



Astrophysics with Low Dispersion Spectra, ESA Gaia, and Inheritance of NASA Astronaut Karl Henize

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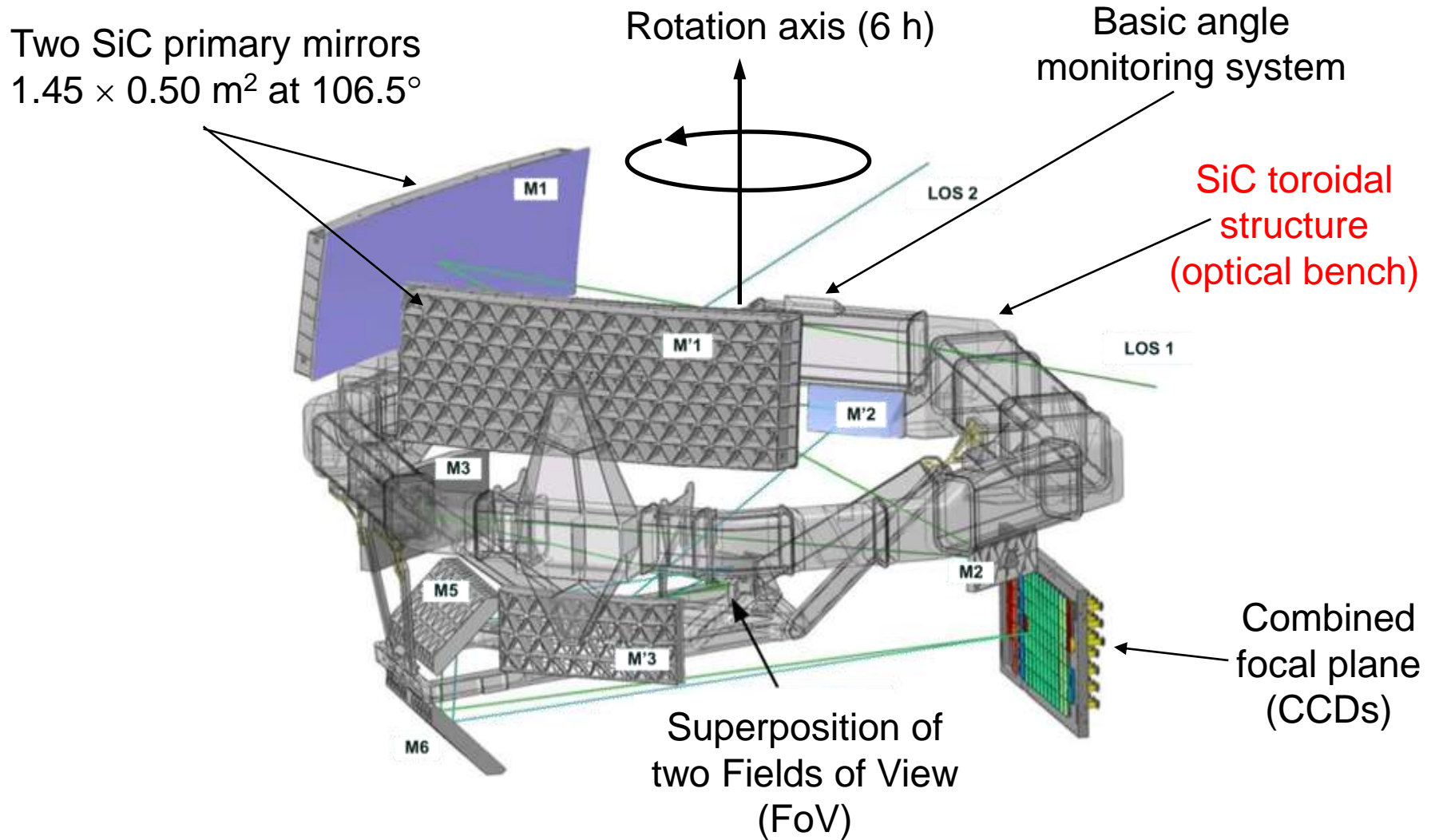
PARI, Pisgah Astronomical Research Institute

Rosman, NC, USA

Reference: <http://sci.esa.int/gaia/>

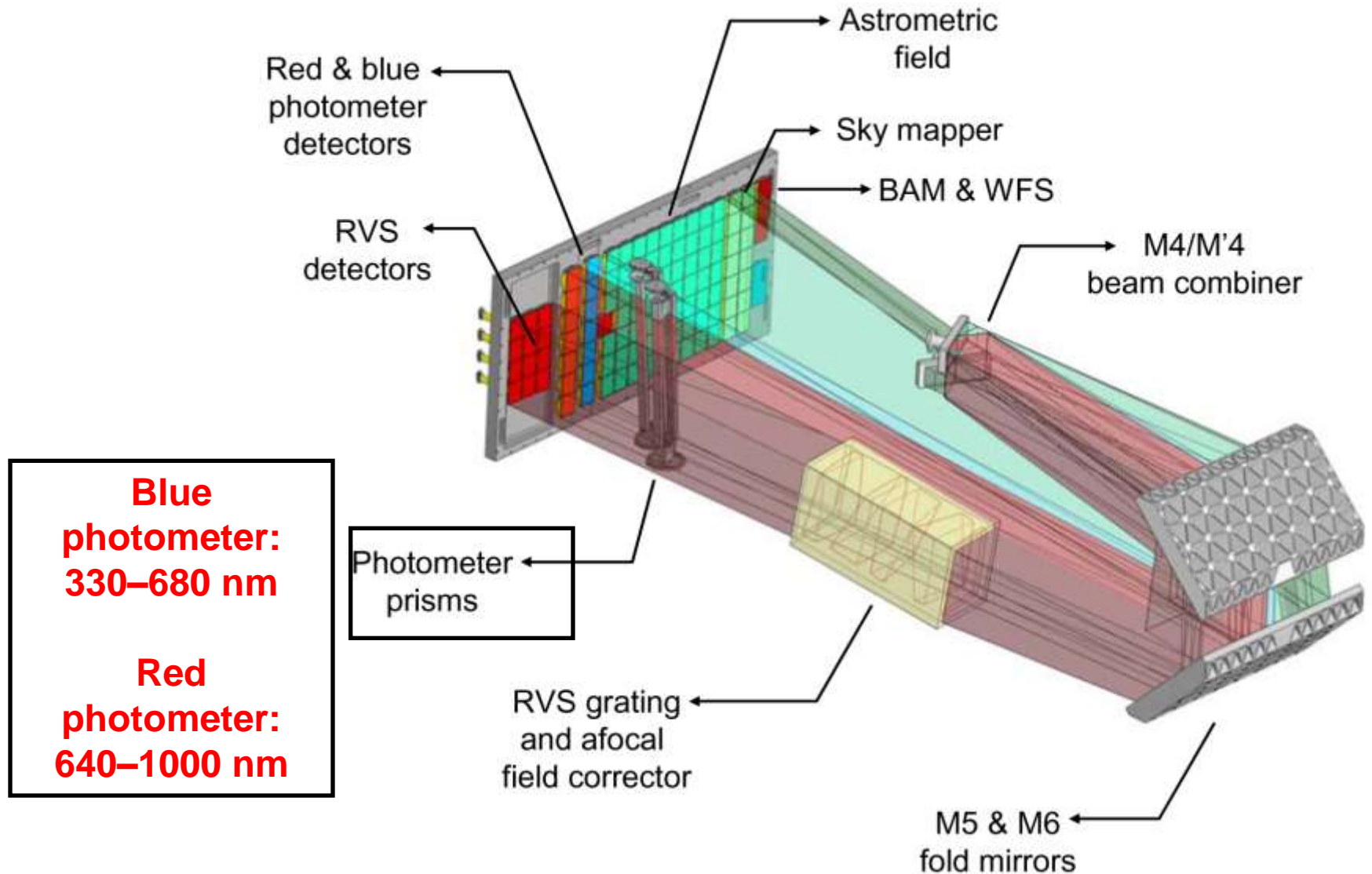
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Gaia Payload and Telescope



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Photometry Measurement Concept

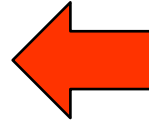


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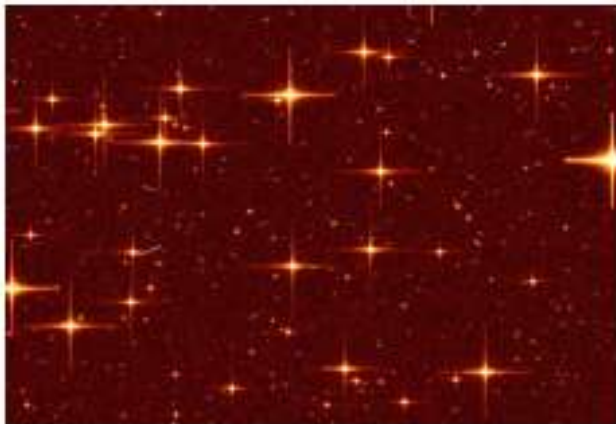
The Three Modes of Gaia

astrometry

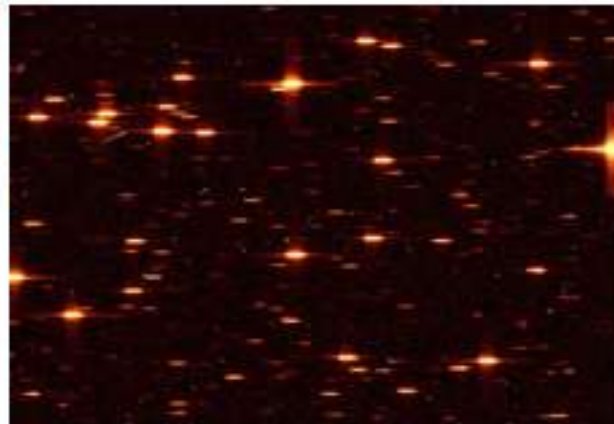
“photometry”



spectroscopy



AF

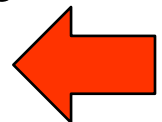


RP



RVS

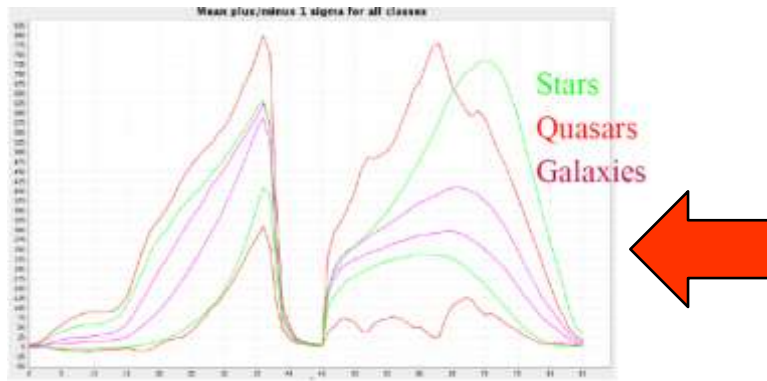
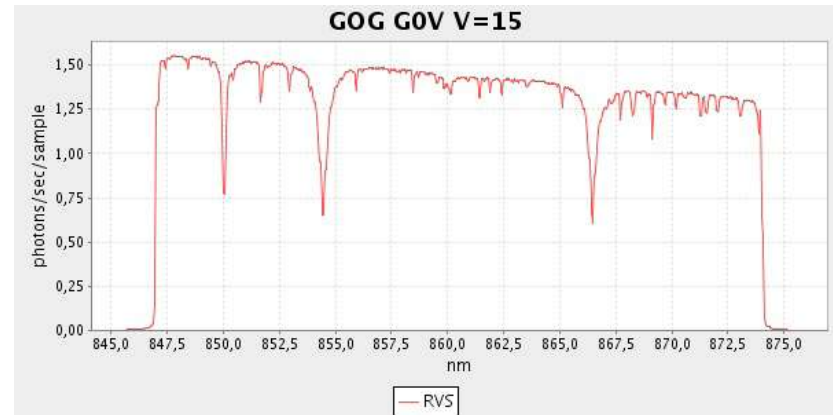
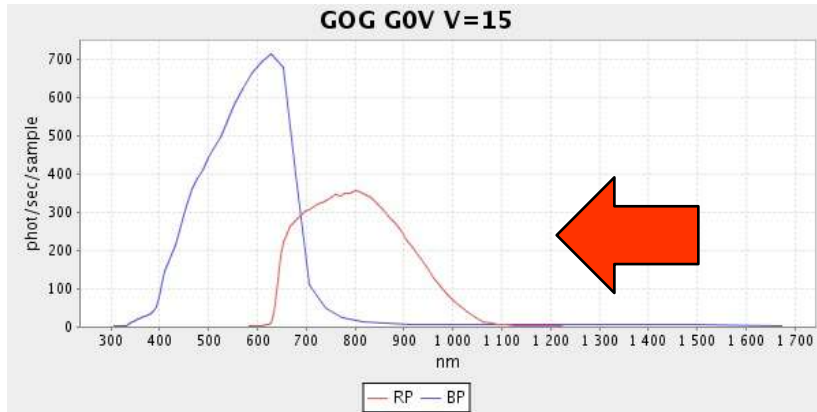
In this talk we focus of the „photometric mode“
RP/BP. In reality this mode generates
ultra low-dispersion prism spectra



The astrophysical strength of Gaia

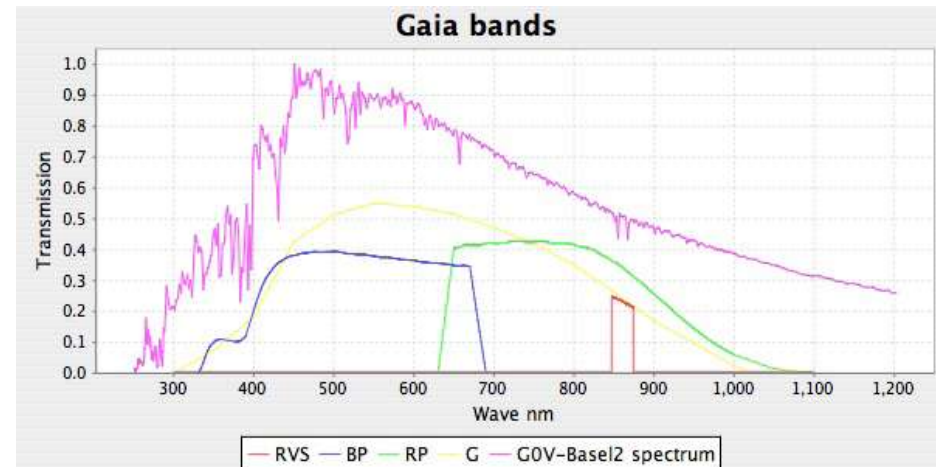
- **Motivation: Astrophysics with Gaia data**
- **The photometric sampling provided by Gaia will not be (for many astrophysical sources) optimal**
- **However, the fine spectro-photometry (in reality ultra low resolution spectroscopy) provided by BP/RP photometers will be unique and important for many astrophysical investigations with Gaia**

Comparing BP/RP and RVS spectra



**GOG output for the G0V star with V = 15.,
BP/RB and RVS**

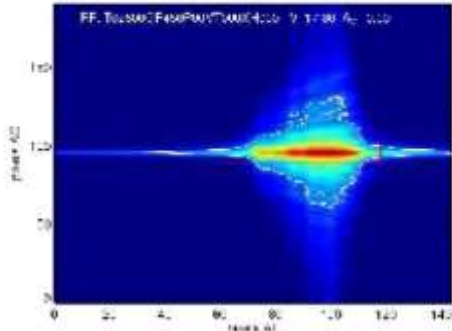
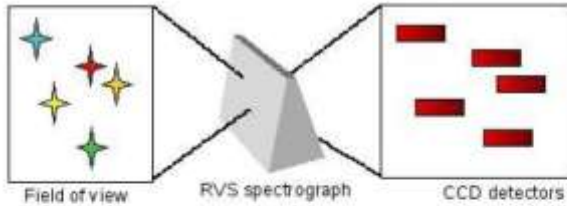
**The simulated 1D Low Disp Spectra by
Gaia**



According to Bailer-Jones et al., 2008

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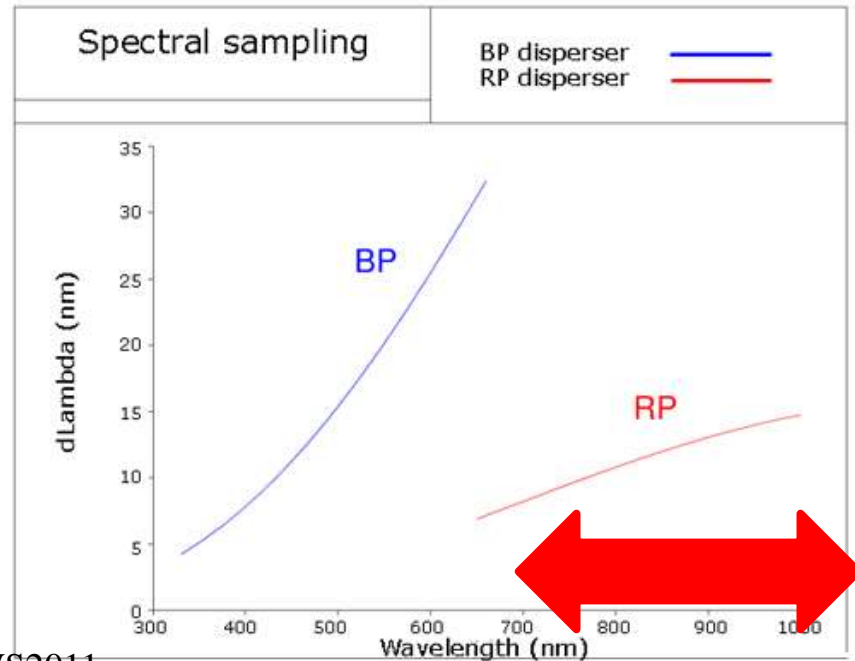
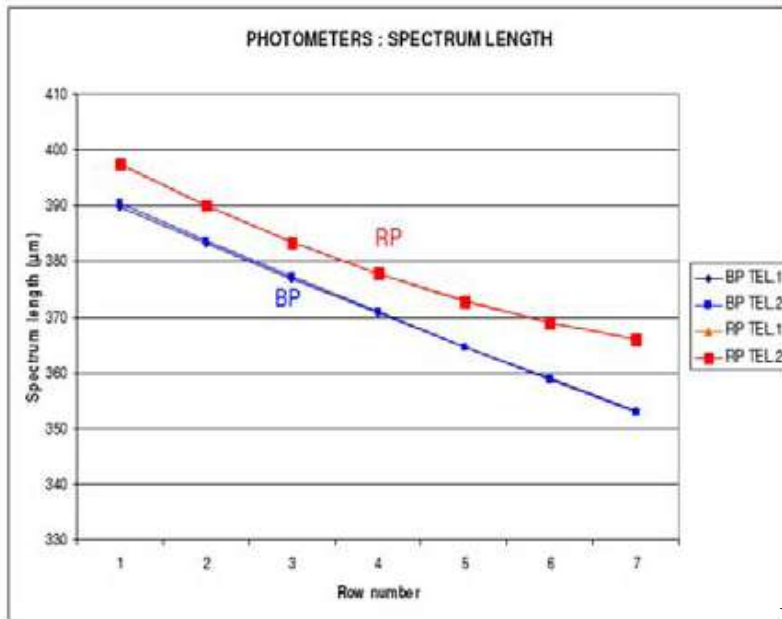
„Photometric“ Mode of Gaia



The use of dispersive element (prisma) generates **Ultra low-dispersion spectra**

One disperser called **BP for Blue Photometer** operates in the wavelength range 330-660 nm; the other called **RP for Red Photometer** covers the wavelength range 650-1000 nm.

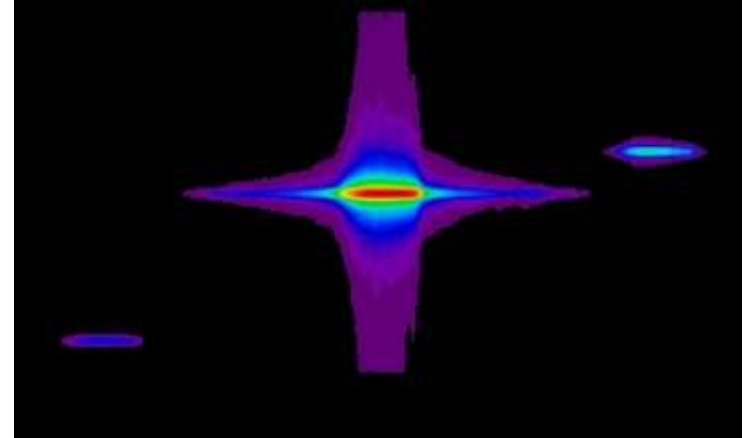
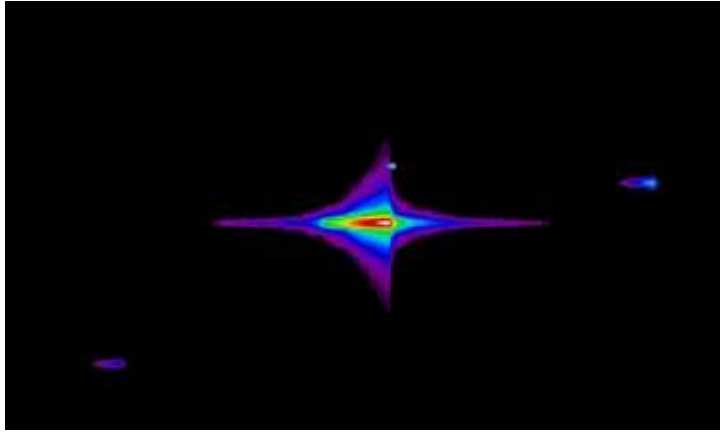
The dispersion is higher at short wavelengths, and ranges from **4 to 32 nm/pixel for BP** and from **7 to 15 nm/pixel for RP**.



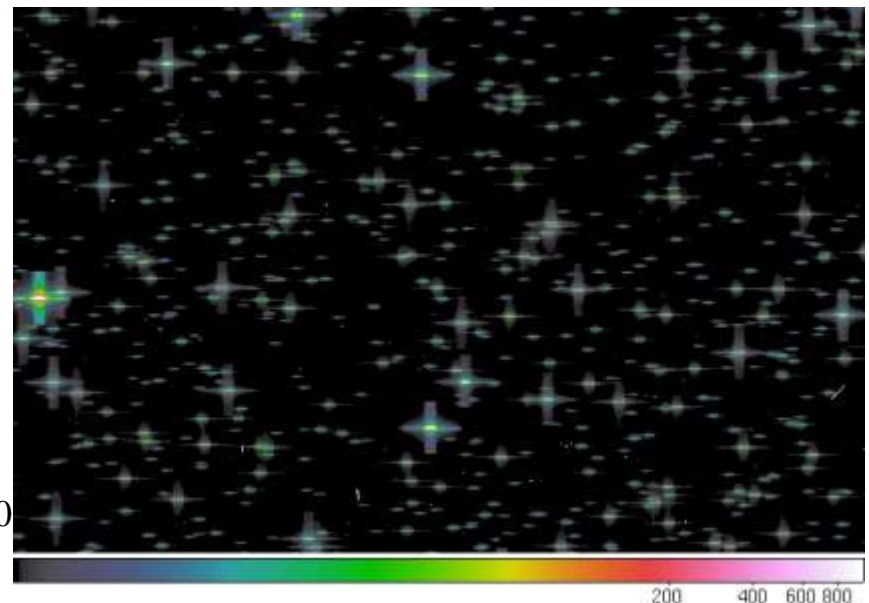
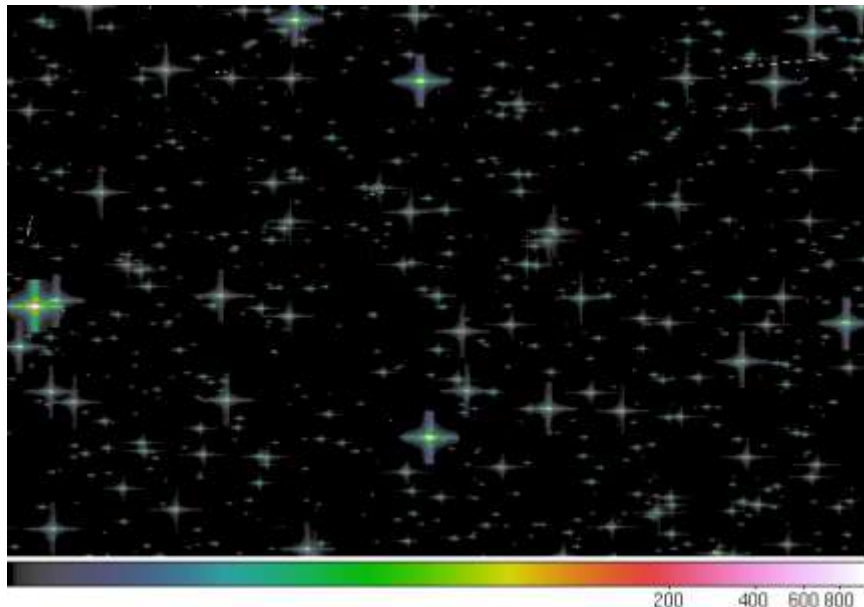
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Near IR

Gaia Gibis Simulator: simulated BP/RP results

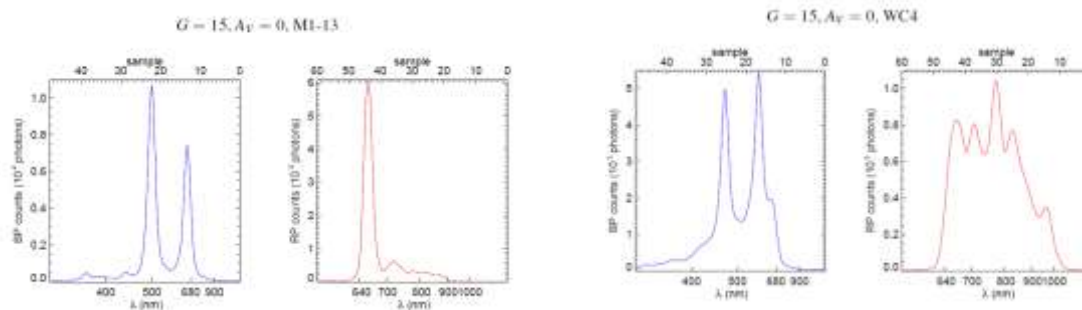


Results for same star fields from GIBIS simulator. From right BP/RP. Images has different values of scale parameters (visualization DS9).



Examples of objects with very strong spectral lines expected to be accessible by Gaia BP/RP

- **Question:** does spectral lines will be visible by Gaia BP/RP?
- **Obvious candidates:** stars with very strong lines i.e. planetary nebulae, WR stars

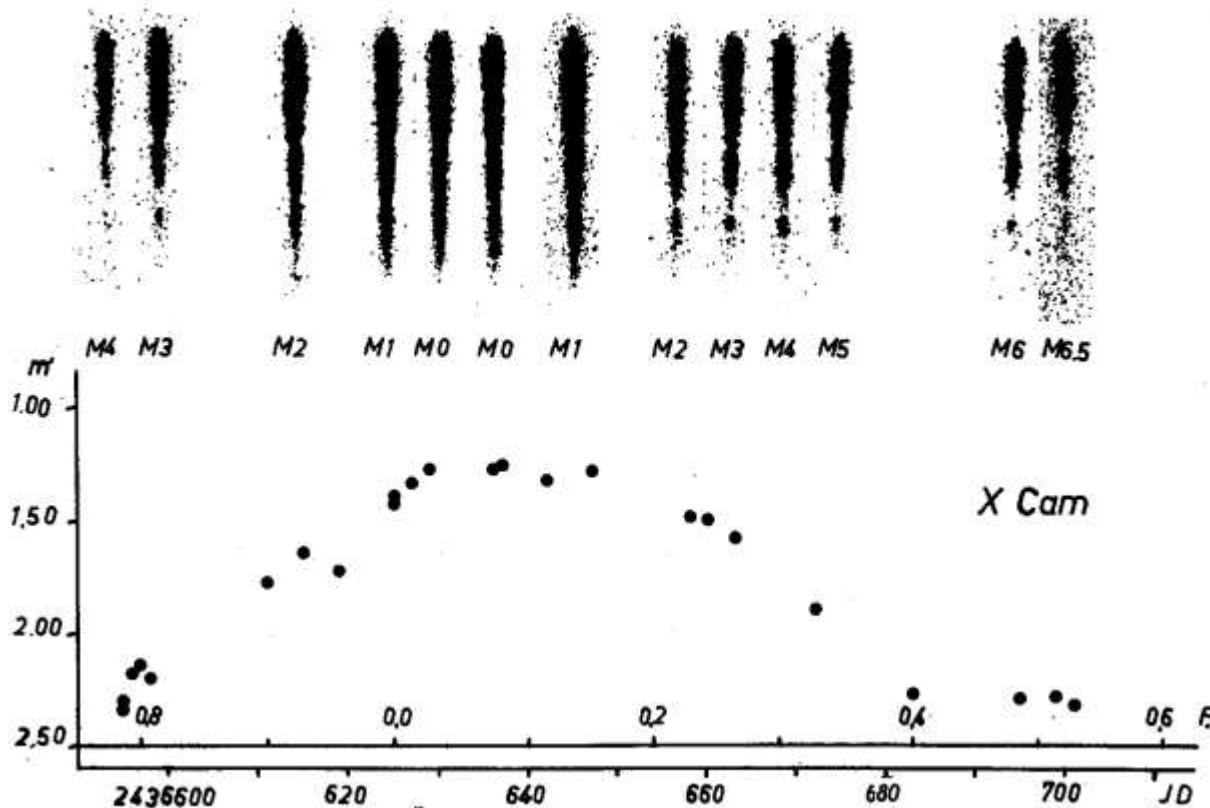


- **But what about other objects?**

The Spectral Type Variability with Gaia?

- It is known that certain types of variable stars (VS) such as Miras, Cepheids, and peculiar VS exhibit **large variations in their spectral types**
- This field is however little exploited, as before were these studies very laborious (plates were mostly visually inspected) and limited. No review on spectral variability among VS exists (Samus, personal comm. 2008)
- The evaluation by computers and dedicated s/w will allow to search and investigate spectral variability in Gaia data and in digitized Spectral plates
- Gaia well suited for this work

Relation of spectral and photometric variations: Mira Variables



T. Jarzeowski,
1959

X Cam

Mira Variable

Spectral Variations
M0 to M6.5

Amplitude 1.4 mag
in R

Spectral Type Variability of Cepheids & Peculiar Stars

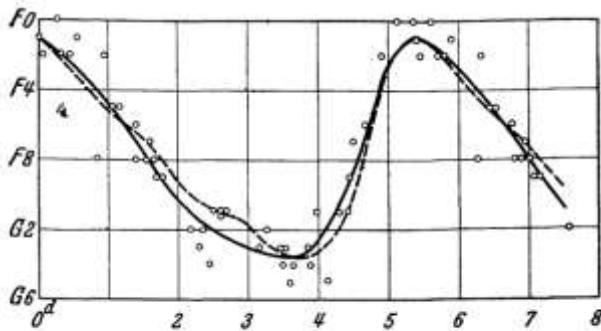


Abb. 1. Mittlere Spektralkurve und visuelle Lichtkurve (gestrichelt) von δ Cephei.

All classical Cepheids definitely vary their spectral types. At maximum, they all have types around F5-F8. At minimum, the longer the period, the later is the spectral type (to K2) (Samus, 2008)

Becker, F. 1938

Shapley, 1916

Spectral type changes of peculiar stars: FG Sagittae changed its spectral type from B to M (Chalonge et al 1977)

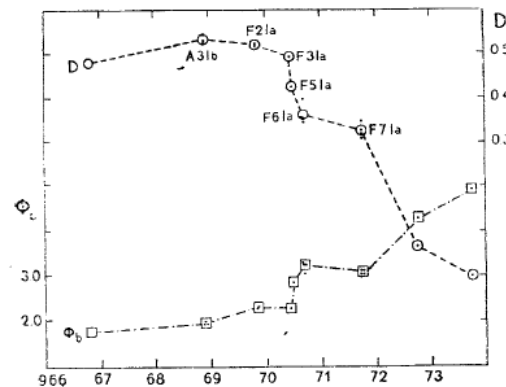


Fig. 1. D and ϕ_b as a function of time. The corresponding BCD spectral types are indicated. The 1966 values are from Roark, 1968. Small black dots: individual measurements.

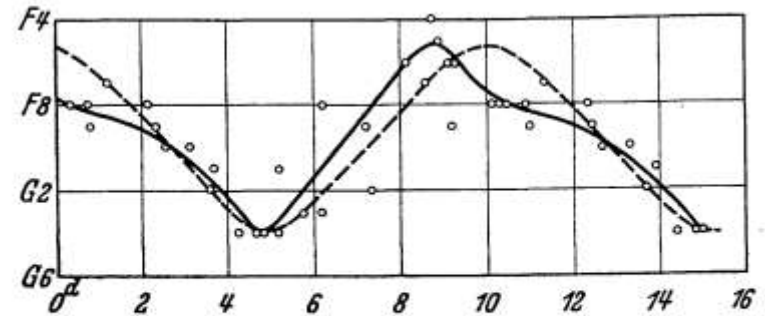


Abb. 2. Mittlere Spektralkurve und visuelle Lichtkurve (gestrichelt) von ζ Geminorum.

**The dispersed stellar images on
astronomical Schmidt plates:
large Low Dispersion Spectra
(LDS) surveys and possible use
for Gaia**

Astrophysics with LDS in the past

- The LDS (**Low-Dispersion Spectroscopy**) astrophysics was evolved and performed at numerous observatories between ca 1930 and 1980
- Mostly LDS with Schmidt telescopes (plates with objective prisma)
- Used for various projects e.g. QSO, emission line and H α surveys, star classifications, etc.
- Little used after 1980

A PUZZLING NEW EMISSION-LINE OBJECT IN CIRCINUS

N. SANDULEAK*

Warner and Swasey Observatory, Case Western Reserve University

Received 1974 October 5

A new emission-line object, showing unusual spectral characteristics has been discovered in an objective-prism survey of the southern Milky Way.

Key words: spectra — emission-line object

PUB. ASTRON. SOC. PACIFIC, Volume 86, August 1974

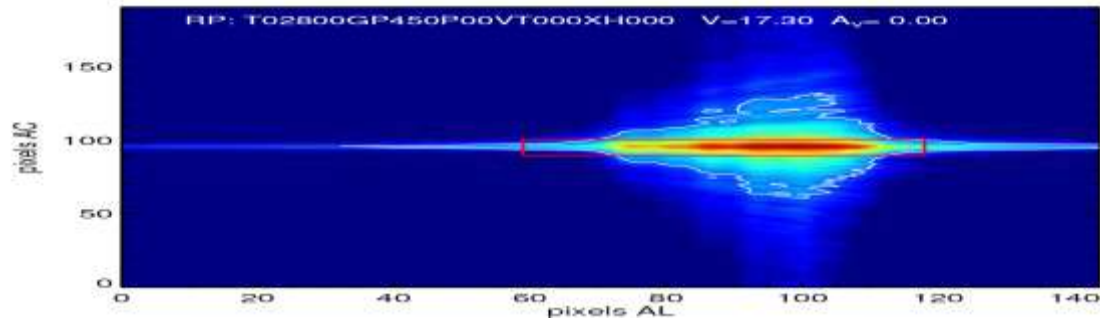
AN INTERESTING GROUP OF EMISSION-LINE STARS IN SCORPIUS

N. SANDULEAK*

Warner and Swasey Observatory, Case Western Reserve University

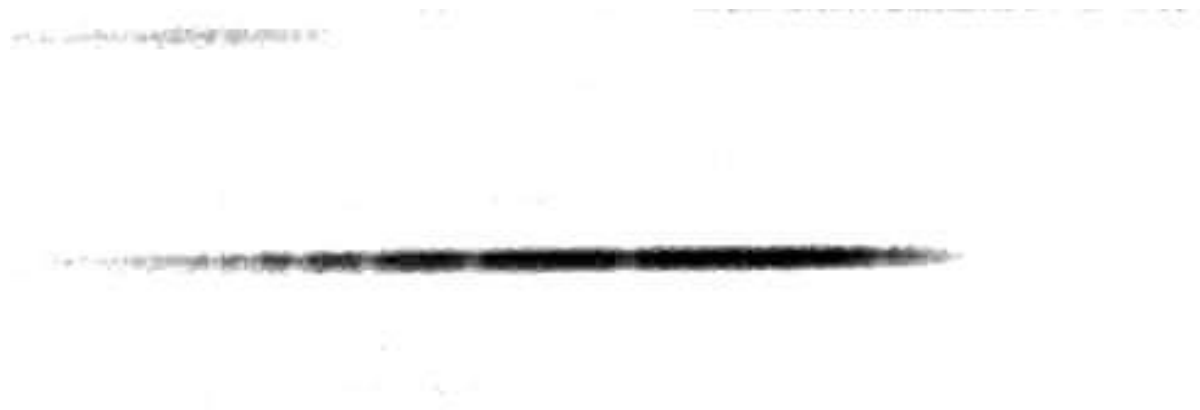
Received 10 April 1974

An objective-prism survey of the southern Milky Way has detected three and possibly four emission-line stars at $l = 348^{\circ}.7$, $b = -0^{\circ}.8$ which appear to constitute a physical group located about 2 kpc from the sun. Two stars are provisionally classified as WN + OB and a third appears to be Of.



Simulated low dispersion Gaia spectrum

**Real low dispersion spectrum from digitised Schmidt
spectral plate**



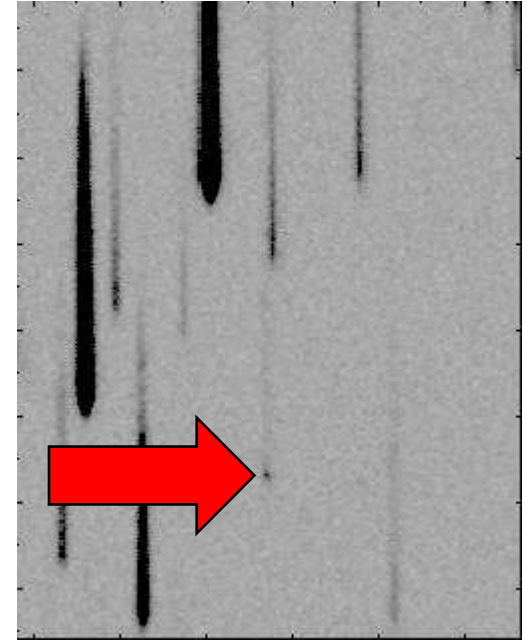
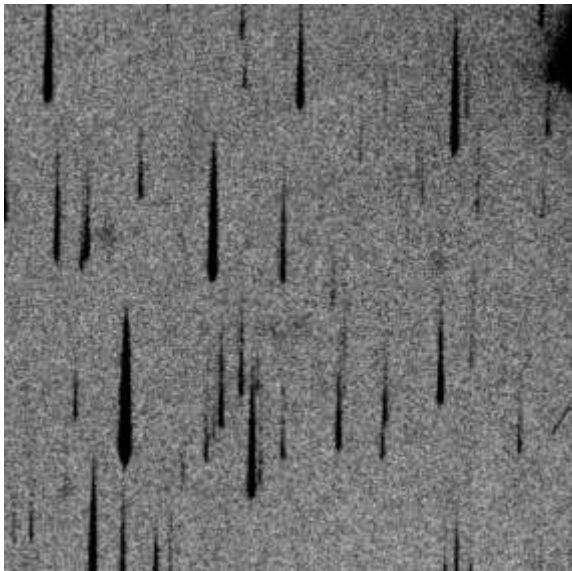
Suitable Low Dispersion Spectral Databases for Gaia

- **Sonneberg Schmidt Camera**
- **Sonneberg Bolivia Expedition: Southern Sky Coverage**
- **Hamburg Quasar Spectral Survey**
- **Digitised Byurakan Spectral Survey**
- **US PARI Spectral Surveys (several)**

Hamburg Quasar Survey

A wide-angle objective prism survey searching for quasars with $B < 17.5$ on the northern sky. The survey plates have been taken with the former [Hamburg Schmidt telescope](#), which is located at Calar Alto/Spain since 1980. For the survey the 1.7° prism was used providing unwidened objective prism spectra with a dispersion of **139 nm/mm at Hgamma**. Under conditions of good seeing the FWHM of the images is $30 \mu\text{m}$ (plate resolution) giving a **spectral resolution of 4.5 nm at Hgamma** on the objective-prism plates.

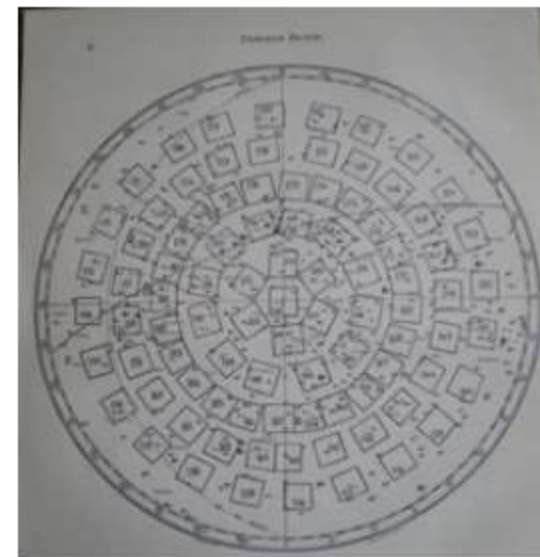
Online access.



Discovery objective prism spectrum of HS 0822+3542, emission line galaxy. The wavelength coverage is 3200\AA (upper end) to 5400\AA (lower end). HS 0822+3542 shows almost nothing but the O[III] 5007\AA emission line (the black dot) is seen, while the continuum is barely visible.



Plates taken ~ 1924-1928,
 about **70 000 prism spectra**
 estimated and published in
 Potsdam Publ. 26-19 in
 1930



Almost complete
 southern sky coverage

Bolivia Expedition Spectral Plates

Coverage of Southern Sky with Spectral and Direct Plates
 Potsdam Observatory, plates stored at Sonneberg Observatory
 Hidden for ~75 years

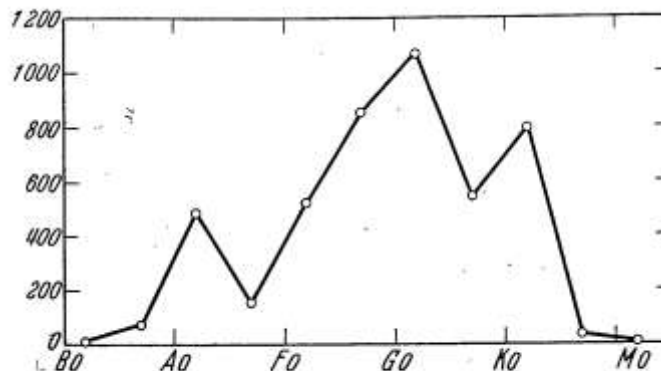


Abb. 2. Anzahl der Sterne pro 100 Quadratgrad.

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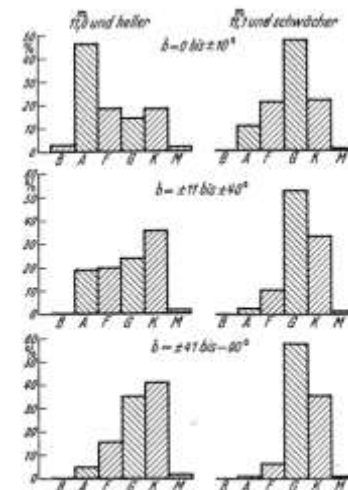
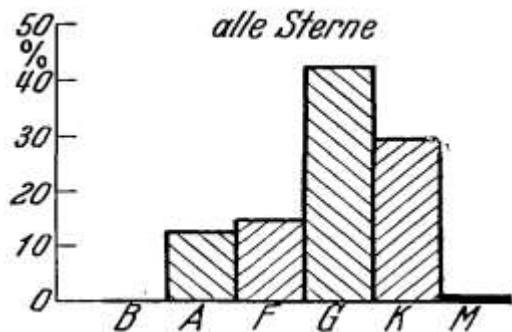


Abb. 4. Prozentuale Verteilung der Sterne nach scheinbarer Helligkeit und galaktischer Breite.



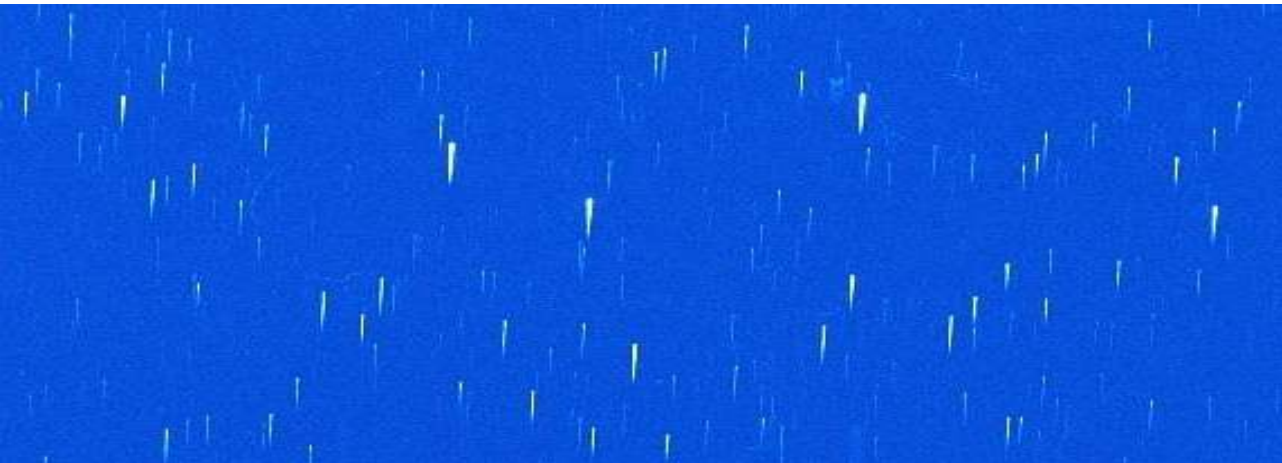
Byurakan Survey

The Digitized First Byurakan Survey (DFBS) is the digitized version of the First Byurakan Survey (FBS). It is the **largest spectroscopic database in the world, providing low-dispersion spectra for 20,000,000 objects on 1139 FBS fields = 17,056 deg²** Online access. Sky coverage: DEC > -15°, all RA (except the Milky Way). Prisma spectral plates by 1 m Schmidt telescope.

Limiting magnitude: **17.5 in V**

Spectral range: 340 – 690 nm, spectral resolution **5 nm**

Dispersion: 180 nm/mm near H-gamma

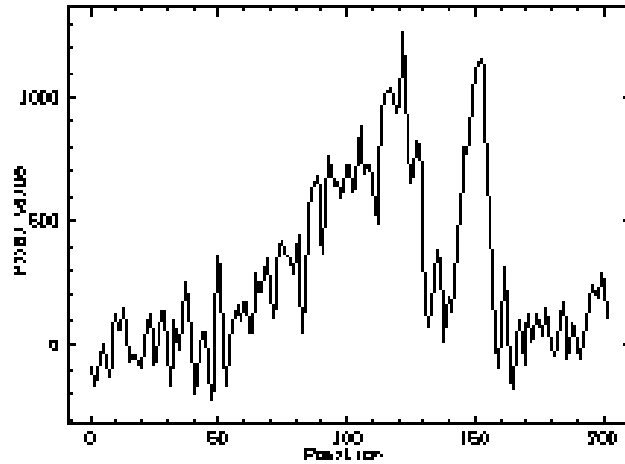


Examples of prominent spectra from Byurakan Survey

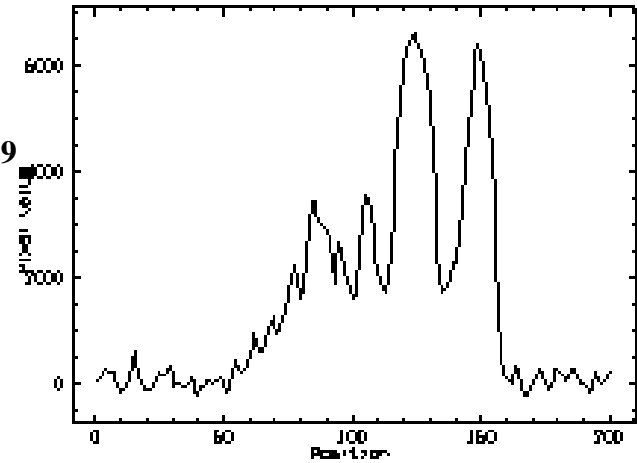
**These objects will be also probably visible
in Gaia BP (Optical) and RP (Near IR)**

Planetary Nebulae

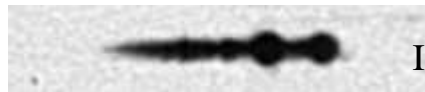
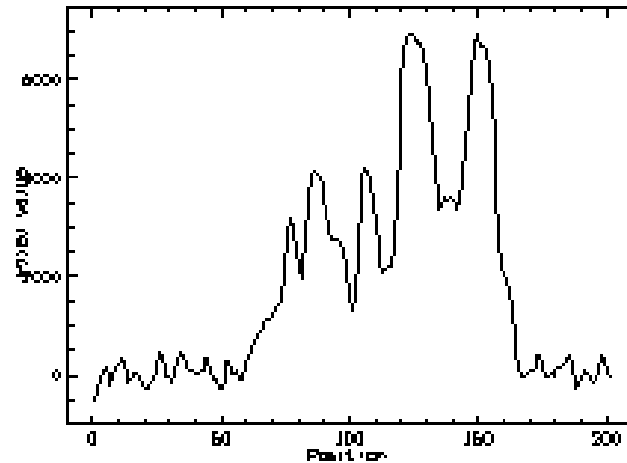
NGC 2242



NGC 7009



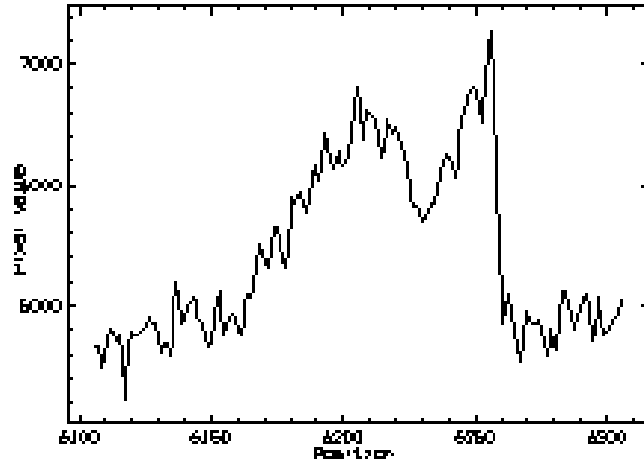
NGC 6210



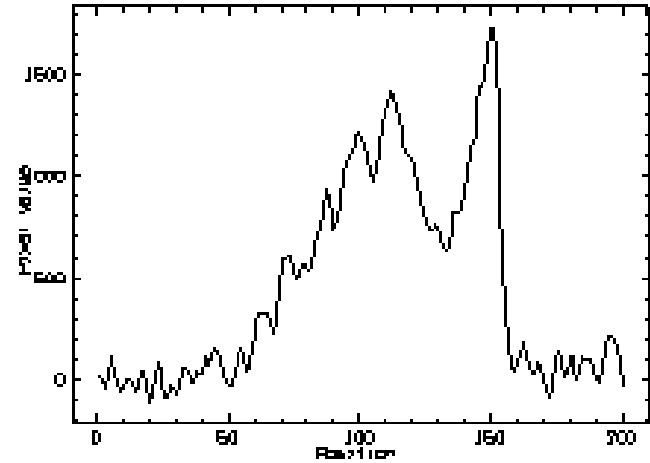
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Quasars

- CSO 409

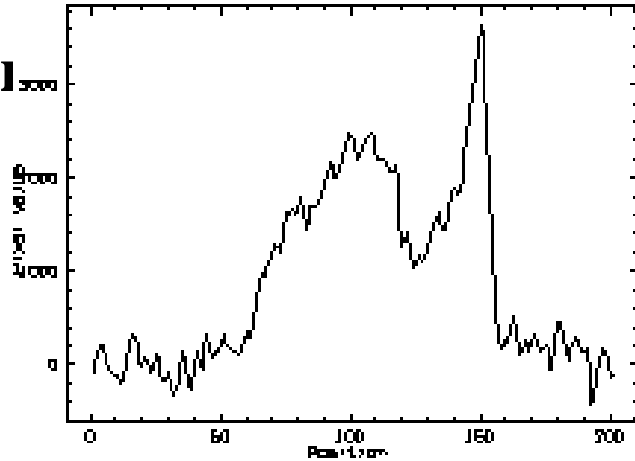


- Pg 1634+706

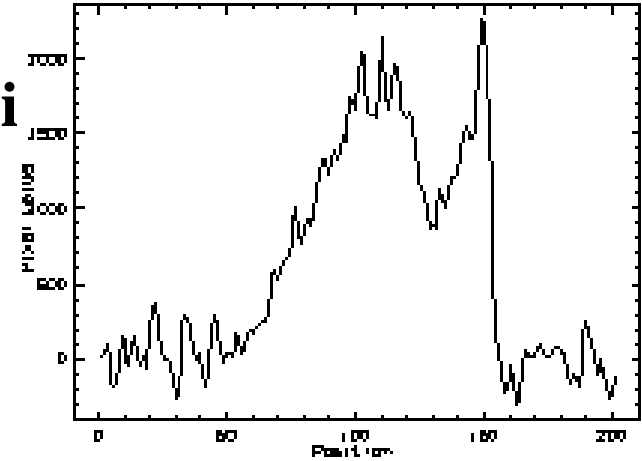


Cataclysmic variables

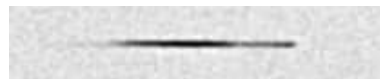
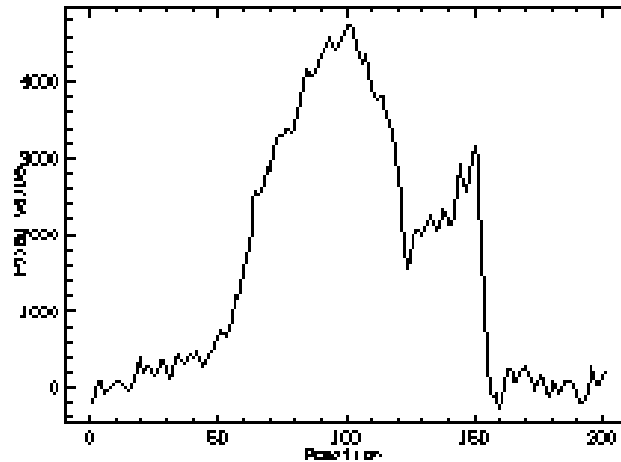
DQ HeI



V1193 Ori



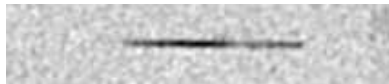
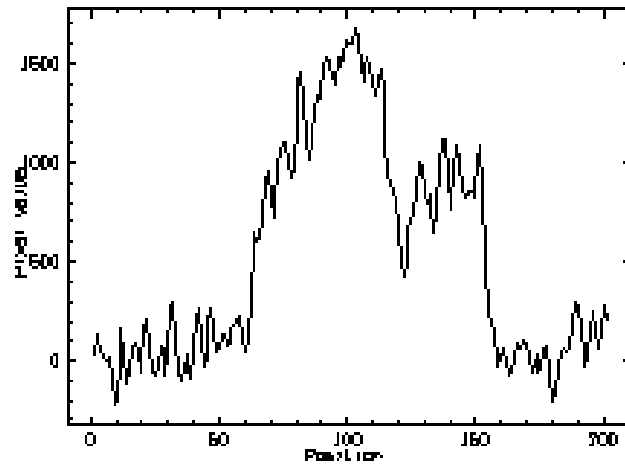
Ux CVn



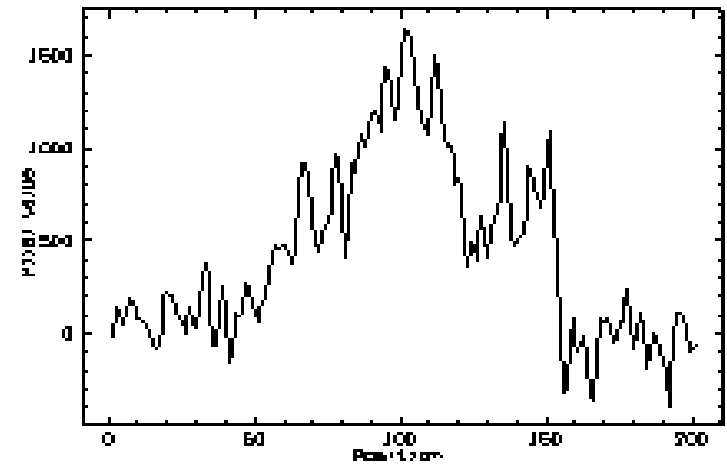
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White dwarfs

- Pg 0109+111 (Do)

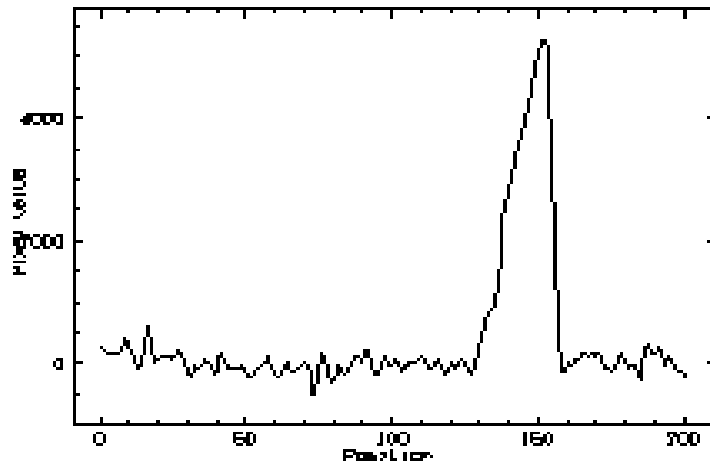


- Pg 1449+168 (Da3)

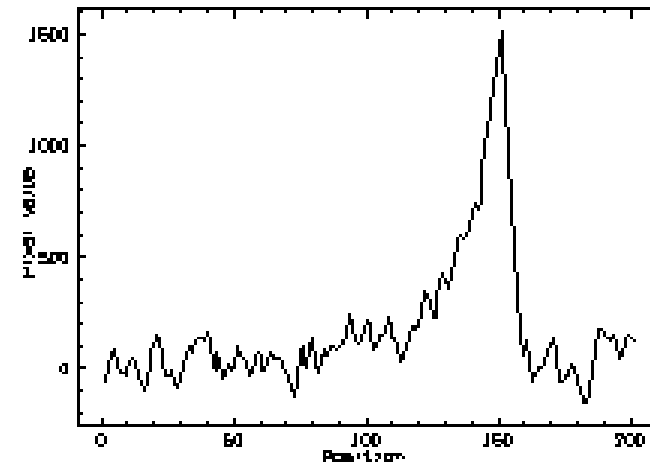


CARBON (C) STARS

- BIS 184

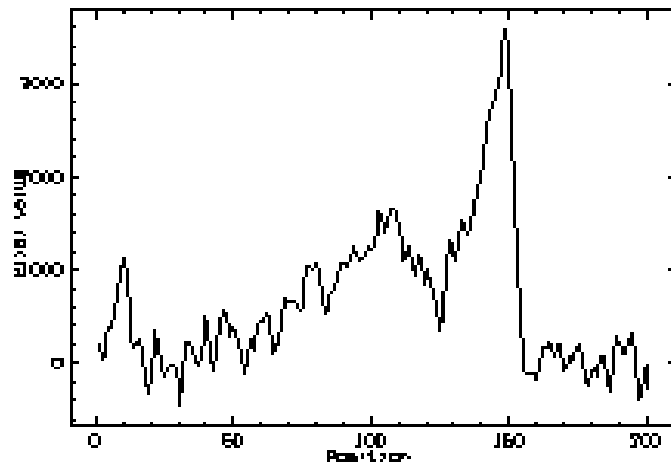


- BIS 001

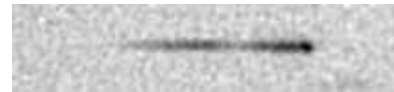


AGN and peculiar galaxies

- BL Lac



- I Zw 1

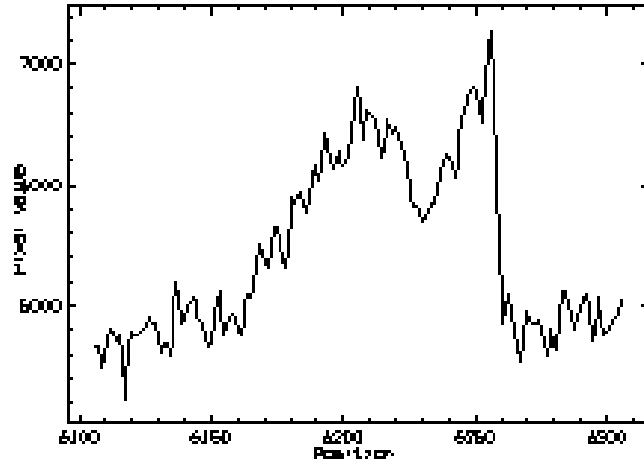


- 3c 120

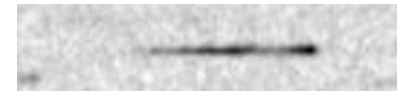
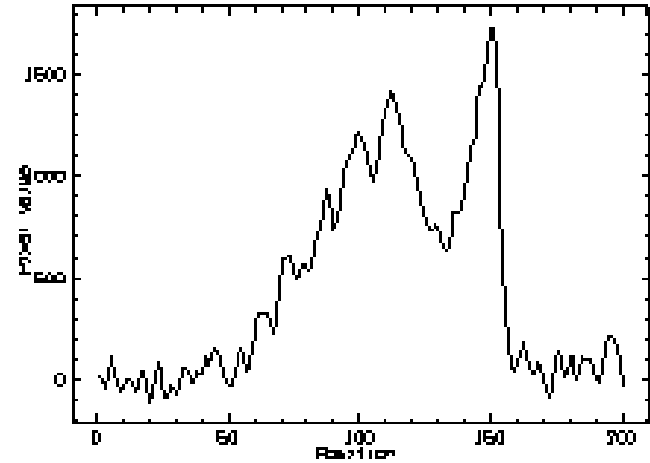


Quasars

- CSO 409



- Pg 1634+706



**Application of algorithms
developed for digitised
astronomical archival plates
for Gaia**

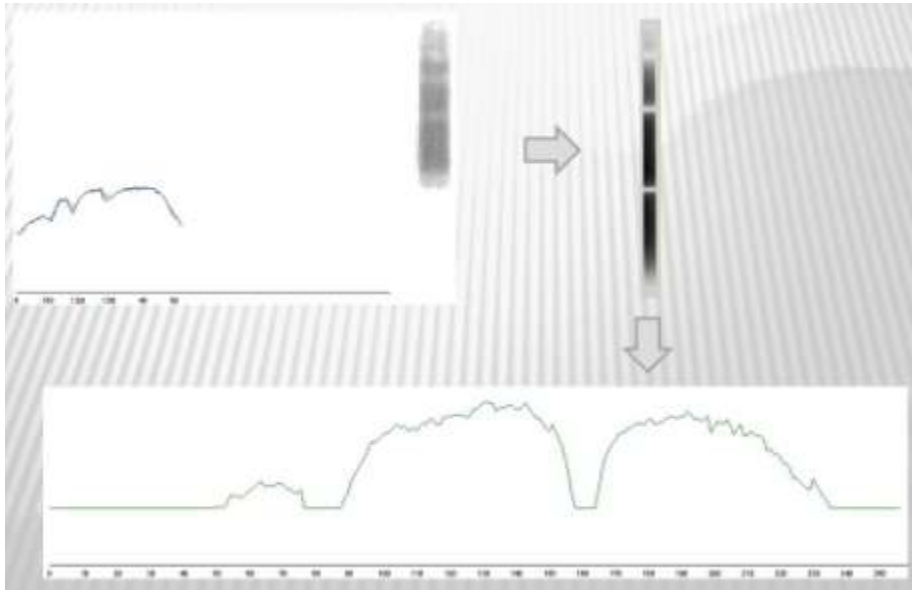
The Motivation

- The archival spectral plates taken with objective prisma offer the possibility to **simulate the Gaia low dispersion spectra and related procedures such as searches for spectral variability and variability analyses based on spectro-photometry**
- Focus on sets of spectral plates of the same sky region covering long time intervals with good sampling – simulating the Gaia BP/RP outputs

Algorithms for automated analyses of digitized spectral plates

- **Developed by informatics students**
- **Automated classification of spectral classes**
- **Searches for spectral variability (both continuum and lines)**
- **Searches for objects with specific spectra**
- **Correlation spectral and photometric changes**
- **Application for Gaia**
- **The digitized spectral plates may serve as independent and real simulator**

Automatic classification of stellar objective prism spectra on digitised plates, a simulation and a feasibility study for low-dispersion Gaia spectra

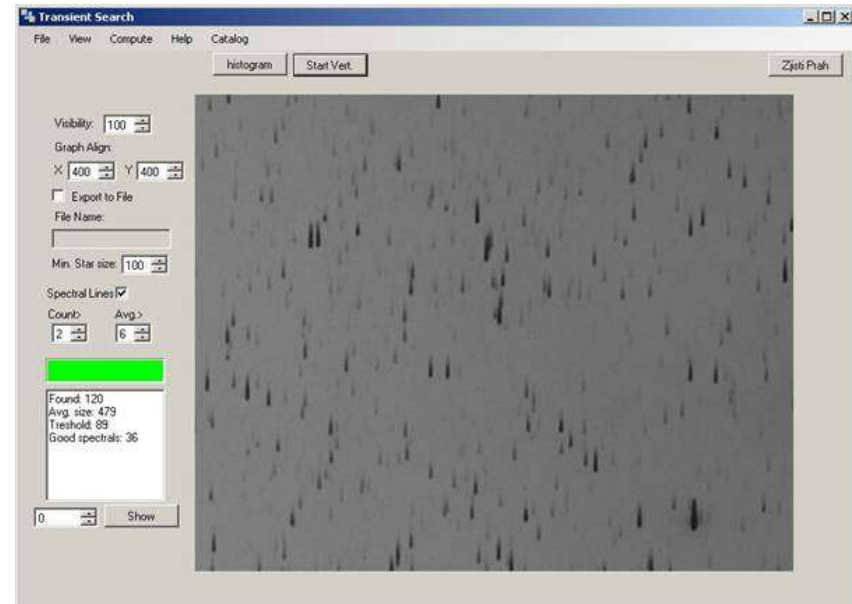


Left: Investigated spectrum

Right: Calibration spectrum

(Hudec L., 2007)

Neuron networks involved

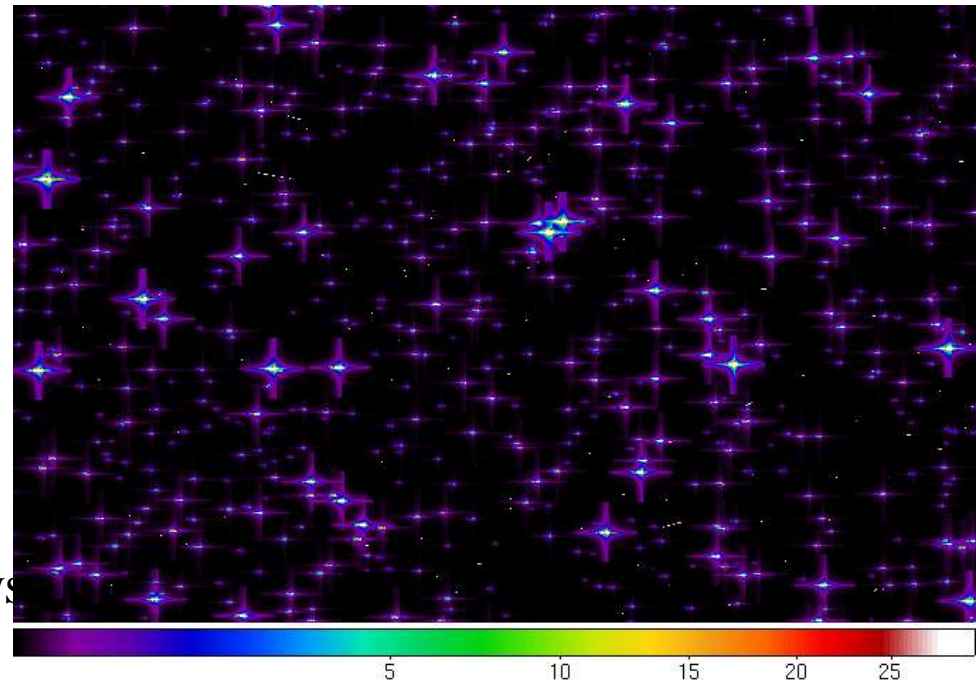
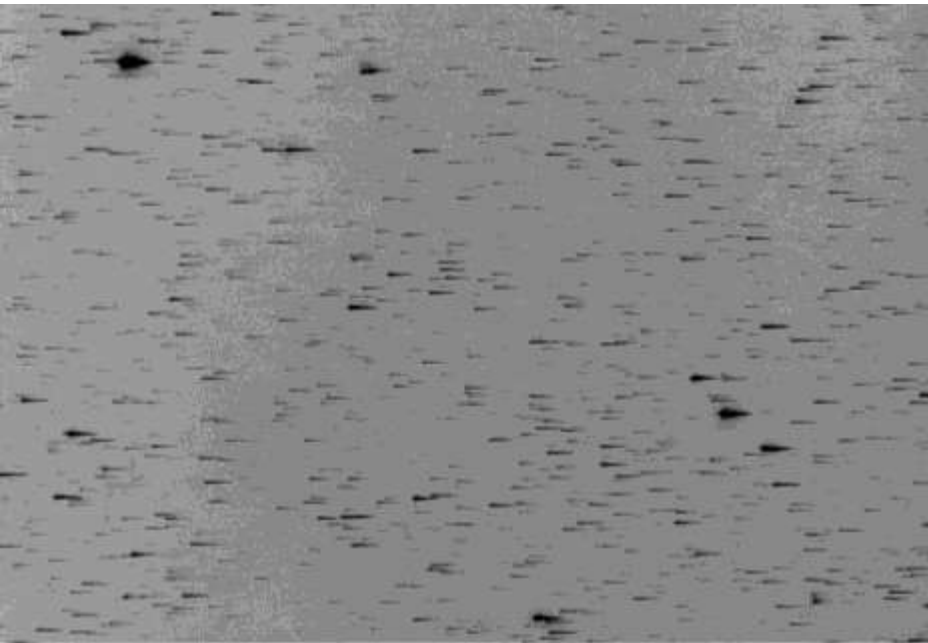


Comparison Gaia BP/RP Low Dispersion Spectra Versus Spectral Low Dispersion Plates

Comparing PARI Schmidt plate vs. Gaia Gibis

plate

Gaia RP



Comparing Gaia vs. Plate Spectral Surveys

	Wavelength range, nm	Limiting magnitude	Dispersion at Hg nm/mm	Spectral resolution at Hg nm
Gaia	330-660, 650-1000	~19	900	~18?
Sonneberg Schmidt	340-650	18	10 , 23	~3
Bolivia Expedition	340-650	14	9	~3
Hamburg	340-540	19	139	4.5
Byurakan	340-690	17.5	180	5
PARI	330-535	18	100-150	~5

1. Note that for plates the spectral resolution is seeing limited hence the values represent best values
2. Gaia BP/RP dispersion ~ 5 to 10 times less than typical digitised spectral prism plate, and spectral resolution ~ 3 to 4 times less, but on plates affected by bad seeing only ~ 2 times less

PARI USA

A section of a PARI Case QSO-Survey, plate #13036, taken on 12/03/1981.

Telescope: 61/91 cm Burrell Schmidt at Kitt Peak, 1.8 deg prisma

Prism dispersion: ~1500Å at 4500Å

Plate FOV: 5-degree by 5-degree

Plate scale: ~100"/mm

Limiting B magnitude: ~18

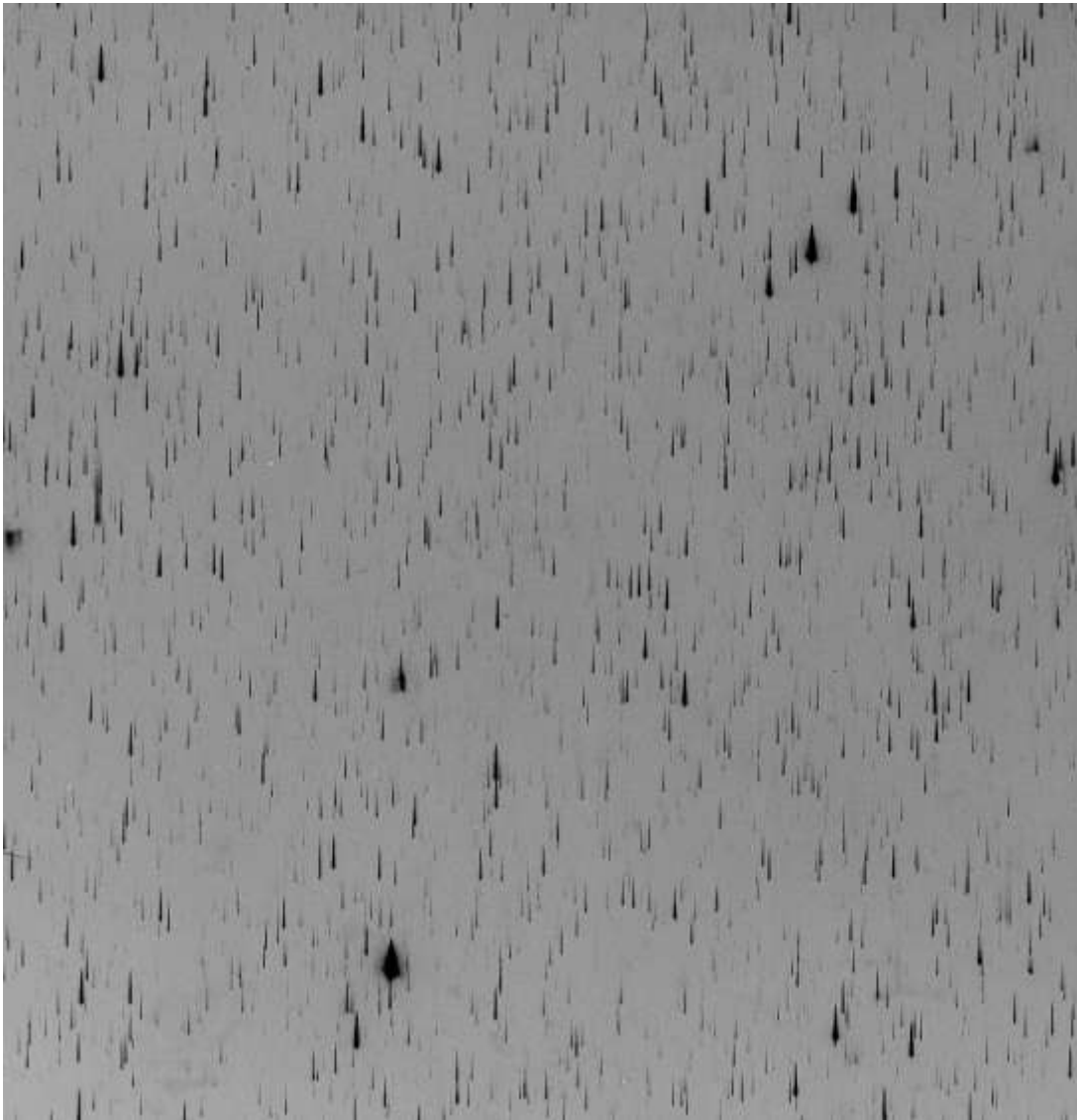
Exposure time: 75 minutes

Emulsion: IIIaJ Baked

Spectral range: 3300Å to 5300Å

Spectral width: <0.03mm

Filter: None



Reference: 1983ApJS,51,117 (Pesch & Sanduleak)

**Can be used as true (incl. lines)
simulator for Gaia**

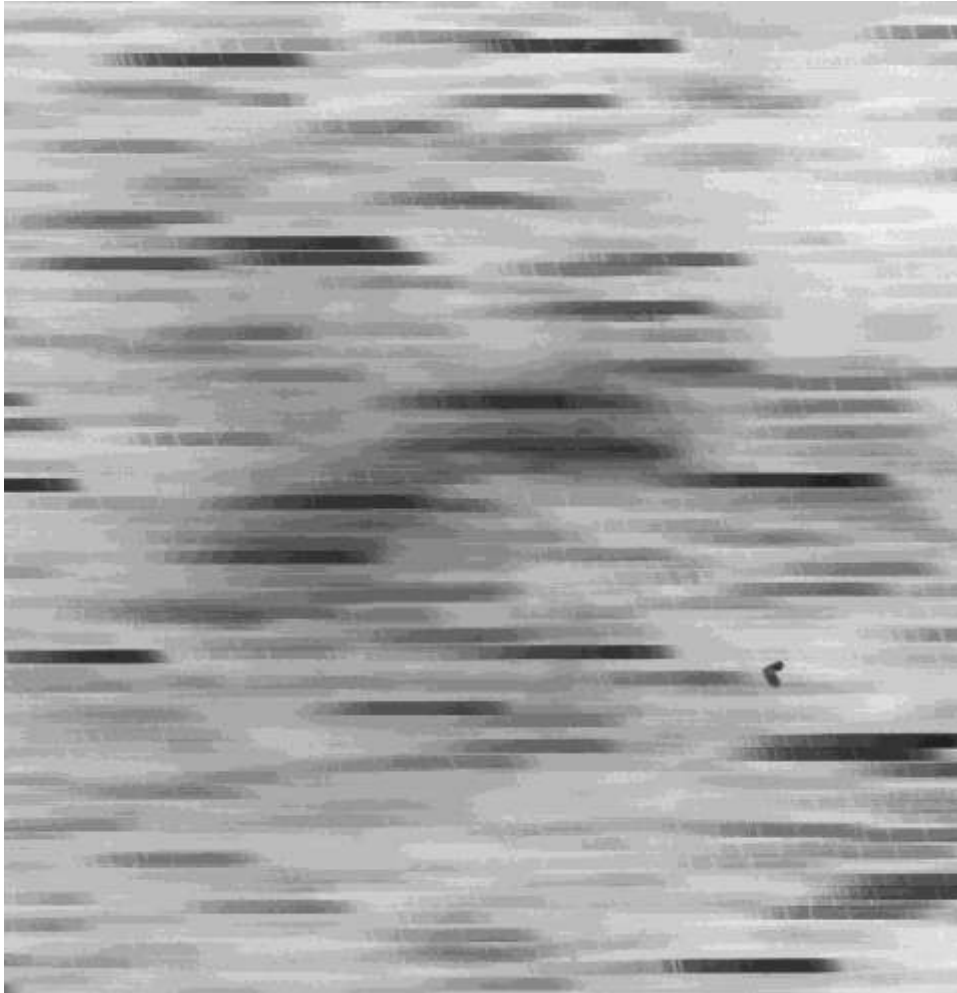


PARI USA

**Scan of a plate from
the PARI Case
Western Reserve Univ.
collection. This plate
(#10246) was taken on
November 17, 1974
(dec= +23.5, RA=
4h50m) and is part of
the Tau Cloud Survey.
The exposure is
72min, Emulsion
103aE, Filter = OG2,
1.8 deg prisma**

**1983ApJS,51,117 (Pesch
& Sanduleak)**

**With larger dispersion one can easily see
lines**



**The Eta Car region from
PARI CTIO Curtis-Schmidt
plate 10464, March 11, 1972
using IIAO emulsion, with 10-
degree prism. (The 2-deg is the
approximate size of the field
cropped).**

(1) Reference: 1971BAAS...3..401H (N.
Houk)

(2) Limiting magnitude: ~9.5

Telescope: Curtis-Schmidt 61/91 cm (twin to
the Case Western Schmidt) f/3.5

Prism: 10-degree

Prism Dispersion: 108 Angstroms per mm at
H-gamma

Prism resolution: 2-Angstroms; widened to
0.8mm

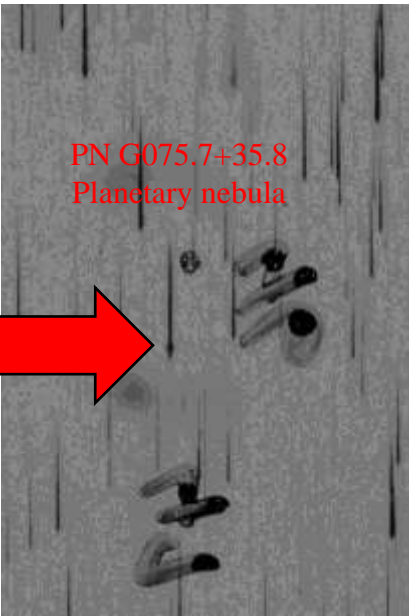
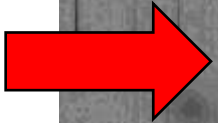
Emulsion: IIAO

Exposure time: 20-minutes

Program: Systematic Reclassification in the
MK system of the entire Henry Draper
Catalogue (HD).

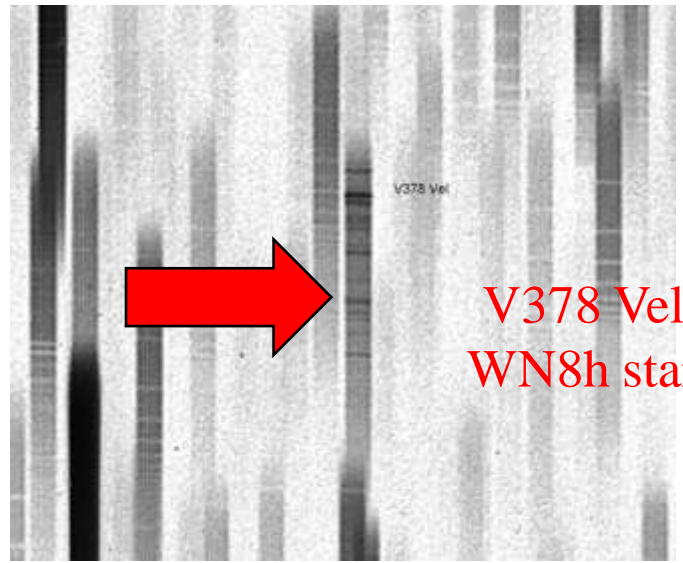
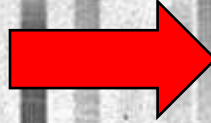
Investigator: N. Houk, University of Michigan

PN G075.7+35.8
Planetary nebula

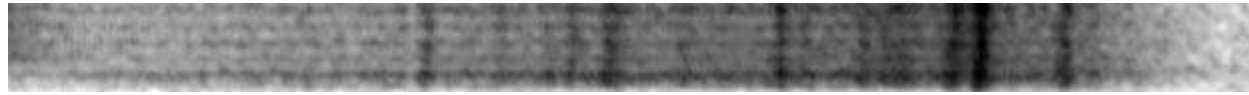


**Examples of objects
with prominent
emission features found
on low dispersion
Plates (Case low
dispersion sky survey),
located at PARI, NC,
USA**

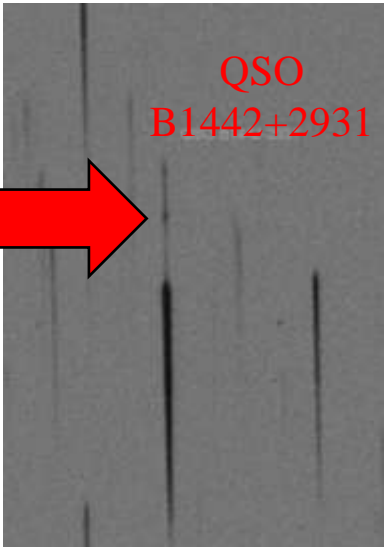
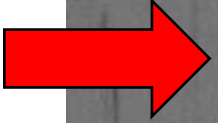
V378 Vel



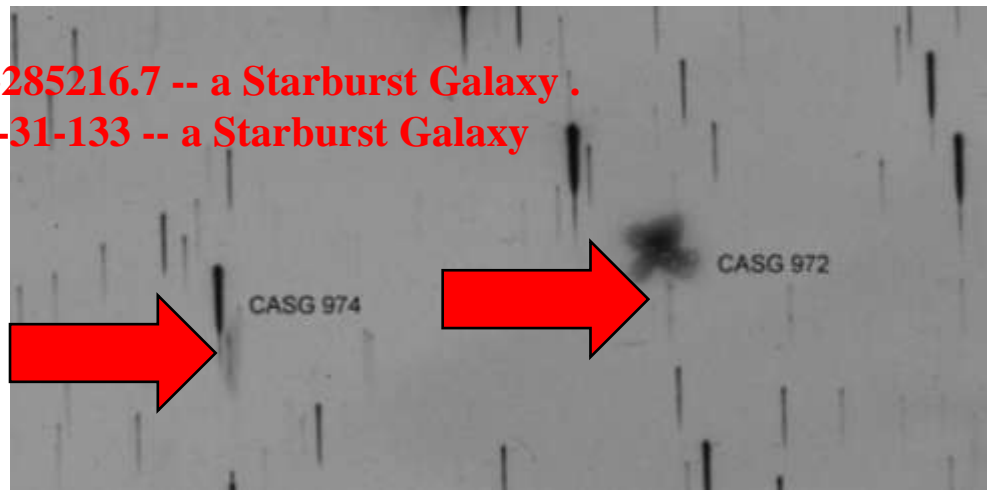
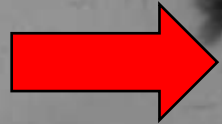
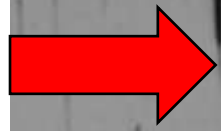
V378 Vel
WN8h star



QSO
B1442+2931



J130545.42+285216.7 -- a Starburst Galaxy .
MCG+05-31-133 -- a Starburst Galaxy



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Newly Investigated US Plate Archives with LDS

- **Lick Observatory: Herbig LDS plates (~1000)**
- **Carnegie Observatories Pasadena: Northern H-alpha survey (~2000)**
- **Yerkes Observatory (~ 500)**
- **KPNO Observatory Tucson AZ (~150)**
- **PARI USA Henize Southern H-alpha survey 300 plates**
- **PARI USA other LDS plates ~10000**
- **Many of these plate series were hidden for centuries**

CU8 Collaboration

- Collaboration with CU8 Gaia Unit, ROB Brussel
- Goal: test their simulated LDS data (for particular emission objects) on real LDS images

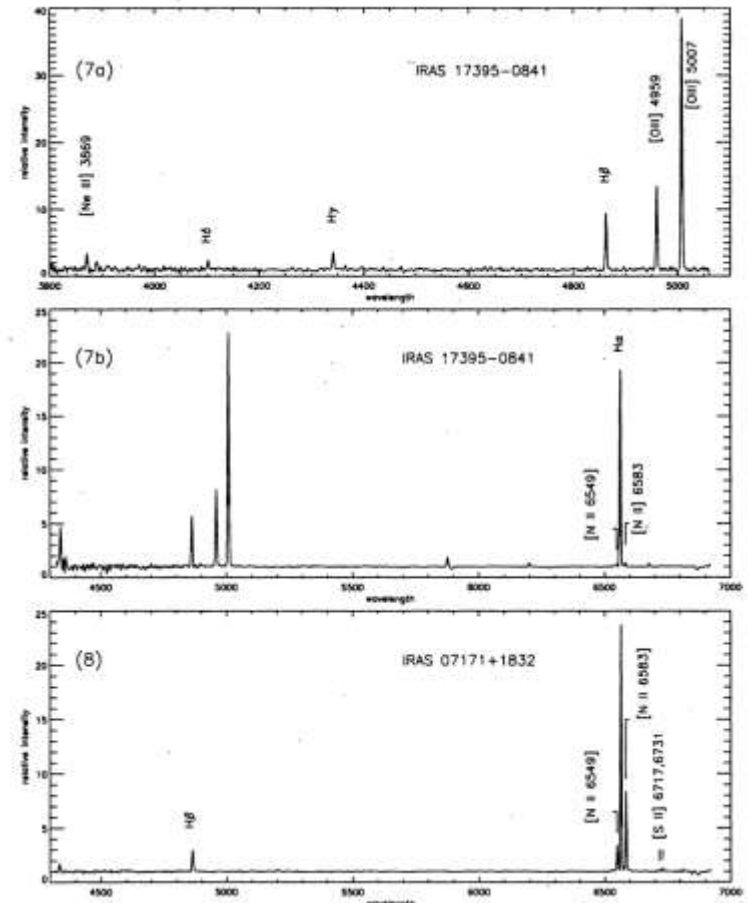
Low resolution spectroscopy of IRAS sources with PN like IR colours

Jyotsna Vijapurkar¹, M. Parthasarathy¹ and John S. Drilling²

¹ Indian Institute of Astrophysics, Bangalore 560 034, India

² Department of Physics and Astronomy, Louisiana State University, Baton Rouge, LA

**Gaia will very probably
effectively
contribute to study of IR/IRAS
sources
as the RP spectrometer covers
the near IR range**



V 407 Cygni

Von L. Meinunger
(Eingegangen 4. Feb. 1966)

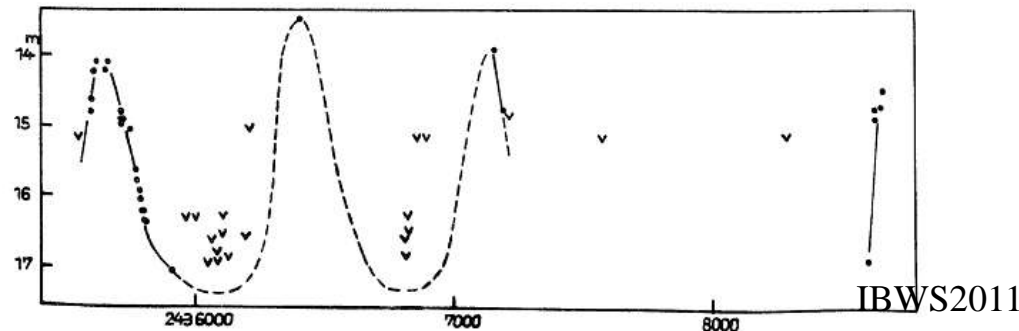
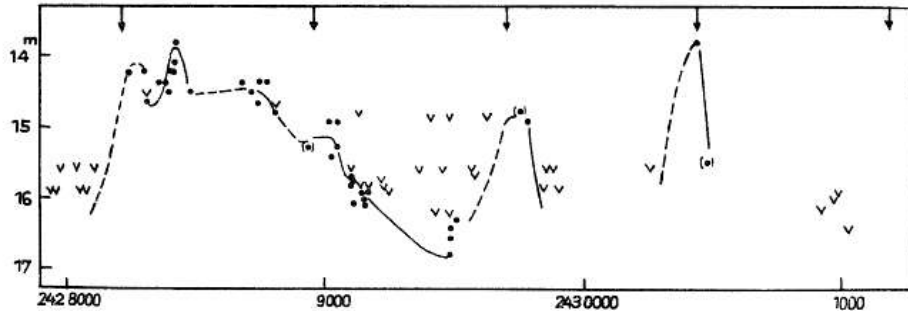
Dieser novaähnliche Veränderliche wurde von HOFFMEISTER entdeckt und erstmalig bearbeitet (Sonneberg Veröff. 1, p.295). Der Stern konnte auf inzwischen neu gewonnenen Aufnahmen des Sonneberger Schmidtspiegels (50/70/172 cm) weiter beobachtet werden.

Der Veränderliche ist offenbar ein Doppelstern, bestehend aus einer Nova und einem Mirastern. Um J.D. 242 8400 erlebte die eine Komponente einen Novaausbruch, dem ein langsamer, stetiger Helligkeitsabfall folgte, der sich bis J.D. 242 9500 verfolgen läßt, in der übrigen Zeit macht das Paar den Eindruck eines normalen Mirasterns, für den folgende Elemente gefunden wurden:

$$\text{Max.} = 242\ 9710 + 745^{\text{d}} \cdot E .$$

J.D.	E	B-R	J.D.	E	B-R
242 9740	0	+30 ^d	243 5650	8	-20 ^d
243 0440	1	-15	6420	9	+ 5
3400	5	-35	7140	10	-20
4214 PA	6	+34	8680	12	+30

PA = Palomar Sky Atlas



V407 Cyg History

Symbiotics binary with Mira variable

Discovered by Cuno Hoffmeister in Sonneberg in 1949 as nova-like variable (Hoffmeister 1949)

In more detail first investigated by Ludwig Meinunger at the Sonneberg Observatory in 1966 (Meinunger, 1966)

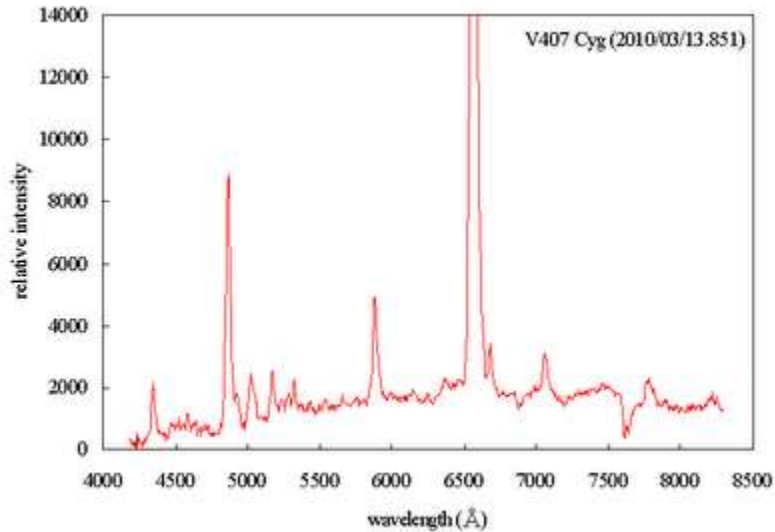
Strange outburst in 1938 followed by Mira like light variations with period of 745 days

Thermonuclear event in 1938?

Nova outburst in 2010
Gamma-rays >100 MeV during nova outburst



V407 Cyg Outburst Spectra



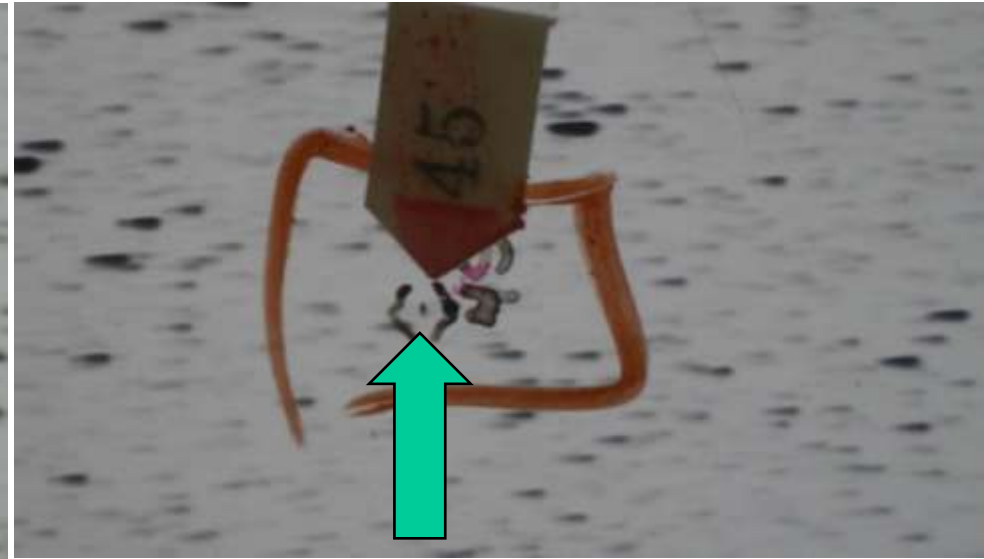
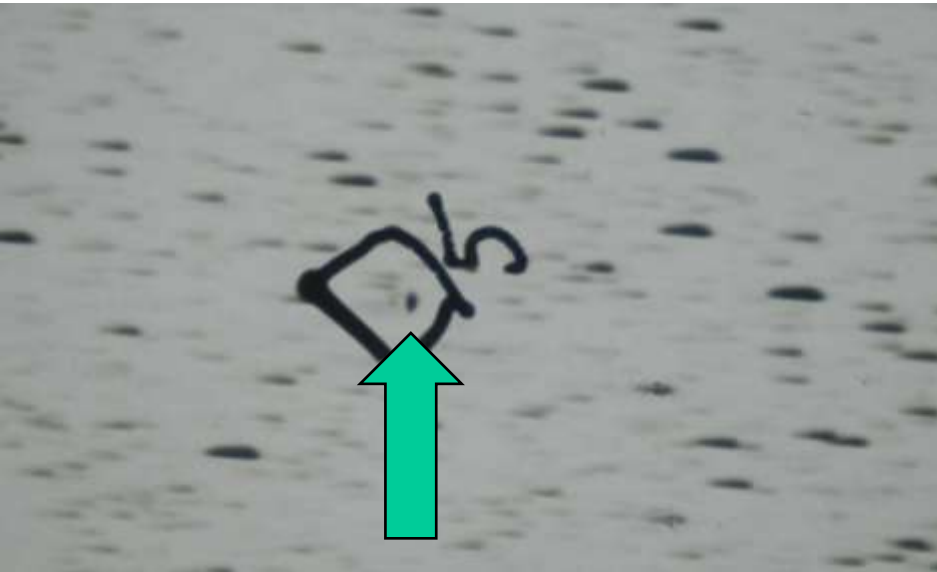
Such prominent spectral features will be observable by Gaia satellite BP/RP ultra-low dispersion spectroscopy

The spectral appearance is a highly peculiar one. The spectrum is completely different from those ever recorded for this object and other symbiotic Mira variables in outburst. The white dwarf companion to the Mira variable is experiencing an outburst similar to that of classical novae, and its ejecta are moving in the circumstellar environment already filled by the ionized wind of the Mira (CBET 2204).

Spectroscopic Gaia Alerts?

- **Some of the objects can drastically change spectra**
- **Prominent emission lines**

Some stars exhibit at low dispersion no continuum just strong emission line



- Karl Henize low dispersion spectral plates (his Dissertation work)
- Full southern sky spectral survey at low dispersion below -25 decl
 - US astrophysicist and NASA astronaut
- Died in 1993 at altitude 21 000 feet while climbing Mount Everest at age of 67
 - Plates re-analysed during my visit to PARI October 2010

Dr Karl Henize

Dr. Henize professor in Northwestern University's Department of Astronomy since 1959. In addition to teaching, he conducted research on planetary nebulae, peculiar emission-line stars, S-stars, and T-associations.

Extended emission line survey program in 1949-1960

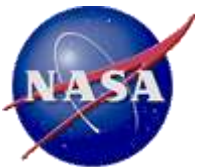
Henize also engaged in studies of ultraviolet optical systems and astronomical programs suited to the manned space flight program. He became principal investigator of experiment S-013 which obtained ultraviolet stellar spectra during the Gemini 10, 11, and 12 flights. He also became principal investigator of experiment S-019 in which a 6-inch aperture objective-prism spectrograph was used on Skylab to obtain ultraviolet spectra of faint stars.

From 1974 to 1978 Dr. Henize chaired the NASA Facility Definition Team for STARLAB, a proposed 1-meter UV telescope for Spacelab. From 1978 to 1980 he chaired the NASA Working Group for the Spacelab Wide-Angle Telescope. Since 1979 he has been the chairman of the International Astronomical Union Working Group for Space Schmidt Surveys and continues to be one of the leaders in proposing the use of a 1-meter all-reflecting Schmidt telescope to carry out a deep full-sky survey in far-ultraviolet wavelengths.



NASA EXPERIENCE: Dr. Henize was selected as a scientist-astronaut by NASA in August 1967. He completed the initial academic training and the 53-week jet pilot training program at Vance Air Force Base, Oklahoma. He was a member of the astronaut support crew for the Apollo 15 mission and for the Skylab 2, 3, and 4 missions. He was mission specialist for the ASSESS-2 spacelab simulation mission in 1977. He has logged 2,300 hours flying time in jet aircraft.

Dr. Henize was a mission specialist on the Spacelab-2 mission (STS 51-F) which launched from Kennedy Space Center, Florida, on July 29, 1985. He was accompanied by Col. Charles G. Fullerton (spacecraft commander), Col. Roy D. Bridges (pilot), fellow mission specialists, Dr's. Anthony W. England, and F. Story Musgrave, as well as two payload specialists, Dr's. Loren Acton, and John-David Bartoe.





Last photo of Karl Henize at Mt Everest



Gravestone of Karl Henize

Karl Henize stuff at PARI

MICHIGAN-MT. WILSON SOUTHERN H α SURVEY
LAMONT-HUSSEY OBSERVATORY
BLOEMFONTEIN, SOUTH AFRICA

NO. LH α 440
DATE 11 June 51
R. A. 1740
DEC. -55.0
EXPOSURE 6 x 40
EMULSION 103aE
OBSERVER HENIZE



**290 high quality plates 15 x 15 inches taken in
1950-1952 in South Africa by dedicated telescope
by Carl Henize**

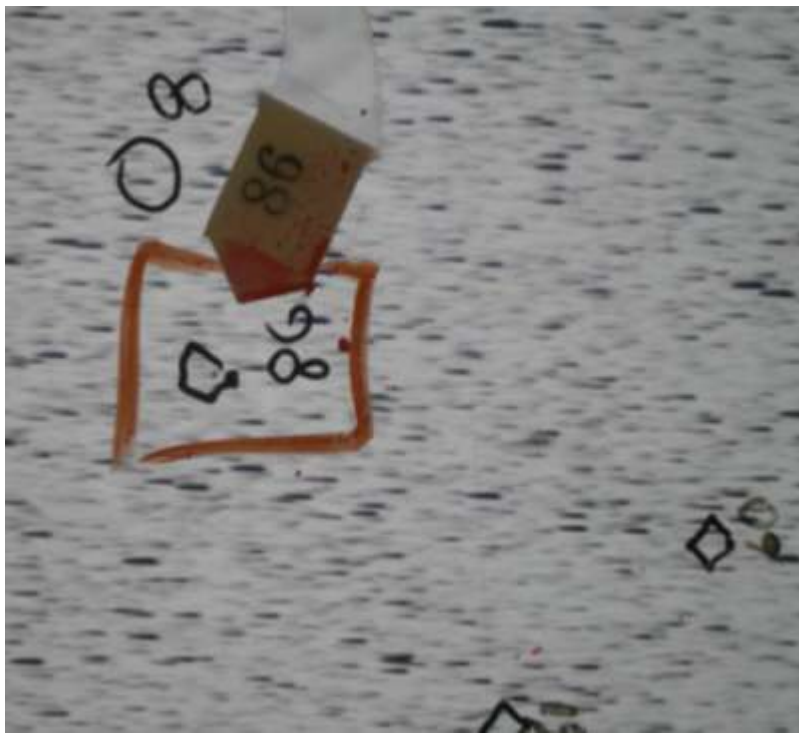
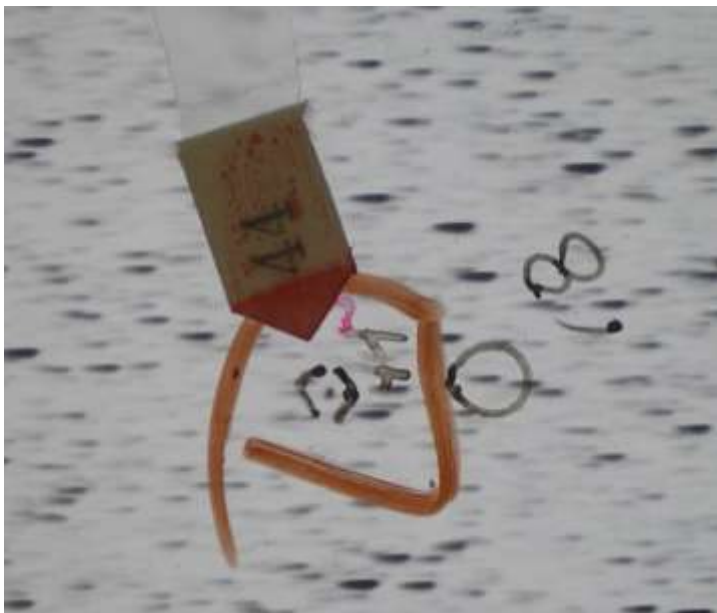




**Plate extensively analysed by
Henize
20 000 spectra investigated by
eye
on every plate**







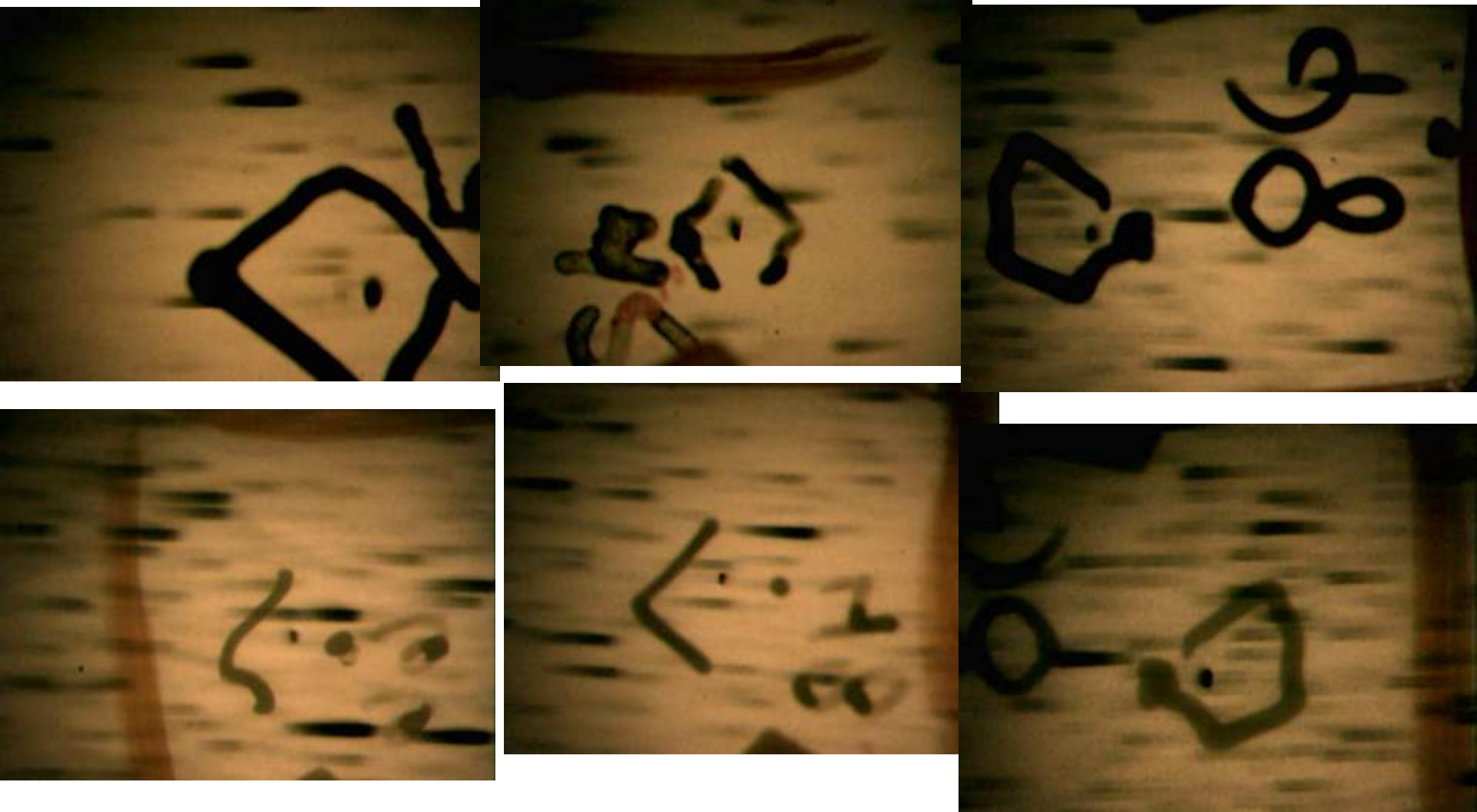
Few examples of prominent emission spectral features found by K. Henize

In objective spectrum sky survey

Michigan-Mt Wilson Southern H α Survey

D25 cm, 45 nm/mm at H α

Henize Objects, Images by USB Microscope



CATALOGUES OF H α -EMISSION STARS AND NEBULAE IN THE MAGELLANIC CLOUDS*

KARL G. HENIZE†

University of Michigan Observatory

Received May 5, 1956

ABSTRACT

Catalogues of 236 emission-line stars and 532 emission nebulae discovered on objective-prism photographs of the Magellanic Clouds are presented in four tables. A fifth table lists exciting stars involved in the Large Cloud nebulae. Finding charts are provided for both Clouds.

OBSERVATIONS OF SOUTHERN PLANETARY NEBULAE

KARL G. HENIZE

Dearborn Observatory, Northwestern University

Received August 4, 1966; revised September 9, 1966

ABSTRACT

An H α survey of the entire southern sky south of -25° declination with the Mount Wilson 10-inch objective-prism camera has resulted in a catalogue of 459 objects classifiable as planetary nebulae or possible planetary nebulae. Of these, approximately 150 are newly discovered. The catalogue gives for both old and new nebulae basic data including intensity of the H α image, intensity of the continuum, degree of resolution of the H α image, and presence of emission lines other than H α . Where possible, nebular diameter and the intensity ratio of [N II] $\lambda 6584$ to H α are also listed. Since one of the more

Emission-Line Stars in an Obscured Region in Chamaeleon. KARL G. HENIZE, *Dearborn Observatory*.—In the course of the Michigan–Mount Wilson southern H α survey a group of ten emission-line stars were found in an obscured area in Chamaeleon centered on R.A. 11^h04^m, Dec. $-76^\circ.5$ (1875) (Henize, thesis, 1954). Hoffmeister (*Trans. IAU XIA*, 268, 1961) has found a concentration of RW Aurigae type variables in this same region. A search

**Examples K. Henize
publications of results from
Southern Halpha Survey**

**Very probably not all his
discoveries were published**

**Many remains just marked on
the relevant discovery plates**

PARI – US Initiative (Repository) for North American Plates - PARI Institute, NC



Recently about 100 000 plates there, plans for more

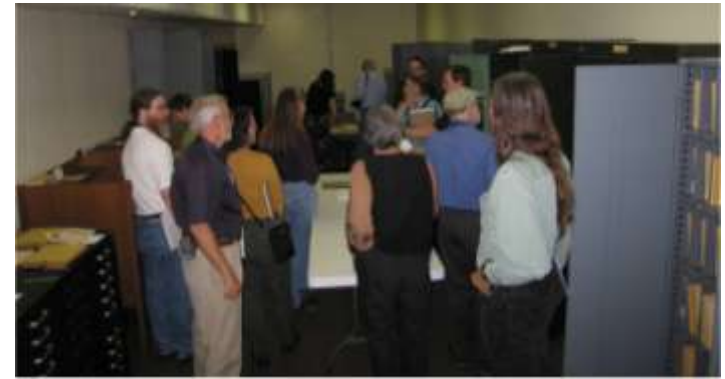
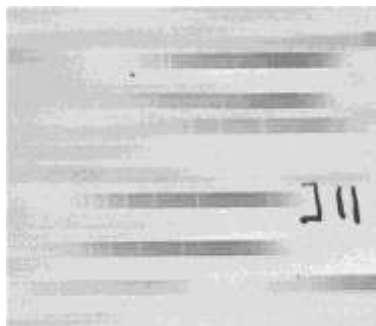


Plate preservation workshop 2007



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Conclusions

- Gaia will provide **ultra-low dispersion spectra** by BP (optical) and RP (near IR) representing a **new challenge for astrophysicists and informatics**
- The nearest analogy is represented by **digitized prisma spectral plates**: Sonneberg, Hamburg and Byurakan surveys
- These digitised surveys can be used for **simulation and tests** of Gaia algorithms and Gaia data. Some algorithms have been tested already.
- Some types of variable stars are known to exhibit **large spectral type changes** – this field is however little exploited and more discoveries can be expected with Gaia data as Gaia will allow to investigate spectral behaviors of huge amounts of objects over 5 years with (for spectroscopy) good sampling
- This analysis is part of ESA IBWS2011 PECS 98058

Acknowledgements

This study is part of ESA PECS Project C98058 “Czech Participation in Gaia” Stellar Department, Astronomical Institute of the Academy of Sciences of the Academy of Sciences of the Czech Republic Ondrejov

The End