Circumstellar stable zones in Nu Octantis

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The possible presence of a massive planet in the Nu Octantis binary star system, with a 5:2 orbit ratio, was proposed by [1], based on radial velocity and astrometric measurements of the motion of the primary star. It was shown by [2] that this hypothetical planet orbit is viable if the orbit is retrograde relative to the stellar orbits. Further work on this system was done by [3], [4], [5], and by other researchers. An interesting alternative possibility was proposed by [4], that the secondary star may have two components and that this may cause the residual motions of the primary star. The study presented here is based on the massive planet hypothesis of [1] [2] (but without implying that it is the only possible explanation for the residuals), and the aim of this paper is to find the stable zones for further hypothetical circumstellar planets.

N-body software is used to examine a system which initially has three members: a primary star with mass equal to 1.4 x the mass of our sun, a secondary star with mass equal to 0.5 x the mass of our sun, and a massive planet with mass equal to 2.5 x the mass of jupiter. The sizes of the stellar orbits, and their orbital eccentricity, are configured to be approximately the same as in the Nu Octantis system. The orbit of the massive planet is configured to produce a near-resonant 5:2 orbital period ratio, with minimised free eccentricity.

Eight planets are added orbiting the primary star at distances 0.2AU, 0.3AU, 0.4AU, 0.5AU, 0.6AU, 0.7AU, 0.8AU, 0.9AU.
And eight planets are added orbiting the secondary star, at the same distances.
Each of these 16 planets is given an initial orbit that is approximately circular around its parent star.

The added planets are assumed to have negligible mass, and no collision detection is performed. This enables the long-term stability testing of all 16 added planets to be performed simultaneously in a single simulation, with the stability result for each individual added planet being completely independent of the presence and behaviour of the other 15 added planets.

Figure 1 shows the initial positions of the 2 stars and 17 planets. The primary star is shown in red and the secondary star is shown in green. The two stars are started at maximum seperation. The massive planet is started at inferior conjuction (directly in between the two stars). The 16 added planets are started at superior conjunction. All planetary orbits are retrograde relative to the stellar orbits.

Figure 2 shows the system at just over 6EY (earthyears), very soon after the simulation is started. At this point the stars have completed just over 2 orbits, and the massive planet has completed just over 5 orbits. The near-resonant 5:2 orbit ratio can be seen in the closed shape of the orbit of the massive planet. All 16 added planets are still present.

Figure 1: Initial positions of the 2 stars and 17 planets

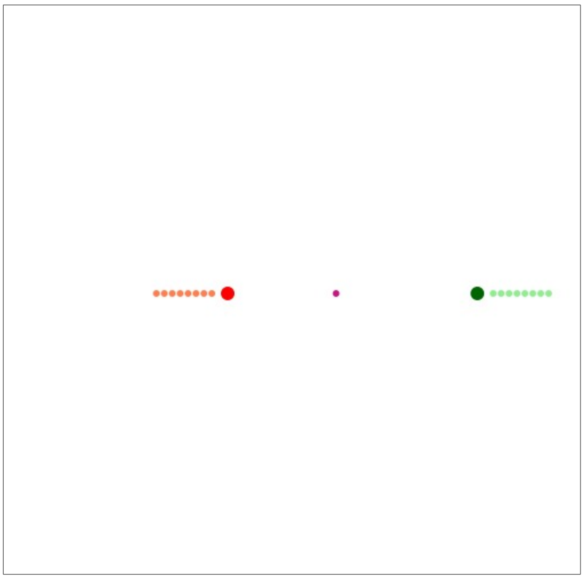
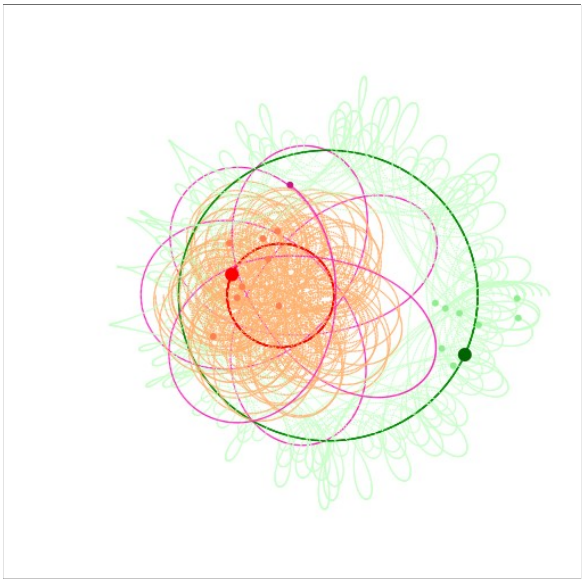


Figure 2: The system after about 6EY



Figures 3 to 6 show the evolution of the planetary orbits around the primary star. The views are centred on the primary star. The orbit of the massive planet is shown in purple. The orbits of the added planets around the primary star are shown in orange.

After 1000EY one of these eight planets has been lost, and seven survive.
After 3000EY another planet has been lost, and six planets survive.
After 4000EY, and after 5000EY, no further planets are lost, and six planets still survive.

Figure 3: Orbits around the primary star after about 1000EY

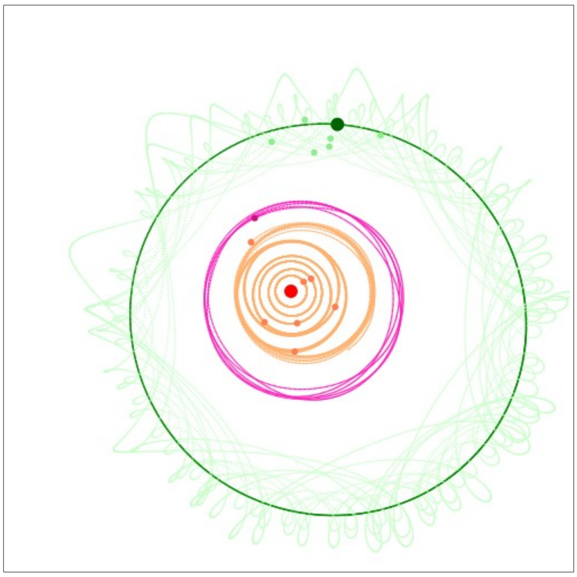


Figure 4: Orbits around the primary star after about 3000EY

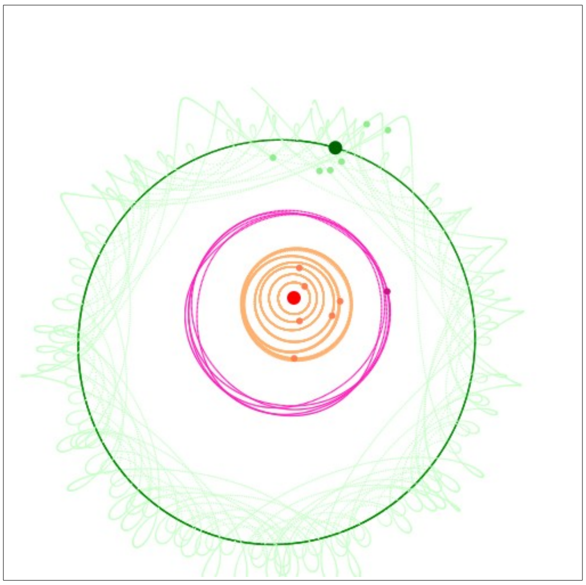


Figure 5: Orbits around the primary star after about 4000EY

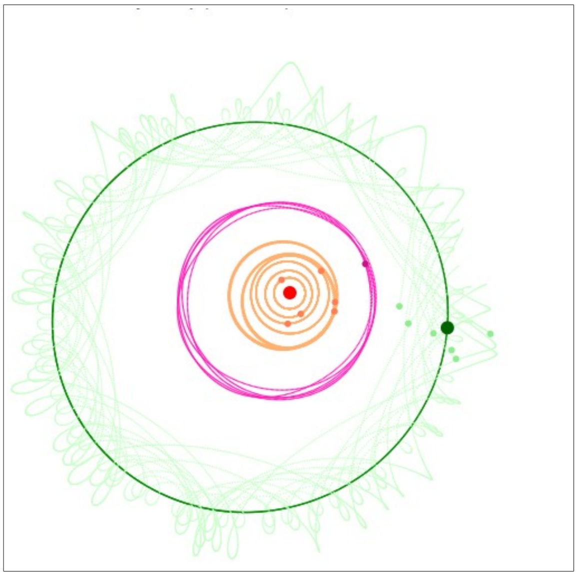
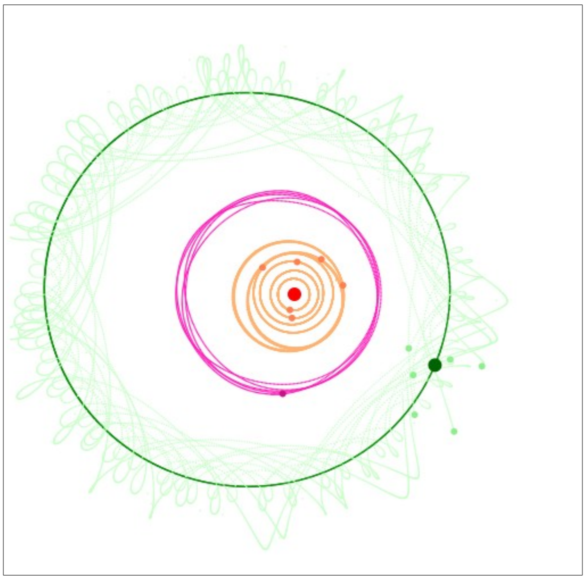


Figure 6: Orbits around the primary star after about 5000EY



Figures 7 to 10 show the evolution of the planetary orbits around the secondary star. The views are centred on the secondary star. The orbit of the massive planet around the primary star is shown in purple. The orbits of the added planets around the secondary star are shown in green.

After 1000EY two of the eight added planets have been lost, and six planets survive.
After 3000EY, at 4000EY, and at 5000EY, no further planets are lost, and six planets still survive.

Figure 7: Orbits around the secondary star after about 1000EY

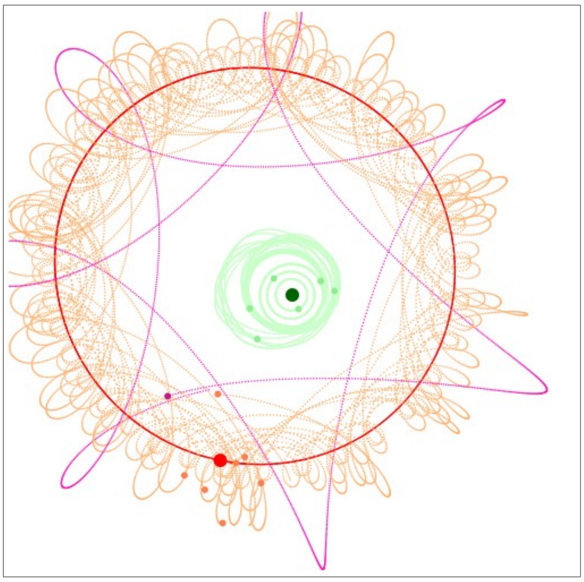


Figure 8: Orbits around the secondary star after about 3000EY

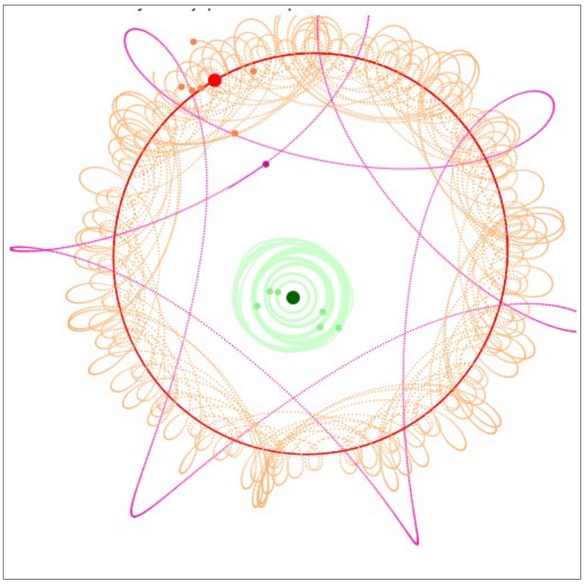


Figure 9: Orbits around the secondary star after about 4000EY

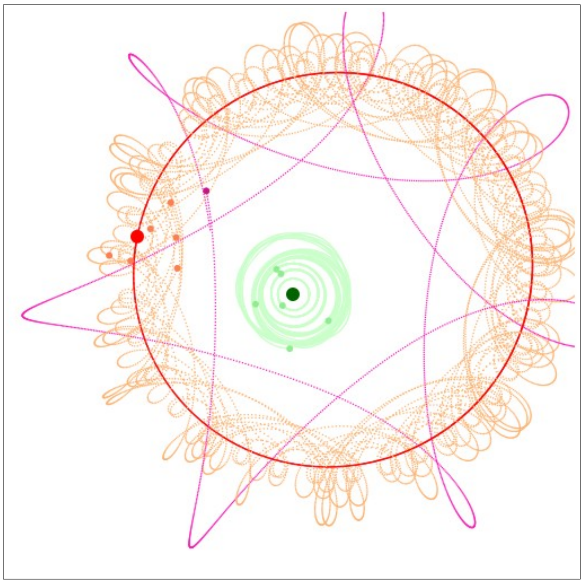
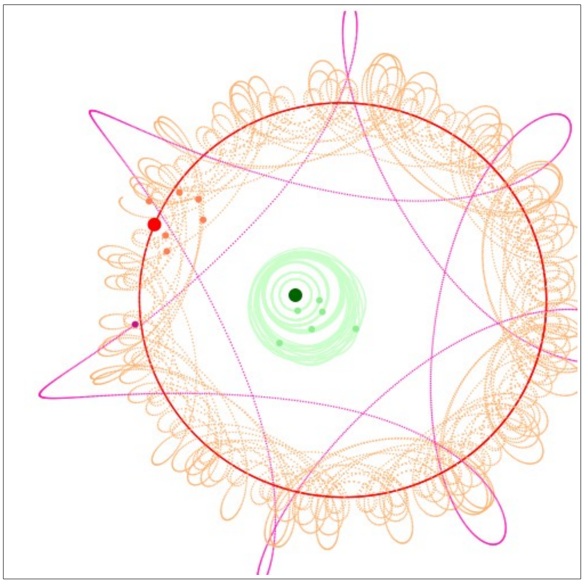


Figure 10: Orbits around the secondary star after about 5000EY



The radii of the stable zones for planetary orbits around each star (in the presence of the massive perturbing planet) are then estimated by measuring the periapse distance of the largest surviving planetary orbit around each star after 5000EY.
The stable zone around the primary star is estimated to have a radius of about 0.63 AU.
The stable zone around the secondary star is estimated to have a radius of about 0.54 AU.

Notes
(a) These results assume that the hypothetical massive planet has a mass equal to 2.5 x the mass of jupiter. If it has a greater mass then the two stability zones will be a smaller.
(b) It is possible that that within each of these two stability zones, some orbital distances may be more stable than others, due to resonances with the orbit of the massive planet.
(c) The planets added in this investigation are hypothetical.
(d) There is third stable zone, for *circumbinary* planets (orbiting *both* stars), which will be described in a seperate paper.

Online N-body simulation
An online orbit simulation is available at [6]. This offers the unusual possibility that the reader may extend these results to time periods exceeding the 5000EY examined here.

Conclusion

In the Nu Octantis binary star system, even in the presence of a proposed perturbing planet with mass equal to 2.5 times the mass of jupiter, there are two stable zones for further hypothetical circumstellar planets, with radii of about 0.63 AU around the primary star and about 0.54 AU around the secondary star.

References

[1] Spectroscopic orbits for K giants β Reticuli and ν Octantis: what is causing a low-amplitude radial velocity resonant perturbation in ν Oct?
Ramm, D. J.; Pourbaix, D.; Hearnshaw, J. B.; Komonjinda, S.
Monthly Notices of the Royal Astronomical Society, Volume 394, Issue 3, pp. 1695-1710.
adsabs.harvard.edu/abs/2009MNRAS.394.1695R

[2] On the reality of the suggested planet in the ν octantis system
J. Eberle and M. Cuntz
The Astrophysical Journal Letters Volume 721 Number 2 L168
iopscience.iop.org/2041-8205/721/2/L168

[3] The Stability of the Suggested Planet in the nu Octantis System: A Numerical and Statistical Study
Billy Quarles, Manfred Cuntz, Zdzislaw E. Musielak
Monthly Notices of the Royal Astronomical Society
arxiv.org/abs/1201.2313

[4] Precession due to a close binary system: An alternative explanation for ν-Octantis?
M.H.M. Morais, A.C.M. Correia
Monthly Notices of the Royal Astronomical Society, Volume 419, Issue 4, pages 3447–3456
arxiv.org/abs/1110.3176

[5] Testing a hypothesis of the ν Octantis planetary system
Mariusz Slonina, Krzysztof Gozdziewski, Cezary Migaszewski, Anna Rozenkiewicz
arxiv.org/abs/1205.1341

[6] Online simulation of these orbits.
Requires a fast modern browser which fully supports these HTML features: DOMParser, Canvas, LocalStorage, JSON.
www.orbsi.uk/space/simulator/simulator.htm?s=00045

Version history

v1: 28 Mar 2015

v2: 30 Mar 2015 (Improved wording to make conclusion clearer).