**NOVAE & SPECTROSCOPY**

Historically, the emergence of "new stars" sometimes very brilliant, called nova, is a subject of fascination. Today, novae are detected by monitoring systematic sky photometry. Many discoveries have been the work amateur astronomers (in video, photography and now CCD).

The phenomenon of "Nova"

Typically, the nova phenomenon is produced in a cataclysmic system: a double star, very tight, which has very specific characteristics. The main star is a white dwarf, a companion star of the series main Cipale, usually red. (Fig. 1) The white dwarf is a star at the end of life: a sphere of about 10000 km diameter containing a mass of material (Carbon, oxygen, helium) corresponding on average, half that of the Sun [About 0.5 M☉]. The density of this area is considerable, as is the gravity at the surface. Its initial temperature is the order of 100 000 K. But this degenerate matter is no longer able to entrain thermonuclear reactions. The fate of a white dwarf cooling is to divide slowly. But the presence of very close companions will turn red radiantly this fate. The two stars orbit in a few hours in a volume equivalent slower than the Sun. The red star fills its Roche lobe and dumps matter, mainly of hydrogen and helium toward the white dwarf. In most systems, this material will wrap around the white dwarf to form an accretion disk. The accumulation of material in the disk causes time to heat up: the temperature disk increases sharply from 7000 to more than 15000 K. The phenomenon brutal and intense light that results is called outburst: within hours of brightness of the system increases by several several magnitudes (2 to 5 in general and up to 8 magnitudes in some stars cataclysmic) and then return to its "Calm" in a few days, the disc having emptied of some of his material. The interval Outbursts of time between two is typically a few tens of days. It there are extreme cases ranging from a few days to years. This phenomenon has led to assign the name "Dwarf nova" in these systems (slow or fast?) are the best known SS Cygni and U Geminorum. Matter after the red companion drawn permanently, and accelerated during the "Outbursts" by the white dwarf because of the strong gravity in its ruling surface. It forms a surface layer cial hydrogen and helium on the surface of the white dwarf. Also due to the strong gravity, the pressure at the base of the layer is huge, growing as the accumulation of material. The result is a very high temperature, increasing to measure of the accretion of matter. When the temperature reaches about 1000000 K, thermonuclear reactions begin: is the nova phenomenon. In a few tens of hours, the brightness increases up to 1 million times for the novae. (See Box 1) Very rare cases (about ten), several exploration systems were detected, a few years or decades apart, these stars lose the "nova" to take that of "recurrent nova". Is known only a dozen, for example U Sco, or T Pyxidis, which has produced a...
Cool star. The red star main series $T = 3000 \text{ K}$

Jet material from the red star feeding the disk accretion.

Compact star hot (Dwarf white)

Accretion disk

Accretion field (H, He)

Accretion disk (Cataclysmic) Wind Stellar (symboliques)

White dwarf O, C (Mg, Ne) envelope H, He

Temperature $\sim 10 \text{ million K}$

Progressive increase of pressure and the temperature.

2a. Accumulation of matter (hydrogen, Helium ...) on the surface of the white dwarf.

2b. Outbreak of thermonuclear reactions.

Strong UV radiation.

Issue of permitted lines H, He, N, Fe

Expulsion of a shell material dense (H, He, Fe, N, O ...)

2c. Expulsion of part of the envelope.

Expulsion of the ejecta and decrease in density

Issue of permitted lines H, He, Fe

Issue of forbidden lines NiIIa, OIII, Fe III

2d. Continuation of thermal reactions monucléaires.

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1. THE STAR OF ITS SPECTRUM

The nova V407 Cygni photographed by Christian Buil (10-04-2010) is at the edge of the nebula America (NGC 7000). This symbiotic star produced a nova-like explosion detected March 10, 2010 at the magnitude 6.8 study by Japanese fans. It has been the subject of intense monitoring. Amateur spectroscopy up to magnitude 14 (V)!

The light from the star is collected by a telescope (SC 25 cm) and then is dispersed by a spectrograph and recorded by a CCD camera. The spectrum obtained is "2D". It is adjusted for different geometric aberrations. Light pollution is cut off. From this image, a pro- over "1D" is calculated after calibrated spectrum in wavelength and corrected for different effects caused by the passage through the atmosphere, instruments, optics and camera sensitivity that depends on the wavelength.

The light scattering requires exposure times accumulated important (typically one hour in this configuration for objects magnitude from 10 to 12). The follow up of this nova mag. 14 required an cumulative exposure time up to 4 hours.*

The spectrograph (here a LISA Shelyak Instruments) mounted on the Telescope (SC 25 cm). The camera keeps homing in a permanent image of the star on the slit of the spectrograph.

After being dispersed by the network located in the spectrograph, the light forms a spectrum recorded acquisition by the camera (Starlight SXV-H9 a).

* The symbiotic stars are binary systems similar to the cataclysmic stars, with one-major-by: a giant star (usually red) replaces the star red of the main series which includes a cataclysmic. As a result, many long orbital periods, hundreds of days to several decades. Some symbiotic stars have been nova phenomena similar to those of classical novae. V407 Cyg is part of this very small group along with T CrB, RS Oph and AG Dra.

Identification a nova

1. CURVE LIGHT

The novae are usually detected by photometry. The general shape of the curves of luminosity (Fig. 3) is similar for all novae.

If the light curve looks the same for all novae, time scales and intensity vary. After an abrupt rise of the luminosity a few hours, the maximum luminosity is reached, after a brief plateau. The brightness then declines by about 3 magnitudes in a "The first decline" followed by a phase transition. This transition may have different different aspects: regular oscillations, deep decline or even rise in brightness. It is followed by the final decline that reduces gradually.
ment and regular brightness to its initial pre-nova.
A classification of the speed of Nova was established by Payne-Gaposchin (1957) as a function of elapsed time for a decreasing-power of 2 and 3 magnitudes from maximum brightness reached. These times are denoted T2 and T3 and express

<table>
<thead>
<tr>
<th>Class</th>
<th>T2</th>
<th>T3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very fast</td>
<td>&lt;10 days</td>
<td>&lt;20 days</td>
</tr>
<tr>
<td>Fast</td>
<td>11 to 25 j</td>
<td>From 21 to 49 j</td>
</tr>
<tr>
<td>Moderately fast</td>
<td>From 16 to 80 j</td>
<td>From 50 to 140 j</td>
</tr>
<tr>
<td>Slow</td>
<td>81 - 150 j</td>
<td>141 to 264 j</td>
</tr>
<tr>
<td>Very slow</td>
<td>&gt; 151 j</td>
<td>&gt; 265 j</td>
</tr>
</tbody>
</table>

Mees days. 5 speed classes were defined (see table).

● CHARACTERISTIC SPECTRUM
The detection of a star "new" or object which the brightness-sity has increased significantly, however, is not sufficient to characterise observation as nova. Only one spectrum of the new object permits to identify with certainty according to their characteristics, first and foremost the type and profile of emission lines. The spectrum of Nova Scuti 2010, V496 Sct, was the first spectrum (Fig. 4) to suggest the character nova (AAVSO Alert Notice 412, November 10, 2009). It was conducted November 9, 2009 at 17:30 UT, before the first spectra professionals.

● THE TWO TYPES OF NOVA
The appearance of the spectrum at maximum light is used to define two main types of novae. The hydrogen lines are always present in emission.

The Fell novae, 60% of novae: the main emission lines in most of the hydrogen lines are multiple lines of ionized iron once (Fe II). (Fig. 5). The lines are narrow: the speed of expansion less than 2500 km.s⁻¹. These lines are frequently preceded by profiles "P Cygni" absorption.

Novae He / N, 40% of novae: the main emission lines (After HI) rays are helium HeII (λ = 4686 Å), HeI (5876 Å) and nitrogen NII (5679 Å), (5001 Å) and NIIya (4640 Å) (Fig. 6). The lines are much larger (expansion velocities in excess of 2500 km.s⁻¹, and easily reaching 8000 km.s⁻¹) with a flattened top and a profile complex. They correspond to systems more energy.

The expansion velocity of the nebular envelope ejected during the phe-nova phenomenon can be determined from the analysis of rays and using the Doppler effect (see Box 2).

Medusa suffragarit utilitas Sabura, quod Oratori AMPutate bellus settlor, quamquam Syrtes corrumpert Zoth-case, C pretiosius agricolaee pessimus divinus senescet aegre utilitas quaedruepei and apparatus bellis vocificat incredibility adlaudabilis orator, sem-Octavius fragilis appears agnascor per-Bellis silent. Cathedra vo
2. MEASUREMENT OF SPEED OF EXPANSION

The analysis of the lines determines the speed at which the envelope of the nebula is expelled when the phenomenon occurs. The Doppler effect provides access to this measure. When a hydrogen atom has a zero velocity relative to the observer, an H-alpha photon emitted by this atom has a wavelength $\lambda = 656.3$ Å. When the same atom has a non-zero speed, positive if it moves if it moves away from the observer, the wavelength, $\lambda$, of the same photon will appear higher (more red) or lower (more blue). The shift in wavelength is given by the formula: $\Delta \lambda = \frac{c \cdot v}{\lambda} \cdot \Delta t$ with $v$ the speed projected along the line of sight and $c$ the speed of light.

Global radiation of the star that is a mixture of regions with different radial velocities (here between +3000 km/s and -3000 km/s) the spectral line will be composed of elements of shifts Doppler broadened and thus be different as shown in figure below.

The evolution spectral of novae

THE PHASES

Just as the brightness varies over time (Fig. 3), the appearance of the spectrum will change over time. The two main factors characterizing changes are temperature and density of the envelope form an area around the expanding nebula system. On distinguishes several phases in the evolution and are represented in Figure 7. We were able to define different areas corresponding to the phases of evolution of a nova: P = permitted lines, auroral rays A = C = ray coronal, N nebular lines.

A nova begins in the left box (P). In this phase of stripes “permitted” densities of the envelope material expelled are so high that only can form stripes “Normal” emission. These include lines produced by hydrogen, helium, nitrogen or iron ion. When the density decreases due to the expansion of the nebular envelope-Laure, the first stripes “forbidden” appear. These lines do little wind shows that in very diluted, if in a vacuum excess of that is inaccessible to laboratory experiments (hence the name assigned to the early twentieth those lines). They are marked [OIII] such as the famous lines [OIII] well known in the magerie nebulae. The first to appear are the auroro-rays (A) as [OIII] (λ = 4363 Å) and low degree of ionization [OIII] (4363 Å), [NII] (5755 Å), [OI] (6300 Å).

When the expansion is continuing and that the density continues to decline therefore, two possibilities arise depending on the temperature:
- The most energy systems (Novae He / N) can lead to very high temperatures allow the formation of ray coronal tions very high excitation energies corresponding to and degrees of ionization very important, especially [Fe VII], [Fe X], or [Fe XIV], that is to say, the ion has lost respectively 6, 9 or 13 electrons. This phase, reached only by a few nova (about 15%), is called coronal phase (zone C).
- If the temperature is lower, the nova goes directly to the nebular phase (N), characterized by the nebular lines, the most known are the forbidden lines of ionized oxygen twice [OIII] (4959 Å and 5007 Å) is the final stage of most novae.

The evolution of a nova can be represented by its trajectory in this diagram (Fig. 7). The nova V407Cyg discussed below has a path equivalent to that of V1688 Cyg. Some novae very fast as the recurrent nova U Sco have their temperature Diminue so quickly that they can achieve the phase lines prohibited.

H-alpha line profile Nova KT Eri November 27, 2009

On the right, the intensity is represented not in terms of the length wave, but the velocity relative to the center of the line. The Doppler effect to determine the expansion velocity of the envelope envelope: about 3200 km.s⁻¹.

7. Graph showing the evolution of novae in function of two parameters. Density of the envelope x-axis expansion (estimated from the density electronic nique) and temperature on the ordinate. The abcissa is reversed: the left side of the graph correspond to the densities the highest. The scales are logarithmic.
SOME SPECTRAL MONITORING

● LA NOVA V496 SCUT
It is found that 9 months after maximum lightness (November 9, 2009), the iron lines have disappeared. The dilution of the envelope ejected in the middle inter-allows the formation of stellar rays spectacular prohibited, including those of the oxygen double ionized [OIII] \( \lambda 4959 \) and 5007, exceeding here rary intensity of hydrogen. The nebular phase-Lair is the final stage of a nova (September 9, 2010).

● LA NOVA V407 SWAN
The evolution of the spectrum can be followed in order quantitative. Figure 9 shows the change of intent density on H-alpha lines (left) and [OIII] \( \lambda 5007 \) nova V407 Cygni of a function of time (number of days since the maximum brightness). The dotted curve (right scale) represents the magnitude of the nova. Growth sudden intensity [OIII] coincides with the beginning of final decline (see light curve). This increase-mentation occurs abruptly along the decline of the intensity of the H-alpha line.

● LA NOVA KT ERI 2009
Shortly after the nova V496 Sct, another nova first appeared in the constellation Eridanus. She took the name of KT Eri. This nova was discovered by H. Yamako November 25, 2009 to a magnitude of 8.1. The subsequent study of images Archived showed that the maximum brightness occurred 11 days earlier, on November 14, at a magnitude of 5.2: this nova visible to the naked eye for 2 to 3 days escaped the vigilant observers. Despite the surveillance automated, there is room for comments tors, even equipped with a simple pair of binoculars. This nova has broad lines of hydrogen the measure used to determine speed expansion of 3200 km / s. The strongest lines after hydrogen is produced by helium and the nitrogen. These two features allow the nova classified as He / N Note the changes Fast rays, in intensity, profile. Some of these lines are identified. Most of them are "blends", resulting from the composition of rays of different species of overlapping. Because of their large width due to the high speed for expansion. To facilitate the presentation of the evolution lines, the spectra were divided by their own continuum, which is thereby flattened.

Conclusion: monitor novae, a new field open to amateurs
The scope of activities of amateur spectroscopy continues to grow. The monitoring of nova is a aspects. Each new event is followed by a team of amateurs from different countries. The resulting results are collected on the site ARAS - Access for Ring Amateur Spectroscopy [www.astrosurf.com/aras/]. ARAS allows to coordinate campaigns international observation (symbiotic, cataclysmiques, novae ...) while pursuing a intense monitoring of Be stars began several years. If the adventure tempts you, do not hesitate to Contact F. Teyssier •

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