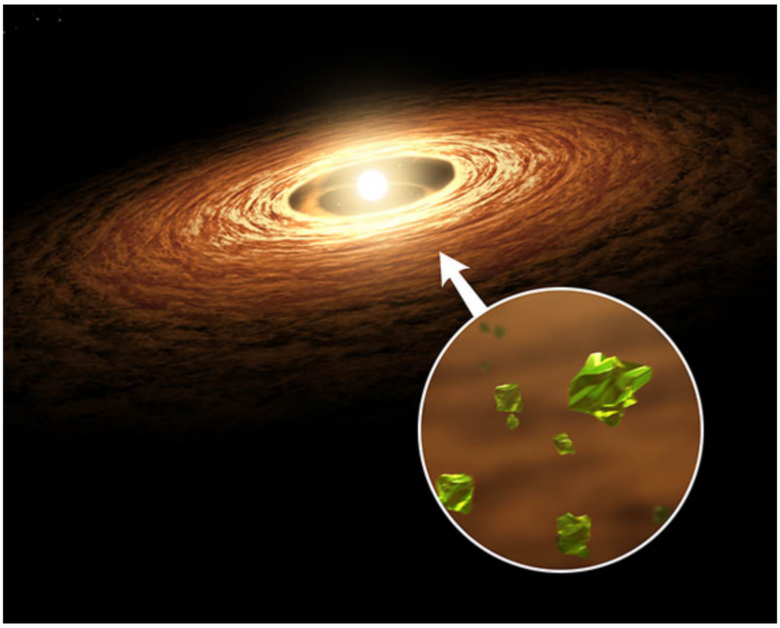
From Dust to Rocky Planets

Workshop

Aug 28, 2010

Konkoly Observatory



Organizing Committee

Péter Ábrahám (Konkoly Observatory)
Dániel Apai (Space Telescope Science Institute)
Csaba Kiss (Konkoly Observatory)
Attila Moór (Konkoly Observatory)

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10:40–11:00	N. Sipos	*Circumstellar environment of young eruptive stars*
11:00–11:20	P. Ábrahám	*Episodic formation of cometary material in the outburst of a young Sun-like star*
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	Session II / Chair : Thomas Henning	
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ABSTRACTS

Protoplanetary Disk Evolution and Early Solar System Chronology

Dániel Apai

Radioisotopic studies of the early Solar System provide detailed insights into the formation and evolution of the first solids, including chondritic components (Ca,Al-rich inclusions, chondrules, chondritic matrix). These primitive materials sample the physical and chemical conditions in the inner proto-solar nebula at the time planetesimals and differentiated bodies formed. Astronomical observations of protoplanetary disks around other stars allow the exploration of similar parameters, but for a larger number of disks and a broader time period. In this talk I will discuss the key cosmochemical and astrophysical constraints on the processing of solids in the first few million years and attempt to place these in a consistent framework that jointly define the initial and boundary conditions for planet formation.

Circumstellar environment of young eruptive stars

Nikoletta Sipos

EX Lupi type objects (EXors) form a subclass of young stellar objects, showing sudden sporadic flare-ups separated by intervals of quiescent periods. Outbursts typically last for a couple of months or a few years and correspond to an optical brightening of 1-5 magnitudes, while between two eruptions they spend several years in a low-state. Eruptive phenomena is hypothesised to occur at a certain evolutionary phase during the early life of stars and they are generally associated with significant variations in mass accretion rates from the circumstellar disk to the young star. The sudden dramatic increase of the accretion rate is supposed to be due to a thermal or gravitational instability in the inner circumstellar disk, or instability caused by the presence of a planetary or stellar companion. Either of the explanations above proves to be valid, the circumstellar environment and especially the inner regions of the circumstellar disk must play an essential role in driving the eruptions. Examining the structure of the inner disks might reveal what makes these objects special among young stars. We found that the SEDs of four out of nine classical EXors, including EX Lupi, the prototype show no or very weak excess at NIR wavelengths which might be indicative of inner disk clearing or a very flattened, evolved inner disk.

Episodic formation of cometary material in the outburst of a young Sun-like star

Péter Ábrahám

The Solar System originated in a cloud of interstellar gas and dust. The dust is in the form of amorphous silicate particles and carbonaceous dust. The composition of cometary material, however, shows that a significant fraction of the amorphous silicate dust was transformed into crystalline form during the early evolution of the protosolar nebula. How and when this transformation happened has been a question of debate, with the main options being heating by the young Sun and shock heating. Here we report mid-infrared features in the outburst spectrum of the young Sun-like star EX Lupi that were not present in quiescence. We attribute them to crystalline forsterite. We conclude that the crystals were produced through thermal annealing in the surface layer of the inner disk by heat from the outburst, a process that has hitherto not been considered. Our monitoring of the mid-infrared features indicates that the abundance of crystalline silicates in the surface layer of the inner disk decreases with time. After investigating different scenarios, we propose that an outward transport of the crystals is the most plausible explanation.

Grain growth in cold molecular cores

Csaba Kiss

Theoretical arguments suggest that dust grains should grow in the dense cold parts of molecular clouds. Evidence of larger grains has been gathered either from the comparison of extinction data with far-infrared/(sub)millimetre emission or from near/mid infrared scattered light observations.

Interpreting the data is, however, usually not very straightforward, since all the layers in the line of sight – probably with different temperatures, densities and grain properties – are mixed in the final extinction and emission maps.

In the work presented here we collected ISO far-infrared data in molecular/cirrus clouds and calculated dust emissivities using a simple dust model. The possibilities for a false detection of emissivity increase were investigated in detail and show that the observed increase likely cannot be attributed to error sources considered.

Two current missions of the European Space Agency, the Herschel and Planck telescopes (working in the far-infrared and millimetre wavelength ranges, respectively), with their improved sensitivity and spatial resolution, offers a unique possibility to study the dust emission and hence grain growth in unprecedented details. Such programs based on Herschel and Planck data will also be discussed in this presentation.

Dust formation in the ejecta of the Type II-P supernova 2004dj

Tamás Szalai

Core-collapse supernovae (CC SNe), especially Type II-plateau (II-P) ones, are thought to be important contributors to cosmic dust production. SN 2004dj, one of the closest and brightest SN since 1987A, offered a good opportunity to examine dust formation processes. To find signs of newly formed dust, we analyzed all available mid-infrared (MIR) archival data from the *Spitzer Space Telescope*.

We re-reduced and analyzed data from IRAC, MIPS and IRS instruments obtained between +98 and +1381 days after explosion, generating light curves and spectra for each epoch. Observed spectral energy distributions (SEDs) are fitted with both analytic and numerical models, using the radiative-transfer code MOCASSIN for the latter ones. We also use imaging polarimetric data obtained at +425 days by the *Hubble Space Telescope*.

We present convincing evidence of dust formation in the ejecta of SN 2004dj from MIR light curves and spectra. A ~0.8% polarization is also detected at a 2-sigma level, which exceeds the polarization due to ISM in that direction. Our analysis shows that dust formed around SN 2004dj in a nearly spherical shell containing amorphous carbon grains, cooling from ~700 K to ~400 K between +250 and +1250 days. Persistent excess flux has been found above 10μm, which is explained by a cold (~115 K) dust component. If this cold dust is of circumstellar origin, it is likely to be condensed in a cool, dense shell (CDS) between the forward and the reverse shocks. Pre-existing, interstellar dust is less likely, but cannot be ruled out. An upper limit of $\sim 8\times 10^4\,M_\odot$ was derived or the dust mass, which is similar to previously published values for other dust-producing SNe.

Stellar-mass-dependent disk structure in coeval planet-forming disks

László Szűcs

Previous studies suggest that the planet-forming disks around very-low-mass stars/brown dwarfs may be flatter than those around more massive stars, in contrast to model predictions of larger scale heights for gas-disks around lower-mass stars. We conducted a statistically robust study to determine whether there is evidence for stellar-mass-dependent disk structure in planet-forming disks. We find a statistically significant difference in the Spitzer/IRAC color distributions of disks around very-low-mass and low-mass stars all belonging to the same star-forming region, the Chamaeleon I star-forming region. We show that self consistently calculated disk models cannot fit the median spectral energy distributions (SEDs) of the two groups. These SEDs can be only explained by flatter disk models, consistent with the effect of dust settling in disks. We find that relative to the disk structure predicted for flared disks the required reduction in disk scale height is anti-correlated with the stellar mass, i.e. disks around lower-mass stars are flatter. Our results show that the initial and boundary conditions of planet formation are stellar-mass-dependent, an important finding that must be considered in planet formation models.

Radial probing of mineralogy of circumstellar disks with stellar interferometry

László Mosoni

In order to study the radial distribution of circumstellar dust, high angular resolution observations are required. In the last years, with the advent of stellar interferometers it became possible. Interferometric observations with telescope arrays allow us to achive milli-arcsecond angular resolution at infrared wavelengths, - i.e. a few AUs at the distance of some 100 parsecs, - thus the innermost regions of circumstellar disks can be spatially resolved. Observations proved that the dust properties are not uniform over the disk. In this talk some interesting results will be presented.

CATHODOLUMINESCENCE PROPERTIES OF NANODIAMONDS IN EXPERIMENT: AN APPLICATION TO THE ASTROPHYSICS OF THE PLANETARY NEBULA. A. Gucsik[1,2], H. Nishido[3], T. Nakazato[3], K. Ninagawa[4] and I. Simonia[5,6] [1]Max Planck Institute for Chemistry, Joh.-J.-Becherweg 27, D-55128 Mainz, Germany, (E-mail: ciklamensopron@yahoo.com); [2]Savaria University Center, University of West Hungary, Károlyi Gáspár tér 4., Szombathely, 9700, Hungary; [3]Research Institute of Natural Sciences, Okayama University of Science, 1-1 Ridai-cho, Okayama 700-0005, Japan; [4]Department of Applied Physics, Okayama University of Science, 1-1 Ridai-cho, Okayama 700-0005, Japan; [5]Physics and Mathematics Faculty of Ilia Chavchavadze Sate University, Tbilisi, Georgia; [6]The Centre for Astronomy of James Cook University, Townsville, Australia

Introduction: The origin of the diamond particles in the planetary nebula systems has been debated for many years. The main purpose of this study is to establish a cathodoluminescence experimental data on the nanodiamond particles that could be used for the astrophysical interpretation of the planetary nebula, for instance NGC 7027.

Samples and Analytical Procedures: K2 (Ultradispersed Detonation Diamonds-UDD) nanodiamonds were mounted in the non-radiative epoxy material. Their size dimensions were grouped into the following groups: less than 3nm (Diamond: A/1 and A/2), between 3-7 nm (Diamond: B/1 and B/2), bigger than 7 nm (Diamond: C/1 and C/2), and a mixture (Diamond: D/1 and D/2) all of them. CL measurements were obtained on carbon-coated, polished (by silicon colloids) thin sections. Color CL imaging was performed on a CL microscope. The system was commonly operated at 15 kV accelerating voltage and a beam current of 0.5 mA. CL colour images were captured using a digital photomicrographic camera system. High-resolution CL images and spectra were acquired using a scanning electron microscope (SEM at Okayama University of Science, Okayama, Japan) equipped with an grating-type monochromator, SEM-CL system. This system was operated at 15 kV accelerating voltage and a probe current of 1.5 nA. CL spectra were recorded in the wavelength range of 350-800 nm with 1 nm spectral resolution and a dwell time of 1 second per step by photon counting.

Results: Cathodoluminescence spectral features of all K2 samples show two broad bands centered at around 388 (3.1 eV; A-center) and 452 (2.69 eV; N-center) nm (Fig. 1). According to Pratesi [1] in an agglomerated state: such agglomerates are called "A Centers" when occur as pairs of nitrogen atoms (type IaA), "B centers" when occur as four nitrogen atoms surrounding a common vacancy (type IaB) and mixtures of them may also occur. Type Ib – mostly represented in synthetic diamonds but very rare (about 0.1%) among natural diamonds – contain nitrogen as isolated single nitrogen atoms called "C Centers". Sometimes type I diamonds may also contain clusters of three nitrogen atoms called "N3 Centers".

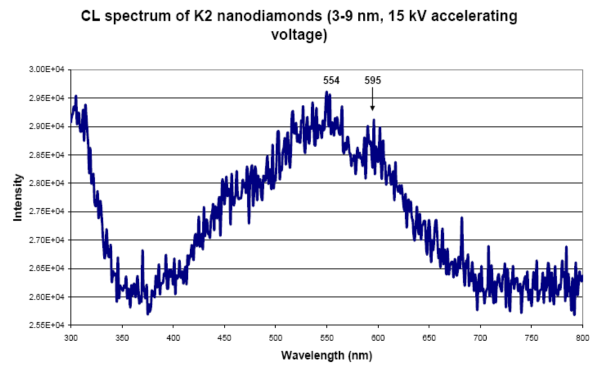

Figure 1. *Cathodoluminescence spectra of K2 nanodiamond samples (grain size:3-9 nm): Intensity vs wavelength.*

Planetary nebula NGC 7027 is C-rich object indicating the presence of nanodiamond dust particles in the dust particles in the dust matter of this nebula is highly possible. The spectral properties of the NGC 7027 nebula are summarized in Table 1, which indicate that the nebula contains N-enriched diamond particles [2]. These spectral data are in a good agreement with our laboratory CL data, too.

Table 1. *Spectral properties of NGC 7027 (data from [2]).*

Spectral Feature (Å)	Spectral Feature (nm)	Temperature (K)
4263	426,3	83
4638	463,8	83
5030	503	77
5773	577,3	77
5780	578	77

Discussion: It is well-known that the Sun formed due to the gravitational collapse of the original solar nebula. In the accretion disk around the proto-sun, terrestrial and giant planets were formed. Nano-and micro sized mineral dust particles (including diamonds) might be formed in meteoroids due two possible scenarios: 1) geological evolution of the terrestrial (rocky bodies) consisted from solar nebula substance; 2) penetration of presolar (interstellar) mineral dust particles in the solar nebula during the gravitational collapse. This indicates that the solar and interstellar nanodiamonds will different in their physico-chemical parameters. The differences are a) isotopic composition; b) impurity composition (ions); c) crystal lattice/structure of substance.

Conclusions: In a conclusion, according to this preliminary laboratory CL data of experimentally-grown diamond samples, diamond particles in nebula NGC7027 may be originated due to ejection of the outer parts of the Red Giants during planetary nebula formation.

References: [1] Pratesi G. (2009) In: A. Gucsik (ed) Cathodoluminescence and its application in the Planetary Sciences, Springer, pp. 160. [2] Simonia I. A. and Mikailov Kh. M. (2006) Astro. Zhour., 50, 960-964.

Petrographical and micro-Raman study of microdiamonds in ALH-77257 (ureilite) and ALH-78113 (aubrite) samples.

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Introduction:

Nakamuta et al. (1) observed dendritic-like olivine, pyroxene and graphite in ureilite, which were formed by igneous process, but the presence of diamond can be assumed in a later impact event(s) in this material. The ureilite is the achondrite of CV-meteorites, which are one of most primitive meteorite classes. The study of primitive meteorites is a route to understand the birth of solar system (2).
Experimentally there are four technologies in producing diamonds: 1) High pressure and high temperature (HPHT diamond); 2) chemical vapor deposition (CVD diamond); 3) detonation synthesis (UDD ultradispersive detonation diamond); 4) treating graphite with high-power ultrasound.
According to Kagi et al (3), the microdiamonds in ureilites (and aubrites) have similar formation mechanism compared to the experimentally produced nanodiamonds.
In nature, the first three processes occur but in large geological, cosmic scale.
Gucsik et al (4-6 and ref. therein) revealed three theories on formation processes on meteoritic nanodiamonds: 1) chemical vapor deposition in solar nebula during birth of solar system (CVD), 2) impact processes, 3) shock wave propagation during collapse of supernovae. Last but not least, the diamonds can growth under high pressure and temperature in litospheric mantle. According to Bérczi et al (7), the ureilite constitutes the upper mantle of differenciated small planetary body.

Experimental Procedure:

The petrographical observations were carried out by a Nikon Eclipse LV100POL optical microscope at Eötvös Loránd University of Budapest, Hungary.
The micro-Raman measurements were performed on a Renishaw RM1000 confocal edge filter-based micro-Raman Spectrometer with 632.8 nm (17mW) laser source at University of Vienna (Austria).

Petrography:

Both of ALH-77257 and ALH-78113 samples contain microdiamonds. The diamonds in aubrite can be observed as 8 µm-sized aggregates, which are built up of µm-size crystallites. But, the diamonds appear as individual phenocrysts in ureilite at the boundary of pyroxene grains. Their size is varied between 10-20 µm. The deformation lamellae can be observed in the biggest crystal.

Raman spectra of diamonds:

The main vibrational mode of the diamond structure is centered at the peak of 1333 cm^{-1}. According to Karczemska et al (8), the shifting of peak of diamond to higher Raman shift means internal stress in diamond structure, whereas shifting of peaks to lower wavenumber means presence of lonsdaelite. Both of Raman spectra of diamond in ureilite and in aubrite shifted to lower Raman shifts. The peak position in Raman spectrum of diamond in aubrite is at 1331 cm^{-1}. According to Gucsik et al. (5), this peak position belongs to the C-C bonding (for carbon sp3 bonding) vibrational mode of microdiamond.

In the spectrum of diamond in ureilite, the peak occurs at 1329.66 cm^{-1}. The UDD (ultra-dispersive detonation diamond) "synthetic denotation" subtype has strong sp3 vibration in same position (1329.7 cm^{-1}) (6). In a comparison to the peak of 1333 cm^{-1}, both of samples show difference in the peak position. The diamond occurs not only in cubic system, but in hexagonal structure too, which is called lonsdaelite. The peak of lonsdaelite is centered between at 1323-1327 cm^{-1} Raman shift (4). Because we observed the Raman peak position of diamond in ureilite at 1329 cm^{-1}, it has assuming a diamond-lonsdaelite mixed structure. However, the cubic diamond is dominant in this structure. In the spectrum of diamond in ureilite, not only diamond is presence, but amorphous carbon phase appears as residue at 1594 cm^{-1} (8). This peak is the G-band of graphite structure depending vibration of sp2 bonding. (5)

Conclusion

According to Gucsik et al (4), the CVD diamonds have peaks at 1150 cm^{-1} and at 1450 cm^{-1}, whereas the shock metamorphic diamonds have peaks only at 1331 cm^{-1} and at around 1600 cm^{-1}. Consequently the investigated diamonds cannot be CVD origin. The diamond in aubrite sample which has peak only at 1331 cm^{-1}, occurs in graphite-containing veins, so the impact origin can be estimated.

The diamonds in ureilite, similarly to the diamonds from the Earth, occur as individual minarals either as inclusion or in intergranular position. So the diamonds in ureilite is assumed grown under lithospheric pressure in upper-mantle of little planetary body as well as shock metamorphic origin. Consequently, the possible lonsdaelite-diamond mixing structure (with diamond dominance) is assumed in both of diamond spectra. In the future, detailed structure analysis will be performed on the samples.

Acknowledgement:

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References:

(1) Nakamuta et al (2005): LPSC XXXVI. 1089.pdf; (2) Bérczi et al (2004) AMP 45/2 55-60; (3) Kagi, Takahashi and Matsuda (1990): Naturwissenschaften 77, 531 - 532 (1990); (4) Gucsik et al (2008): Organic Matter in Space; Proceedings IAU Symposium No. 251, 335-341; (5) Gucsik et al (2008) LPSC XXXIX 1201.pdf; (6)Gucsik et al., (2010) 33rd NIPR Symphosium, pp. 13-14; (7) Bérczi et al (2008) http://www.federatio.org/tkte/atlasz11.pdf; (8) Karczemska et al (2009) AIP Proceedings 59-71; (9) Iakoubovskii et al (1999): Diamond and Related Materials 8 1476-1479;

A micro-Raman spectroscopy study of γ-$(Mg,Fe)_2SiO_4$ ringwoodite from the shock vein of NWA 5011 meteorite: Constrains to shock conditions.

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Introduction: High-pressure minerals are common in highly shocked (S6) L6 chondrites. These minerals provide evidence of very high pressure and temperature conditions during impact events [1]. The NWA 5011 meteorite contains few microns to several millimeter wide shock veins, which show complex mineralogy. The abundant high-pressure phases and intensive melting features exhibit high porosity of the bulk rock, and significant shearing mechanism during impact.

Sample and Experimental Procedure: Two polished thin sections have been made for optical and instrumental investigations, respectively. The mineral assemblages and texture were characterized with a Nikon Eclipse LV100POL optical microscope. The phase identification and Raman spectra were recorded with a Renishaw RM-2000 Raman spectrometer attached to a Leica DM/LM microscope.

The NWA 5011 meteorite was found in Morocco, in 2005. The date of fall is unknown. The NWA 5011 is an L6-type chondrite containing abundant shock veins having sizes between few microns and several millimeters. The main modal components are as follows: olivine, orthopyroxene, feldspar (generally in form of maskelynite), troilite. Minor components include ilmenite and chromite.

Results: The NWA 5011 consists of shock-induced melt veins and nest-like melt pockets. The shock veins show abundant high-pressure mineral polymorphs of olivine. This phase related to in or adjacent of the shock veins. No phase transitions can be observed outside the shock veins, which suggests, that the mechanism of transition process needs high temperatures rather than high pressures [2].

The ringwoodite is the most spectacle high-pressure polymorph in shock veins of NWA 5011 exhibiting various colors from deep blue to colorless (Fig. 1). The ringwoodite grains have similar chemical compositions to olivine grains of the chondritic part ($(Mg_{1.44}\ Fe_{0.56})\ Si_{1.00}O_4$); ($Fo_{72}$-$Fa_{28}$). In the Raman spectra the spinel structure shows peaks at 795 and 840 cm^{-1}. An additional peak appears at around 875 cm^{-1}, which wasn't observed in ringwoodite spectrum before. The peak was detected in well crystallized ringwoodite grains, which excludes glassy material as its origin. According to Prof. Paul McMillan (in personal communication) it could be related to a defect induced vibrational mode, or a new Ca-orthosilicate phase [3]. However, the Ca-orthosilicate origin can be excluded, because the CaO content of ringwoodite is below 0.1 wt% (for Ca-orthosilicate it should be above 30 wt%). It is worth to note that Raman spectra were recorded in the central part of a 200 µm long and 150 µm wide ringwoodite grain, and not in the vicinity of the grain boundaries. The presence of this peak in the spectrum will be confirmed by using another excitation energy.

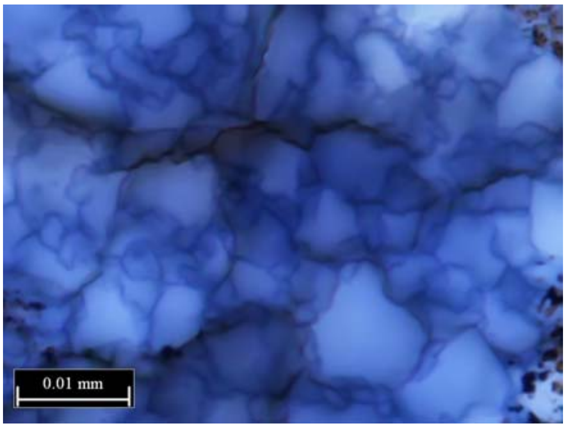

Fig. 1. Polycristalline ringwoodite in the shock melt vein of NWA 5011.

The pressure and temperature are very heterogenous along the shock vein. In known of the chemical composition of ringwoodite we can determine the lower rate of pressure and temperature conditions. Consequently, the crystallization temperature was around 1800°C, and pressure 17-18 GPa. We didn't observe back-transformation products of ringwoodite, therefore the cooling rate has had to be between 8000-10000°C·s^{-1} which rate coming from similar natural sample data [4]. This indicates that ringwoodite was immediately frozen after pressure release. Therefore, we assume that the unknown peak in ringwoodite spectrum related to a sign of a mixed structure.

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References: [1] Xie et al., (2001) LPSC XXXII, (abstract), #1805. [2] Sharp T.G. and DeCarli P.S. (2006) In Meteorites and Early Solar System II. [3] Piriou B. and McMillan P. (1983) Am. Mineral.., Vol. 68, 426-443. [4] Chen et al., (1998) Science in China, Vol. 41, 522-528.