STAR RATINGS OF BARYONS

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With the advent of new information about baryon resonances now coming from JLab and other facilities, it is timely to review the star rating system introduced by the Particle Data Group. The existing system suffers from subjective definitions of its various ratings. We propose a revised rating system to help facilitate the ongoing work of researchers in the Baryon Resonance Analysis Group (BRAG).

1. Introduction

The existing rating system for baryon resonances is as follows[1]:

****	Existence is certain, and properties are at least fairly well explored.
***	Existence ranges from very likely to certain, but further confirmation is desirable and/or quantum numbers, branching fractions, etc. are not well determined
**	Evidence of existence is only fair.
*	Evidence of existence is poor.

It is apparent that this system is very subjective and there is little distinction between the 1- and 2-star states (both of which describe *candidate* states.) Sometimes those doing quark-model calculations treat 1- and 2-star baryons on an equal footing with 3- and 4-star baryons, which is obviously *not* advisable. There is a need to separate clearly the issue of the existence of a resonance from that of the certainty of its extracted parameters.

2. Proposed New Rating Scheme

Since the evidence for existing 1- and 2-star states is quite similar, we propose that *all candidate* (non-established) baryons be given a 1-star rating. These states are commonly found in single-channel analyses of (usually) new data. This category is still very useful because it alerts the community to new possibilities; however, any use of these candidates in theoretical studies (*e.g.*, calculation of baryon properties from a quark model) must be discouraged. It is important *not* to perform averages and estimates of masses, widths, and partial widths for candidate states. Summaries of the results of various analyses for candidate states should be made in a table, with the most recent results published first.

Established resonances will be defined as those whose presence *significantly improves* a multichannel fit to amplitudes for all important channels in the state's partial wave and energy range. Further study will suggest a quantitative measure of "significant improvement," for example, by a given fractional reduction in the χ^2 per degree of freedom of the fit. This implies that a state can be established only by examining fits that use data from all important channels, and which publish χ^2 per degree of freedom both with and without the presence of a given state. Established states would be those which, in one or more analyses, improve χ^2 per degree of freedom, but with a fractional improvement below a certain threshold.

Originally, one of us (DMM) thought about introducing a 5-star rating to make a clear distinction for the best established states. Upon reflection, we now agree it is better only to revise the existing four categories. We propose that to be a 4-star state, its existence should be certain, its quantum numbers (I, J^P) must be *measured*, and its total width must be known well enough that

$$\frac{\Gamma_{\rm max}}{\Gamma_{\rm min}} \leq 1.3 \ ,$$

where $\Gamma_{\rm max}$ ($\Gamma_{\rm min}$) is the maximum (minimum) limit for its width. Using ranges in the 2002 edition of the *Review of Particle Physics*,[1] by these criteria the only 4-star N, Δ, Λ, and Σ baryons would be the following:

$N(939)\frac{1}{2}^+$	$\Delta(1232)\frac{3}{2}^+$	$\Lambda(1116)\frac{1}{2}^+$	$\Sigma(1193)\frac{1}{2}^+$
$N(1520)\frac{3}{2}^-$	$\Delta(1950)\frac{7}{2}^+$	$\Lambda(1405)\frac{1}{2}^-$	$\Sigma(1385)\frac{3}{2}^+$
$N(1650)\frac{1}{2}^-$		$\Lambda(1520)\frac{3}{2}^-$	$\Sigma(1775)\frac{5}{2}^-$
$N(1675)\frac{5}{2}^-$		$\Lambda(1820)\frac{5}{2}^+$	$\Sigma(2030)\frac{7}{2}^+$
$N(1680)\frac{5}{2}^+$			

In principle, one should probably also include some criterion on how well a state's mass is determined. In practice, however, this turns out not to be a very strong constraint. For example, all of the states listed above except one satisfy $M_{\max} - M_{\min} \leq 20$ MeV. The exception is $N(1650)\frac{1}{2}^-$ whose mass is uncertain by about 40 MeV.

What is left is to determine the assignment of 2- or 3-star ratings to the remaining established baryons. The 3-star states should probably be established baryons that have fairly well-determined masses and branching fractions. *This should be made quantitative.* For example, if we require $(x_{\pi N})_{\max}/(x_{\pi N})_{\min} < 2$ for N, Δ or $(x_{\overline{K}N})_{\max}/(x_{\overline{K}N})_{\min} < 2$ for Λ, Σ, then the new 3-star states would include:

$N(1440)\frac{1}{2}^+$	$\Delta(1620)\frac{1}{2}^-$	$\Lambda(1670)\frac{1}{2}^-$	$\Sigma(1670)\frac{3}{2}^-$
$N(1535)\frac{1}{2}^-$		$\Lambda(1690)\frac{3}{2}^-$	
		$\Lambda(1800)\frac{1}{2}^-$	
		$\Lambda(1890)\frac{3}{2}^+$	
		$\Lambda(2100)\frac{7}{2}^-$	

Finally, 2-star states should be established baryons that do not satisfy the criteria for 3- or 4-star states. These might include the following states:

$N(1700)\frac{3}{2}^-$	$\Delta(1600)\frac{3}{2}^+$	$\Lambda(1600)\frac{1}{2}^+$	$\Sigma(1660)\frac{1}{2}^+$
$N(1710)\frac{1}{2}^+$	$\Delta(1700)\frac{3}{2}^-$	$\Lambda(1810)\frac{1}{2}^+$	$\Sigma(1750)\frac{1}{2}^-$
$N(1720)\frac{3}{2}^+$	$\Delta(1905)\frac{5}{2}^+$	$\Lambda(1830)\frac{5}{2}^-$	$\Sigma(1915)\frac{5}{2}^+$
$N(2190)\frac{7}{2}^-$	$\Delta(1910)\frac{1}{2}^+$	$\Lambda(2110)\frac{5}{2}^+$	$\Sigma(1940)\frac{3}{2}^-$
$N(2220)\frac{9}{2}^+$	$\Delta(1920)\frac{3}{2}^+$	$\Lambda(2350)\frac{9}{2}^+$	$\Sigma(2250)$
$N(2250)\frac{9}{2}^-$	$\Delta(1930)\frac{5}{2}^-$		
$N(2600)\frac{11}{2}^-$	$\Delta(2420)\frac{11}{2}^+$		

Other states are presently listed by the Particle Data Group,[1] but we feel that the present evidence for them is too weak to consider them established. Such states would have a 1-star rating under our proposed system.

3. Summary

We have proposed a new organizational scheme for rating baryons. Under this scheme, the star system in use for many years would be retained, but the categories would be defined more quantitatively. The lowest category (1-star) would be used only for candidate states (*e.g.*, those seen in initial analyses of a new experiment.) Only states that are verified in a multichannel analysis would be rated higher. Any state that is considered established should show up in more than one reaction; thus, inclusion of that state must result in an improvement in a simultaneous fit to a variety of data. Researchers studying the properties of baryons should only use the states in the three highest categories, 2-, 3-, and 4-stars. Distinction among these categories should result from a quantitative comparison.

The proposal described here is intended as a starting point for a dialog that we hope to initiate among interested members of BRAG. We have suggested here using the ratio of maximum to minimum values of parameters extracted from multichannel analyses, but better criteria might be devised. Ultimately we hope to establish a new "BRAG rating system," which will become the standard in our field. It might also be advantageous to introduce a similar rating system for mesons to help evaluate the quality of evidence for particular states.

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References

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