INFORME ESPECÍFICO DE APLICABILIDAD DE LA CAPACIDAD TECNOLÓGICA DIFERENCIAL ASTROFÍSICA EN LA OBTENCIÓN DE IMÁGENES BIOMÉDICAS EN EL RANGO VISIBLE

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SPECIFIC REPORT ON THE APPLICABILITY OF THE ASTROPHYSICAL DIFFERENTIAL TECHNOLOGICAL CAPACITY IN OBTAINING BIOMEDICAL IMAGES WITH VISIBLE RADIATION

Entregable Actividad 2.1.3

Contenido

1 Introduction

Electromagnetic radiation at a wavelength in the range from 400 to 950 nm is considered visible range (VIS). The VIS part of the spectrum can be divided into different colours, depending on the wavelength [1].

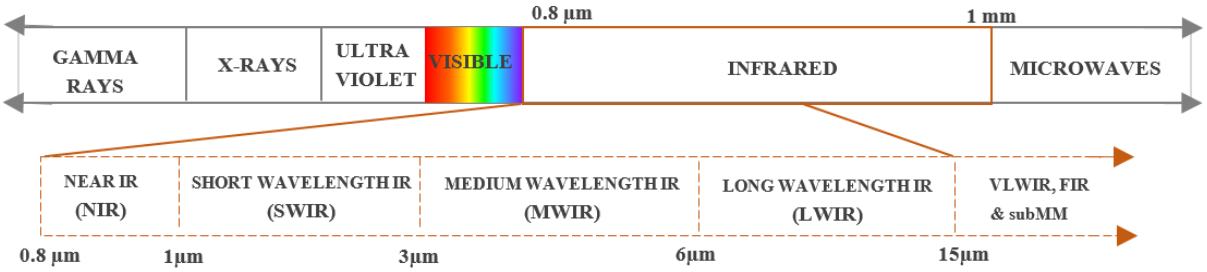

Figure 1. Electromagnetic Spectra [1].

The primary natural source of VIS radiation is the sun, although artificial VIS sources include a wide variety of lamps, fluorescent and incandescent sources, leds, and some types of lasers among others. Light is composed of packets of energy called photons and in the visible spectra light can be considered as non-ionizing electromagnetic radiation (400 nm to 950 nm) [2] [3].

Light energy is capable of causing heating, mechanical effects and chemical reactions. The transfer of light energy through photon absorption can lead to many different consequences in photomedicine. Photomedicine includes both the study and treatment of diseases caused by exposure to light and on the other hand the diagnostic and therapeutic applications of light for detecting and curing disease [3].

Traditionally, diagnostic medicine involved light and optics. In this line, old-fashioned medicine doctors would examine his patient under a bright light or a colored light, using of a hand lens to improve upon what he could see unaided. Then came the advent of various imaging technologies such as X-ray, computed X-ray tomography, magnetic resonance imaging, positron-emission tomography, single photon emission computed tomography etc. [3].

Nowadays, there are many new approaches for using light to see inside the body to detect and diagnose disease. Researchers are developing optical imaging technologies relying on visible and near-infrared (NIR) light and these new applications in photomedicine combined with the latest technology will have an important role in the future of our society.

Some of the current applications of the VIS spectrum in biomedicine are listed in Table 1.

Wavelength (nm)	**Applications**
200 – 400	Forensic analysis, drug detection

280 – 400	Medical imaging of cells
300 – 365	Curing of polymers
350 -- 514	Dermatology, Ophthalmology, PDT, Surgery (Ar laser)
580 --600	Dermatology (Flash lamp pumped dye)
~460	Absorption of Bilirrubin
~430	Absorption Oxihemoglobin
~550	Absorption DeoxiHemoglobin
720 – 800	Bone cutting

Table 1: UV-VIS applications in medicine [1].

2 Absorption of VIS light by Skin (Cellular Level Elements)

Usually the skin is referred as the human armour, as an impenetrable fortress to shield humans from harm. Although, the truth is that visible light penetrates into biological tissues more than one might think. Red and NIR light penetrates deeper than green, blue or violet light. You can visualize this phenomenon by shining a white flashlight through your hand, observing a red glow on the other side (the blue and green wavelengths having been absorbed). Red light penetrates more because it is not strongly absorbed by blood and because it tends to scatter more. Therefore, red or NIR light is generally used to "see" deeper into the body. Optical imaging techniques could be cheaper, less invasive and less toxic, because light is non-ionizing compared with the previous techniques mentioned above. Although human tissue is less transparent than shorter or longer wavelengths (X-rays and Radiowaves), its safeness makes it a very powerful technique [4].

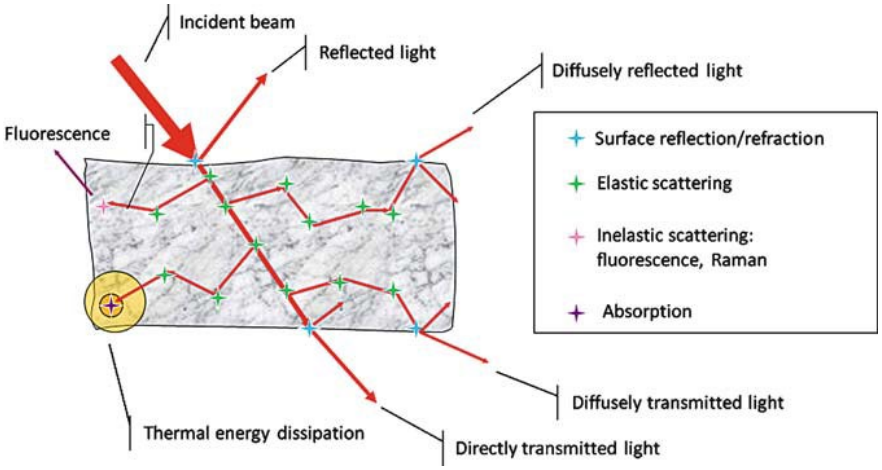

Figure 2. Schematic of light propagation in tissue [2]

The interaction between light and tissue involves scattered photons, observed photons and re-emitted after being absorbed in tissue photons. Some of the techniques used are the optical coherence tomography [5], in vivo confocal microscopy [6] and light scattering spectroscopy [7]. Examples of the second class are the pulse oximeter for measuring blood oxygenation [8] [9], diffuse optical tomography [10] and photoacoustic imaging and spectroscopy. Examples of the third class include autofluorescence imaging [11], in vivo confocal fluorescence microscopy (Goldman et al., 2005), and Raman spectroscopy [12].

The most relevant process in the light-tissue interaction is the absorption of the incident light. Absorption in the visible wavelength range by skin is mainly caused by two types of chromophores: melanin and hemoglobin. Absorption by other cellular level elements such as cells or fibers is negligible, being principally responsible of causing scattering of light [4] [5]. As a result, the spectral reflectance property of skin as a whole can be explained by the light absorption by melanin and haemoglobin [6].

3 Melanin

Melanin is produce by humans and other animals for protection against exposure to ultraviolet B (UVB) radiation [7] [8]. In the visible wavelength range, melanin determines absorption in the epidermis. Absorption of melanin decrease with the increase of the wavelength, causing that the effect of melanin on epidermis absorption properties is more pronounced at shorter wavelengths. Interactions with the shorter wavelength and UV, UVB radiation is directly absorbed by DNA whereas UVA radiation acts essentially through photosensitization, generating a triplet species, O_2, and subsequently generating other radical species that can damage both DNA and other epithelial cell biomolecules [9]. UVA penetrates

deeper in the dermis than does UVB, and it is the major UV source responsible for skin photoaging and the development of several types of skin cancer [10].

Despite these facts, visible portion of the spectra and the effect of visible and IR irradiation on the skin have been less studied than other electromagnetic bands [11] [12]. Recent studies showed that visible light disturbs the epidermal barrier, and this disturbance induces pigmentation and inflammatory responses [13] [14]. However, a great deal of controversy remains concerning the effect of visible light on the skin, most likely because of the lack of a mechanism that explains the observed effects [15].

Results indicate that, in addition to UV [7], visible light also induces pigmentation in certain skin types. Mahmoud and co-workers [12] showed that visible light induces skin darkening in people with skin types IV and V but not in individuals with type II skin. The darkening induced by visible light depended on the pre-irradiation melanin content of the skin, suggesting that melanin may directly damage skin cells upon exposure to visible light.

4 Hemoglobin

The spectral absorption properties of melanin and hemoglobin have been reported in many early studies [25] [26]. In the visible wavelength range, melanin determines absorption in the epidermis. Absorption of melanin is monotonously decreasing with the increase of the wavelength. Therefore, the effect of melanin on epidermis absorption properties is more pronounced at shorter wavelengths. When analysing the absorption peaks of human tissue, the Hemoglobin absorption peaks appear around 410 and 540 nm. Absorption of the epidermis, dermis, and fat in the NIR region is determined by water and lipid content and in the proximity of 1200 nm, water and lipid absorption bands overlap. Therefore, this peak is more pronounced for the subcutaneous fat as compared to the epidermis and dermis. At the same time, the epidermis and dermis exhibit stronger absorption in the range from 1350 to 1600 nm [2].

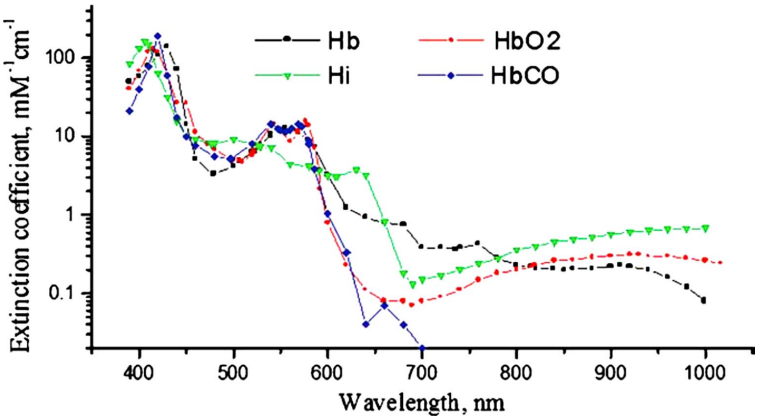

Figure 3: Absorption of hemoglobin derivatives. Source: Van Assendelft, Spectrocscopy of Hemoglobin Derivatives [2]

Water will not absorb light in the visible spectral range, but at the wavelengths longer than 1100 nm, it becomes the major tissue chromophores. For example, the light from resurfacing lasers, which include the erbium:YAG (Er:YAG) 2940 nm and carbon dioxide (CO 2) 10600 nm lasers, is mainly absorbed by water.

Lipids show several sharp absorption bands around 915, 1205, 1715, and 2305 nm. At these wavelengths, absorption of subcutaneous fat dominates that of the overlying skin layers, that is, epidermis and dermis. This is the reason why selective and noninvasive fat removal by light is possible [2].

5 Visible imaging applications at IAC facilities

The Medical Technology group at the IACTEC engineering group is part of the Instituto de Astrofísica de Canarias (IAC) and it is deeply interested in applying the well-known astrophysical technology to biomedical imaging.

The IAC is a leader institution, with substantial years of experience, in the characterization of visible and infrared detectors, as well as in the development of acquisition systems and data processing for ground based and space instruments. Thus, the IAC provides dedicate facilities and instrumentation to characterize detectors in the ultraviolet and visible part of the spectrum. In addition, there are wide varieties of applications where you excite with a wavelength and the emission spectra is within the visible range of the electromagnetic spectrum.

The Department of Optics is dedicated to the design and development of optical systems for telescopes and astronomical instrumentation, both for the visible and infrared ranges. It specializes in the specification, design, assembly, integration and verification of optical systems, including the design and

characterization of optical fiber-based systems. The Department has specific equipment and manages the Optics, Optical Fibers and Optical Coatings laboratories [1].

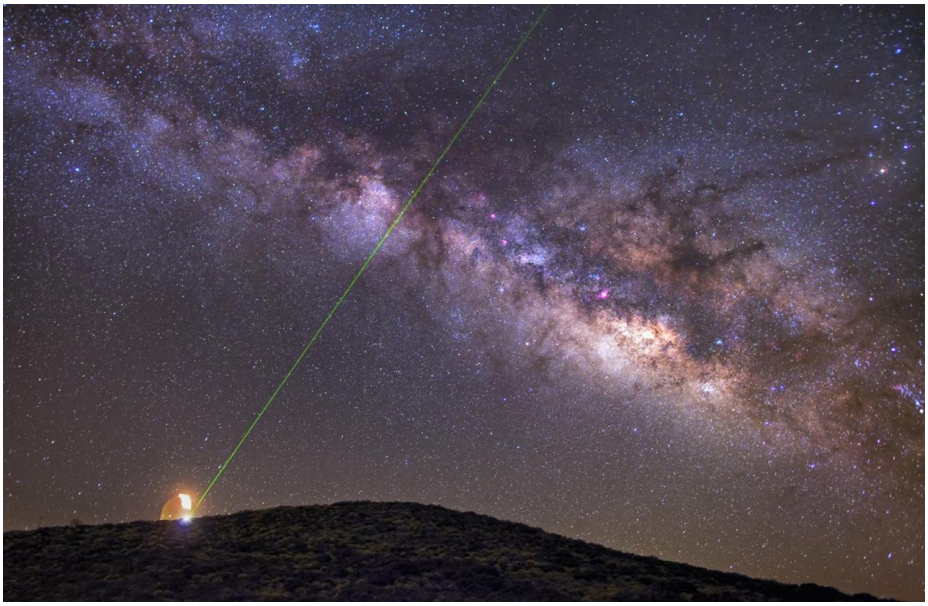

Figure 4. Green Laser from the OGS for communications tests (Daniel López).

New technology developed and used on a regular basis from IAC research teams in the Visible Range of the electromagnetic field, open a wide window of opportunity for Medical applications. Quantification of oxygen percentage at dermis tissue by contactless devices, or the analysis and detection of different neuropathies by medical images are some of the applications studied by the Medical Technology group.

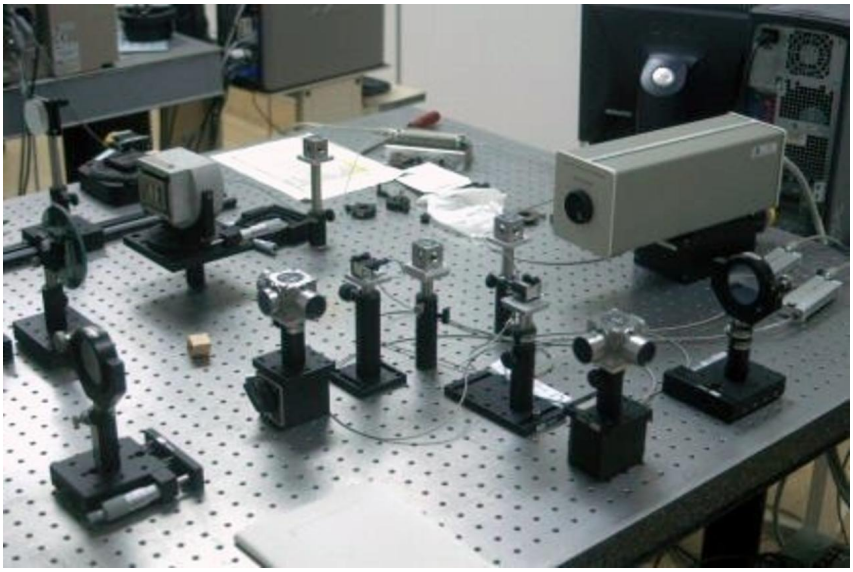

Figure 5. Optical Set Up in IAC laboratory

Another example of application would be at the hospitals. Nowadays, the detection system used clinically for fluorescence-guided resection requires switching and /or dimming the illumination source. This leads to an extended surgery time, since some time is needed to adjust human vision to such changes. In fact, when residual tumour is no longer confidentially distinguished from normal brain tissue, the illumination is switched to violet-blue and the room light is dimmed. Furthermore, ambient light in the tumour cavity may interfere with the fluorescence signal.

Finally, another project to be carried out is to provide a detection system for fluorescence-guided resection in which switching from different colour illumination is enabled under the microscope without interrupting the operation (to switch the illumination source). In fact, filter characteristics must be chosen to enable combined perception of certain colours of the excitation light together with the fluorescence.

6 References

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