What Hubble really meant by late and early type: simply more or less complex in appearance

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ABSTRACT
It is widely written and believed that Edwin Hubble introduced the terms ‘early’ and ‘late types’ to suggest an evolutionary sequence for galaxies. This is incorrect. Hubble took these terms from spectral classification of stars to signify a sequence related to complexity of appearance, albeit based on images rather than spectra. The temporal connotations of the terms had been abandoned prior to his 1926 paper on classification of galaxies.

Key words: history and philosophy of astronomy — stars: classification — galaxies: classification

1 INTRODUCTION
The terms ‘early’ and ‘late type’ in astrophysics have been applied to both stars and galaxies. Spectral classification of stars follows an early-to-late sequence O-B-A-F-G-K-M with recent additions of L-T (Kirkpatrick et al. 1999). This classification closely relates to a sequence in temperature from hot to cool stars. Morphological classification of galaxies is based on a number of factors, including ellipticity, the size of the nuclear region relative to the spiral arms, and the smoothness of the image. A commonly used classification is the revised and extended Hubble system (de Vaucouleurs 1959; Sandage 1961, 1975) that is based on Hubble’s (1926) original scheme for ‘extragalactic nebulae’, and Eddington’s (1919) earlier ideas. It follows an early-to-late sequence, ellipticals-lenticulars-spirals-irregulars, E-S0-Sa-Sb-Sc-Sd-Sm-Im (ignoring the barred/unbarred characteristic). Sandage (2005) has reviewed the history of this development.

At first glance, there appears to be no relation between the early to late type sequences of stars and galaxies other than the terminology. Before the implications of \( E = mc^2 \) (Einstein 1905) were realised, and to explain the Hertzsprung-Russell diagram, it was natural to suppose that stars cooled from early to late spectral types because there was no established mechanism for Myr stability of stellar atmospheres (cf. cooling of brown dwarfs, Burrows et al. 1997). There is now a wide-spread but mistaken belief that Hubble chose this terminology because he thought that the morphological sequence was also a temporal sequence. For example, Binney & Merrifield (1998) wrote “Hubble suggested that galaxies evolved from the left-hand end of this sequence to the right. This now discredited speculation lives on in the convention ... early-type ... late-type galaxies.” White, Coles & Lucchin (2002) noted “Although it is now not thought this evolutionary sequence is correct, Hubble’s nomenclature, in which ellipticals are ‘early’ type and spirals and irregulars ‘late’, is still commonly used.” Similar explanations can be found in other textbooks (e.g., Tayler 1993; Shore 2003; Carroll & Ostlie 2006). The main aim of this article is to show that these explanations for the origin of the terminology are incorrect, and to illuminate the correct explanation.

2 SEQUENCES IN COMPLEXITY OF APPEARANCE
The temporal meanings of ‘early’ and ‘late’ were questioned for stellar spectra by the early 1920’s because of, for example, the discovery of red giants and the suggestion of a nuclear timescale by Eddington (1919). Stratton (1924) quotes a 1922 International Astronomical Union report “The terms ... are very convenient. It is well, however, to emphasize that they denote positions early or late in the spectral sequence ... without any necessary connection whatever with an early or late stage of physical evolution.” Responding to a suggestion that the terms be dropped by Hepburn (1924), preciently Stratton said “it may be doubtful whether words so strongly entrenched in the literature of the subject can now be displaced ...” In fact they have not been.

In Hubble’s 1926 paper on the morphological sequence of galaxies the footnote on page 326 is revealing: “Early and late, in spite of their temporal connotations, appear to be the most convenient adjectives for describing relative positions in the sequence. ... They can be assumed to express a progression from simple to complex forms. An accepted precedent for this usage is found in the series of stellar spectral types. There also the progression is ... from the simple to the complex ... the temporal connotations ... have been deliberately disregarded.” Furthermore, Hubble (1927) noted “The nomenclature, it is emphasized refers to position in the sequence, and temporal connotations are made at one’s peril. The entire classification is purely empirical and without prejudice to theories of evolution ...” By the early 1920’s the temporal connotations of ‘early’ and ‘late’ had been largely disregarded for stellar spectra. Hubble knew this and used the terminology choosing the direction of the mor-
Ivan K. Baldry

Figure 1. Stellar spectra: sequence from early to late types derived from Valdes et al. (2004). The data have been normalised using a quadratic fit and are plotted from 450 to 650 nm at nm resolution; relative intensity scale is 0.3 to 1.1

The history of science is simplified in science textbooks because their primary aim is “persuasive and pedagogic” (Kuhn 1996). Yet the particular inaccuracy discussed in this paper, while minor, does a disservice to Hubble and observational astronomy, and provides no clarification. By the early 20th century, astronomy was a mature science, and in the mid-1920’s the concept of ‘extragalactic’ had only recently been largely accepted. Hubble’s 1926 paper is the first to use this term in a published title. Therefore, for Hubble to preempt a theory of ‘galaxy evolution’ by suggesting that galaxies evolved along the sequence is an historian’s fallacy. Hubble was a careful observational astronomer and it is quite clear from his 1926 and 1927 papers, quoted above, that he assumed the temporal implications of ‘early’ and ‘late’ had been dropped prior to his usage of them. I postulate that he would not have presumed to establish a theory of galaxy evolution at this stage. Even in his more comprehensive book published a decade later (Hubble 1936), he was strictly neutral with regard to evolution. He, however, was influenced by Jeans’ development of liquid rotating spheroids and did earlier hint at evolution based on Jeans’ dynamics, even as he insisted that his classification was strictly based on morphology with no interjections about origins (Sandage 2005).

Why not have used the terms ‘simple’ and ‘complex’? These would have preempted theory. In fact, many morphologically classified early-type galaxies have been shown to have complicated internal dynamics such as kinematically decoupled cores (de Zeeuw et al. 2002). The terms ‘simple in appearance’ and ‘complex in appearance’ are clunky in comparison with ‘early’ and ‘late’, and it should be noted that the complexity of appearance is a guide to the order of the sequence not the definition. In the case of stellar spectra, the order is generally quantified by the strengths of various absorption transitions on atmospheric temperature in stars, and star-formation triggering in galaxies.

In summary, when introducing the terms ‘early’ and ‘late’ for the morphological classification of galaxies, the historical context is explained incorrectly in many texts. I have shown that the logical reason relates to the complexity of appearance within the sequence. This reason should improve a student’s grasp of why these, apparently arbitrary, terms are used for both stars and galaxies. Rather than abandoning the terms, I propose that Hubble’s intention be kept in mind when using them since the temporal connotations should by now be well and truly dispelled.

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What Hubble really meant by late and early type

Figure 2. Galaxy morphologies: sequence from early to late types derived from 
Nakamura et al. (2003) classifications and Sloan Digital Sky Survey colour images scaled as per Lupton et al. (2004). Types are E, S0, Sa, Sb (top row), Sc, Sc, Sd, Im (bottom row).

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