THE POTENTIAL FOR CURRENT TIDAL-TECTONIC ACTIVITY ON CHARON FROM OBLIQUITY TIDES. Alyssa R. Rhoden[1], Wade Henning[2], Terry A. Hurford[3], Bruce G. Bills[4], Douglas Hamilton[2], and Matthew E. Walker[5], [1]JHU-APL, 11101 Johns Hopkins Rd., Laurel, MD, 20723 [2]Astronomy Department, University of Maryland – College Park, MD [3]NASA GSFC, Code 693, Greenbelt, MD [4]JPL, Pasadena, CA [5]UCLA, Los Angeles, CA

Introduction: Tidal-tectonic activity provides information about the interior structure of a satellite and may be an indicator of subsurface liquid. Furthermore, identifying and modeling tidal-tectonic fractures can help constrain a satellite's thermal-orbital evolution. Tidal fractures on Europa and Enceladus appear to have formed mainly in response to eccentricity-driven tidal stress (e.g. [1][2][3]), although obliquity tides also affect fracture formation on Europa [4][5].

Charon's current eccentricity is indistinguishable from zero [6], ruling out the possibility of eccentricity-driven fractures in the present day. However, the evolution of Charon's orbit may have included a high-eccentricity phase [e.g. 7]. Depending on the interior structure and orbital distance of Charon during this epoch, tidal stresses would have been comparable to those inferred from tidal fractures on Europa, even for conservative eccentricity values [8]. Whether such fractures would still be preserved on Charon's surface is unknown.

Recent work has determined that Charon's damped spin pole would be tiled by 1.43° to 3° depending on assumptions about its shape [9]. The goal of this study is to assess the potential for present-day tidal-tectonic activity on Charon due to obliquity tides rather than eccentricity tides. We calculate principal tidal stresses induced by the reported obliquity values using three plausible interior structure models (based on [8]). We find that, in most cases, the maximum principal stresses due to obliquity are comparable to eccentricity-driven stresses on tidally-active icy satellites, supporting the idea that Charon could be active today.

Because obliquity-driven fractures form at different azimuths from those caused by eccentricity or orbital recession, and because they would likely be more recent, it should be possible to identify them within the geologic record. If obliquity-driven fractures are not observed on Charon, it would suggest one of three possibilities: (1) Charon's surface fails at a significantly higher stress than Europa's surface, (2) the interior is highly viscous, or (3) the obliquity is significantly smaller than expected.

Methodology: As described in [8], we calculate tidal stresses in a rheologically-layered body, following the formulation of [10], which utilizes the propagator matrix method. We have validated the code against published results for Europa [from 10].

The interior structure models we test include an ocean layer underneath an ice shell. The shell is further separated into a 5-km-thick brittle upper layer with viscosity 10^{21} Pa*s and a 30-km-thick ductile lower layer for which we vary the viscosity. Values for each case are listed in Table 1; additional physical and rotational parameter values are identical to those reported in [8]. For these simulations, we use Charon's current orbital period and zero eccentricity.

Table 1: Interior structure parameters and max stresses

	Case A	Case B	Case C
Ductile ice viscosity (Pa*s)	10^{13}	10^{14}	10^{15}
Max principal stress (kPa)			
oblq = 1.43°	39.1	33.4	16.5
oblq = 3.00°	82.0	69.9	34.5

Results and Discussion: Tectonic activity due to tidal stress has been identified on Europa and Enceladus (e.g. [1][2][3]). On Europa, tidal stress from eccentricity and obliquity is of order 100 kPa, but fractures are consistent with stresses as low as 20 kPa [5]. If Charon's surface fails under similar stress magnitudes, obliquity tides should generate tidal fractures in almost all of the cases we tested (see Table 1). Only the case with highest viscosity and lowest obliquity results in a maximum principal stress below 20 kPa. It, thus, seems plausible that Charon could be tidally active due to its obliquity.

It is also possible that the stresses are larger than we have computed here. The obliquity values were derived for a homogenous body [9]; the obliquity would likely increase for a layered body. In addition, if the ice shell is cooling, thermal stresses could combine with the tidal stress caused by obliquity to meet the failure threshold [11].

A major unknown factor in this analysis is the current state of Charon's interior. Each of these interior models includes an ocean layer, which may not be relevant for Charon, at present. However, our previous analysis of Charon showed that tidal stresses increase with ice shell thickness when the ductile ice viscosity is low [8], so even a thick shell could experience high tidal stress if it's still warm. A subject of future work will be to test an ocean-free model to determine whether large stresses can still be produced. Even if the shell has cooled sufficiently to shut off obliquity-driven tidal-tectonic activity, evidence may still be preserved in the geologic record.

Conclusions: Our analysis suggests that Charon's obliquity could drive present (or recent) tidal-tectonic activity. Such activity could be confirmed by the New Horizons spacecraft and would help constrain Charon's interior structure, obliquity, and failure properties. Obliquity-driven fractures would form at different azimuths from the eccentricity-driven fractures described in [8]. Through careful mapping and statistical analysis, it should be possible to determine the tidal stress mechanism(s) that led to the formation of different fracture populations, offering additional clues about the evolution of the Pluto-Charon system. If no obliquity-driven fractures are observed, it would suggest that Charon's ice shell is cold and brittle and/or the failure threshold of Charon's ice is significantly larger than that of Europa's.

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