perhaps for times comparable with geological time. It follows, then, that near some star rather like the Sun there are civilizations with scientific interests and with technical possibilities much greater than those now available to us.

* Now on leave at CERN, Geneva.
† Now on leave at the Imperial College of Science and Technology, London, S.W.7.

To the beings of such a society, our Sun must appear as a likely site for the evolution of a new society. It is highly probable that for a long time they will have been expecting the development of science near the Sun. We shall assume that long ago they established a channel of communication that would one day become known to us, and that they look forward patiently to the answering signals from the Sun which would make known to them that a new society has entered the community of intelligence. What sort of a channel would it be ?

The Optimum Channel

Interstellar communication across the galactic plasma without dispersion in direction and flight-time is practical, so far as we know, only with electromagnetic waves.

Since the object of those who operate the source is to find a newly evolved society, we may presume that the channel used will be one that places a minimum burden of frequency and angular discrimi-

The 21 cm line

No. 4772 April 15, 1961 NATURE 205

INTERSTELLAR AND INTERPLANETARY COMMUNICATION BY OPTICAL MASERS

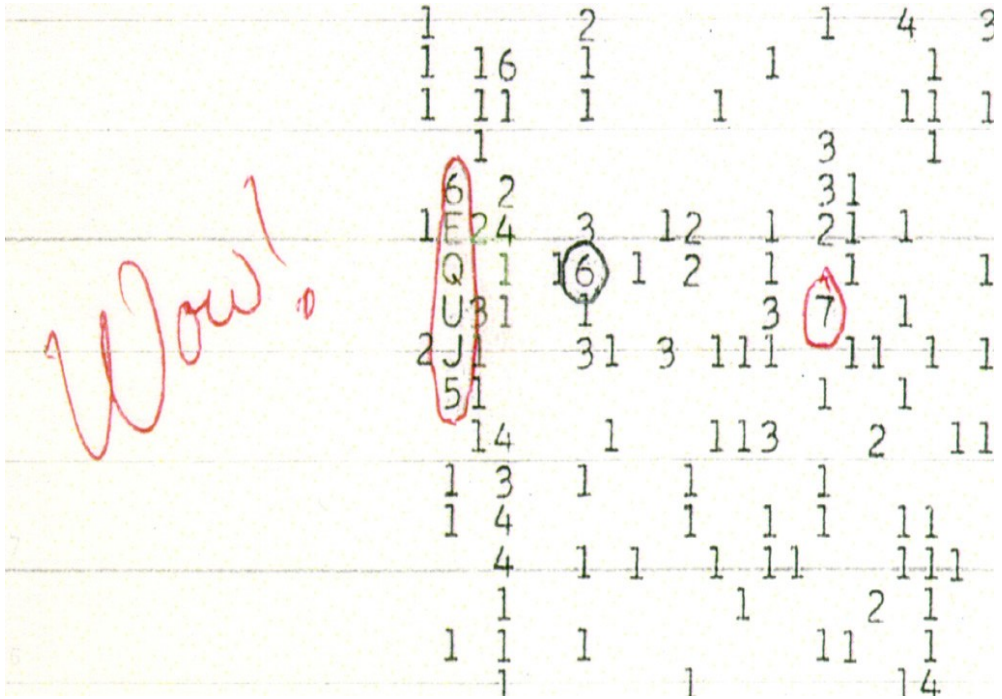
By Dr. R. N. SCHWARTZ and Prof. C. H. TOWNES*
Institute for Defense Analyses, Washington, D.C.

LONG-RANGE communication by radio-waves is already well known, and the possibility of interstellar communication by radio-waves in the microwave region has been suggested in several interesting proposals[1–3] to search for signals from intelligent beings on planets associated with nearby stars. The supposition is that curiosity such as our own would motivate advanced civilizations associated with stars other than our Sun to make determined efforts to communicate with whatever other intelligent life

frequency-interval of about 10 kilocycles per sec.[7]. The latter case is much closer to theoretical expectations[4] for an ideal maser in so far as coherence is concerned. There seems to be no general reason, other than the necessary dissipation of power, why solid-state optical masers cannot operate continuously at high power and with a short-term monochromaticity close to theoretical expectations, or hence with frequency-widths very much less than 1 megacycle/sec.

Laser pulses

WOW signal



- 15th of August 1977
- From Sagittarius
- 72 seconds long
- Strong narrow-band signal

Prof. Jocelyn Bell – discoverer of pulsars (also known as Green Little Men)

Searching for astro-engineering (pro)

- Dyson spheres or Dyson swarms (Slysh 1985, Annis 1999, Timofeev et al. 2000, Jugaku & Nishimura 2004, Carrigan 2009).
- Galaxies full of hypothetical Dyson spheres (Wright et al. 2014, 2015; Zackrisson et al. 2015).
- Outliers in big datasets, e.g. the light curve of Tabby's Star.

- **Plus: Inexpensive and efficient for finding SETI targets. Finds also interesting astrophysical outliers.**

Searching for astro-engineering (cons)

- Difficult to estimate probabilities to natural events poorly described by theory.

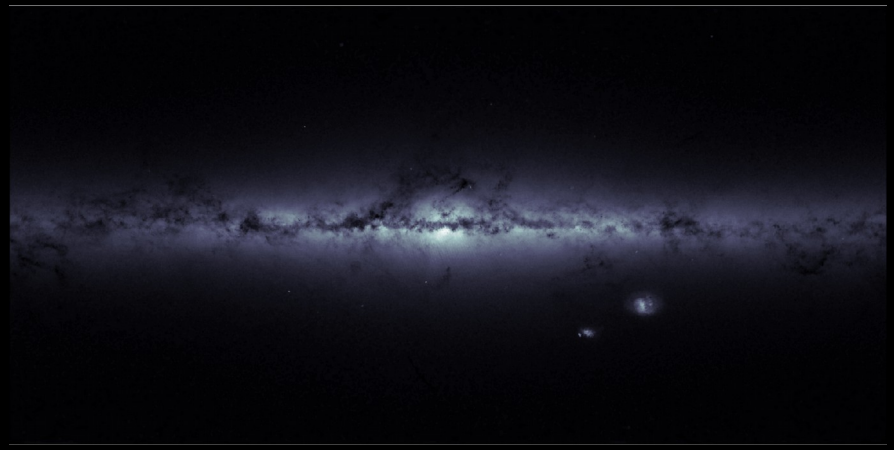
- Difficult to separate extreme astrophysics (e.g. obscured AGN) from artificial signatures. **Better theories needed.**

- Just because we can't explain the behaviour, doesn't mean it is any unknown or unusual physics.

Let's turn it around… instead of possible effects of alien engineering in large data sets – search for *impossible* effects for conventional astrophysics.

>> New astrophysics, or, ETs!

Vanishing stars & Advanced extraterrestrial intelligence: Searches by Comparing Observations (VASCO)



Team of explorers

- Josefine Bergstedt, Uppsala Universitet
- Dr. Bart Buelens, Methodology Department of Statistics (Netherlands)
- Iñigo Imaz, Uppsala Universitet
- Dr. Torgny Karlsson, Uppsala Universitet
- Dr. Lars Mattsson, Nordita (Stockholm)
- Dr. Joakim Munkhammar, Uppsala Universitet
- Dr. Rafael de Souza, Eötvös Loránd University
- Beatriz Villarroel, Uppsala Universitet (project lead)
- Dr. Erik Zackrisson, Uppsala Universitet

Vanishing galaxies & Milky Way stars

- Objects that disappear **without a trace.**
- Eventual variable objects will be found with reobservations.
- **Candidate + its neighbourhood: good SETI targets.**

Other scientific opportunities I. The AGN Unification

- The AGN Unification theory explains how Type-1 and Type-2 AGN are the same objects viewed through different angles through torus.
- **The AGN Unification is, however, wrong. Evolution?**

nature physics

LETTERS

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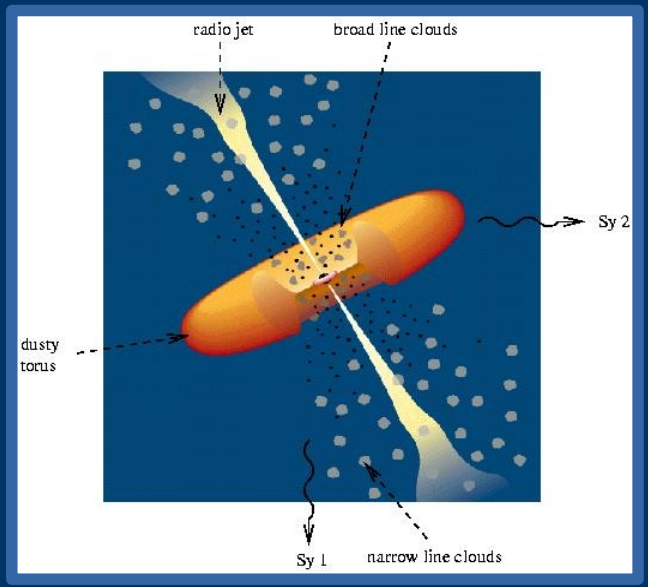
The different neighbours around Type-1 and Type-2 active galactic nuclei

Beatriz Villarroel[1,2*] and Andreas J. Korn[1]

One of the most intriguing open issues in galaxy evolution is the structure and evolution of active galactic nuclei (AGN) that emit intense light believed to come from an accretion disk near a super massive black hole[1,2]. To understand the zoo of different AGN classes, it has been suggested that all AGN are the same type of object viewed from different angles[3]. This model—called AGN unification—has been successful in

So are Type-1 and Type-2 AGN truly representing the same kind of object?

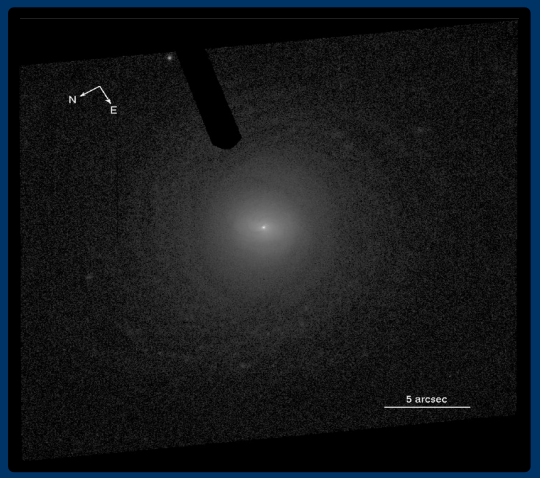
The main idea of our hypothesis is that if Type-1 and Type-2 AGN are intrinsically the same objects, only viewed from different angles, their neighbours should, in a statistical sense, not differ systematically. On top of this, the AGN should interact in similar ways with them.

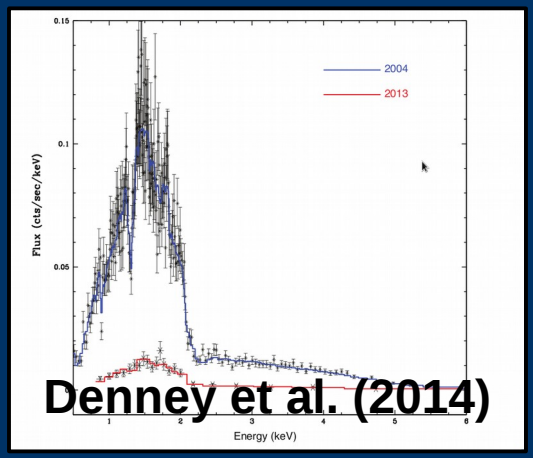


Other scientific opportunities I. The AGN Unification

- Very variable on short time-scales (months-years).
- Switch between Type-1 and Type-2.
- Why? Dust obscuration or TDEs not the cause! (LaMassa et al. 2015, Husemann et al. 2016)
- Might defy both **unification** AND **evolution theories** *(e.g. Denney et al. 2014, LaMassa et al. 2015, Koay et al. 2015)*
- The most extreme are the faintest, often near the detection limit.
- **Might "disappear" in a survey but will be found with a more powerful telescope.**

Mrk 590





Denney et al. (2014)

Other scientific opportunities II. Hypothetical “failed supernovae”

- So far, a hypothetical idea. First “confirmation” made a few weeks ago by Adams et al. (2016).
- A fraction of core-collapse Sne from progenitors of mass range M ~ 18 - 25 are “failed” – no supernova is seen and the star collapses “directly” into a black hole.
- Estimated rate of failed supernovae in Milky Way is once every 150 – 300 years (Gerke et al. 2014).
- Will emit neutrinos (IceCube archives) and gravitational waves (LIGO).
- **Gaia can reveal the whole process.**

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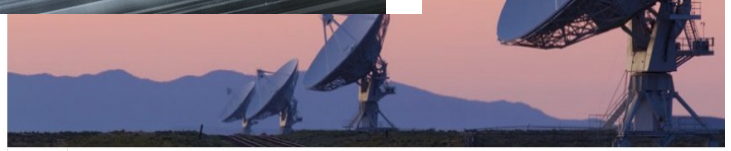
DAILY NEWS 1 July 2016

Impossible vanishing stars could be signs of advanced alien life



Answers › Blogs › Ken Ham › Can Vanishing Stars Point to Alien Civilizations?

Can Vanishing Stars Point to Alien Civilizations?

by Ken Ham on July 24, 2016

It seems every week there's a new study regarding supposed alien life in outer space and yet another possibility of how we can find these elusive supposed beings. The newest attempt to find advanced alien civilizations involves looking into our universe for vanishing stars. The thought behind this method, proposed by a team of scientists from Uppsala University in Sweden, is that "perhaps . . . [the aliens are] harnessing energy from it using a Dyson sphere—a ball of solar panels around the star that blocks the light from our telescopes. Or maybe the aliens would want to hide

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OUR SKY NOW AND THEN: SEARCHES FOR LOST STARS AND IMPOSSIBLE EFFECTS AS PROBES OF ADVANCED EXTRATERRESTRIAL CIVILIZATIONS

BEATRIZ VILLARROEL, INIGO IMAZ, AND JOSEFINE BERGSTEDT
Department of Physics and Astronomy, Uppsala University, Box 516, SE-751 20 Uppsala, Sweden;
beatriz.villarroel@physics.uu.se

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ABSTRACT

Searches for extraterrestrial intelligence using large survey data often look for possible signatures of astroengineering. We propose searching for physically impossible effects caused by highly advanced technology by carrying out a search for disappearing galaxies and Milky Way stars. We select ~10 million objects from USNO-B1.0 with low proper motions ($\mu < 20$ mas yr^{-1}) imaged on the sky in two epochs. We search for objects not found at the expected positions in the Sloan Digital Sky Survey (SDSS) by visually examining images of ~290,000 USNO-B1.0 objects with no counterpart in the SDSS. We identify some spurious targets in the USNO-B1.0. We find one candidate of interest for follow-up photometry, although it is very uncertain. If the candidate eventually is found, it defines the probability of observing a disappearing-object event in the last decade to less than one in one million in the given samples. Nevertheless, because the complete USNO-B1.0 data set is 100 times larger than any of our samples, we propose an easily accessible citizen science project in search of USNO-B1.0 objects that have disappeared from the SDSS.

Key words: astrobiology – extraterrestrial intelligence – surveys

1. INTRODUCTION

The possibility of finding intelligent life beyond our own planet is an ongoing dream. So far, we have not seen or heard the slighest hint. Efforts to search for indirect signatures of astroengineering from extraterrestrial civilizations in survey data are currently expanding and these searches often make use of large data sets. Such studies have the advantage that they can yield new insights into important astrophysical phenomena as an exciting by-product. Some of these efforts have targeted stars in the Milky Way (e.g., Jugaku & Nishimura 1991; Timofeev et al. 2000), while others have turned to extragalactic scales (e.g., Annis 1999; Wright et al. 2014a, 2014b; Griffith et al. 2015). Assuming that all advanced Kardashev II-IV civilizations (Kardashev 1964) attempt to build Dyson spheres (Dyson 1960) throughout their galaxy to harvest energy from stars, a significant fraction of the waste heat from the Dyson spheres will be irradiated as mid-infrared emission. When looking for high-consuming alien civilizations producing a waste-heat luminosity of $\sim 10^{11}$ $L_{\odot}$ from each galaxy, it was shown with *Wide-field Infrared Survey* (*WISE*) data (Wright et al. 2010) that such super civilizations must be extremely rare (Wright et al. 2014b). Recent studies using other methods (Zackrisson et al. 2015; Lacki 2016; Olson 2016) support the conclusion that Kardashev II-IV civilizations in the local universe are very rare and difficult to find. The difficulty to distinguish between mundane causes and the signatures of astroengineering, further complicate the searches.

In this paper, we propose replacing the search for possible signatures of astroengineering with a search for impossible (or nearly impossible) effects for conventional astrophysics. Quoting Arthur C. Clarke's Third Law, "Any sufficiently advanced technology is indistinguishable from magic." Exam-

supernovae is equally interesting and can indicate the existence of an advanced extraterrestrial civilization with an interest in hiding a star from their enemy. However, it can also point toward unknown or exotic physics, like stars disappearing into wormholes.

We perform a search for objects lost from our sky over the last decades. A similar idea of constructing an anti-transient survey of stars in nearby galaxies to search for the hypothesized failed supernovae from massive stars, was originally proposed by Kochanek et al. (2008), and later also carried out by Gerke et al. (2014). Failed supernovae can only happen to stars within the mass range of 18–25 solar masses and are significantly less common than optically bright supernovae. In 2015, two candidates for failed supernovae were detected (Reynolds et al. 2015) in nearby galaxies. It should be noted that not a single supernova in the Milky Way has been detected in the last 150 years; therefore, the number of failed supernovae should be zero.

In this paper, we conduct a study and present results from a search for advanced extraterrestrial civilizations by looking for objects that mysteriously disappeared from the sky in the last decade. We use the United States Naval Observatory (USNO) B1.0 catalog (Monet et al. 2003), which stores information about roughly one billion objects and is complete down to $v \sim 21$. The USNO-B1.0 objects have negligible proper motion (<20 mas yr^{-1}) and were all detected during at least two epochs in the Palomar Observatory Sky Survey (first POSS survey: 1950–1966; second POSS survey: 1977–1999) before being included in the catalog. This minimizes detections of asteroids, comets, fast-moving objects, and chance detections. Afterward, we match these objects against a third epoch using the Sloan Digital Sky Survey (SDSS; York et al. 2000) and

Villarroel, Imaz & Bergstedt, 2016, Astronomical Journal, 152, 76

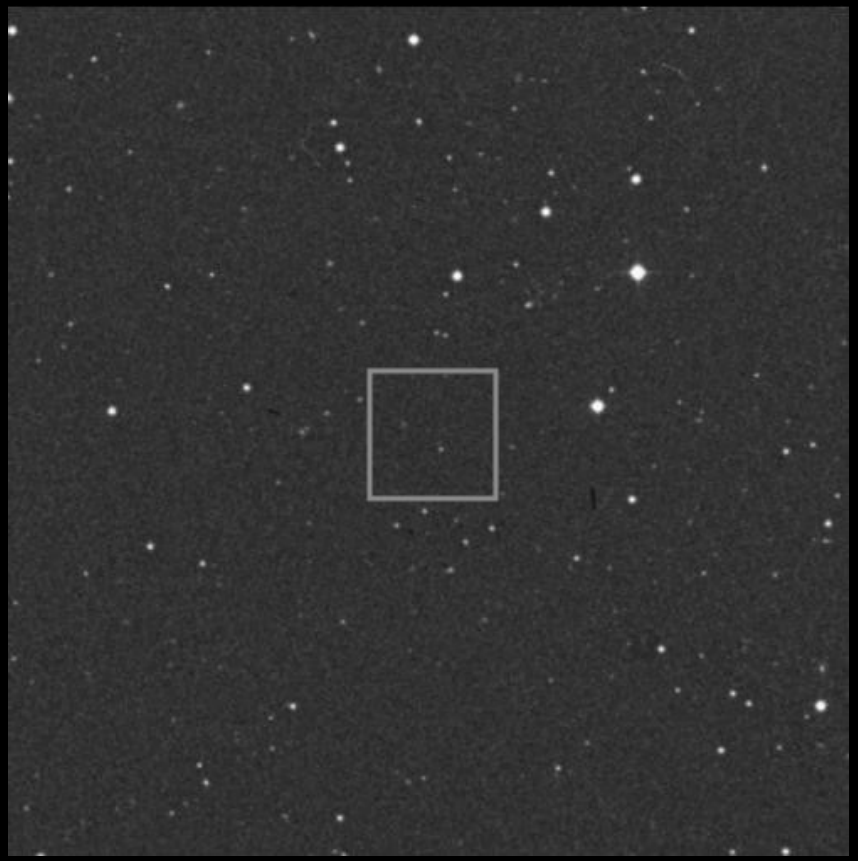
USNO catalogue

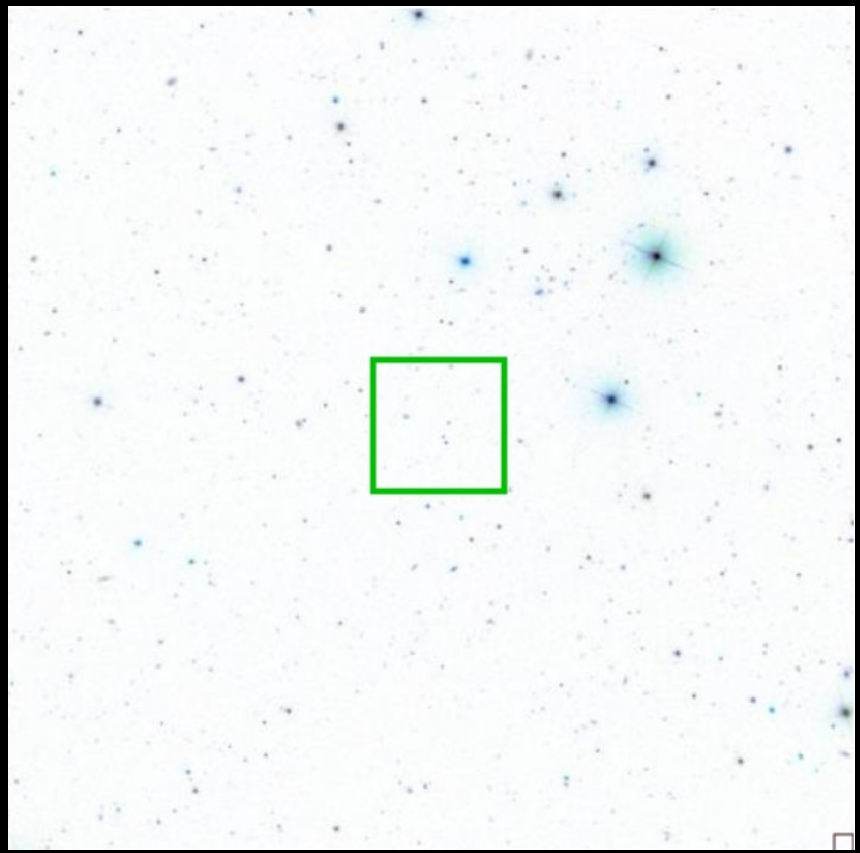
- Photographic plates from POSS survey 1 & 2
- Epoch 1 (1949-1966, epoch 2: 1977-1999)
- Limit “r ~ 20”
- Every object was **detected in, at least, two different epochs.**
- **We use objects with low/no proper motion** (< 20 mas/year) and exclude comets, asteroids and nearby stars.

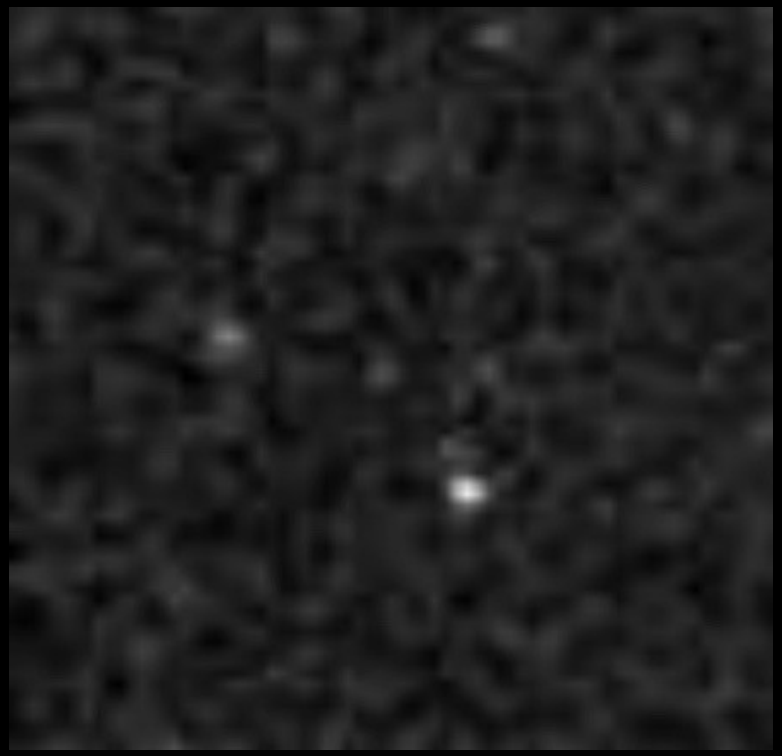
SDSS catalogue

- Modern (started in 2000)
- CCD plates
- Limit “r ~ 23”
- Has a function that shows all objects within 0.2 arcmin from given coordinate.
- Only use objects within SDSS detection.
- About 290 000 images to examine.

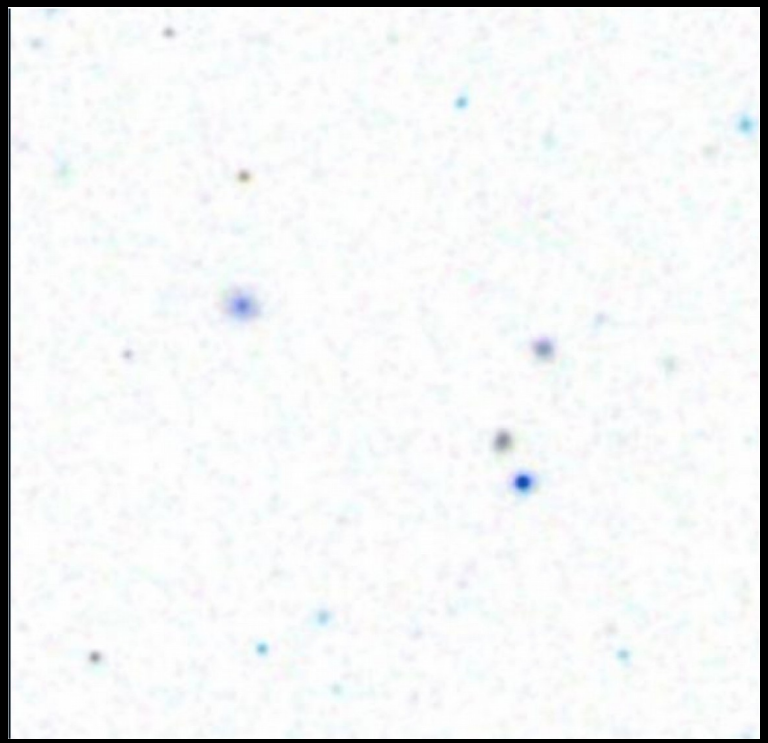
A **dubious** candidate







POSS-1 (pic from 1950s)



SDSS (after 2000)

Follow-up observations

- POSS2 detection is **very faint.** Reanalysis of original POSS1 and POSS2 images needed (false positive?).

- Planned observations with 3.6m Devasthal Optical/IR Telescope (of ARIES) in India led by **Dr. Alok Gupta**.

Dr. Alok Gupta

- Extreme variables will be found upon reobservation.

Plans: going full-scale with Gaia

- Previous trial: we checked ~ 10 million objects.
- Must include proper motions: accurate astrometry needed.
- We want to target **1 billion stars**.
- Gaia monitors targets ~ 70 times during 5 years.
- We will apply for money.

Three main missions

- Comparing Gaia data to USNO data:
  - Pilot project once DR2 is out.
- Comparing different epochs within Gaia.
  - Pilot project once DR2 is out.
  - Predicting the number variable objects near the detection limit in Gaia.
- Can we automatize the detection of vanishing stars in Gaia? (Help from Gaia Alerts?)

Conclusions

- Searching for vanishing stars is a new way of looking for ET.
- Gaia has the data needed for our mission.
- Valuable (and cool) side results are expected: extreme AGN, perhaps failed supernovae. Or new physics?
- With appropriate data processing methods, also the Large Synoptic Sky Survey could discover some **anti-transients**.

Thanks for your attention!