The Mathematics of extratropical cyclones originating in the south of the South American continent

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Abstract—**Extratropical cyclones are common in the South Atlantic. They generally arise with the passage of cold fronts to the south of the South American continent, crossing the south of Chile and Argentina, in the regions of Puerto Natales, Punta Arenas (Chile), Rio Galegos, Rio Grande, El Calafate and Ushuaia (Argentina). The extratropical cyclone analyzed presented at its peak the very characteristic shape of a Chinese dragon. Many others were also analyzed. They present a mathematical form of a double Cotes Spiral curve. Here called the Dragonhead cyclone (DC), indicate a structural similarity with spiral galaxies, especially NGC 5247, in the constellation Virgo. With an area of influence and a size of around 3,247 thousand km2 at its peak, it moved quickly in a WNW direction, with an average speed of 76 km/h, with winds of 84 km/h at 100 km from the nucleus, as it passed north of the Falkland Islands (Malvinas Islands). In the data collected (Gobato et al., 2018-20222), and analyzed from the Dragonhead cyclone, it is clear that all extratropical cyclones that appear south of the South American continent, below 40° latitude, have the shape of a spiral curve, like the spiral galaxy. Most of these are in the form of a double Cote's spiral curve.**

Index Terms—**Spiral Galaxies, Falkland Islands, Extratropical Cyclone, Argentina, Chile, Chubut, Santa Cruz.**

I. INTRODUCTION

AS stated in the introduction the characteristic shape of hurricanes, cyclones, typhoons is a spiral. In mathematics, a spiral is a curve which emanates from a point, moving farther away as it revolves around the point. [1], [2], [3], [4], [5], [6], [7], [8], [9], [10]

After an analysis of the different types of spirals , it was found that the shape that came closest to the EC spiral, Figures (2), (6) and (7), is a double Cotes's Spiral. [3], [4], [5], [6], [7], [8], [9], [10] It was determined the mathematical equation of the shape of the extratropical cyclone, in case of Dragonhead.

A double spiral was also used by Lindblad (1964) [11], Figure (8), of which Gobato et. al (2020, 2021, 2022) [12], [13], [14], [15], [6], [16], [17], [18], [19], came to the conclusion that spiral galaxies assumed the Cote's Spiral curve, as did some extratropical cyclones, south of the South American continent.

A. *Cyclone*

A cyclone [20], [21] is a large air mass that rotates around a strong center of low atmospheric pressure, counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere as viewed from above (opposite to an anticyclone). [20], [21], [22], [23], [24].
A subtropical cyclone is a weather system that has some characteristics of a tropical cyclone and some characteristics of an extratropical cyclone. They can form between the equator and the 50th parallel. [20], [21], [25], [26], [27], [28], [24], [29]

These storms usually have a radius of maximum winds that is larger than what is observed in purely tropical systems, and their maximum sustained winds have not been observed to exceed about 32 m/s (64 knots). Subtropical cyclones sometimes become true tropical cyclones, and likewise, tropical cyclones occasionally become subtropical storms. Subtropical cyclones in the Atlantic basin are classified by their maximum sustained surface winds: Subtropical depressions have surface winds less than 18 m/s (35 knots), while subtropical storms have surface winds greater than or equal to 18 m/s. [22], [12], [19], [13], [30], [14], [31], [15], [32], [25], [26], [27], [33] [28], [34], [24], [29], [1], [35], [2], [3], [6]

Tropical cyclones are compact, circular storms, generally some 320 km (200 miles) in diameter, whose winds swirl around a central region of low atmospheric pressure. The winds are driven by this low-pressure core and by the rotation of the Earth, which deflects the path of the wind through

a phenomenon known as the Coriolis force. As a result, tropical cyclones rotate in a counterclockwise (or cyclonic) direction in the Northern Hemisphere and in a clockwise (or anticyclonic) direction in the Southern Hemisphere. [22], [12], [19], [13], [30], [14], [31], [15], [32], [25], [26], [27], [33] [28], [34], [24], [29], [1], [35], [2], [3], [6]

B. *NGC 5247 Spiral Galaxy*

Spiral galaxies [11], [36], [37], [38] form a class of galaxy originally described by Edwin Hubble in his 1936 work The Realm of the Nebulae and, as such, form part of the Hubble sequence. Most spiral galaxies consist of a flat, rotating disk containing stars, gas and dust, and a central concentration of stars known as the bulge. These are often surrounded by a much fainter halo of stars, many of which reside in globular clusters. [36], [37]

Spiral galaxies are named by their spiral structures that extend from the center into the galactic disc. The spiral arms are sites of ongoing star formation and are brighter than the surrounding disc because of the young. [11], [36], [37], [38]

Fig. 1: HAWK-I image of NGC 5247 Galaxy [37]

The Figure (1) shows NGC 5247, a grand design barred spiral galaxy, located 60–70 million light-years away. The galaxy lies face-on towards Earth, thus providing an excellent view of its pinwheel structure and multiple arms. It is in the zodiacal constellation of Virgo (the Maiden). [37]

The image was made in infrared light with the HAWK-I camera on ESO's Very Large Telescope at Paranal Observatory in Chile. HAWK-I is one of the most powerful infrared imagers in the world, and this is one of the sharpest and most detailed pictures of this galaxy ever taken from Earth. The filters used were Y (shown here in blue), J (in light blue), H (in green), and K (in red). The field of view of the image is about 6.4 arc minutes. [37]

NGC 5247 is a face-on unbarred spiral galaxy located some 60 million light years away in the constellation Virgo. It is a member of the Virgo II Groups, a series of galaxies and galaxy clusters strung out from the southern edge of the Virgo Super cluster. This grand design spiral galaxy displays no indications of distortion caused by interaction with other galaxies. It has two spiral arms that bifurcate after wrapping halfway around the nucleus. The disk is estimated to be 4.9 ± 2.0 kly (1.5 ± 0.6 kpc) in thickness and it is inclined by roughly 28° to the line of sight. [37], [38]

C. *Cote's spiral*

In physics and in the mathematics of plane curves [3], [39], [4], [5], [6], [7], [8], [9], [10], [11], a Cote's spiral (also written Cotes' spiral and Cotes spiral) is one of a family of spirals classified by Roger Cotes.
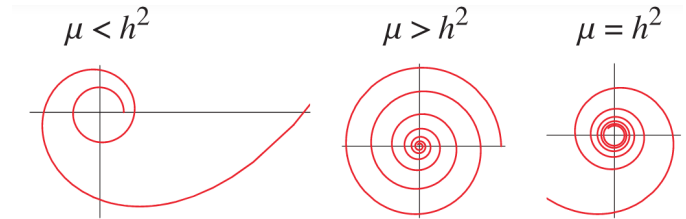

Fig. 2: Shapes of curves called Cote's spiral gives the solution to the central orbit problem. [7], [9], [5], [8], [3], [4], [29], [39]

II. DEVELOPMENT

After an analysis of the different types of spirals [3], [39], [4], [5], [6], [7], [8], [9], [10], [11], it was concluded that the form that came closest the spiral, Figures (1), (2), (4), (5), (6), and (7), is a double Cotes's Spiral, for the case $\mu < h^2$, Figure (2).

It was determined the mathematical equation of the shape of the DC, in the shape of a spiral called Cotes's Spiral", for the case $\mu < h^2$ Figure (2) and (6) [3], [39], [4], [5], [6], [7], [8], [9], [10], [11], [12], [14], [15], [40], [41], [42], [43], [44], [45].

A spiral that gives the solution to the central orbit problem under a radial force law

$$\ddot{r} = -\mu[r]^{-3}\hat{r} \tag{1}$$

$$r = A\sec(k\theta + \epsilon), \tag{2}$$

where,

$$k^2 = 1 - \frac{\mu}{h^2}, when \mu < h^2 \tag{3}$$

where A and ε are constants, and h is the specific angular momentum [4], [39], [5].

Analyzing the shape of the Spiral shape called "Cotes's Spiral" for $\mu < h^2$ [4], [39], [5], it appears that adding two constants to Equation (2) makes the necessary adjustments for the Isobaric ones. In the case of DC, the spiral that gives the solution to a radial force law is given by Equation (1).

An adjustment in Equation (2) is necessary to obtain the graph of Figure (7). Then, adding the constants $B \neq 0$ and C where for $\mu < h^2$.

The equation is defined for the Dragonhead Cyclone:

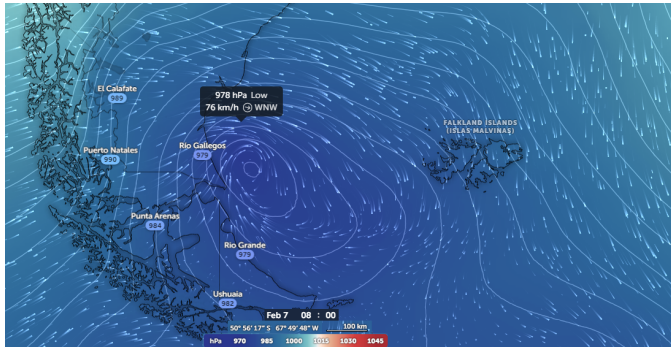$$r = BA \sec(k\theta + \epsilon) + C, \qquad (4)$$

Fig. 3: The Figure (3) shows isobaric and wind lines at 500 m height, in the south of the American continent. [Adapted Authors] [46]

Fig. 4: Image of the Dragonhead cyclone (DC), at 8 am (UTC), February 7, 2024. [Adapted Authors] [46]

III. ANALYSIS AND RESULTS

With winds coming from the Pacific Ocean, the cold front crosses southern Chile and Argentina. Forming from the region of Puerto Natales, Punta Arenas (Chile), El Calafate, Rio Galegos, Rio Grande and Ushuaia (Argentina), as shown in Figure 1, 4h UTC on February 7, 2024. The cold coming from the Pacific collides with a mass of hot air coming from the north of the province of Santa Cruz and central-south of
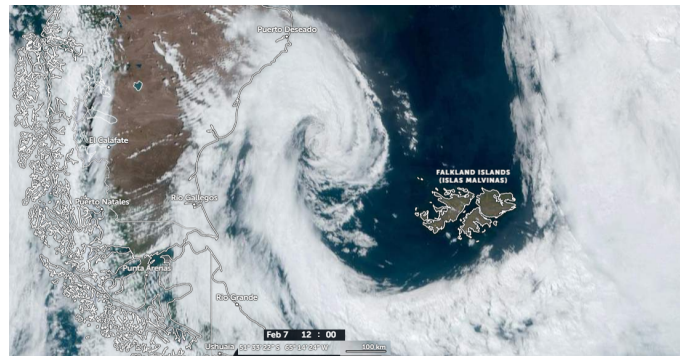

Fig. 5: Image of the DC, at 12 am (UTC), February 7, 2024. [Adapted Authors] [46]
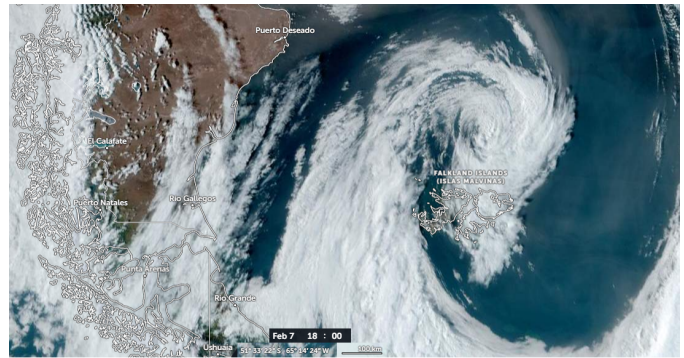

Fig. 6: Image of the **Dragonhead cyclone**, at 6 pm (UTC), February 7, 2024. With the well-defined shape of a dragon's head. [Adapted Authors] [46]
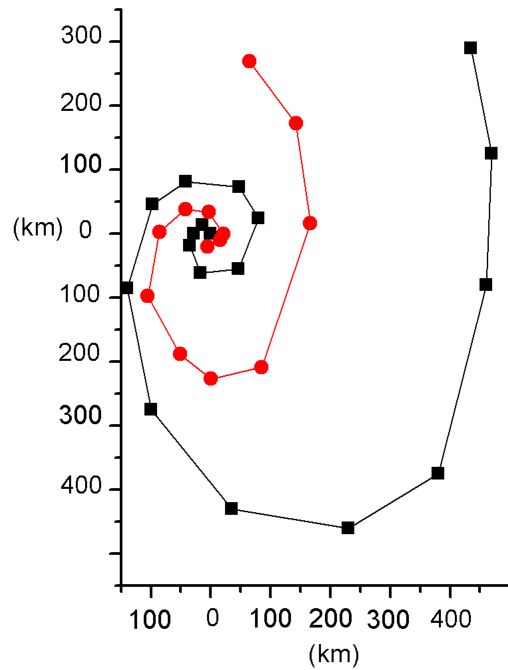

Fig. 7: Graphic plot of the dimensions and shape of the Dragonhead cyclone, as at 18 am (UTC), February 7, 2024. [Authors]
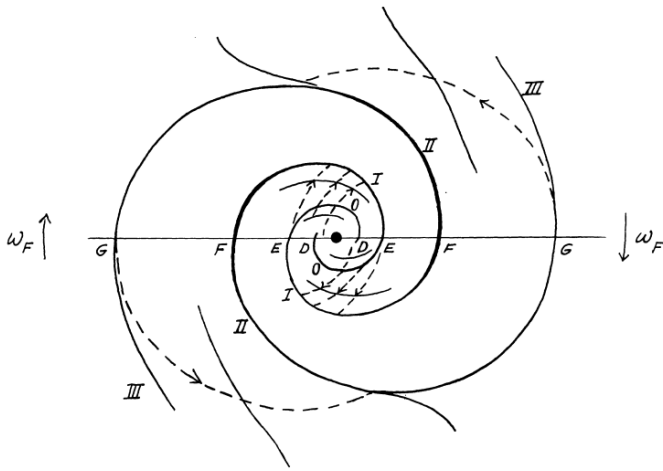
Fig. 8: "The application to the permanence of the spiral structure in galaxies arises because the outermost part of an arm will be attracted by, and will tend to become assimilated with, the neighbouring parts of the inner structure. In an analoguos way matter close to the nucleus will have a tendency to be assimilated in an outward motion with the inner parts of the spiral structure. The two regions of circulation is given here. We may suppose that there are two points F in the structure where the angular motion ω_F is equal to the local circular angular velocity. We can introduce a coordinate system which follows ω_F centre. The successive inter-sections with the diameter through the points F are indicated by the letters D, E, F, G. We make the supposition that, as long as the mass of III is small, the motion of particles in the arcs II is circular motion in the general gravitational field. The gravitational force from the interior spiral structure will not appreciably change the radial direction of the general field, of which it will form an integral part.", (Lindblad, 1964). [11]

TABLE I: **Dragonhead cyclone**
Coordinates / Pressure(P)(mbar). Time hour(h) (UTC), D(day) February 07, 2024 from 08:00 am and 06:00 pm.

D	February 7, 2024	Coordinates	Pressure (hPa)
h	08:00 am (UTC)	52°46'08"S 67°49'48"W	978
h	06:00 pm (UTC)	51°33'22"S 65°14'24"W	970

Chubut.

On February 7, 2024 at 18:00 UTC, the cyclone reached an area of influence of 3,247 thousand km2. It had a head/neck of elliptical dimensions measuring 639 km by 552 km, whose core was located at 45°36'S, 21°31'W, north of the Falkland Islands. With winds of 84 km/h, it had already traveled 640 km in 10 hours, with an average of 64 km/h.

It had a pressure of 978 hPa, February 7, 2024 at 08:00 am (UTC), 100 km north of the nucleus Figure 6, with winds of 76 km/h, with a nucleus at 970 hPa. Taking off in the WNW direction.

It appears that the spiral shape of the Dragonhead is very similar to the shape of the spiral galaxy NGC 5247,

presenting the same shape.

The analogous shape of Dragonhead cyclone and the NGC 5247 Galaxy, studied here is clear. These present a double Cote's spiral. Studied by Lindblad [11], but with the Cote's spiral form, (Gobato et al. 2022) [17], [18], [12], [19].

The Figure (2) show shapes of curves called Cote's spiral gives the solution to the central orbit problem.

The Table (1) shows the coordinates of Dragonhead cyclone, February 07, 2024, am/pm, a central vortex pressure of 951 hPa, with an approximate dimension of 10 km.

The Figure (3) shows isobaric and wind lines at 500 m height, in the south of the American continent.

The pressure at 500m height in the cities of El Calafate, Puerto Natales, Ushuaia, Rio Grande, Rio Galegos, are 989, 990, 984, 982, 979 and 979 hPa, respectively. In the Falkland Islands (Malvinas Islands) it is between 984 and 990 hPa.

The Figures (4-6) show the trajectory of the dragonhead cyclone between 08:00 am (UTC) and 06:00 pm, February 7, 2024.

The Figure (7) it represents the dimensions of the points collected from Figure (6), in km, using the Isobaric [30-31] found in Figures (3-6). Other spiral galaxies, vortex storms, have also been analyzed. [12], [13], [14], [15], [6], [16], [17], [43], [18], [19]

IV. CONCLUSIONS

Extratropical cyclones are common in the South Atlantic. They generally arise with the passage of cold fronts to the south of the South American continent, crossing the south of Chile and Argentina, in the regions of Puerto Natales, Punta Arenas (Chile), Rio Galegos, Rio Grande, El Calafate, and Ushuaia (Argentina). The extratropical cyclone analyzed, presented at its peak the very characteristic shape of a Chinese dragon. Mathematical analyzes of the shape of a double Cotes's Spiral. Here called the Dragonhead cyclone, indicate structural similarity with spiral galaxies, especially NGC 5247, in the constellation Virgo. With an area of influence and a size of around 3,247 thousand km2 at its peak, it moved quickly in a WNW direction, with an average speed of 76 km/h, with winds of 84 km/h at 100 km from the nucleus, as it passed north of the Falkland Islands (Malvinas Islands).

In the data collected [12], [13], [14], [15], [6], [16], [17], [43], [18], [19], [26] and analyzed from the Dragonhead cyclone, it is clear that all extratropical cyclones that appear south of the South American continent, below 40° latitude, have the shape of a spiral curve, like the spiral galaxy. Most of these are in the form of a double Cote's spiral curve.

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