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学位論文題目	The Spectro-Polarimetric Approach to the Circumstellar Envelope of Variable Stars （変光星を取り巻く星周物質の偏光分光観測を用いた研究）
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論 文 内 容 要 旨

Polarization is one of the useful information sources in the study of circumstellar envelope. By observing polarization from the star, we can obtain information on scattering process such as the geometry and density distribution. A history of polarimetry in stellar astronomy is at most fifty years and shorter than other observational methods. Although polarization has been discovered in many types of stars, most of applications are still qualtitative, except for the field of interstellar matter guided by Serkowski and his collaborators. In addition, new scattering processes such as Raman scattering and Hanle effect causing polarization also have been detected or predicted in recent years. Thus, the situation in the field of astronomical polarimetry is still chaotic and immature at present, although polarimetry is excepted to become valuable because of improvement of all kinds of resolutions in 10 m telescope age. The aim of this thesis is to control such a chaotic situation from theoretical, observational, and technical faces, and to produce the base for the coming generation of polarimetric astronomy.

We have carried out spectropolarimetry of R CrB stars in attention to the time variation, using our home instrument, HBS(Kawabata et al.,1999). Among those, the spectropolarimetric monitoring to R CrB went on over about three years from Jan.1998 to Mar. 2001. Of 36-night data, we discovered *the transient polarization* in light maximum phase when any intrinsic polarization had not been detected ever. This phenomenon can be quantitatively explained by dusty puff off the line of sight, which is considered to be the first direct evidence for *a randomly puffing-off model* currently accepted as an explanation of observational behaviors in R CrB stars. In order to investigate the transient polarization more deeply, I carried out numerical calculations by the Monte-Carlo method. Simulations suggest that transient polarization can be produced by a dusty cloud formed near the star at $\sim 2\ R_*$ where it is known as a hostile environment for condensation into dust. An estimation of total dust mass in the cloud

also supports this suggestion. The importance of rapid construction of a dust formation theory in a hostile environment is carved in relief.

The photosphere of nova is considered to deviate from an ideal spherical structure, which is confirmed by deep imaging of post novae (Slavin et al., 1995; Gill & O' Brien, 1998). It is an attracting problem when the deformation starts in the brightness evolution. In order to solve such a problem, we carried out spectropolarimetry of some novae in early phases and discovered the presence of intrinsic polarization, This may be the first detection of deformation in the photosphere. In addition, the sudden change in a polarization vector was also detected in the decline phase of the brightness. The results from the Monte-Carlo simulations indicate that electron scattering in the ellipsoidal photosphere can reproduce the observed polarization even if multiple scattering is dominative. However, polarization shows a tendency different from that expected from the elimination of single scattering approximation. It is also found that a jump in the P.A could occur when a nova is observed at an inclination angle in a certain range.

The velocity field in the circumstellar envelope is one of the most important information. These can be extracted from polarization line profiles of the emission or absorption lines. However, there is few spectropolarimeter with high spectral resolution for such observation. Thus, we have been developing a high resolution echelle spectropolarimeter, LIPS,since 1998. LIPS has the resolving power of R = 10000 and the accuracy in polarimetry of $\Delta P < 0.1\%$. In this project, I am in charge of design of optics and instrumental box. For keeping an accuracy of $\Delta P < 0.1\%$, LIPS must be so compact and light as to be mounted on the Cassegrain focus. I designed a compact optical system and a strong instrumental box with the help of FEM analysis. A constructed instrument satisfies our specification. Moreover, I designed and manufactured diffraction limited lens units whose aberrations are adequately removed. Then, I investigated the characteristics of *ripple*, which is seen in spectra through after a super-achromatic waveplate of Pancharatnam type and seriously degrades the data quality. I investigated the physical origin through examinations and simulations. Based on those studies, I succeeded in reducing ripples of a super-achromatic waveplate. LIPS is in the phase of engineering observations. It will provide unexpected and fruitful results in near future.

Finally, I simulated the polarization line profile of Hα in AB Aur, which is one of a few polarization spectra actually observed before. This trial is not only the case study on an analysis of polarization line profile but also to demonstrate what will be brought by the data obtained with LIPS. I include the resonance scattering into a model in addition to electron scattering, which sometimes can be dominant near atomic lines. I can well reproduce polarization line profiles of polarization degree and P.A with a velocity component of rotation of about 50 kms^{-1} at the inner edge of the disk containing turbulence in addition to an expanding component. This result supports the equatorial disk model for Herbig Ae star proposed by Catala et al.(1999). Moreover, it is found that the separation between two peaks seen in polarization and their ratio give promising diagnostics of the inclination angle and expanding velocity of the disk, and that the comparison of polarization profiles between different lines could bring information on optical thickness in the circumstellar envelope.

論文審査の結果の要旨

宇宙に関する知見をもたらす電磁波はStokes Parameters {I,Q,U,V} を用いて記述されるが，天体からの光は極めて微弱であることから，従来の研究は専ら強度Iの波長分布，空間分布および時間変動の精緻な解析に重きを置いていた。しかし，今や「すばる」など大口径望遠鏡時代を迎え，多量の光子を高い空間分解能と高い量子効率で集めることが可能になり，Q，U，Vが保有する電磁波の偏光特性の解読に大きな期待が集まりつつある。

池田優二提出の論文は，星周エンベロープを伴う変光星を研究対象として選び，{I,Q,U} すなわち直線偏光に関する分光偏光学的手法の有効性を観測・理論・装置開発の３つの観点から論じたものである。まず第２章で，現有の低分散偏光分光器を用いて自らが行った超巨星R CrB星の３年間にわたるモニター観測の結果を解析して物理過程を論じた。とくに，この型の変光星を特徴づける急激な光度変化が見られない平時において，偏光特性のみが著しく特異な振る舞いを示す偏光変動を世界で初めて検出し，その考察を通じて，恒星活動に付随する星周エンベロープの起源と空間分布及び時間発展を，統一的に説明するモデルを構築した。第３章では可視光域の広い波長範囲を同時に高分散・高精度で測定しスペクトル線の偏光プロファイルを描く，世界で初の，Echelle型偏光器のＲ＆Ｄを行った。仕様達成のためには光学素子の偏光特性の把握と課題解決が求められるが，池田優二は開発の中核的役割を果たし，試験器を2002年２月ハワイ大学望遠鏡に搭載する段階にまでこぎ着けた。第４章では，分光偏光解析のcase study として，代表的なHerbig Ae星であるAB Aur星のHα輝線の偏光プロファイルを用いて，星周ガス円盤の幾何学的配置と運動学的情報取り出しに関する理論的考察を行った。これは第３章の成果を活かす上で必須の作業であり，分光偏光学的情報のポテンシャルを明確に示すものである。

以上，池田優二提出の論文は天文学研究に分光偏光法という新しい領域を開拓し，その成果は銀河系内のみならず活動銀河核など遠方の天体の解明にも貢献するものである。このことは著者が自立して研究活動を行う上で必要な高度の研究能力と学識を有することを示しており，よって池田優二提出の論文は，博士（理学）の学位論文として合格と認める。