FRANCOIS TEYSSIER
www.astronomie-amateur.fr
Member AFOEV * * AAVSO, ARAS *

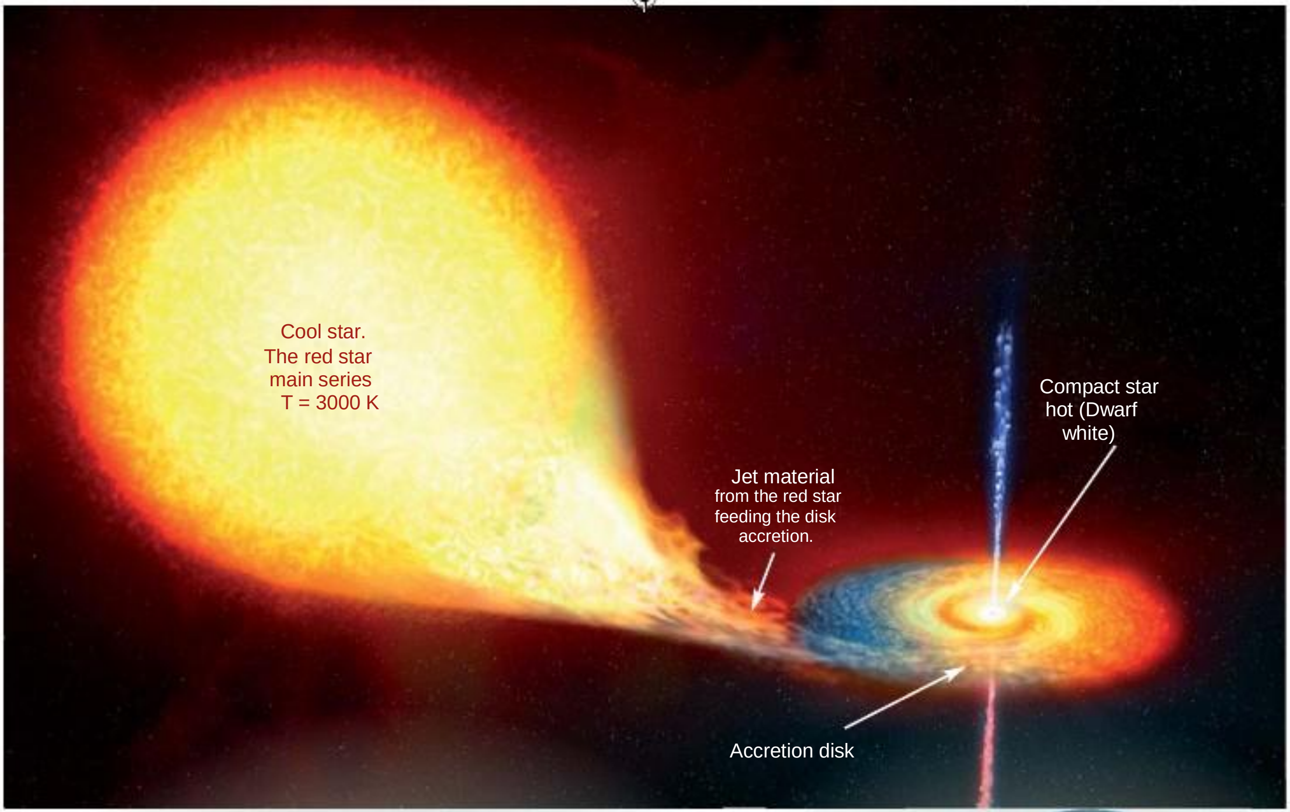
NOVAE & SPECTROSCOPY

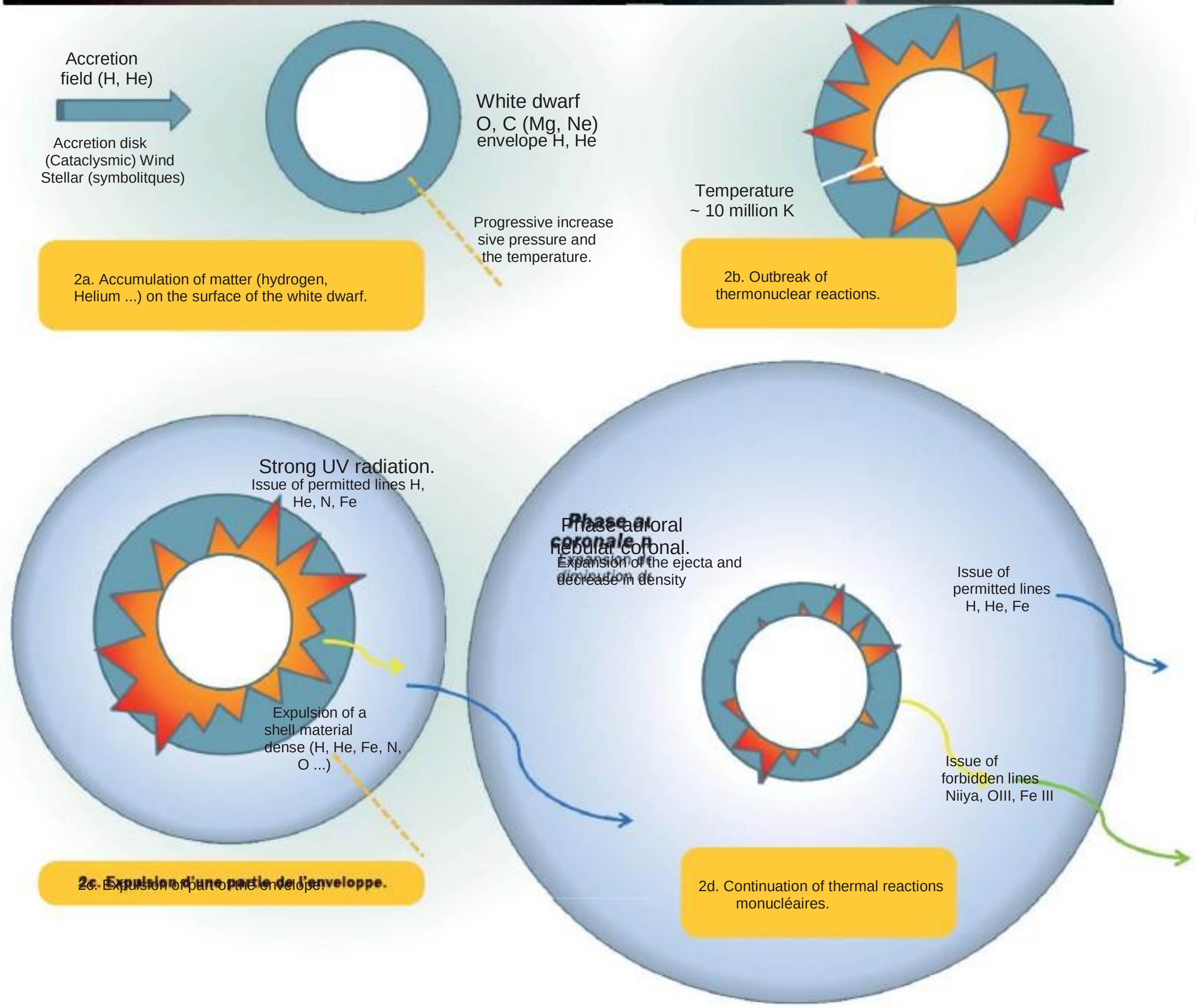
Historically, the emergence of "new stars" sometimes very brilliant, called nova, is a subject of fascination. Today, novae are detected by monitoring systematic sky photometry. Many discoveries have been the work amateur astronomers (in video, photography and now CCD).

L are recent developments in the spec- Amateur spectroscopy can carried kill a regular monitoring of these objects in the area where their spectroscopic variations are spectacular. Thus that amateur astronomers contribute the detection and understanding of these extreme events. (See Box 1)
The spectra presented in this article obtained by the author using a spec- trographe LHIRES (Shelyak Instruments) with a network of 150 lines per milli- be. It has since been replaced by a special LISA specially designed for spectroscopy Amateur objects and low light to obtain better resolution tion (network of 300 lines / mm).

The phenomenon of "Nova"

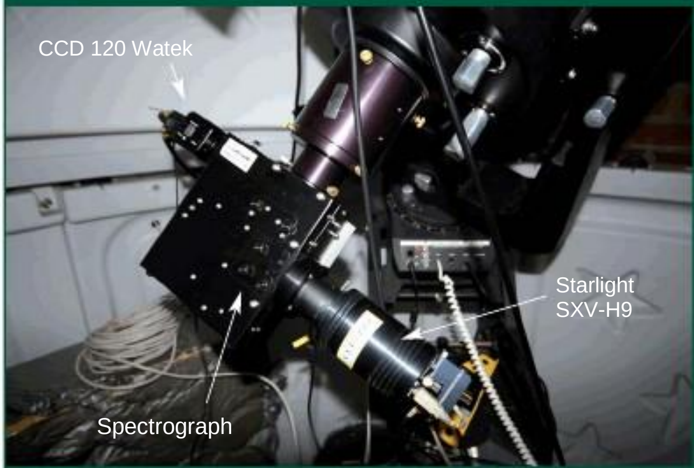
Typically, the nova phenomenon is pro- product in a cataclysmic system: a double star, very tight, which has very specific characteristics.
The main star is a white dwarf, a companion star of the series main Cipale, usually red. (Fig. 1)
The white dwarf is a star at the end of life: a sphere of about 10000 km dia- meter 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 en- tretenir thermonuclear reactions. The fate of a white dwarf cooling is to dir slowly. But the presence of very close companion will turn red radi- calement 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 he- lium toward the white dwarf. In most systems, this material will wrap around the white dwarf to form a accretion disk. The accumulation of material in the disk causes time time to heat up: the temperature the 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 typical- cally a few tens of days. It there are extreme cases ranging from a few days to years. This phe- 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 a very high temperature, increasing to measure of the accretion of matter. When the temperature reaches about 10000000 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 more violent (variation of 10 magnitudes generally up to 16). These reactions occurring on the surface of the star, much of the material accu- mule is ejected at high speeds (from few hundred to several thousand km. s-1) and forms an envelope of matter expanding. Despite this ejection matter, thermonuclear reactions are continues at a slower pace in the remainder of the surface layer and thus create a strong UV radiation that will "Light" excite the gas envelope expelled leading to the formation of stripes spectroscopic emission. It was sche- Matis these steps in Figure 2.
The explosion does not destroy the system. The accumulation of material at the surface of the white dwarf continues, preparing the conditions of a new explosion in a period of time generally considered ment to many thousands of years. In Very rare cases (about ten), several exploration sions 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 Pyxis, which has produced a


Cool star.
The red star
main series
T = 3000 K
Compact star
hot (Dwarf
white)
Jet material
from the red star
feeding the disk
accretion.
Accretion disk

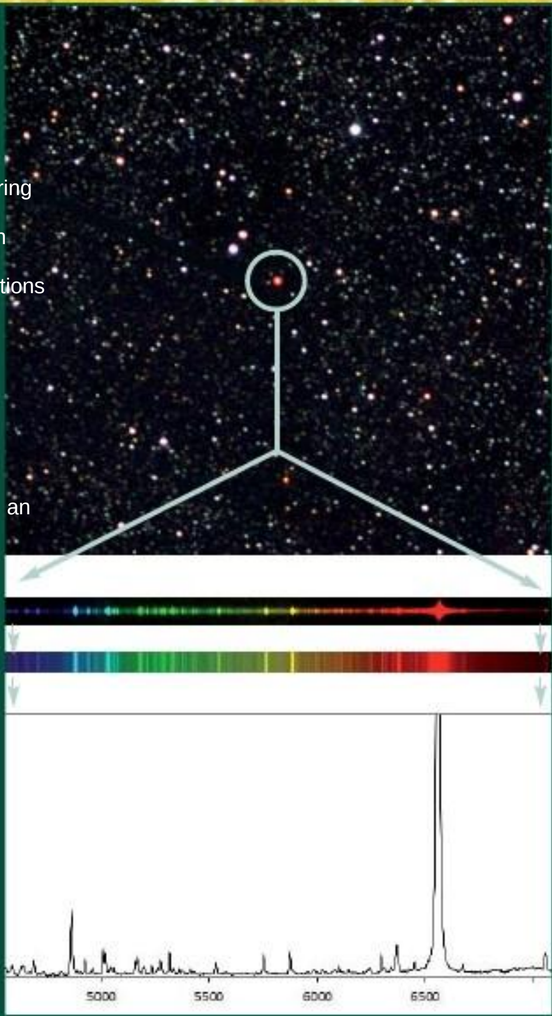

Accretion
field (H, He)
Accretion disk
(Cataclysmic) Wind
Stellar (symbolitques)
White dwarf
O, C (Mg, Ne)
envelope H, He
Progressive increase
sive pressure and
the temperature.
2a. Accumulation of matter (hydrogen,
Helium ...) on the surface of the white dwarf.
Temperature
~ 10 million K
2b. Outbreak 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.
Phase auroral
nebular coronal.
Expansion of the ejecta and
decrease in density
Issue of
permitted lines
H, He, Fe
Issue of
forbidden lines
Niiya, OIII, Fe III
2d. Continuation of thermal reactions
monucléaires.

1. THE STAR OF ITS SPECTRUM

The nova V407 Cygni photographed by Christian Buil (10-04-2010) is edge of the nebula America (NGC 7000). This symbiotic star * produced a nova-like explosion detected March 10, 2010 at the mag- 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 cudgel, light pollution is cut off. From this image, a pro- over "1D" is calculated after calibrated spectrum in wavelength and corrected
different effects caused by the passage through the atmosphere, instruments
optics and camera sensitivity that depends on the wavelength.
The light scattering requires exposure time accumulated important tives (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 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).

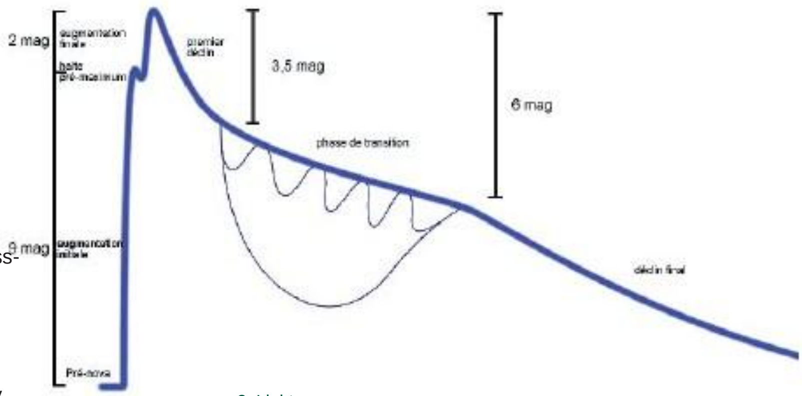
* The symbiotic stars are binary systems similar to the cataclysmic stars, with one-major-by: a giant star (usually red) replaces the sta red of the main series which includes a cataclysmic. As a result, many long orbital periods, hundreds of days to several decades. Some symbiotic stars have been novae 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.

innovative new phenomenon in early 2011.

Identification a nova

•CURVE LIGHT

The novæ are usually detected by photo- metry. The general shape of the curves of luminous- sity (Fig. 3) is similar for all novae.
If the light curve looks the same for all novae, time scales and intention sity vary. After an abrupt rise of the light- nosité a few hours, the maximum light- nosité is reached, after a brief plateau. The brightness- sity 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



3. Light curve.

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

Class	T2	T3
Very fast	<10 days	<20 days
Fast	11 to 25 j	From 21 to 49 j
Moderately fast	From 16 to 80 j	50 to 140 j
Slow	81 -150 j	141 to 264 j
Very slow	> 151 j	> 265 j

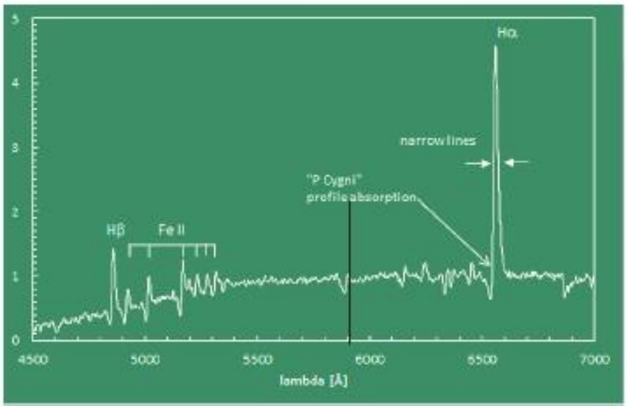
Mees days. 5 speed classes were defined (see table).

• THECharacteristic spectrum

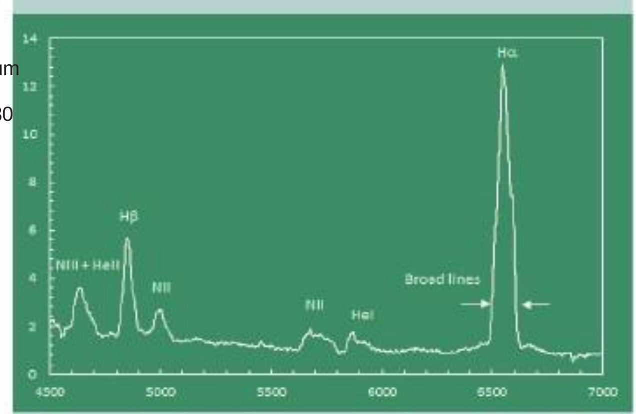
The detection of a star "new" or object which the brightness-sity has increased significantly, however, is not sufficient to charac-riser observation as nova. Only one spectrum of the new object per-is to identify with certainty according to their characteristics ticks, first and foremost the type and profile of emission lines sion. 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

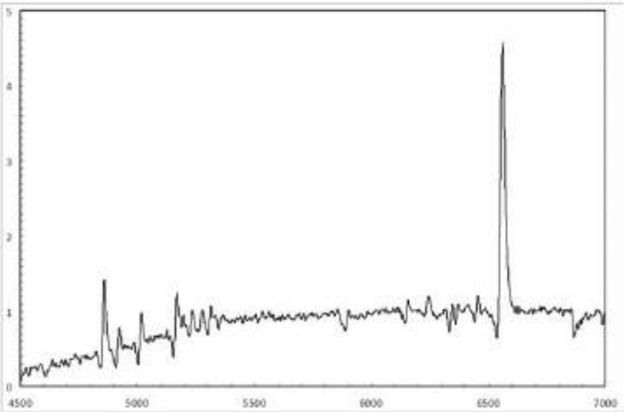
The appearance of the spectrum at maximum light is used to define two main types of novae. The hydrogen lines are always days present in emission.
The FeII novae, 60% of novae: the main emission lines in most of the hydrogen lines are multiple lines of ionized iron once (Fe II). (Fig. 5). The lines are 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 6000 km.s-1) with a flattened top and a profile complex. They correspond to systems more energy.



5. FeII novae. They are characterized by narrow lines (<2500km.s-1) and the presence of ionized iron lines once (FeII). Example: V496 Sct November 9, 2009.



6. Novae He / N. They are characterized by broad lines and the presence of hydrogen lines, helium and nitrogen. Example: KT Eri November 27, 2009.



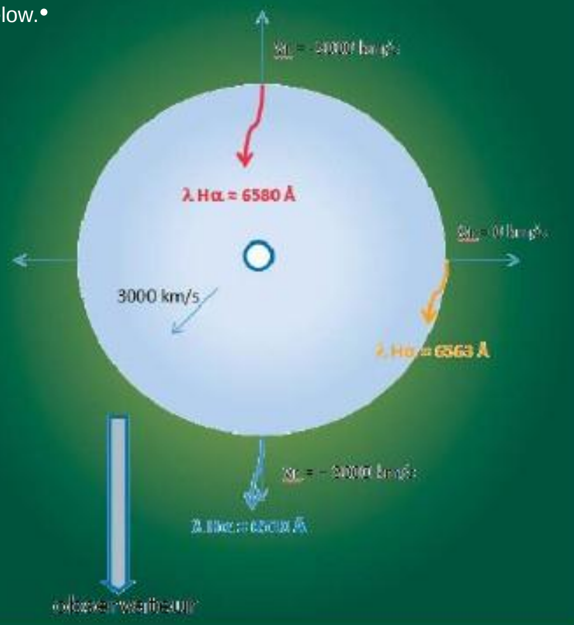
4. Spectrum identification of Nova V496 Scuti realized the November 9th, 2009 at 17 h 30 UT. The Balmer lines and Iron ionized once (FeII), narrow in transmission, preceded by a P Cygni profile in absorption are characteristic of a nova-like Fe II.

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 corrumperet Zoth-case, C pretosius agricolae pessimus divinus senesceret aegre utilitas qua-drupei and apparatus bellis vocificat incredibility adlaudabilis orator, sem-Octavius fragilis appears agnascor per-Bellis silent. Cathedra vo

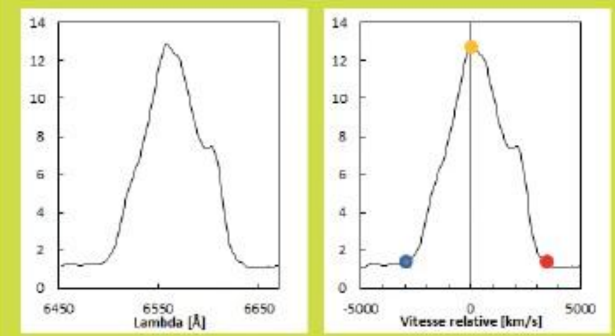
2. MEASUREMENT OF SPEED OF EXPANSION
FROM line profiles

The analysis of the lines determines the speed at which the enve
nebular envelope is expelled when the phenomenon.
The Doppler effect provides access to this measure.
When a hydrogen atom has zero velocity relative to the obser-
observer, an H-alpha photons emitted by this atom has a wavelen
⎣0
6 = 562.8 A. When the same atom has a non-zero speed, positiv
if it moves, if negative approaches, the wavelength, ⎣, of
same photon will appear higher (more red) or lower (more
blue). The shift in wavelength is given by the formula: = vr
(Δλ / λ) with xc Vr speed projected along the line of sight ⊗⎣
= ⎣□⎣0 and c speed of light.
Global radiation of the star that mixture of regions with
different radial velocities (here between + 3000 km / s - 3000 km
the spectral line will be composed of elements of shifts
Doppler broadened and thus be different as shown in figure
below.•



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

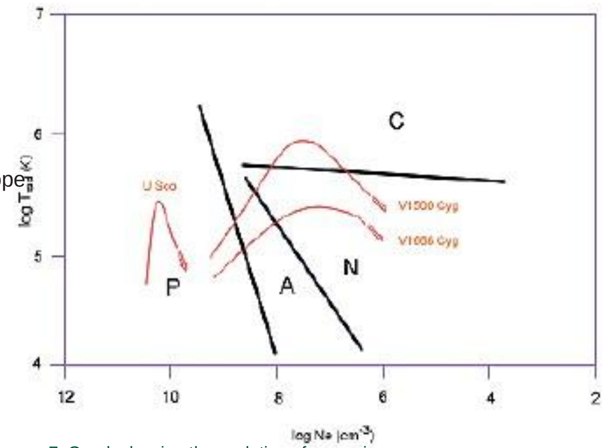
On the right, the intensity is represented not in terms of the length wave, but the velocity relative to the center of the line.
The Doppler effect to determine the expansion velocity of the envelope envelope: about 3200 km.s-1.



The evolution spectral of novae

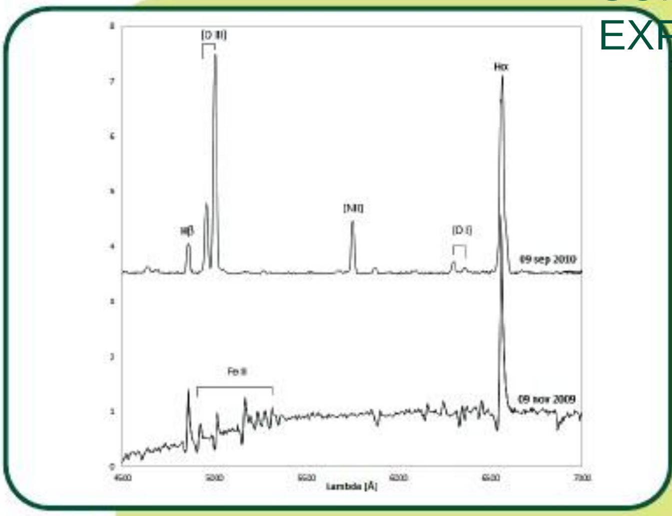
•THE PHASES

Just as the brightness varies over time (Fig. 3), the appearance of spectrum will change over time. The two main factors characterized ing changes are temperature and density of the envelope form an area around the expanding nebular système.On distinguishes several several phases in the evolution and are represented in Figure 7.
We were able to define different areas corresponding to the phases of evolution
tion of a nova: P = permitted lines, auroral rays A = C = ray coronary tions, 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-Laire, 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 [] such as the famous lines [OIII] well known in the ima-Gerie nebulae. The first to appear are the auro-rays eral (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 at very high temperatures allow the formation of ray coronary 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 iron has lost respectively 6, 9 or 13 elec-trons. 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 novæ.
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 Dimi-tinue so quickly that they can achieve the phase lines prohibited.



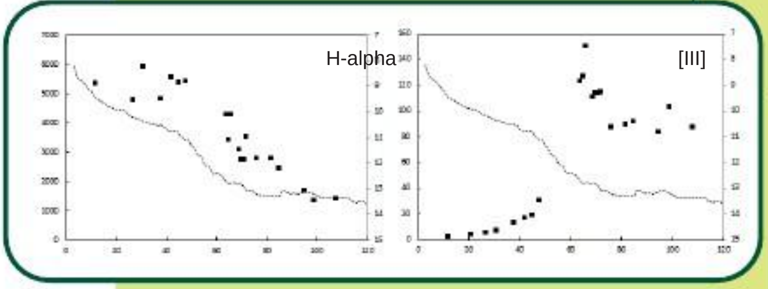
7. Graph showing the evolution of novae in function of two parameters. Density of the envelope x-axis expansion (estimated from the density electronic nique) and temperature on the ordinate. The abscissa is reversed: the left side of the graph correspond to the densities the highest. The scales are logarithmic.

SOME SPECTRAL MONITORING EXPEMPLES



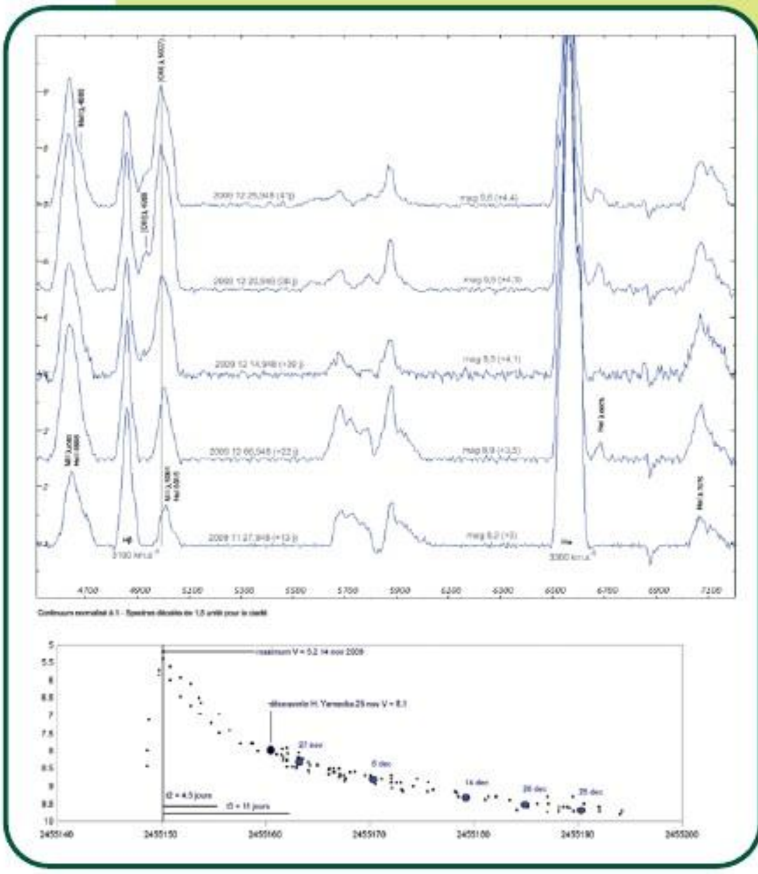
•LA NOVA V496 SCUT

It is found that 9 months after maximum light-
nosité (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] ⎣⎣ 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
sity on H-alpha lines (left) and [OIII] (λ
= 5007 Å) 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
tion 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, cata-
clysmiques, novae ...) while pursuing a
intense monitoring of Be stars began several
years. If the adventure tempts you, do not hesitate to
Contact.F. Teyssier ▪