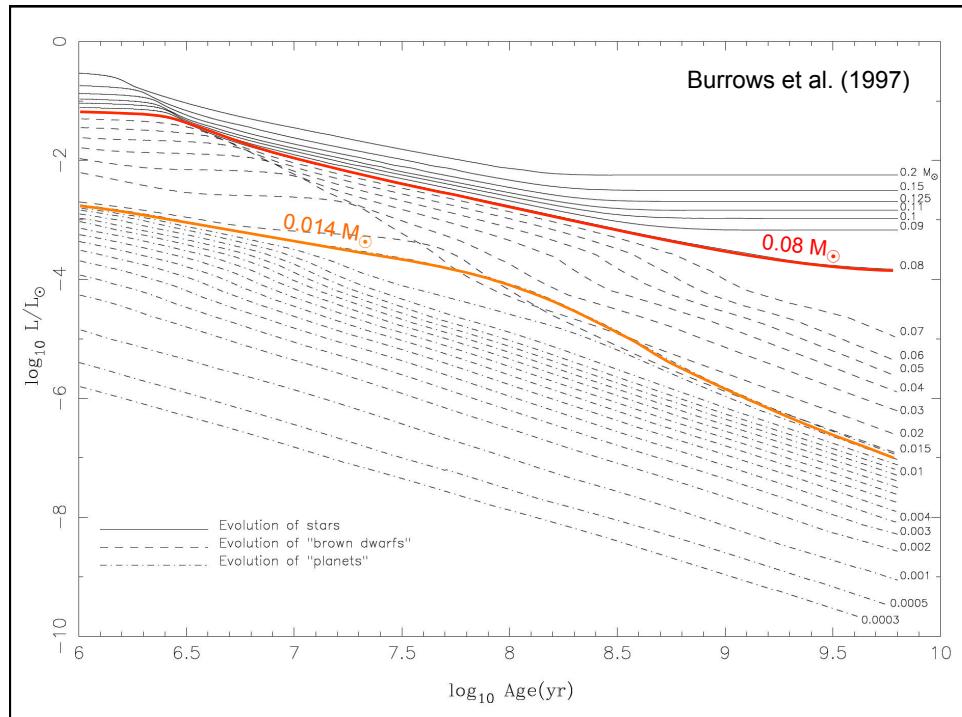


太陽系外惑星の観測

惑星とは何か？

単独の星	質 量	中心核での核融合反応
恒星	太陽の8%以上 木星の80倍以上	水素の熱核融合反応が起こる (中心温度が1千万度以上になる)
褐色矮星	太陽の1.3%から8% 木星の13倍以上80倍以下	水素の熱核融合反応は起こらない。重水素の熱核融合反応は起こる(中心温度が100万度以上になる)
準褐色矮星 (惑星質量天体)	太陽の1.3%以下 木星の13倍以下	いかなる熱核融合反応も起きない



惑星とは何か？

質量が木星の13倍以下

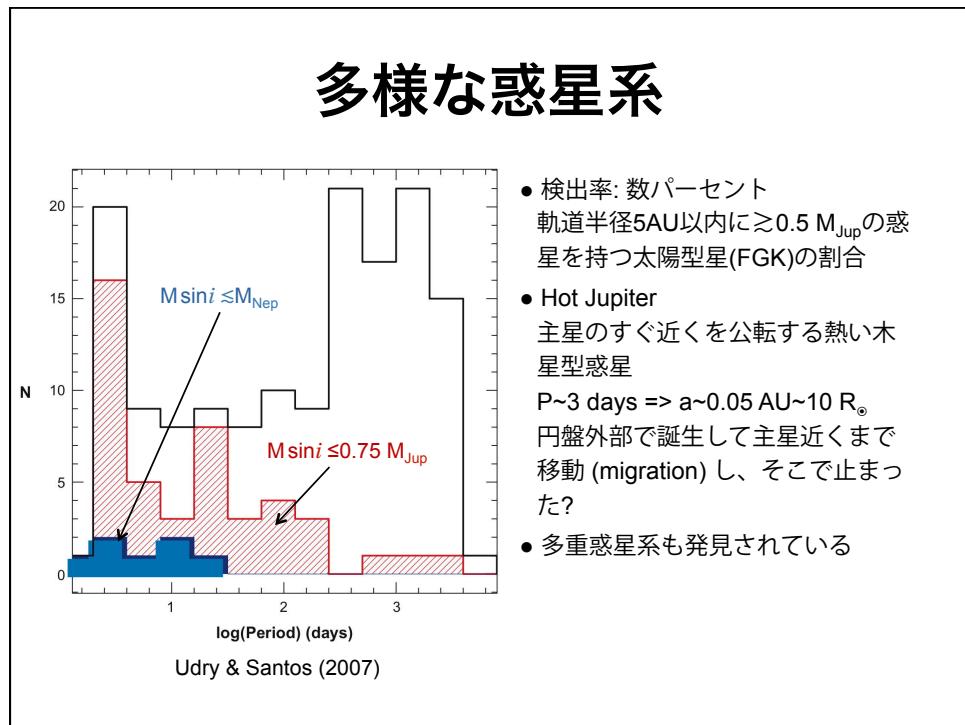
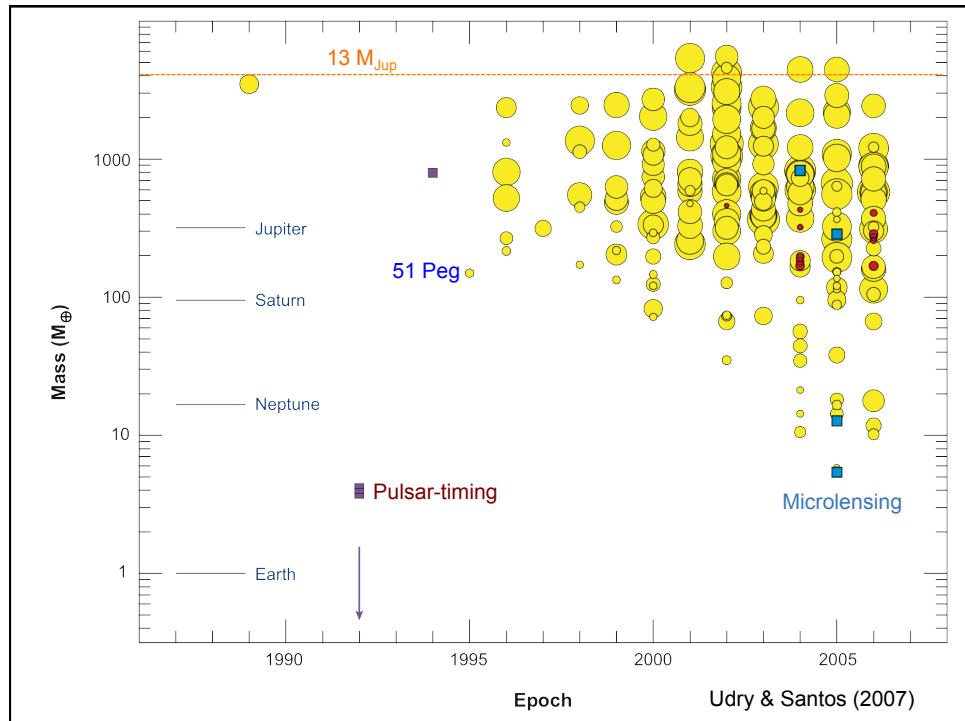
惑星質量天体 (浮遊惑星)

他の(恒)星のまわりを公転している

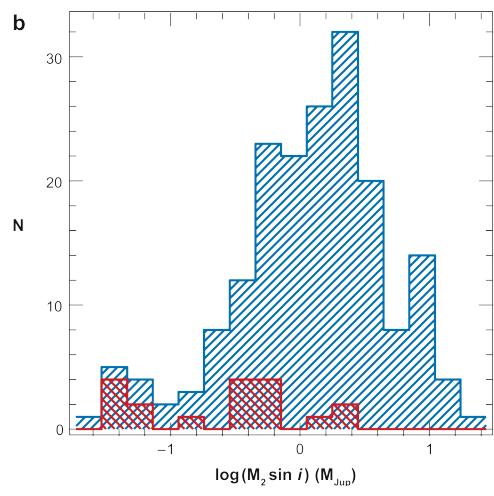
現状では、このあたりの線より上の条件を満足すれば、「惑星」と言われる

原始惑星系円盤からできる

岩石の核を持つ

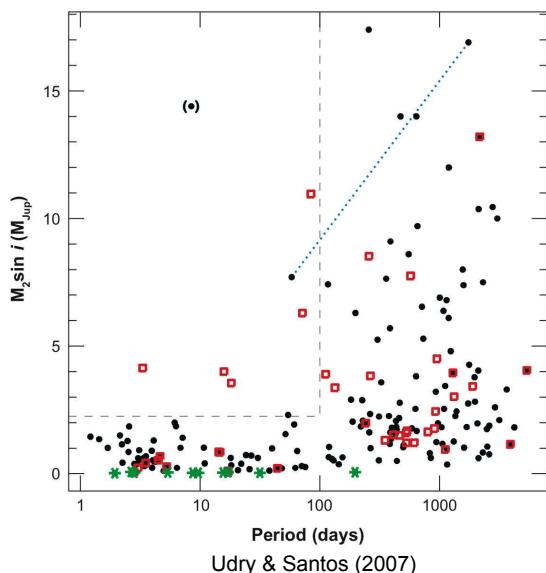


惑星の質量分布



- $M \sin i \gtrsim 10 M_{\text{Jup}}$ で数が減少 => Brown Dwarf Desert
(ただし、 $a \gtrsim 5$ AUでの低質量伴天体(惑星または褐色矮星)探査は、まだ十分ではない)
- 小さいMでの減少は視線速度法の検出感度による

質量の軌道依存性



$P \lesssim 100$ days には $M \sin i \gtrsim 2 M_{\text{Jup}}$ の惑星がほとんどない

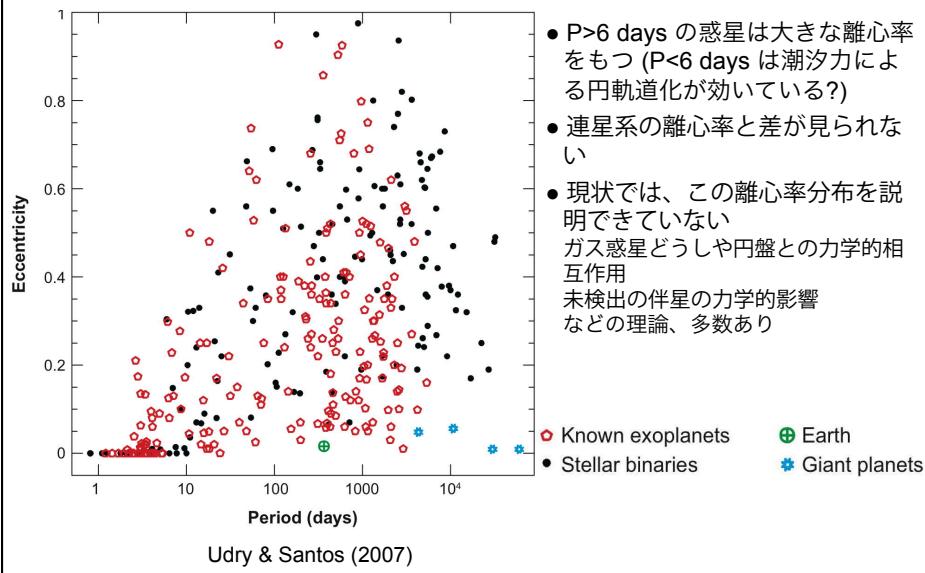
惑星移動 (Migration) の結果か?

重い惑星ほど移動しにくい。

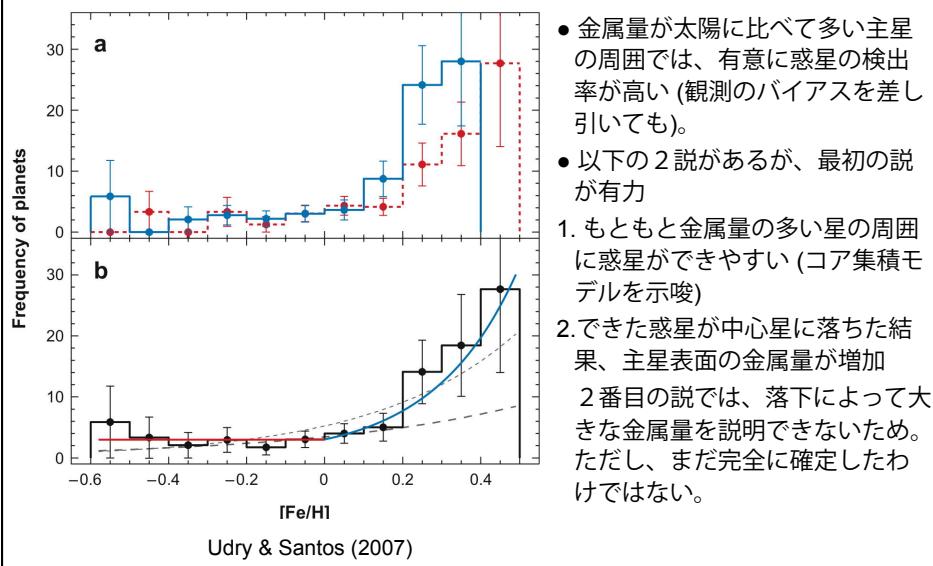
星近傍では、惑星から星への質量落下や、ガス蒸発の可能性がある。

- Planets around single stars
- Planets in binaries
- Solid planets

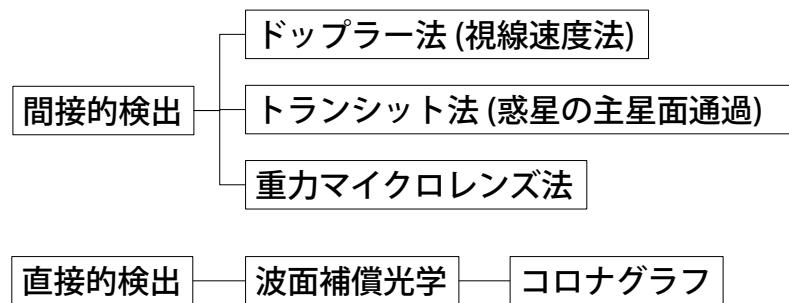
離心率



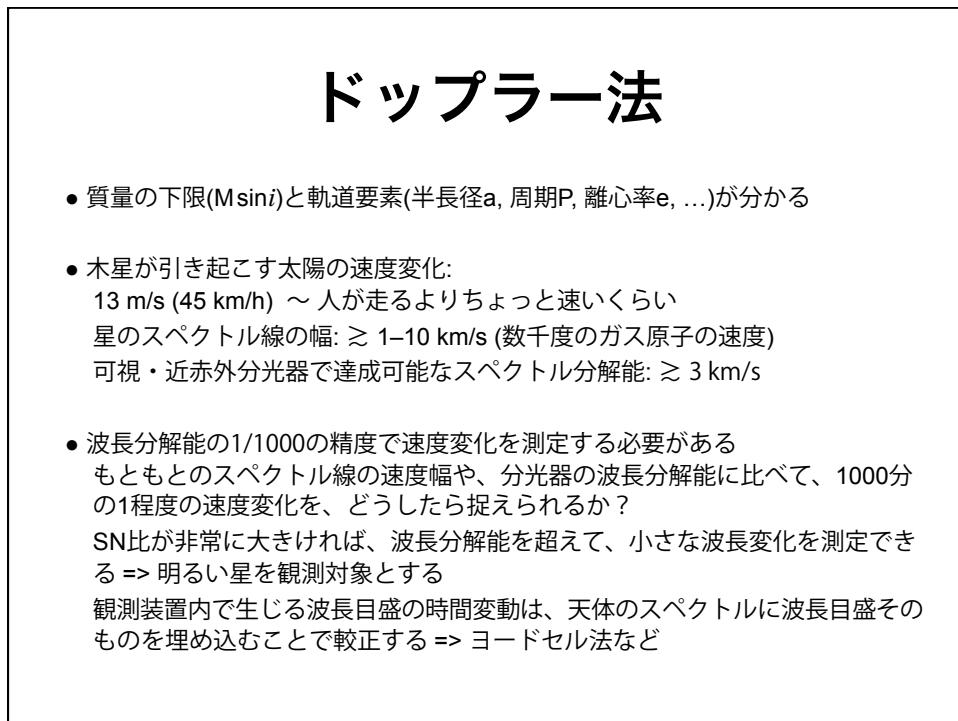
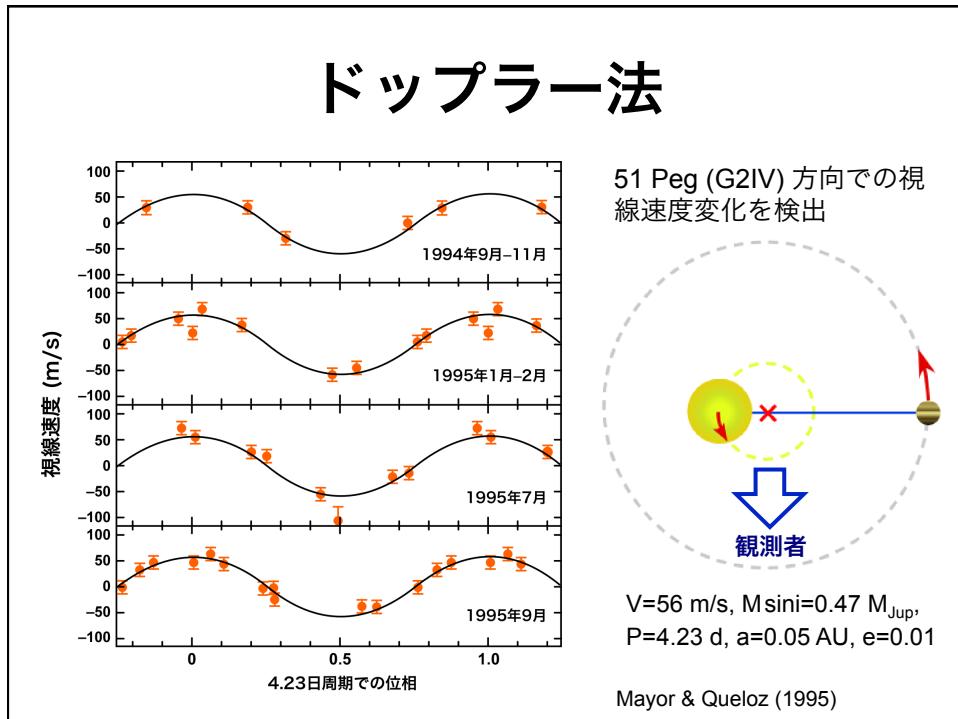
主星の金属量との関係



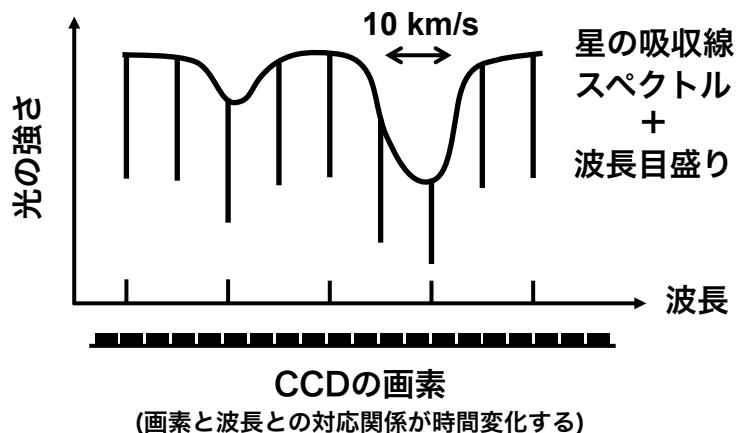
観測手法



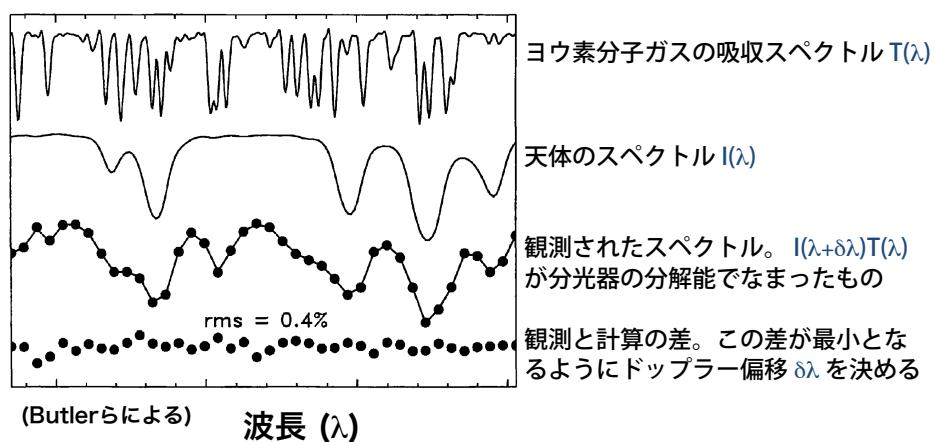
間接検出

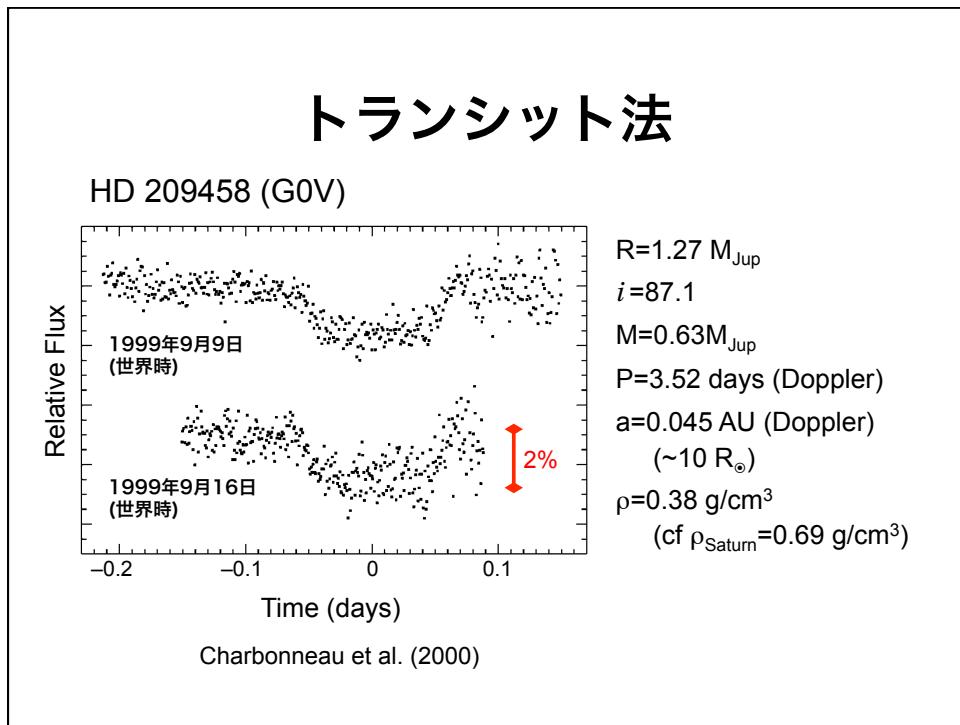
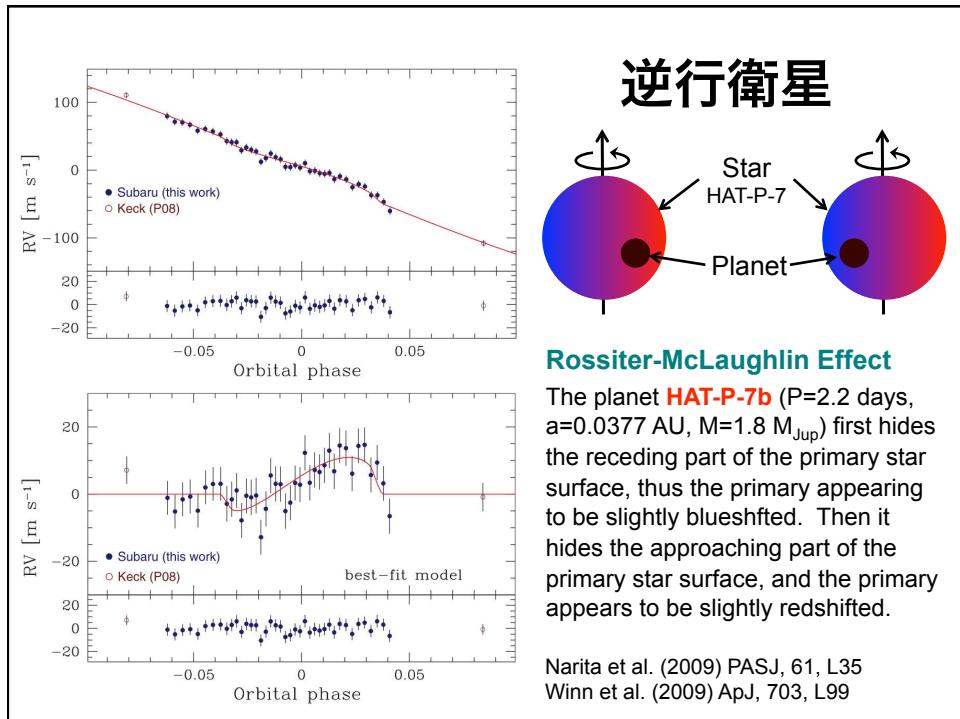


ドップラー法（ヨードセル法）

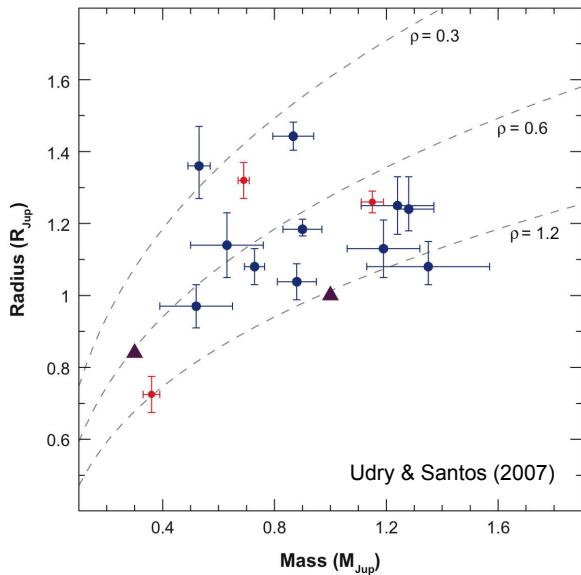


ドップラー法（ヨードセル法）





トランシット法



- ドップラー法と合わせれば、質量(下限ではない)と半径が分かり、平均密度も分かる
- 半径が大きく異なる恒星どうしの連星系を検出する確率が高く、注意が必要
=> ドップラー法による確認が必須
- ドップラー法のhot jupiters (P~3 days)に比べて、周期 (P=1-2 days)が、短いものが多い(謎)

重力マイクロレンズ法

$$t_E = R_E / v_t \sim \sqrt{M / M_{Jup}} \text{ (days)}$$

where $R_E = \sqrt{\frac{4GM}{c^2} \frac{D_{lens}(D_{source} - D_{lens})}{D_{source}}}$

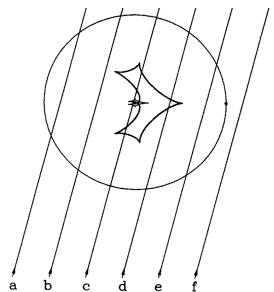


FIG. 1.—Geometry of microlensing by a binary, as seen in the sky. The primary star of $1 M_\odot$ is located at the center of the figure, and the secondary of $0.1 M_\odot$ or $0.001 M_\odot$ is located on the right, on the Einstein ring of the primary. The radius of the ring is 1.0 mas for a source located at a distance of 8 kpc and the lens at 4 kpc. The two complicated shapes around the primary are the caustics: the larger and the smaller corresponding to the $0.1 M_\odot$ and $0.001 M_\odot$ companions, respectively. If a source is located outside these regions, then only three microlimages are formed, while a source inside them forms five microlimages. The parallel straight lines indicate the trajectories of sources for which the light variations are shown in Fig. 2.

Mao & Paczynski (1991)

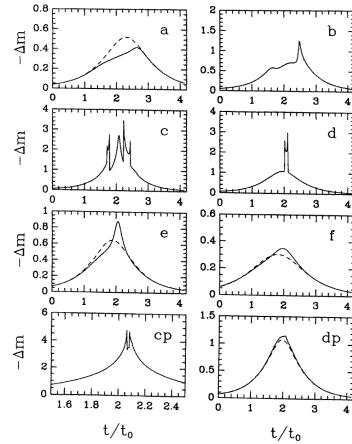
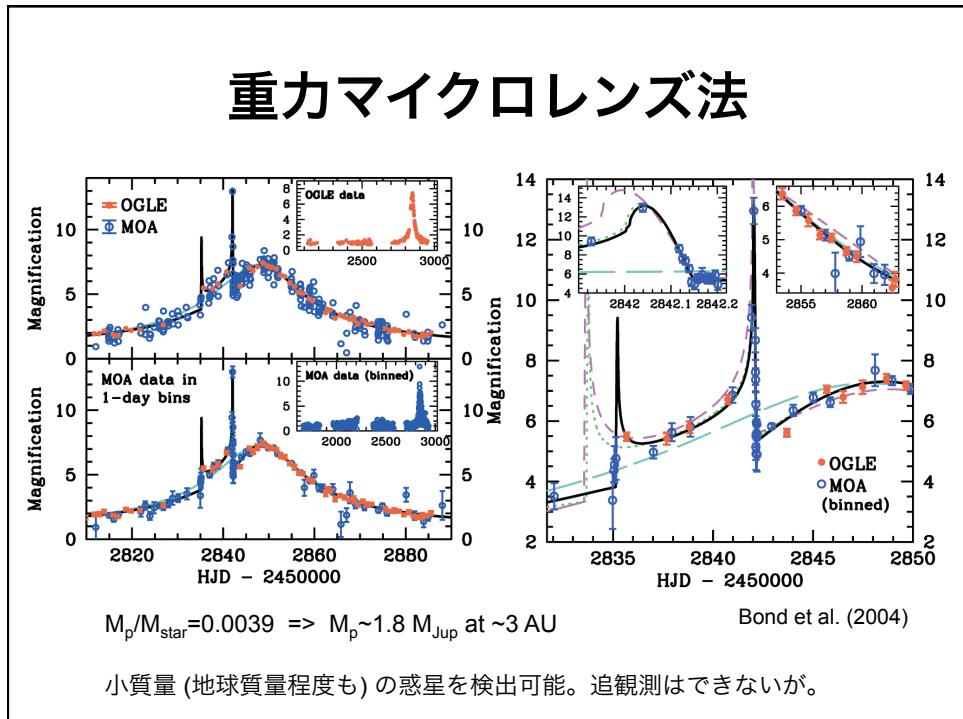
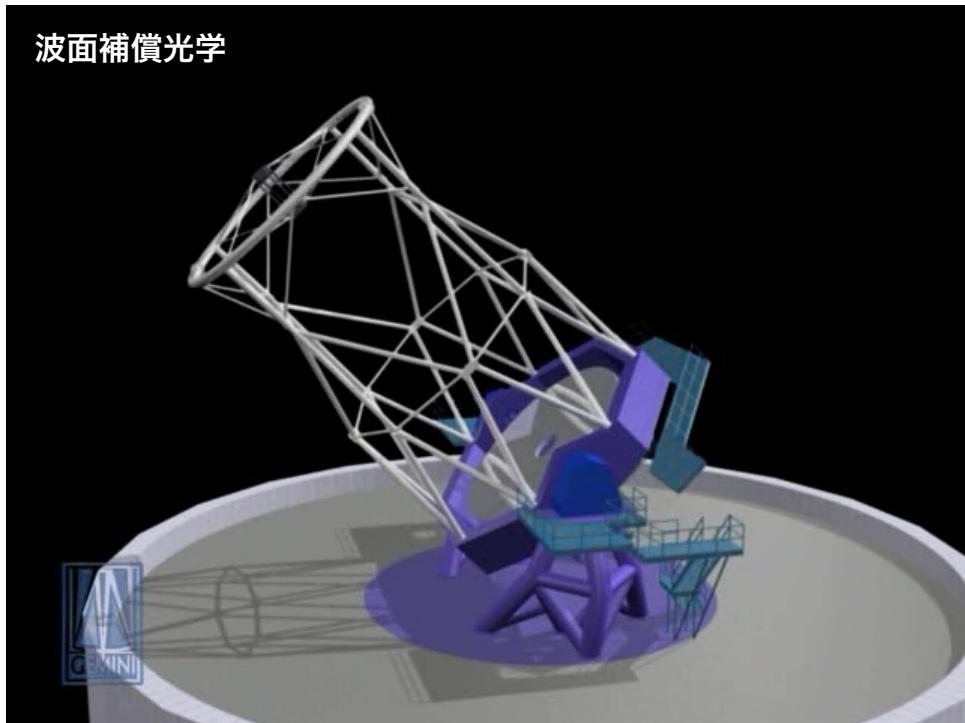


FIG. 2.—The light curves shown correspond to the six source trajectories in Fig. 1. The source is modeled as a uniform disk of radius $R_s = 10^4$ cm. The first six light curves, a-f, correspond to the case with a $0.1 M_\odot$ companion. The last two, cp and dp, correspond to the case with a $0.001 M_\odot$ companion. Notice very high spikes when a source crosses a caustic, or approaches a cusp, as in the light curves c, d, and cp. The low-amplitude light curves a, e, f, and dp, are shown together with the dashed light curves expected for single-mass microlenses matching the wings.



直接検出



2M1207B (褐色矮星と惑星質量星の連星)

