# Do we need a system of classification for extrasolar planets?

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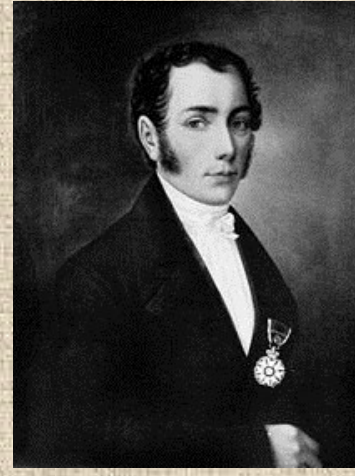[2] Astronomical Institute of the Slovak Academy of Sciences, Bratislava

## Abstract

Spectral classification of stars is now common and widely used. Only a few people know that its evolution into today's form has taken a matter of decades and that in its infancy was the subject of ridicule. This year is the 20th anniversary of the discovery of the first extrasolar planet 51Peg b. Almost two thousand planets and thousands of planet-candidates have been discovered since then. Isn't it high time to start talking about a system of classification? Every day new planet-candidates are being discovered and with the volume of planets expected to dramatically accelerate, without a good system of classification in place, the backlog of planets waiting to be analyzed would slow down research dramatically. We can discuss how this classification (taxonomy) should look like and be presented according to the existing system of classification published by Plávalová (2012). This classification uses four main parameters which cover the mass, semi-major axis, temperature, eccentricity, plus one optional parameter which is not always known.

## A brief history of classification

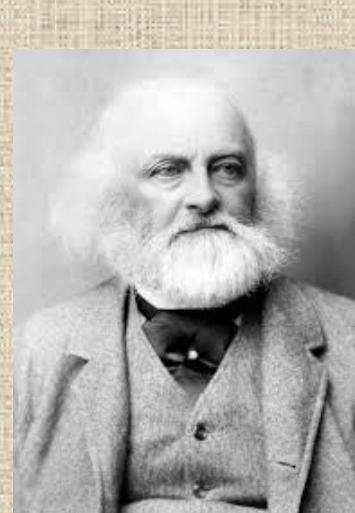### Stellar classification

**1814**

Joseph Fraunhofer invented the spectroscope and was the first to observe solar and stellar spectra.
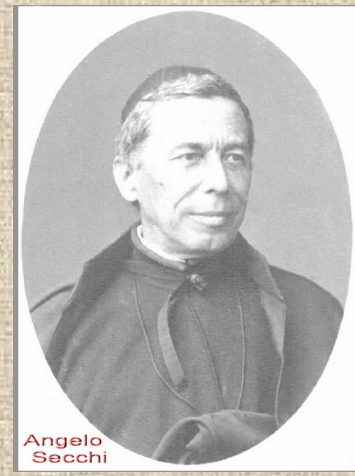
**1862**

Lewis Morris Rutherfurd amassed sufficient spectra to attempt the classification of stars into three groups. Modern equivalent groups would be the late-type stars, the late-B to early-F stars, and the OB stars.

**1860-1870**

Pietro Angelo Secchi classified the spectra of stars into two classes, basically the early I and the late-types II. In 1866 he added what are now the M-types III, and two years later he identified some faint red stars as type IV, the carbon stars. Later yet he felt compelled to separate some emission-line stars into a further class, V.

**1881-1890**

Williamina Fleming classified more than 10,000 star. It used a scheme in which the previously used Secchi classes (I to IV) were divided into more specific classes, given letters from A to N. Also, the letters O, P and Q were used, O for stars whose spectra consisted mainly of bright lines, P for planetary nebulae, and Q for stars not fitting into any other class.
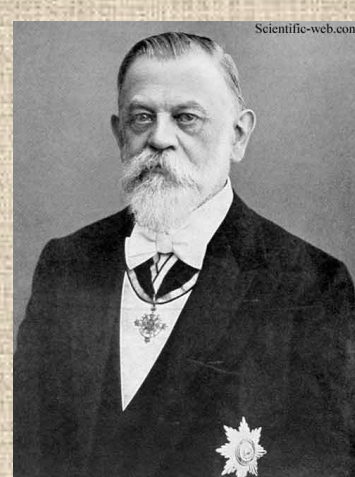
**Around 1890**

Joseph Norman Lockyer offered his own spectral classification scheme. The differentiation of stars into ascending and descending temperature branches was based on his "meteoritic hypothesis" for the origin and subsequent evolution of stars. His classifications were never generally accepted, he did at least distinguish the spectra of giants and supergiants.
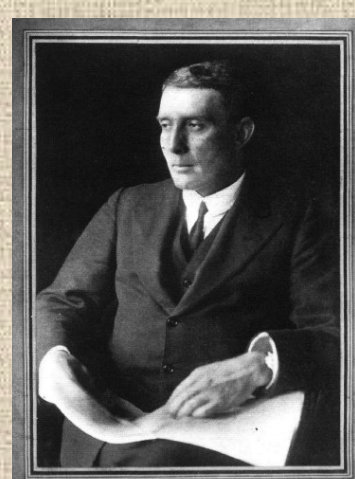
**1895**

Hermann Carl Vogel combined Secchi's classes III and IV, since they were both based on broad bands, and went on to subdivide the resulting three classes. However, the discovery of helium both in stars and on earth was to revise his scheme, subdividing his class Ia.

**1897**

An amateur astronomer, Sir Francis Kennedy McClean's spectral classification system was able from the beginning to include the stars with neutral helium absorption. It was modelled on Secchi's, with Vogel-like revisions, and his groups corresponded to the MK series of B, A, F, G-K, M, and carbon stars.

**1943-1953**

A new system of stellar spectral classification MKK, was introduced in 1943 by William Wilson Morgan, Philip Childs Keenan, and Edith Kellman [10]. This two-dimensional (temperature and luminosity) classification scheme is based on spectral lines sensitive to stellar temperature and surface gravity which is related to luminosity (whilst the Harvard classification is based on surface temperature only). Later, in 1953, after some revisions of standard stars and classification criteria, the scheme was named the Morgan–Keenan classification, or MK and this system remains in modern use today [11].

### Planet classification

**1969**

Peter Van de Kamp [15] reported a periodic "wobble" in Barnard star's motion, apparently due to planetary companions. In 1973 astronomers George Gatewood and Heinrich Eichhorn [4], using data obtained with improved equipment on the 30-inch Thaw Refractor telescope, did not detect any planets but instead detected a change in the colour-dependent image scale of the images obtained from by Van de Kamp.

**1988**

Bruce Campbell, Gordon A.H. Walker, and Stephenson Yang reported an interesting phenomenon [2]; the radial velocity variations of binary star γCephei, seemed to suggest the existence of a Jupiter-like planet around one of the stars, but by 1992 had changed their minds [14]. However, by 2003, Hatzes et al. [6] confirmed the existence of the planet around γCephei.

**1991**

Andrew Geoffrey Lyne announced the first ever pulsar planet discovered around PSR 1829-10 [1]. However, this was later retracted, just before the first real pulsar planets were announced.

**1992**

Aleksander Wolszczan and Dale Frail announced the discovery of a multi-planet planetary system around the millisecond pulsar PSR 1257+12 [16].

**1995**

The first exoplanet to be discovered which orbits a main sequence star, 51 Peg b, was discovered by Michel Mayor and Didier Queloz [9].

**2003**

David Sudarsky, Adam Burrows, and Ivan Hubeny created the so called Sudarsky's classification [13] of extrasolar gas giant planets, for the purpose of predicting their appearance based on their temperature. Gas giants are split into five classes (numbered from Roman numerals) according to their modelled physical atmospheric properties.

**2007**

Simone Marchi [8] used as many inputs as possible for the analysis, in particular the planetary mass, semi-major axis, eccentricity, stellar mass and stellar metallicity. He identify the best procedure to follow: a multivariate statistical analysis (PCA) to find the most important variables, and then hierarchical cluster analysis. His best solution consists of five clusters.

**2009**

Lundock et al. [7] had acquired spectra for all of the solar system planets and many smaller bodies using TRISPEC. The spectra are divided by their characteristic shapes into three distinct groups: gas planets, soil planets, and ice planets. Venus represents a fourth possible group.

**2012**

Eva Plávalová [12] proposed an extrasolar planet taxonomy scale with four main parameters which cover the mass, semi-major axis, temperature, eccentricity, plus one optional parameter, surface parameter, which is not always known.
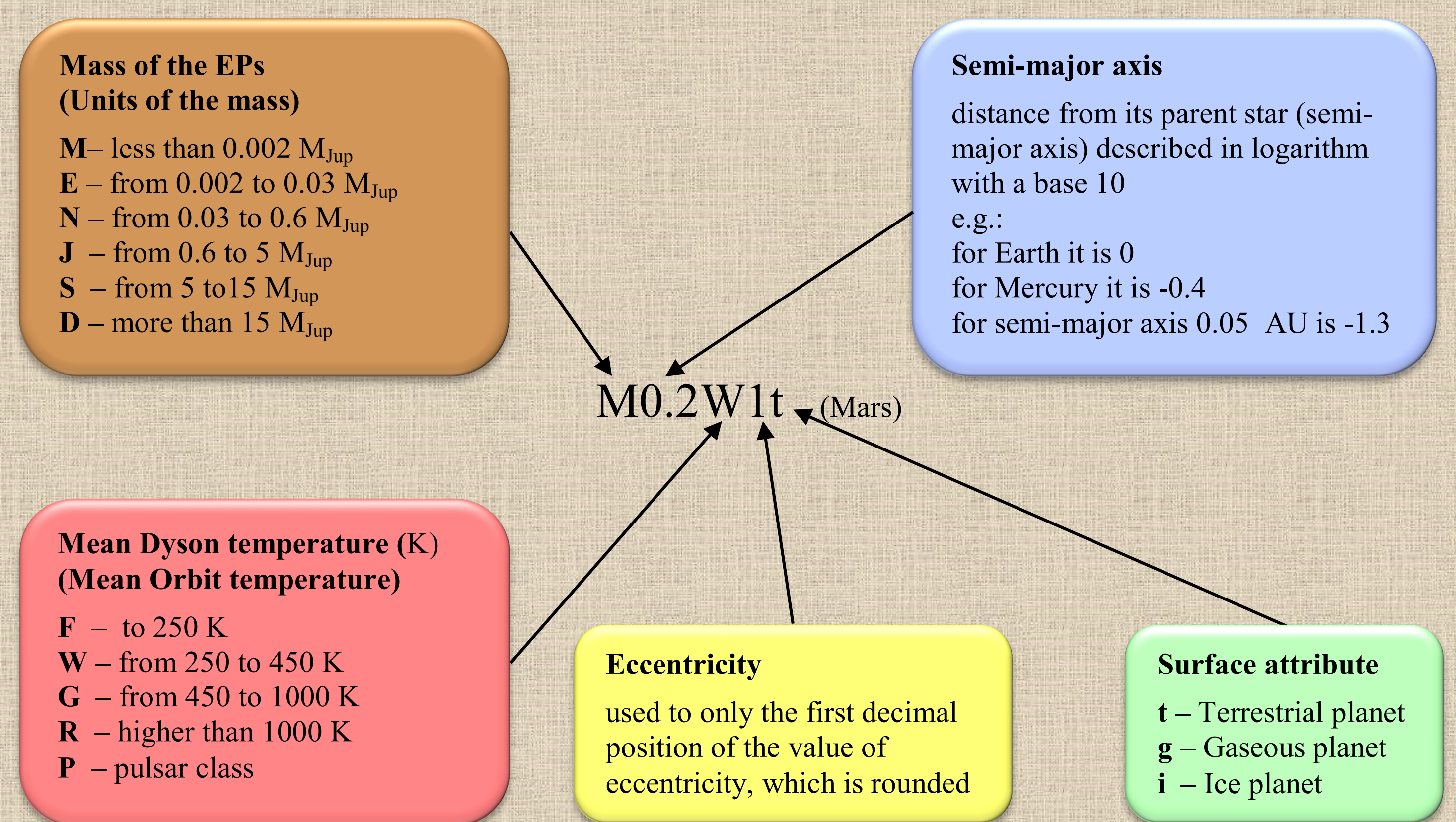
## System of classification of extrasolar planets



**Figure 1:** Schematic explanation - a definition of the taxonomy of the planets for which we are able to determine the taxonomy scale.

**Mass of the EPs (Units of the mass)**
M– less than 0.002 $M_{Jup}$
E – from 0.002 to 0.03 $M_{Jup}$
N – from 0.03 to 0.6 $M_{Jup}$
J – from 0.6 to 5 $M_{Jup}$
S – from 5 to15 $M_{Jup}$
D – more than 15 $M_{Jup}$

**Semi-major axis**
distance from its parent star (semi-major axis) described in logarithm with a base 10
e.g.:
for Earth it is 0
for Mercury it is -0.4
for semi-major axis 0.05 AU is -1.3

$$M0.2W1t \leftarrow \text{(Mars)}$$

**Mean Dyson temperature (K) (Mean Orbit temperature)**
F – to 250 K
W – from 250 to 450 K
G – from 450 to 1000 K
R – higher than 1000 K
P – pulsar class

**Eccentricity**
used to only the first decimal position of the value of eccentricity, which is rounded

**Surface attribute**
t – Terrestrial planet
g – Gaseous planet
i – Ice planet

### How it works?

This system uses four abbreviated parameters, written as a code, to allow for rapid recognition of a planet's characteristics.

The first parameter takes the form of the units of the mass, where M is less than 0.002 $M_{Jup}$ and roughly represents the mass of Mercury, E is a mass from 0.002 to 0.03 $M_{Jup}$ (roughly the mass of Earth), N is a mass from 0.03 to 0.6 $M_{Jup}$ (roughly the mass of Neptune), J is a mass from 0.6 to 5 $M_{Jup}$ (roughly the mass of Jupiter), S is a mass from 5 to 15 $M_{Jup}$ (Super Jupiter) and unit D is for planets with a mass more than 15 $M_{Jup}$.

The second parameter is the planet's distance from its parent star (semi-major axis) described in logarithm with base 10.

The third parameter is the Mean Dyson Temperature (MDT) of the planet, for which we established four main temperature classes according to the state phase of water; F represents the Freezing class, W the Water Class, G the Gaseous Class, and R the Roasters Class. We devised one additional class, however, P representing the Pulsar Class, which concerns extrasolar planets orbiting pulsar stars. The Dyson temperature is a temperature that has an artificial sphere the size of a planetary orbit (Dyson sphere) [3]. The MDT is the arithmetical mean of the Dyson temperature taken from 10 equal segments, according to the second Keplerian law.

The fourth parameter is eccentricity, where we used only the first rounded decimal position for its value. Many extrasolar planets were published without a known value for their eccentricity, and then the classification code is written without a fourth parameter.

If the attributes of the surface of the planet are known, we are able to establish a fifth additional parameter where t represents a terrestrial planet, g a gaseous planet, or i an ice planet.

### Examples

The code for Earth is E0W0t, for Uranus N1.3F0i and for 55 Cnc e is E-1.8R1. In practise, using the whole code is sometimes unnecessary. Then we can use a minimal code which for example could contain only the units of mass with the MDT, for example, Earth could be written as EW, 55 Cnc e as ER and Uranus as NF.

| Planet | Classification code | Minimal code |
|---|---|---|
| Solar system | | |
| Mercury | M-0.4G2t | MG |
| Venus | E-0.1G0t | EG |
| Earth | E0W0t | EW |
| Mars | M0.2W1t | MW |
| Jupiter | J0.7F0g | JF |
| Saturn | N1F1g | NF |
| Uranus | N1.3F0i | NF |
| Neptune | N1.5F0i | NF |
| Planets orbiting 55 Cnc | | |
| 55 Cnc b | J-0.9R0 | JR |
| 55 Cnc c | N-0.6G1 | NG |
| 55 Cnc d | J0.8F0 | JF |
| 55 Cnc e | E-1.8R1 | ER |
| 55 Cnc f | N-0.1W0 | NW |
| Miscellaneous extrasolar planets | | |
| 11 Com b | D0.1R2 | DR |
| 14 And b | S-0.1R0 | SR |
| 75 Cet b | J0.3G | JG |
| Kepler 9b | N-0.8R1 | NR |
| Kepler 9c | N-0.6G1 | NG |
| CoRoT-9 b | J-0.4G1 | JG |
| HD 117207 b | J0.6F2 | JF |

**Table 1:** Taxonomy identification for a few of the many discovered extrasolar planets.

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